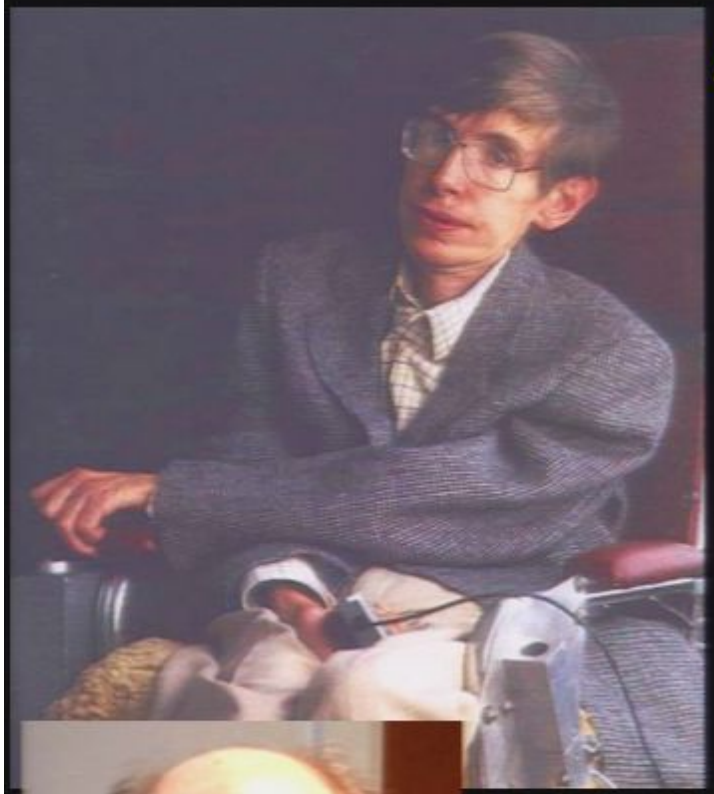
Title: Relativity 6

Date: Aug 15, 2008 03:30 PM

URL: http://pirsa.org/08080021

Abstract:

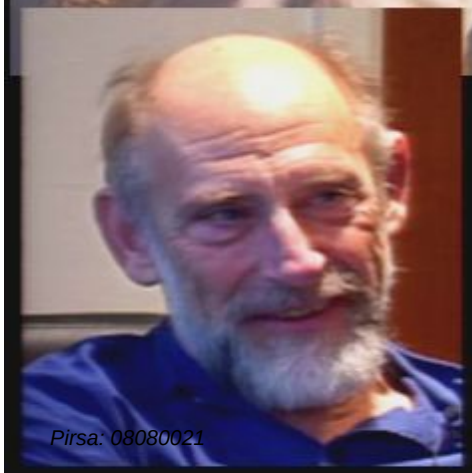
The Blackhole Stars Today



Hawking

Bekenstein

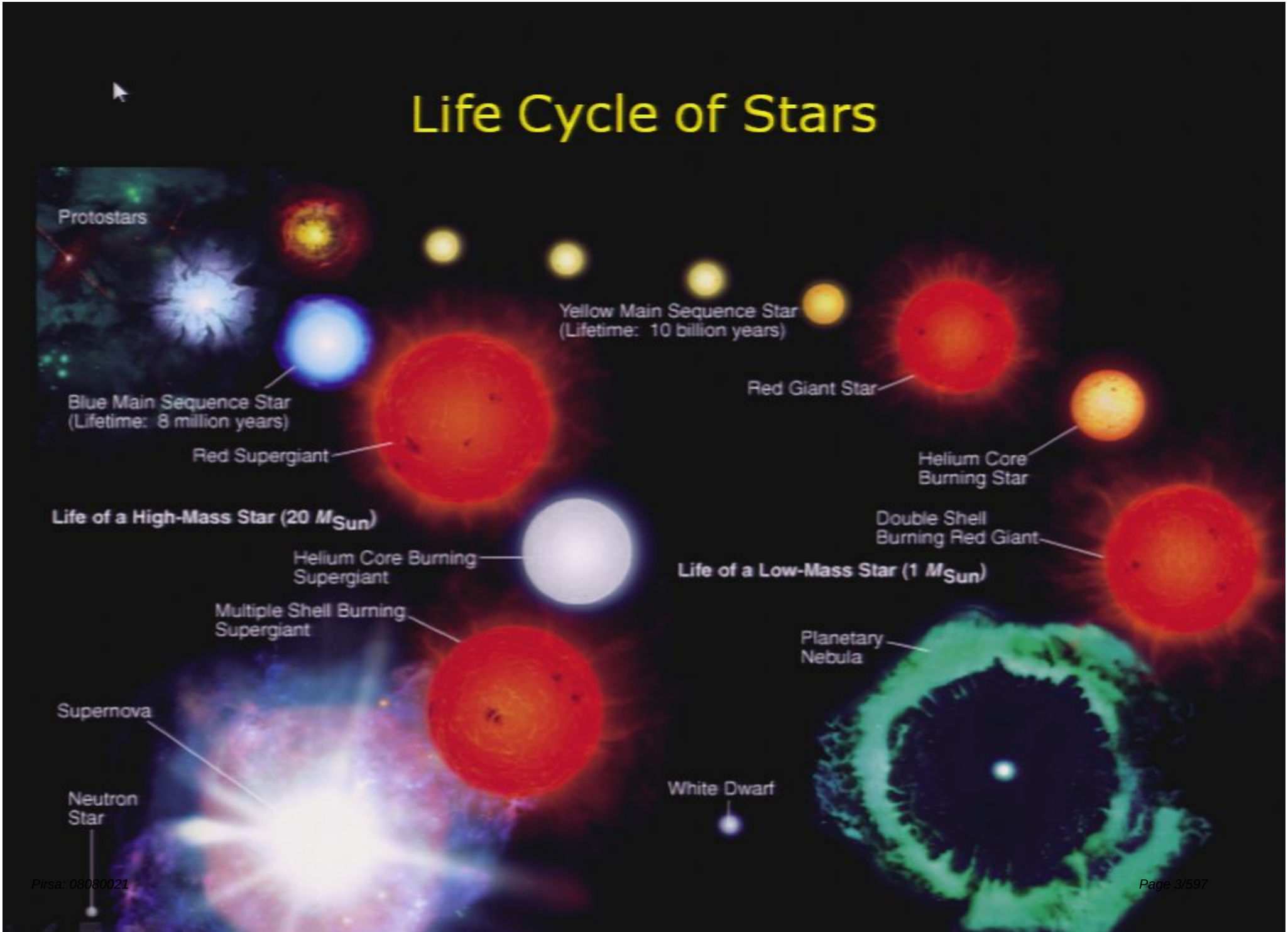
Thorne



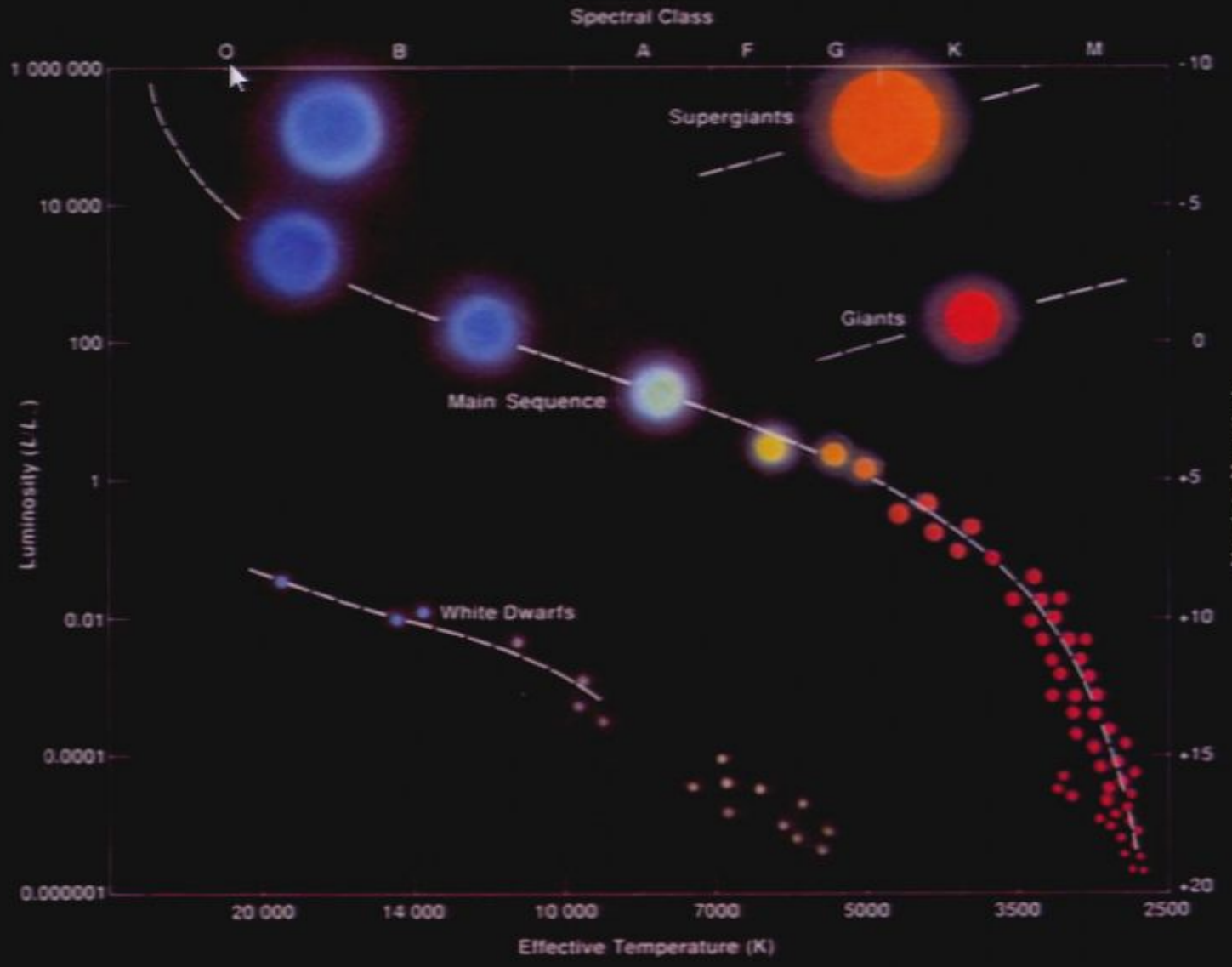
Susskind

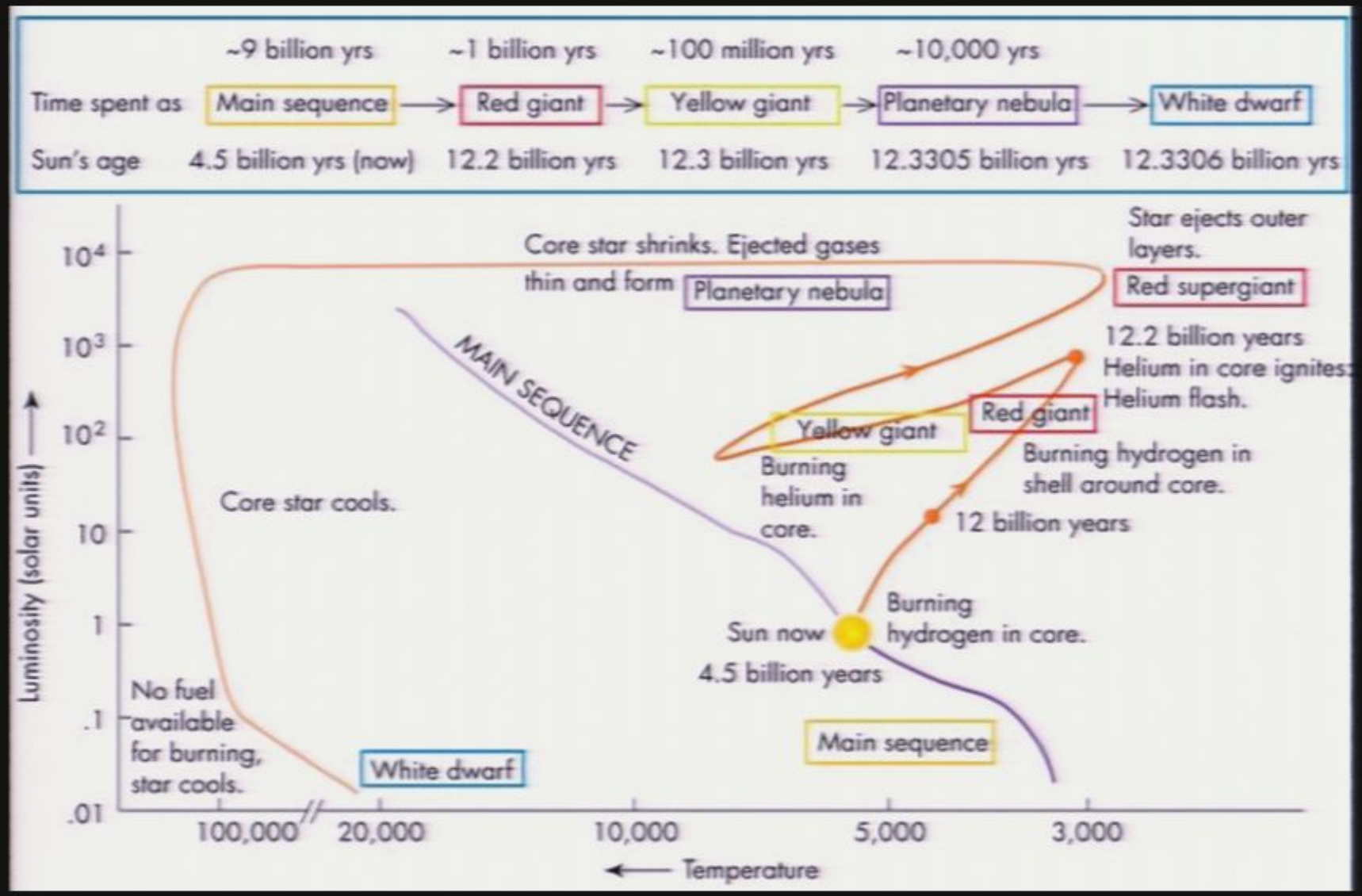
Werner Israel

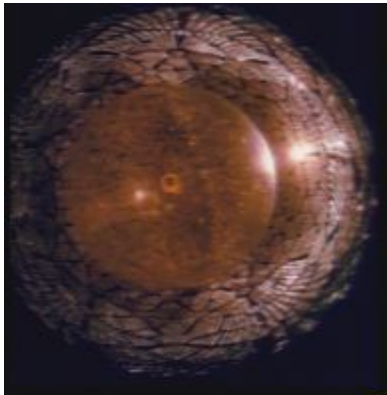
Robert Wald


Life Cycle of Stars
Protostars
Blue Main Sequence Star
(Lifetime: 8 million years)
Red Supergiant
Yellow Main Sequence Star
(Lifetime: 10 billion years)
Red Giant Star
Helium Core
Burning Star
Double Shell
Burning Red Giant
Life of a High-Mass Star (20 M_{Sun})
Helium Core Burning
Supergiant
Multiple Shell Burning
Supergiant
Supernova
Neutron
Star
Life of a Low-Mass Star (1 M_{Sun})
Planetary
Nebula
White Dwarf

Hertzsprung-Russel Diagram




~9 billion yrs
~1 billion yrs
~100 million yrs
~10,000 yrs
Time spent as
Main sequence
Red giant
Yellow giant
Planetary nebula
White dwarf
Sun's age
4.5 billion yrs (now)
12.2 billion yrs
12.3 billion yrs
12.3305 billion yrs
12.3306 billion yrs
Star ejects outer layers.
Core star shrinks. Ejected gases thin and form
Planetary nebula
Red supergiant
12.2 billion years
Helium in core ignites: Helium flash.
MAIN SEQUENCE
Red giant
Yellow giant
Burning hydrogen in shell around core.
Burning helium in core.
12 billion years
Core star cools.
Burning hydrogen in core.
Sun now
4.5 billion years
No fuel available for burning, star cools.
White dwarf
Main sequence
Luminosity (solar units)
10^4
10^3
10^2
10
1
.1
.01
100,000
20,000
10,000
5,000
3,000
Temperature



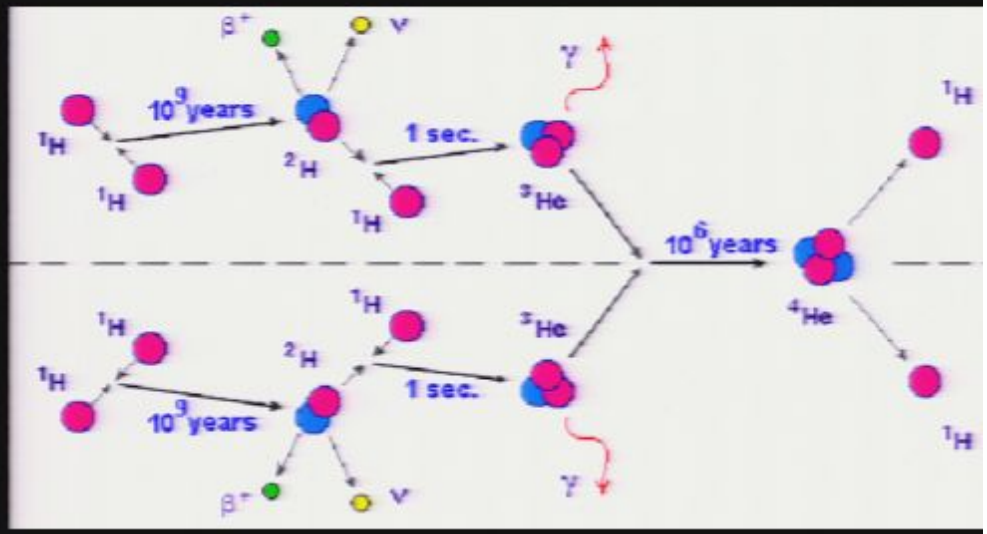
Stellar Energy

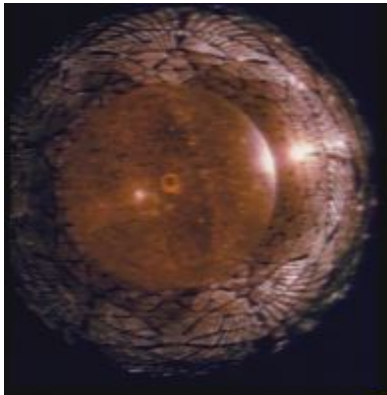
Proton-Proton Chain [4H → He + energy]

Two hydrogen nuclei merge to produce deuterium nucleus, a positron,and a neutrino. Add another hydrogen and you get helium 3 and a gamma photon (energy). Two Helium 3 merge and produce helium 4 and two Hydrogen nuclei.

Proton-Proton Reaction

Neutron
Proton





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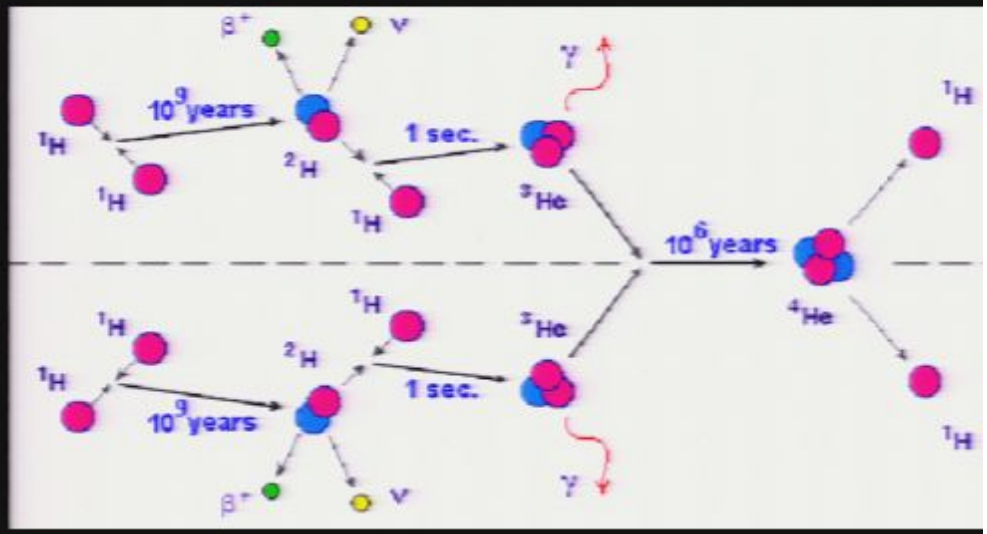
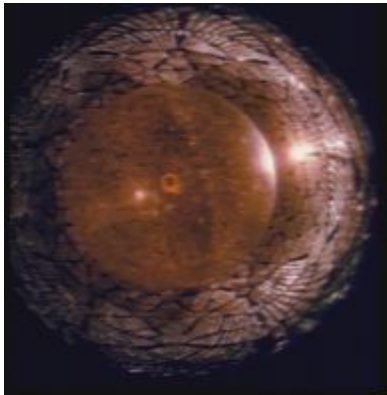
Two 1H Atoms Combine

● = Neutron
● = Proton





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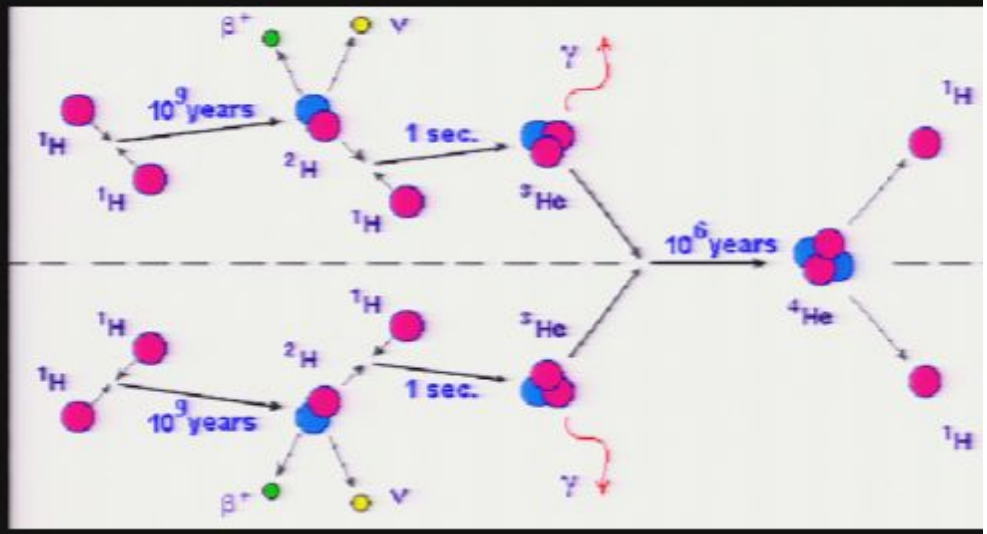
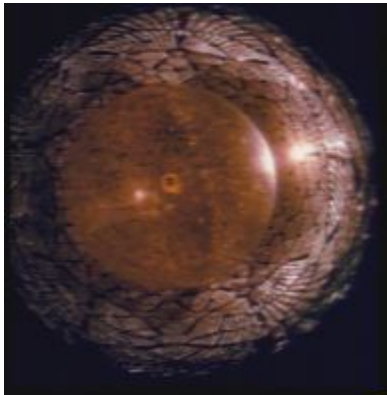
2He Is Formed

Neutron
Proton





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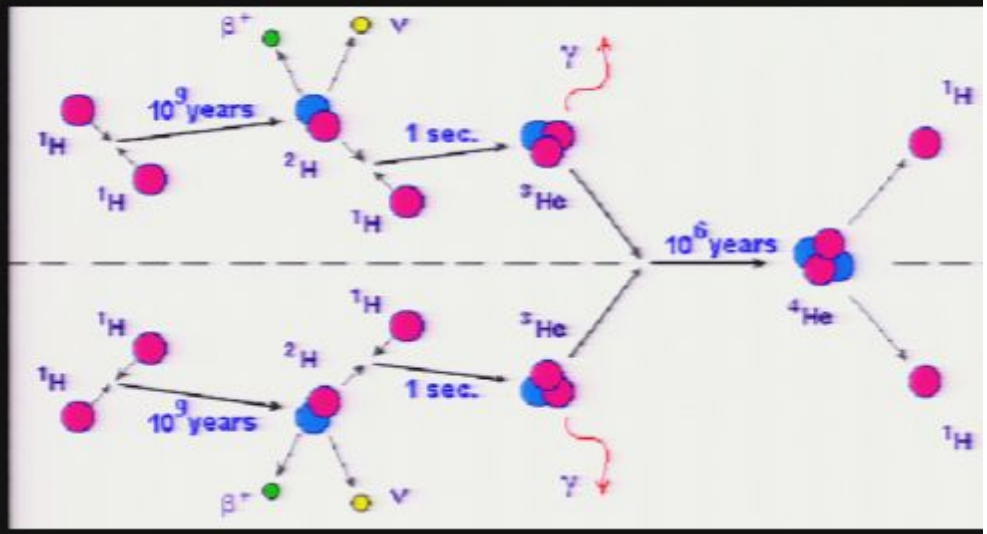
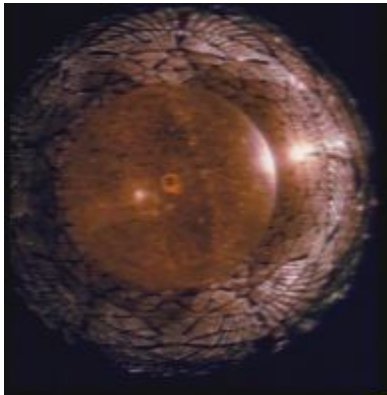
Proton Decays Into A Neutron

Neutron
Proton





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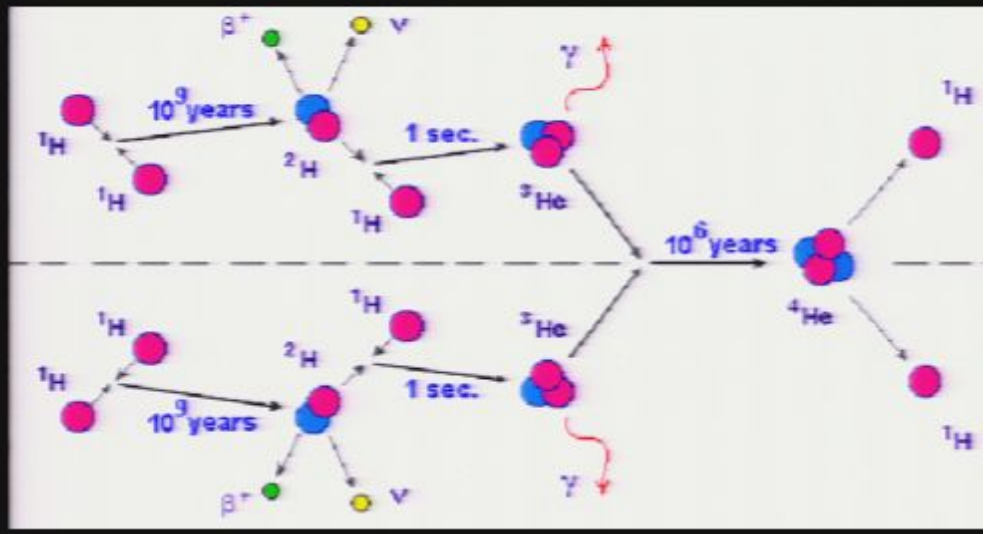
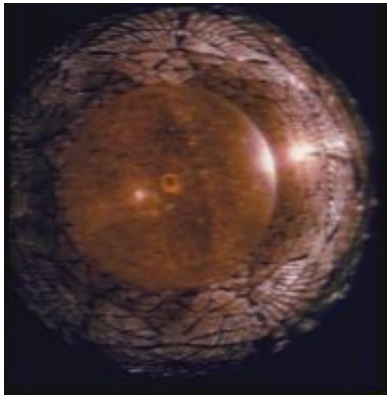


Stray 1H Fuses with 2H

Neutron
Proton

Positron

Neutrino



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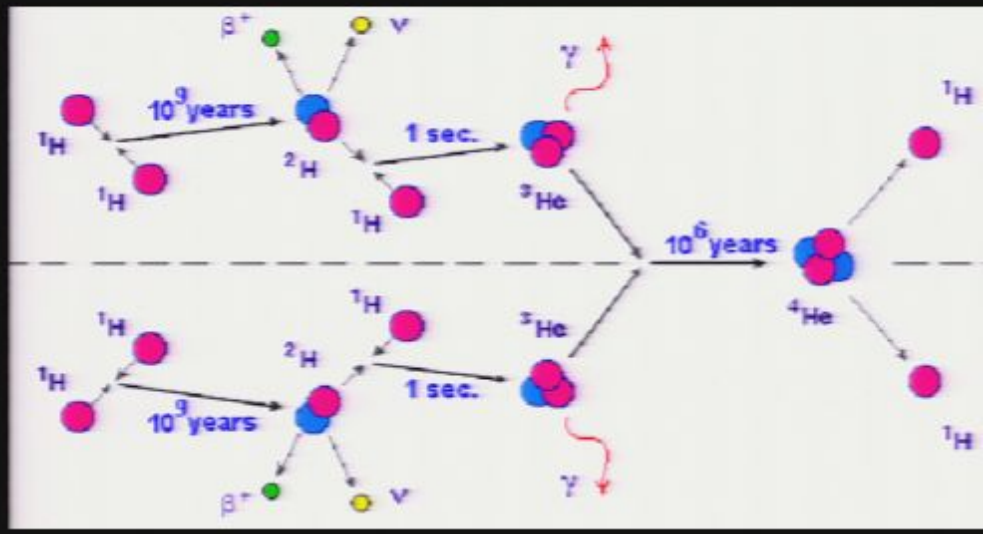
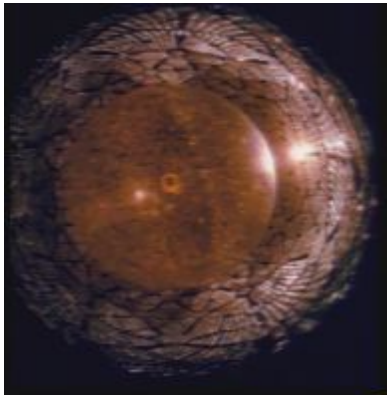
3He Is Created

Neutron
Proton





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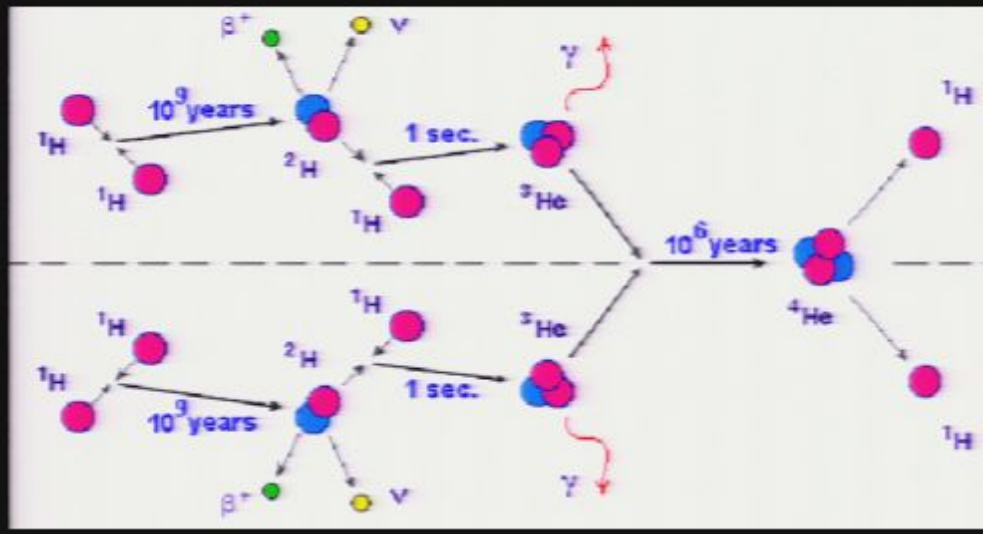
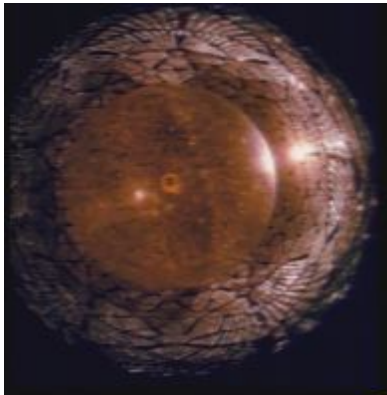
Two 3He Fuse Together

Neutron
Proton





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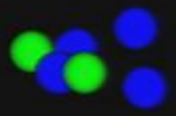
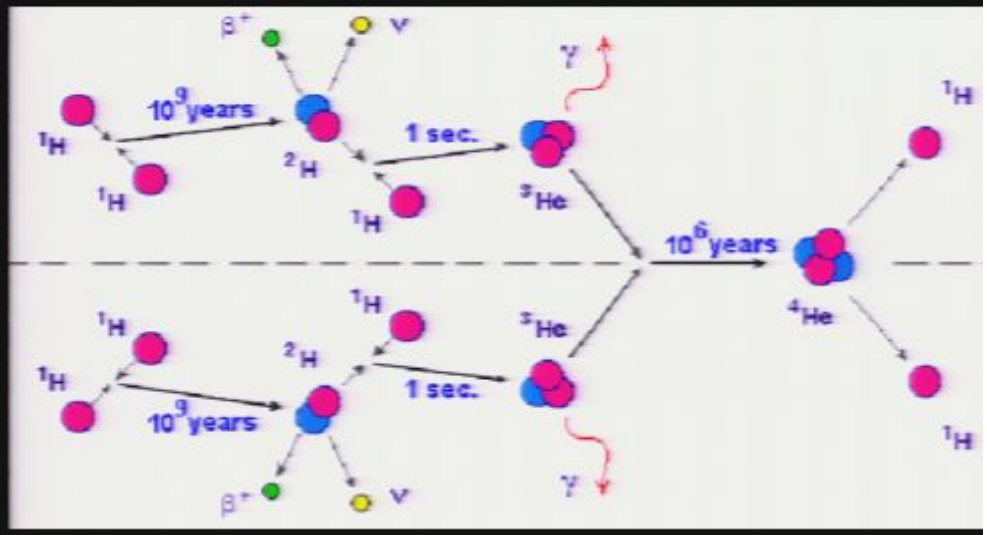
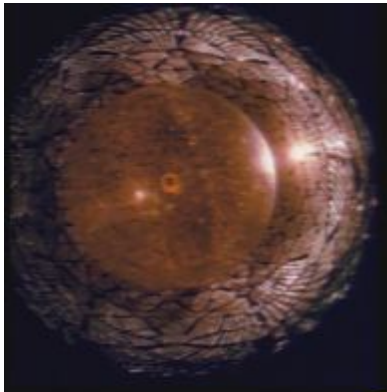
Two 1H Atoms Released

Neutron
Proton







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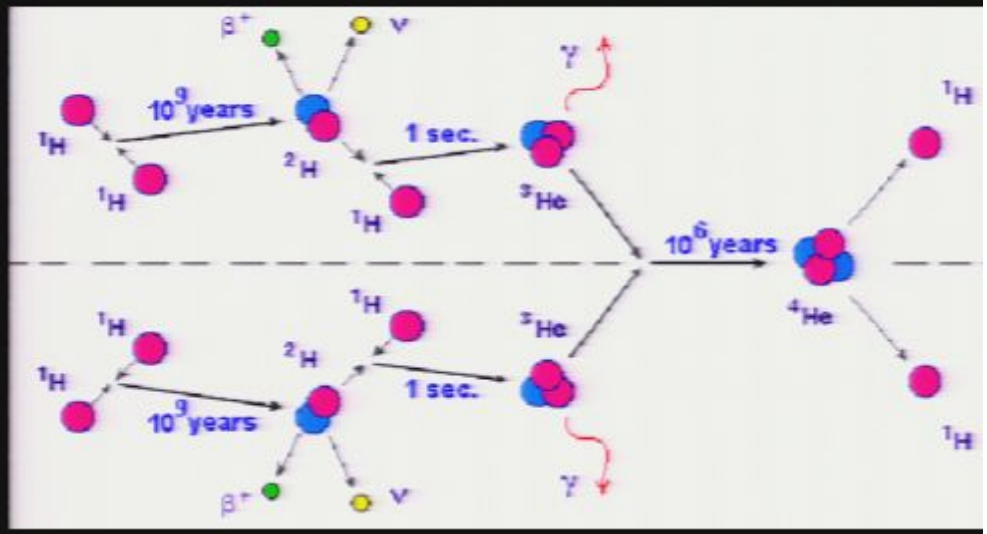
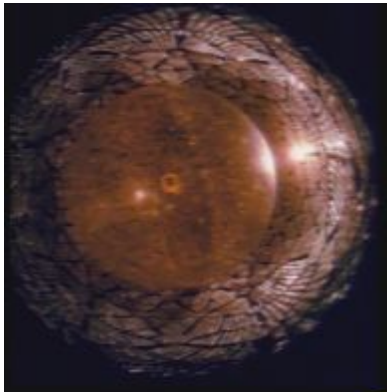


4He Is Formed

Neutron
Proton



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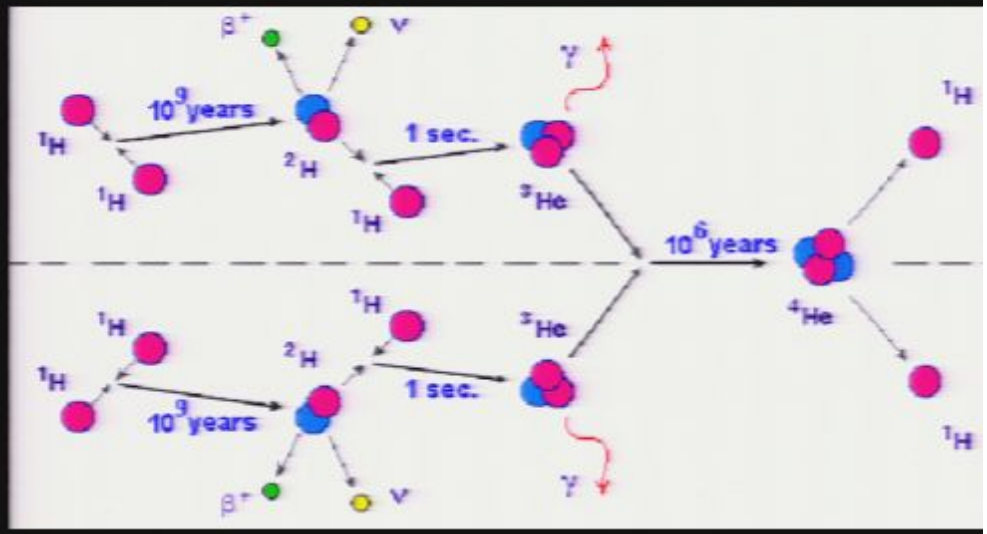
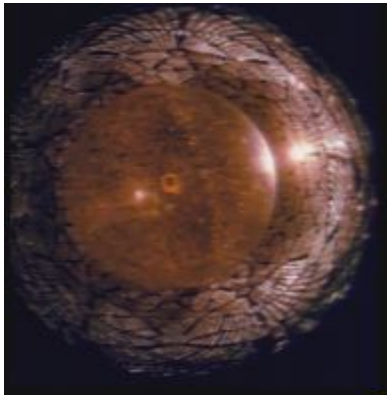
Proton





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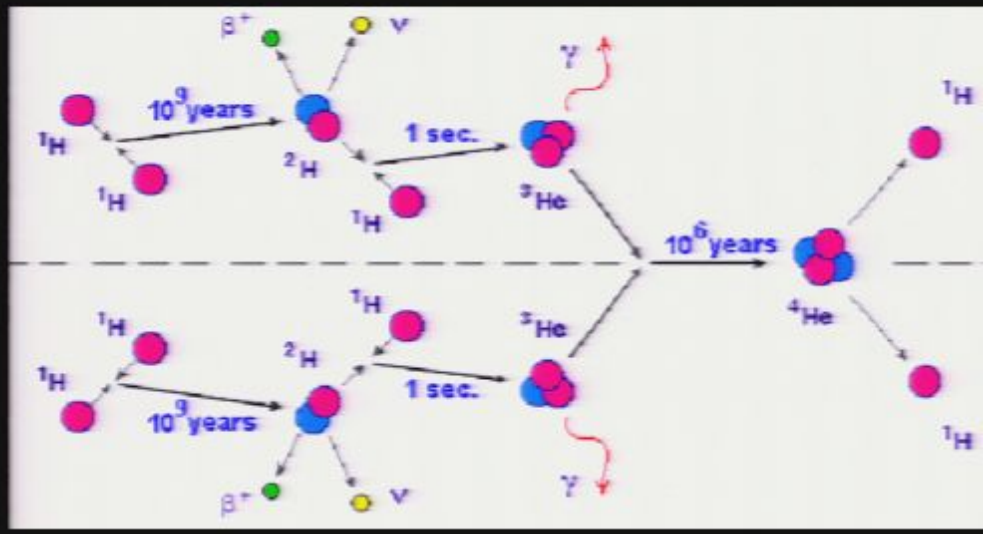

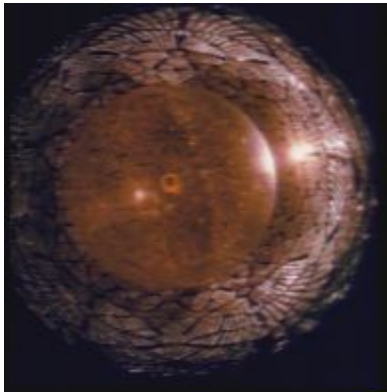

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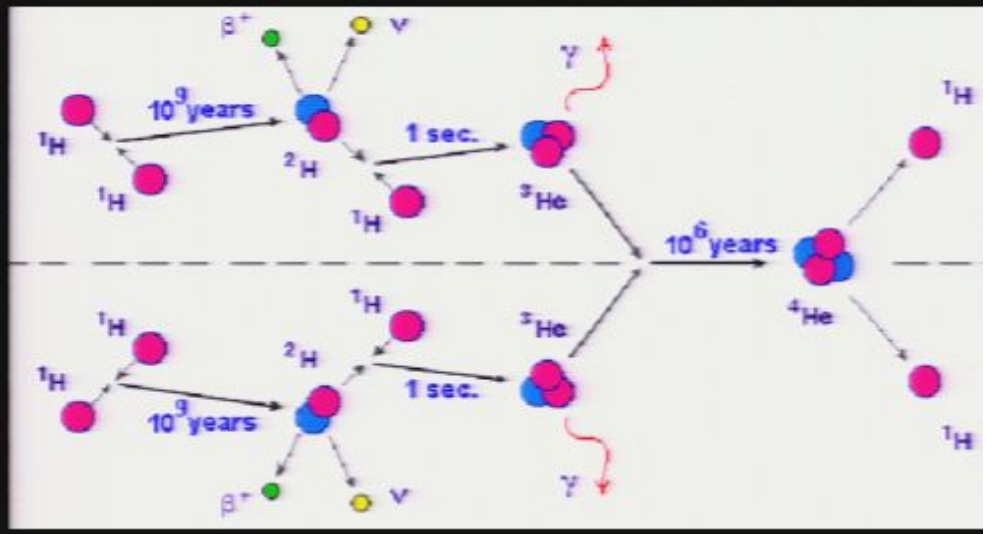
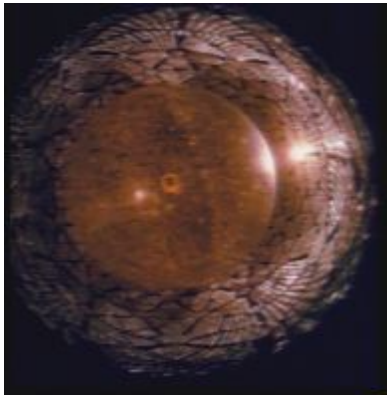
2 He Is Formed

Neutron
Proton





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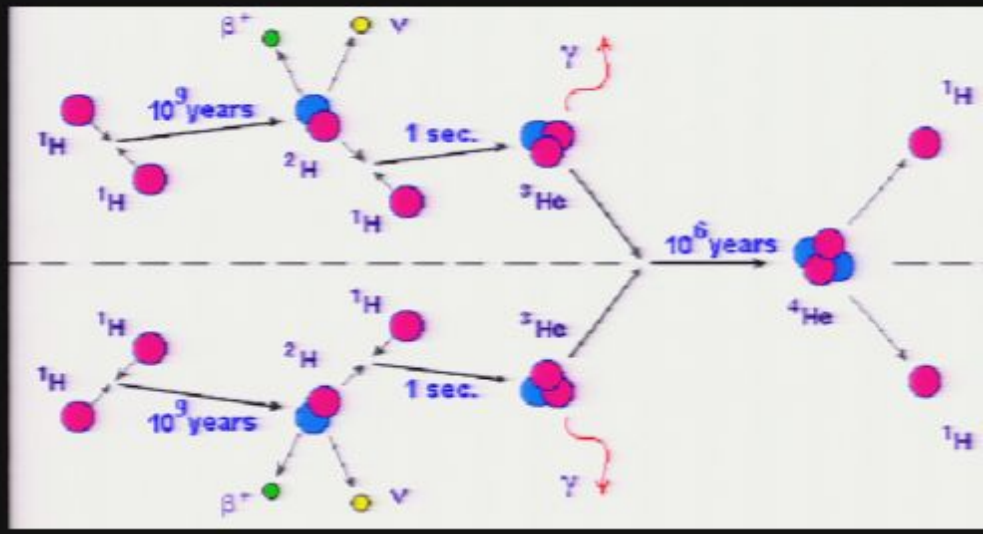

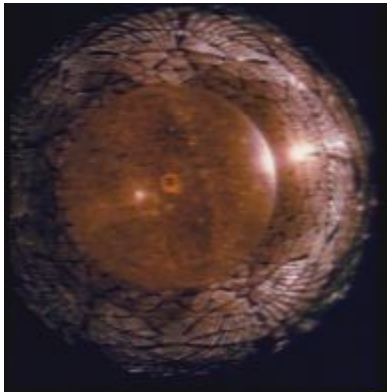

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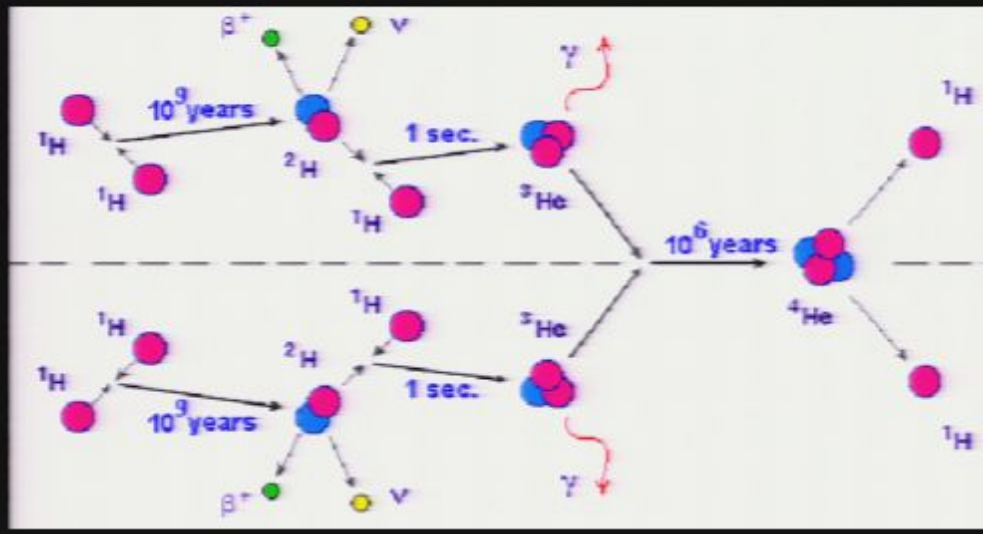
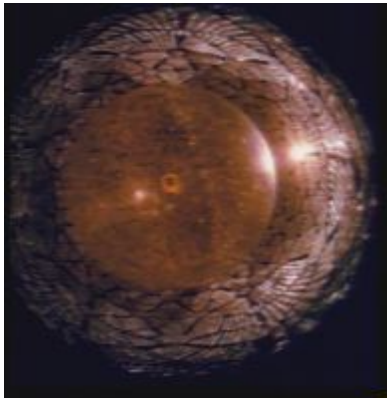
Neutron
Proton

Positron
Neutrino





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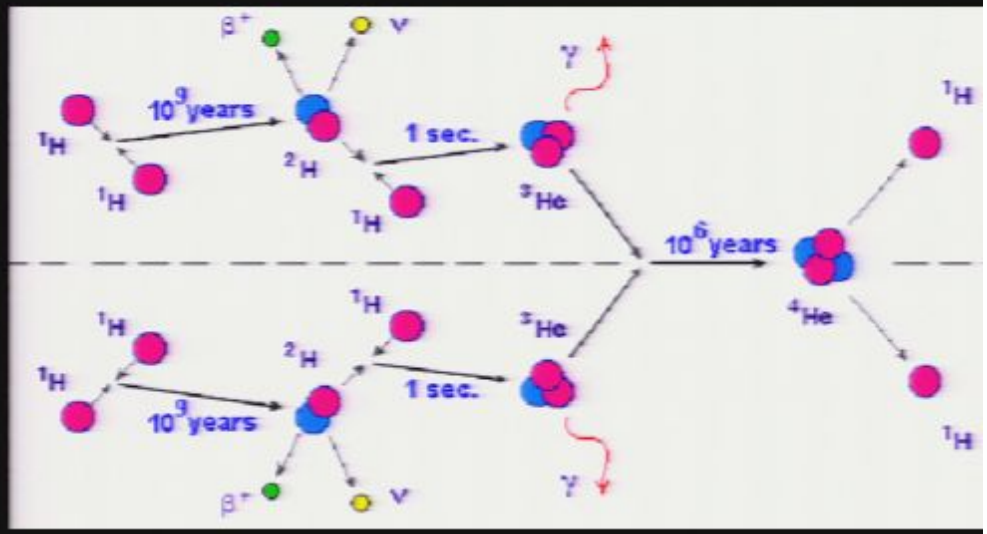

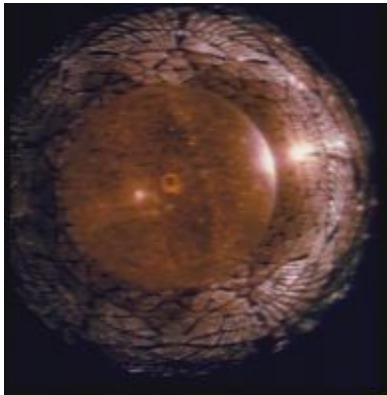

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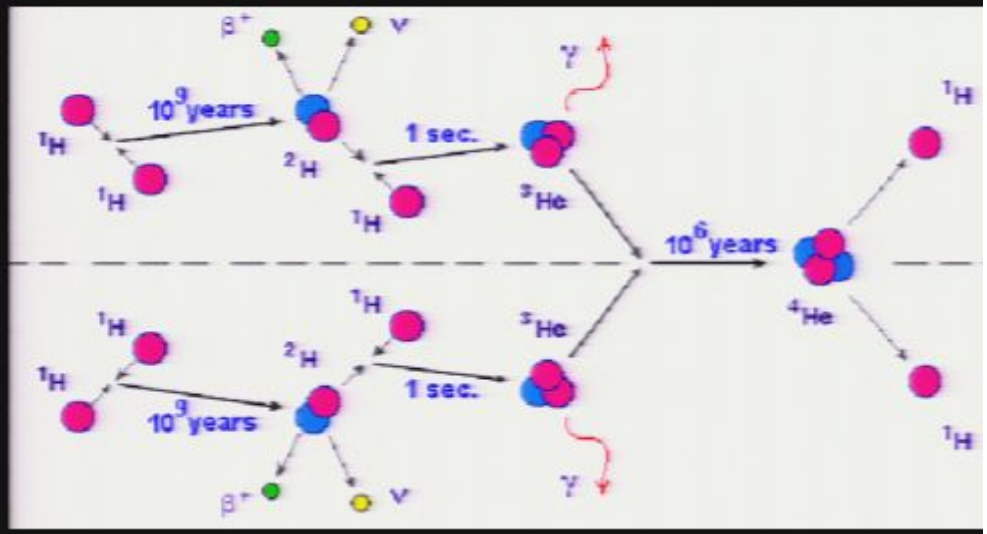
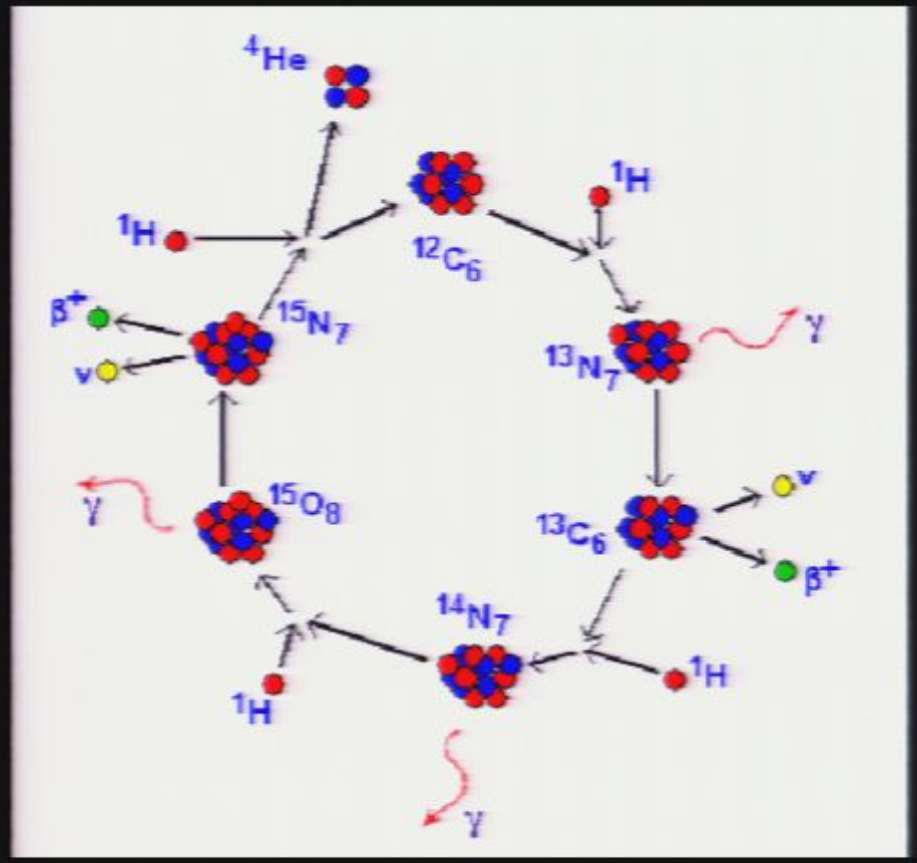
Proton



CNO Cycle

- *The higher the temperature, the more important the production of energy from the CNO.*
- *For stars less than 1 solar mass proton-proton cycle dominates.*



Carbon-Nitrogen-Oxygen (CNO) Cycle

● = Neutron ● = Proton

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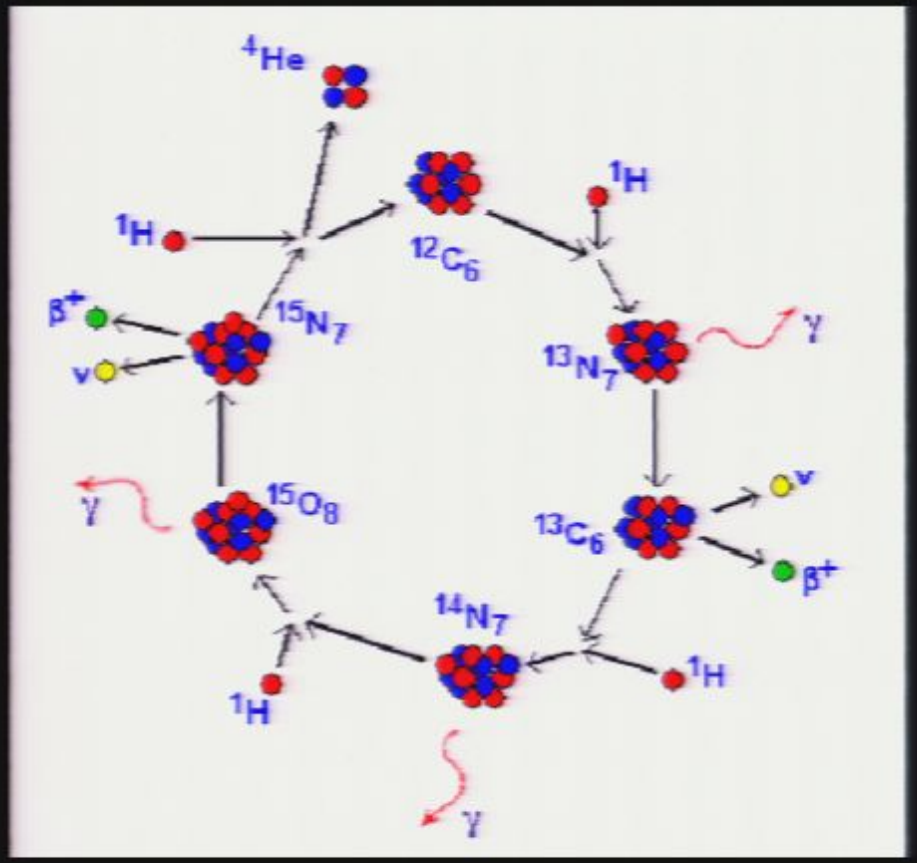

Stray 1H Absorbed Into 12C, Forming 13N

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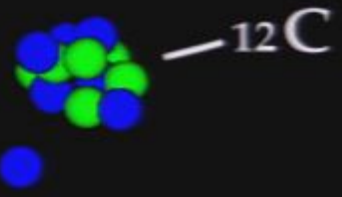

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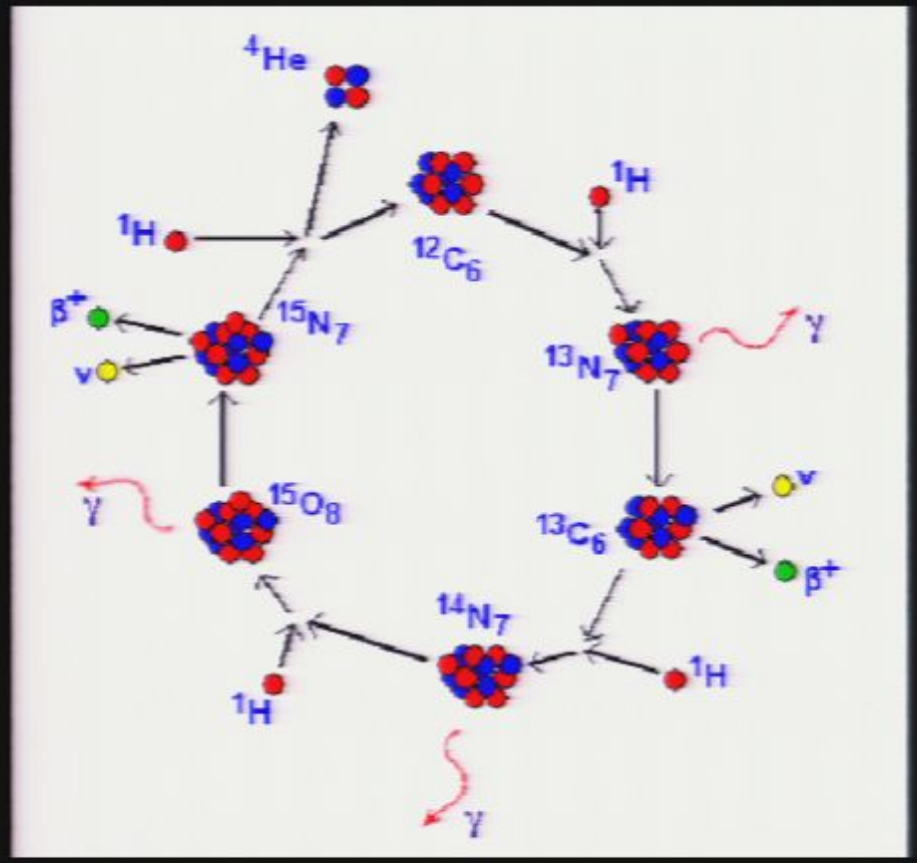
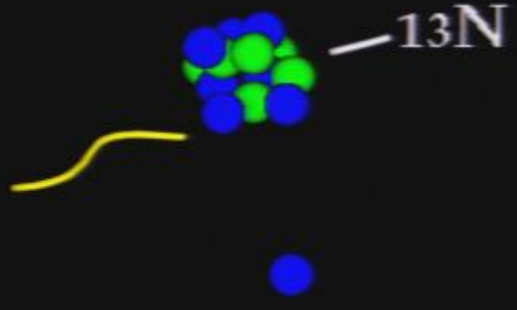


Gamma Ray Released

Neutron Proton



CNO Cycle

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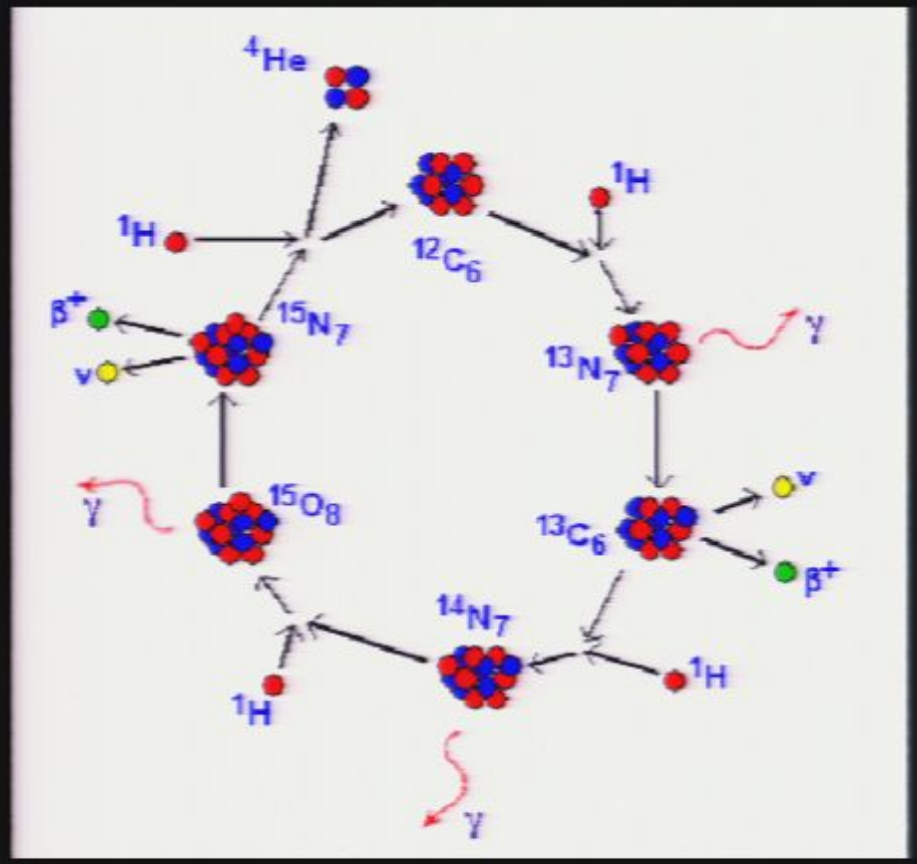
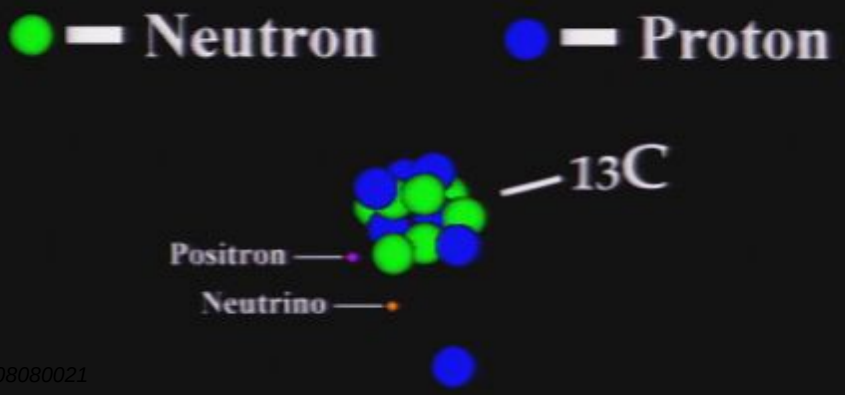


^{13}N ß$^+$ Decays Into ^{13}C



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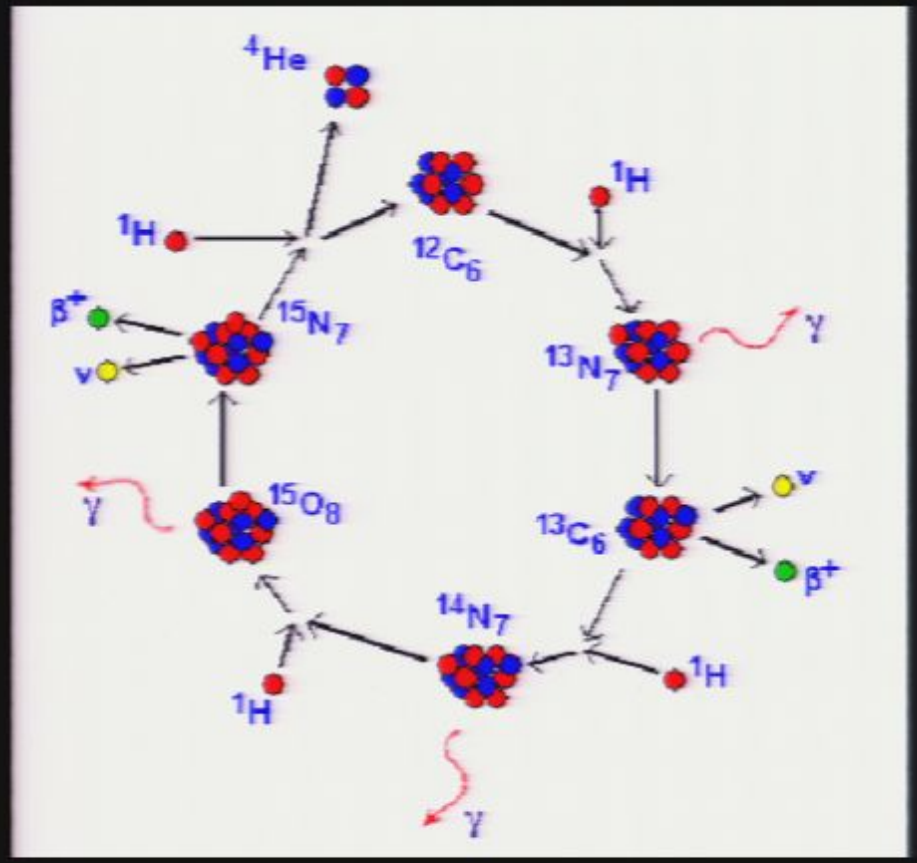
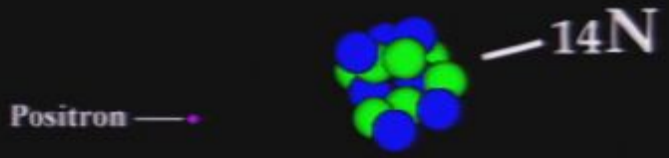


Stray 1H Absorbed Into 12C, Forming 14N

● = Neutron ● = Proton



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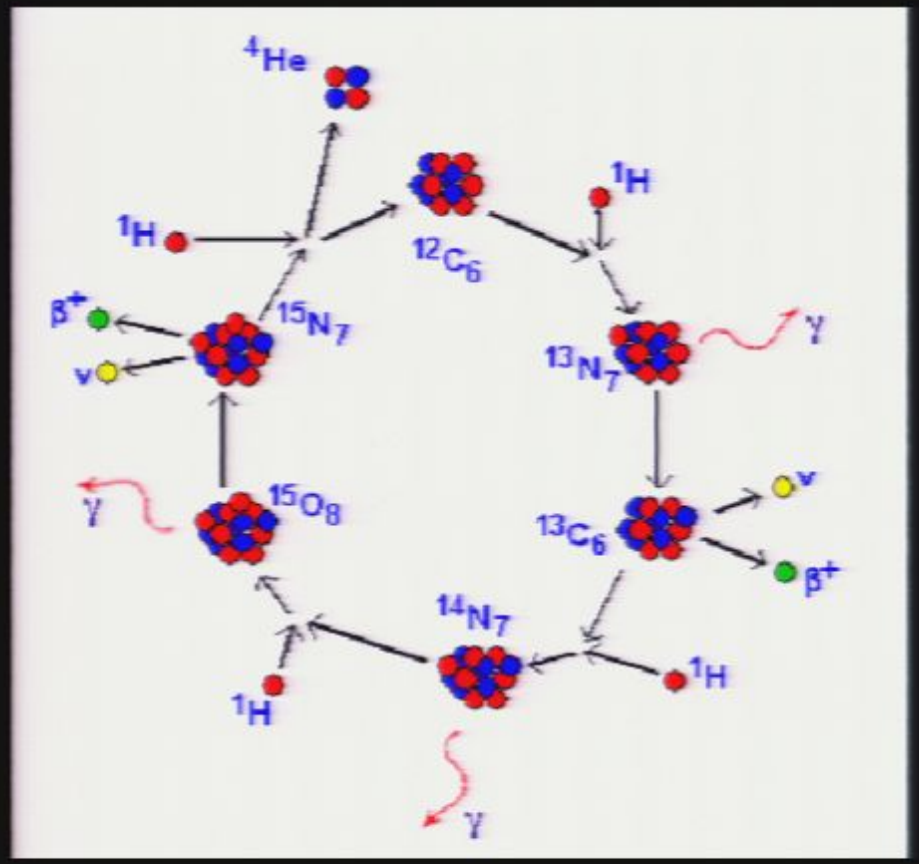
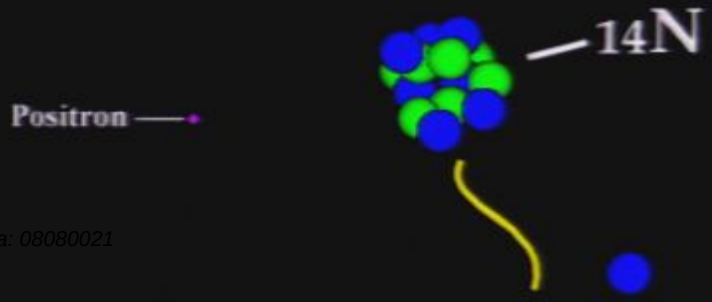


Gamma Ray Released

Neutron Proton



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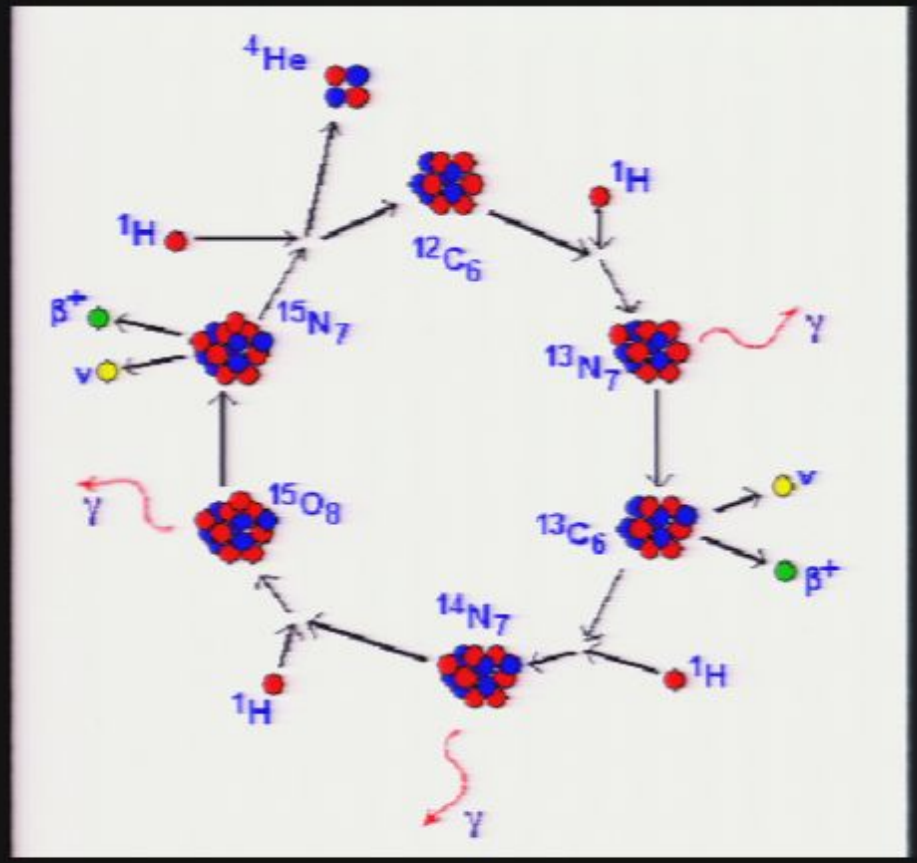
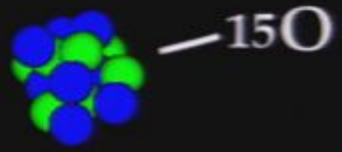


Stray 1H Absorbed Into 14N, Forming 15O

● = Neutron ● = Proton



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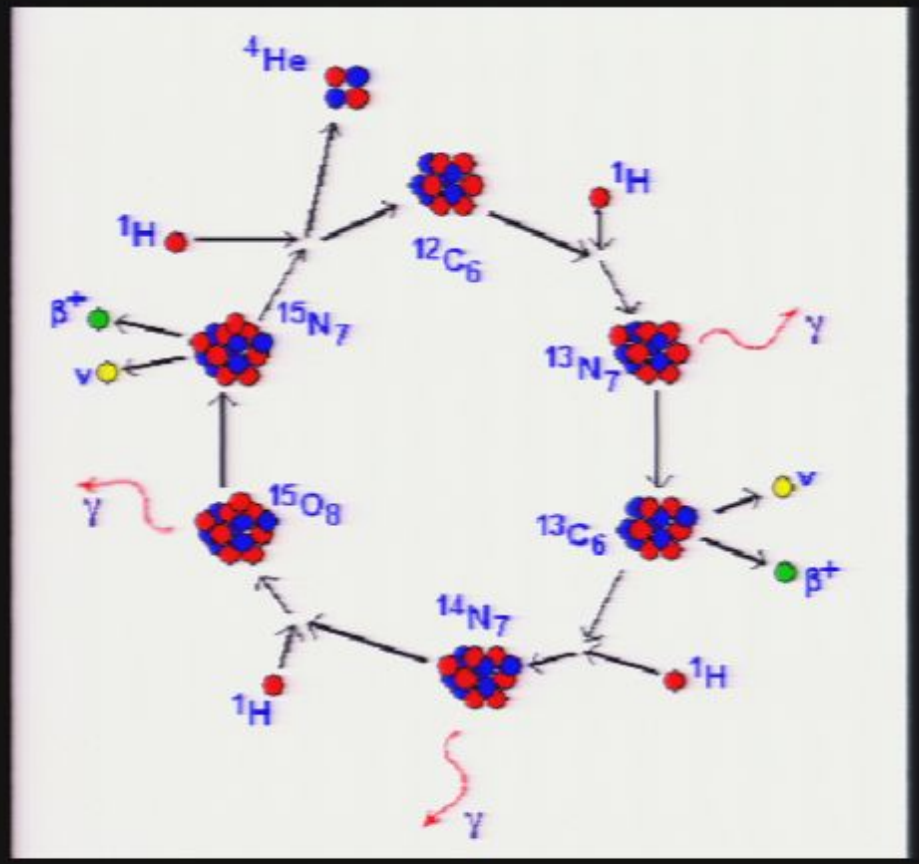
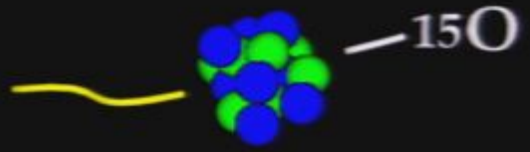


Gamma Ray Released

Neutron Proton



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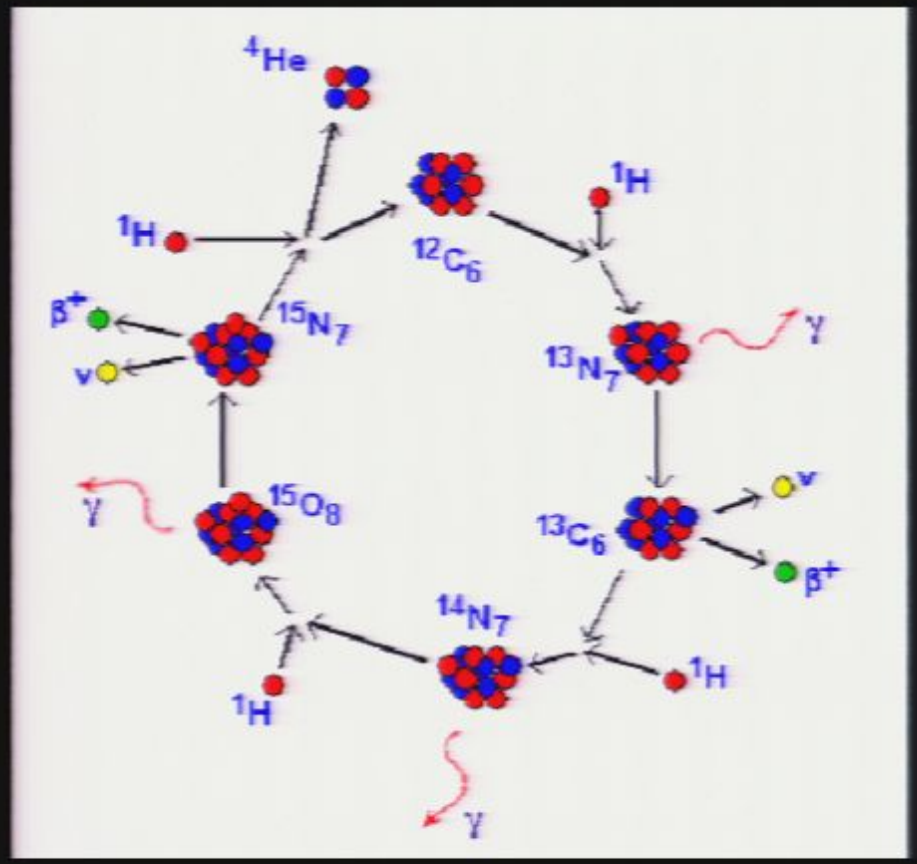
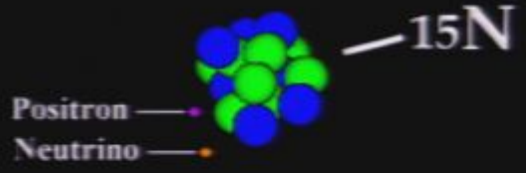


^{15}O ß$^+$ Decays Into ^{15}N

Neutron — Proton



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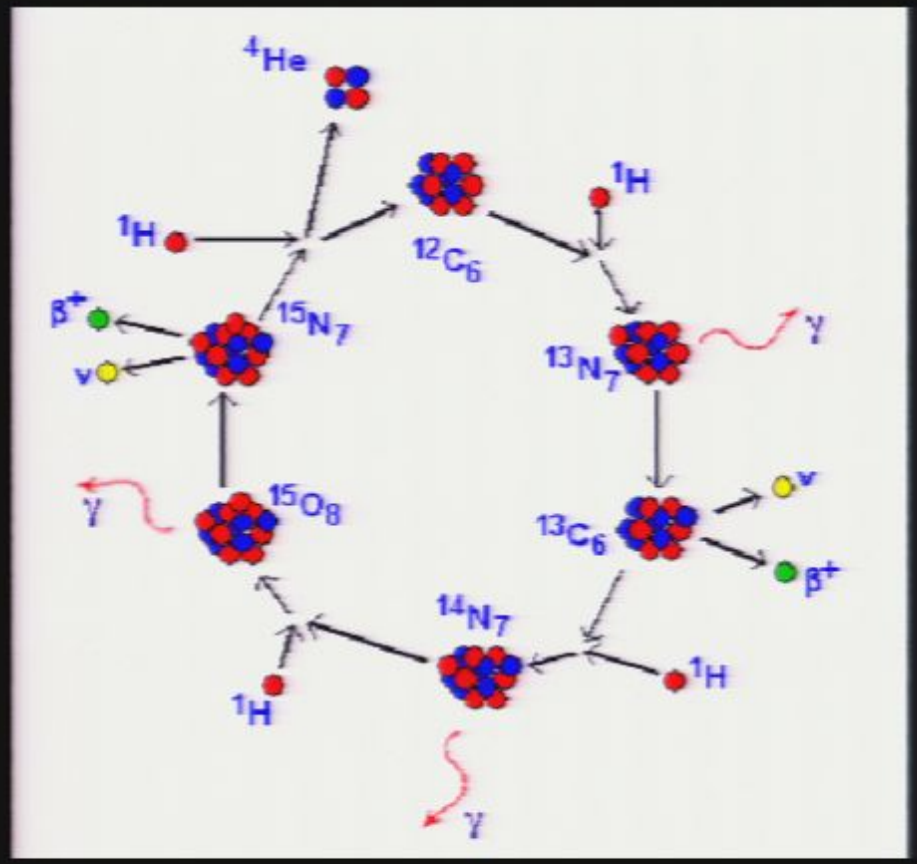
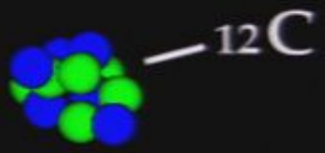


Alpha Particle Released, and 12C Remains

● = Neutron ● = Proton



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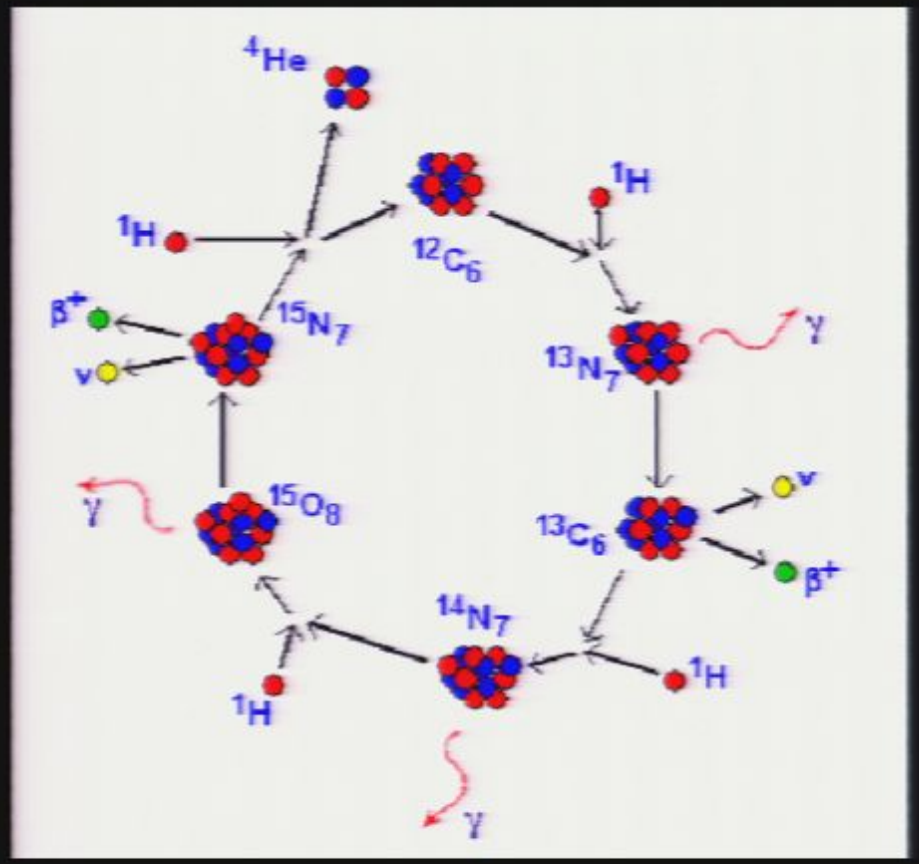
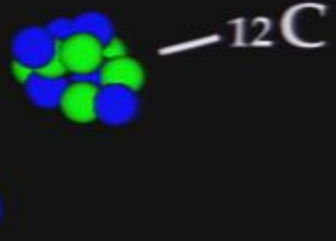


Carbon-Nitrogen-Oxygen (CNO) Cycle

● = Neutron ● = Proton



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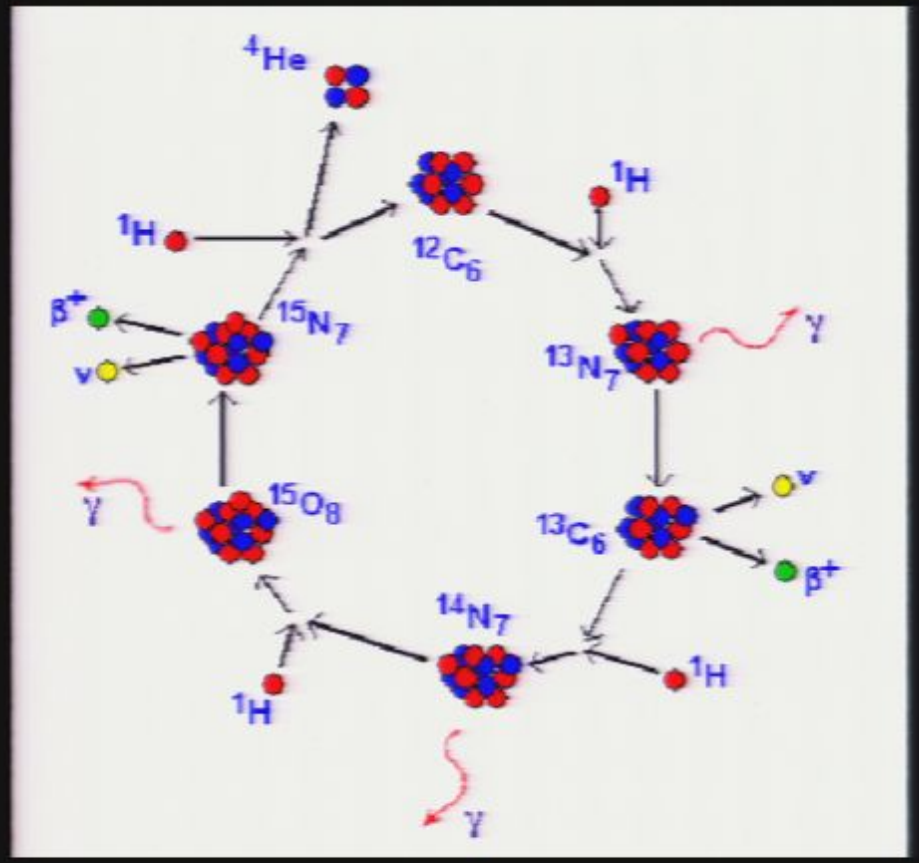
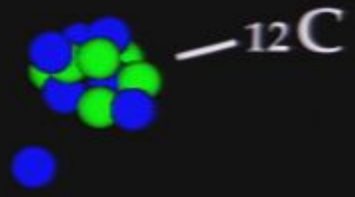


Stray 1H Absorbed Into 12C, Forming 13N

● = Neutron ● = Proton



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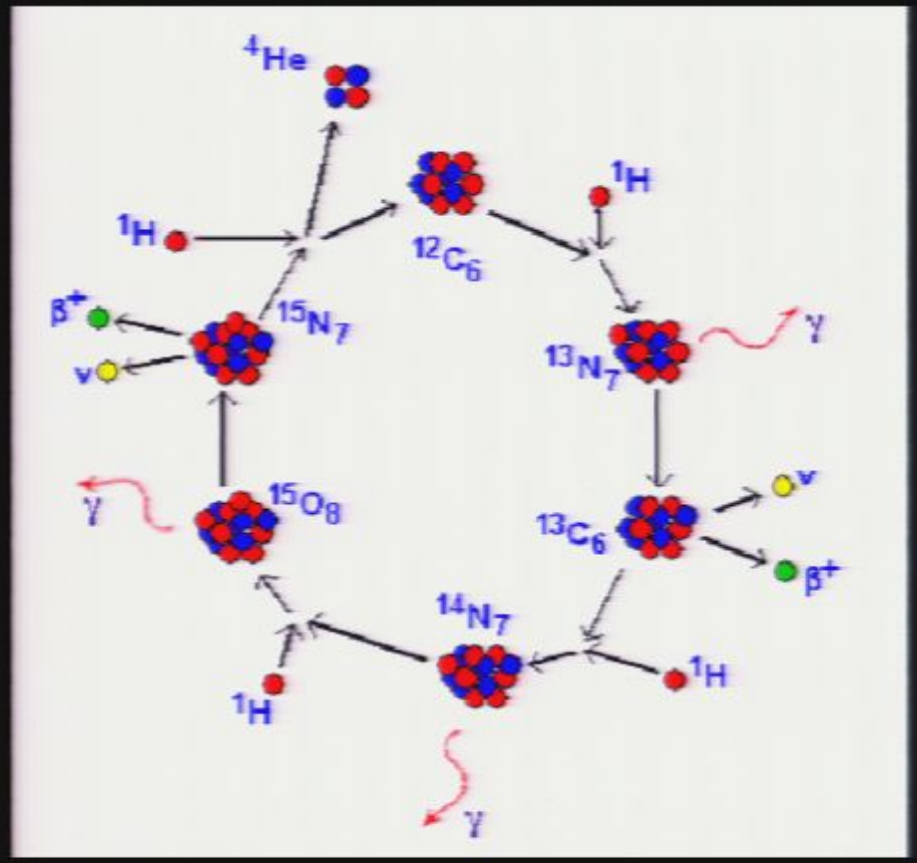
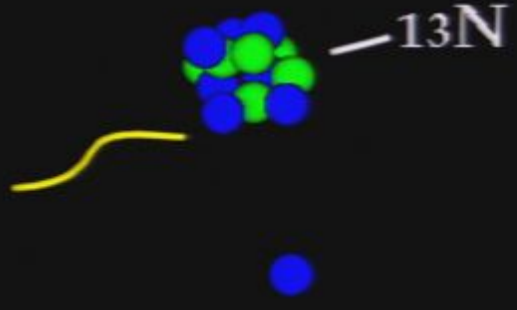


Gamma Ray Released

Neutron Proton



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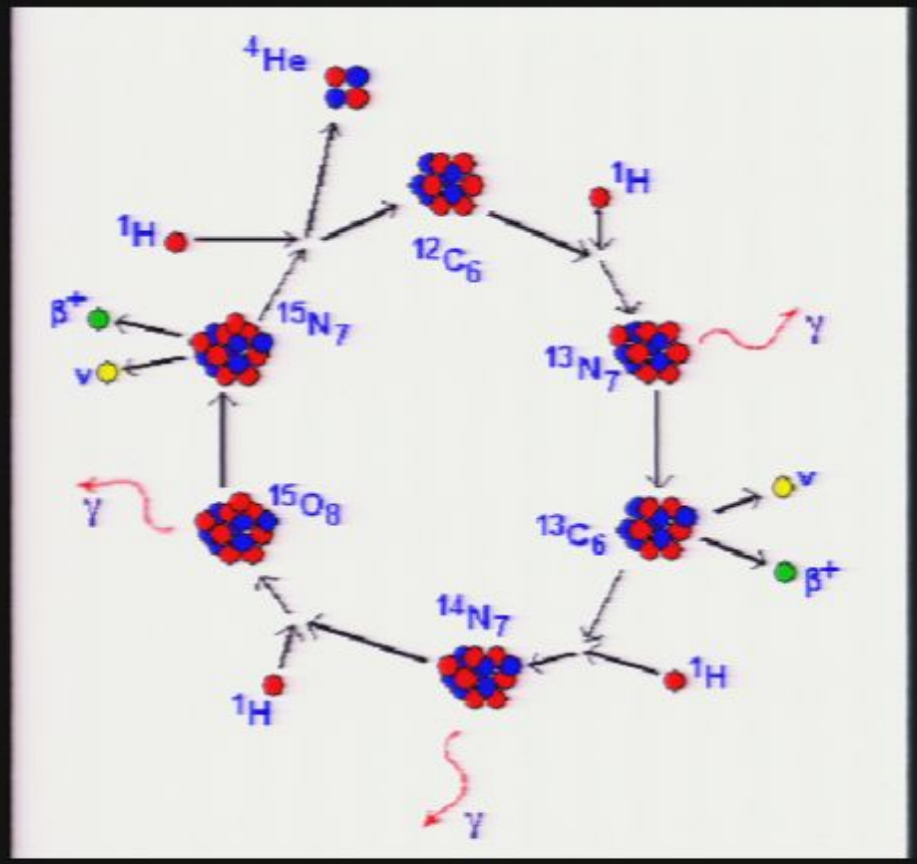
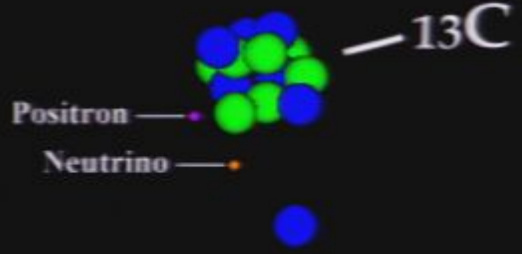


13N ß+ Decays Into 13C

Neutron — Proton



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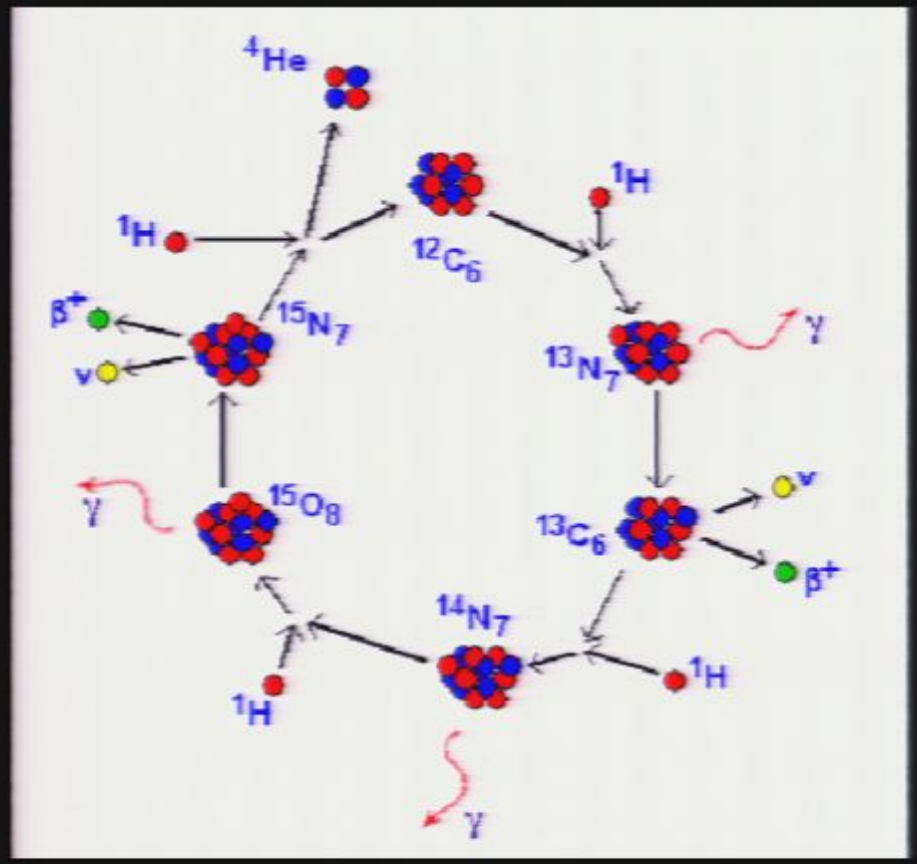
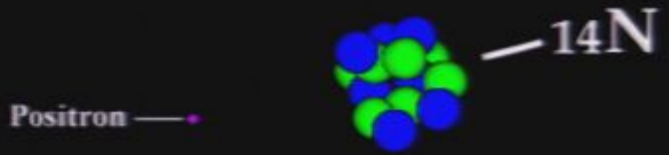


Stray 1H Absorbed Into 12C, Forming 14N

● = Neutron ● = Proton



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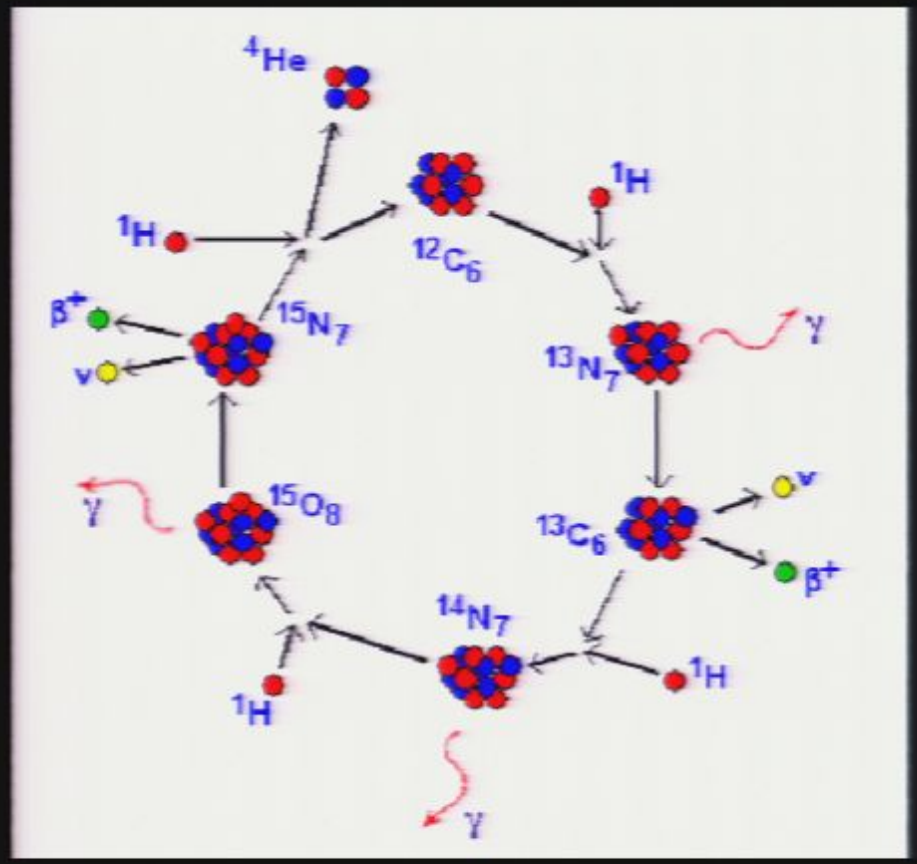
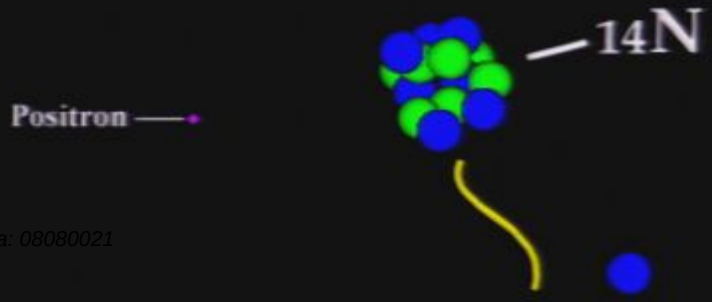


Gamma Ray Released

Neutron Proton



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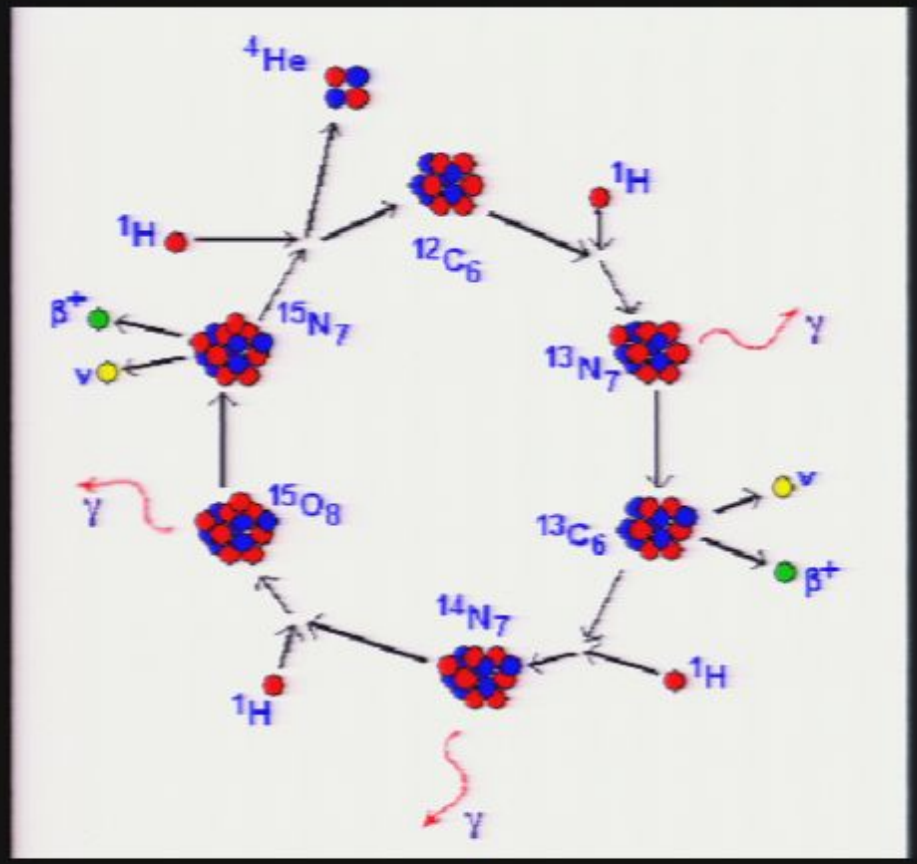

Stray 1H Absorbed Into 14N, Forming 15O

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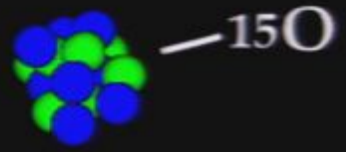

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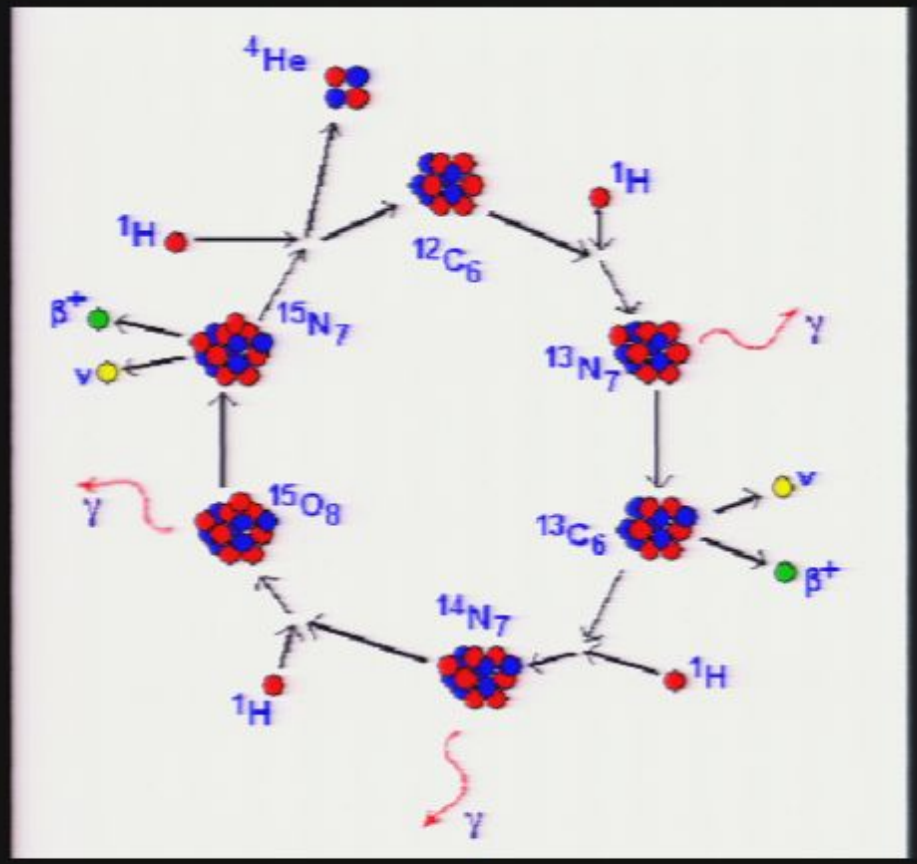

Gamma Ray Released

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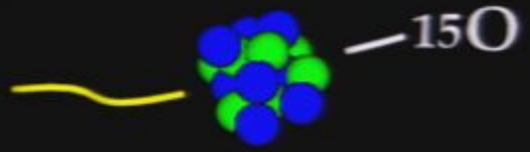

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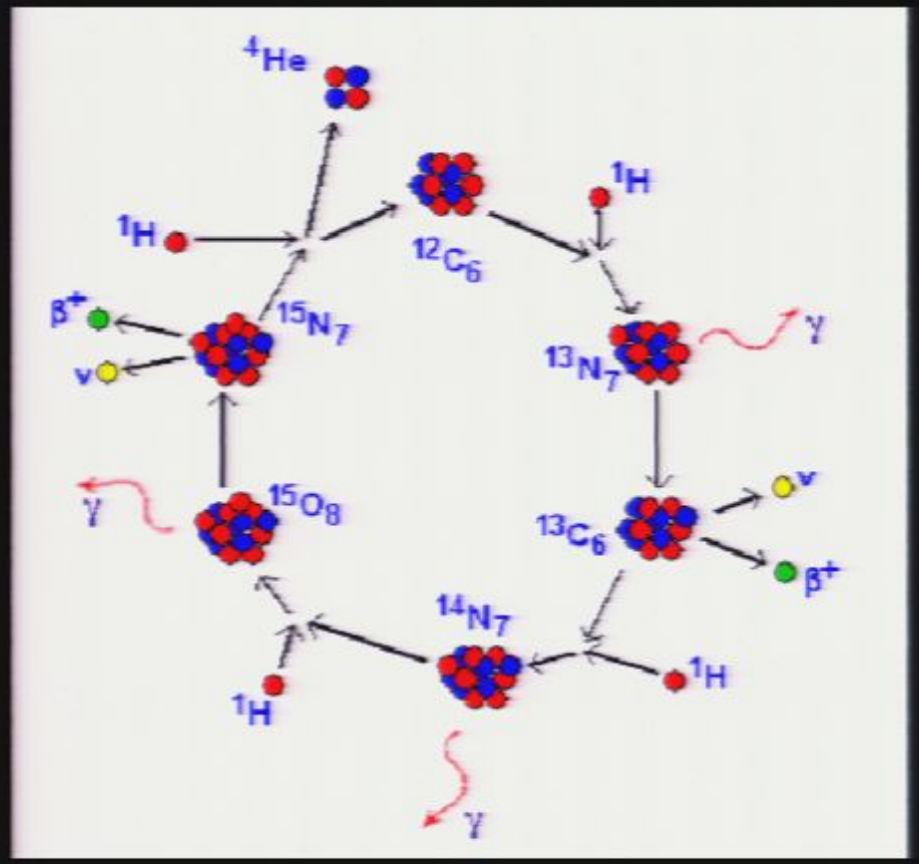
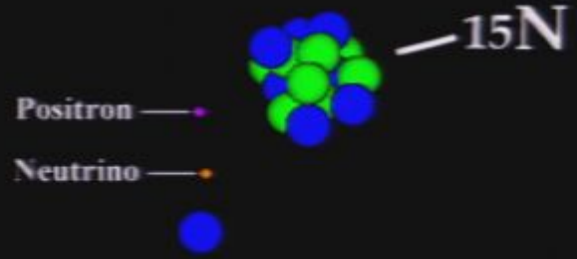


15O ß+ Decays Into 15N

Neutron — Proton



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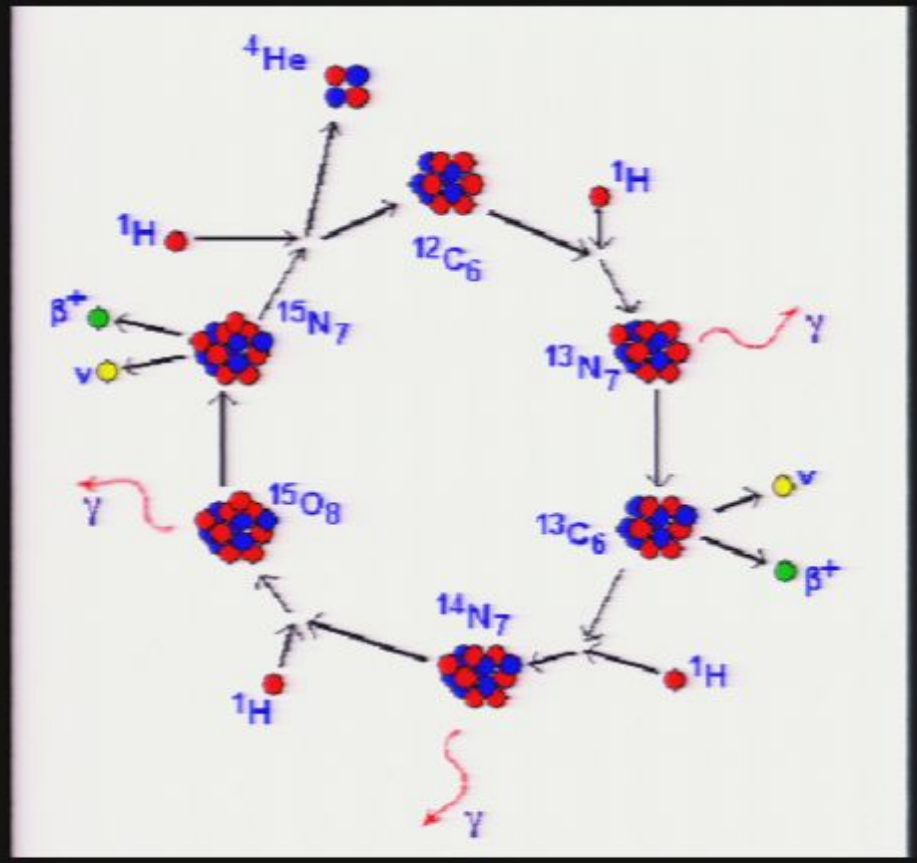
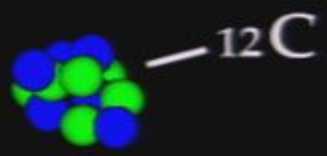


Alpha Particle Released, and 12C Remains

● = Neutron ● = Proton



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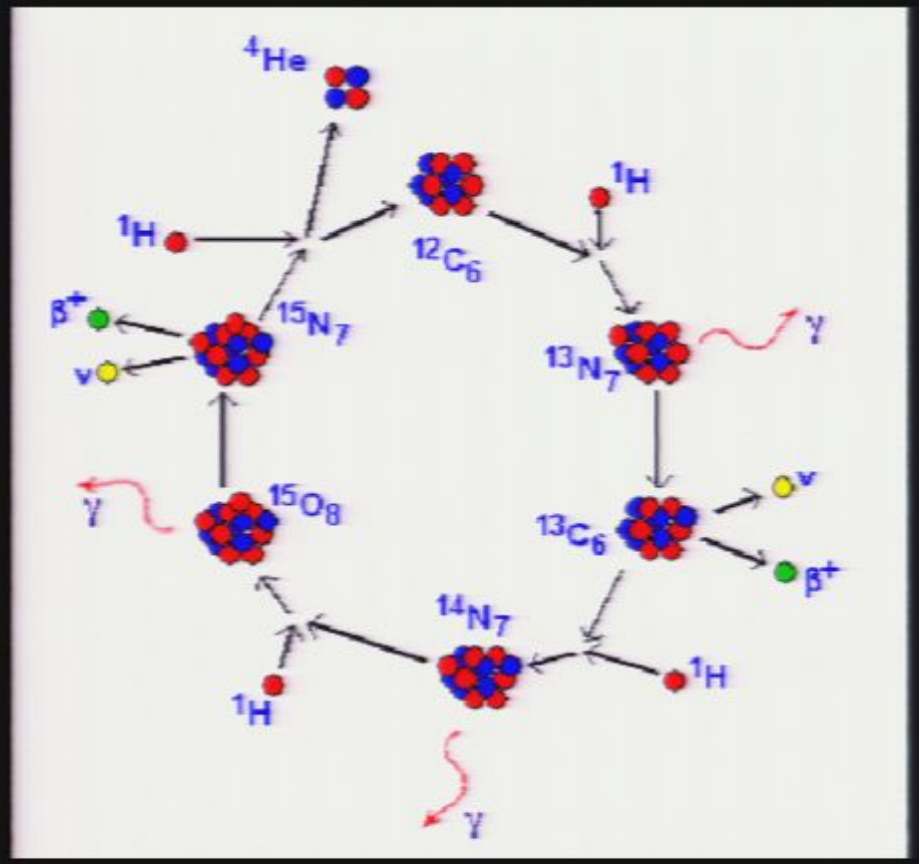

Carbon-Nitrogen-Oxygen (CNO) Cycle

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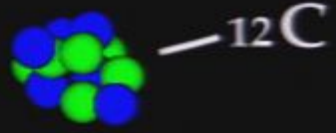

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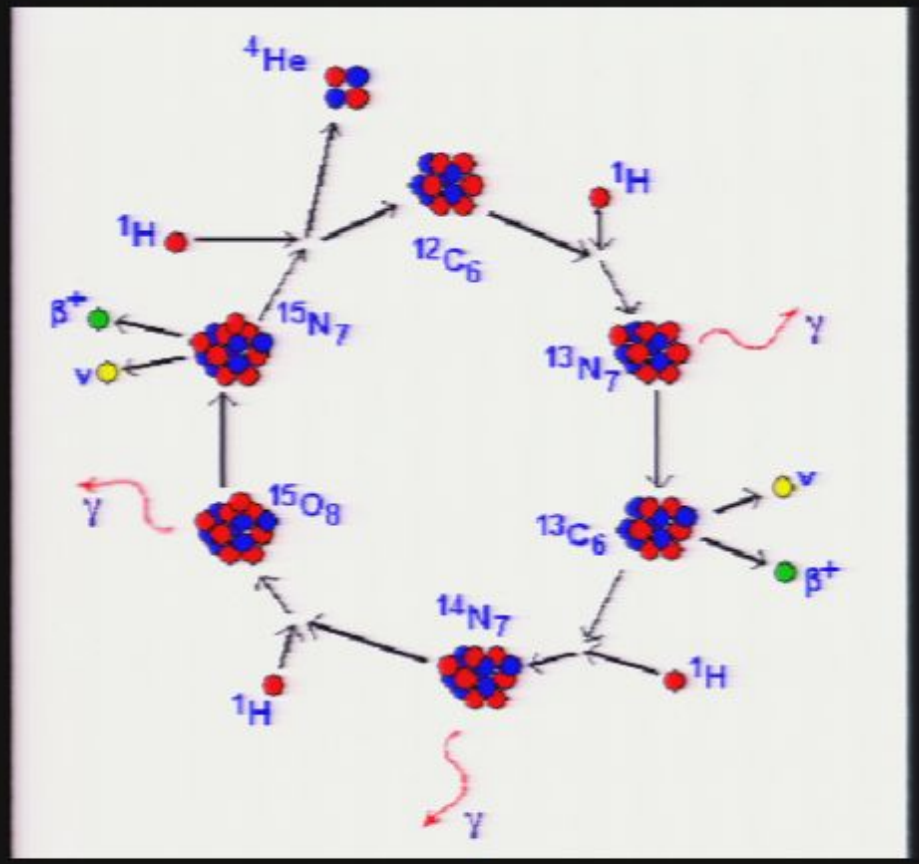

Stray 1H Absorbed Into 12C, Forming 13N

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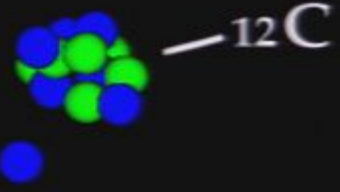

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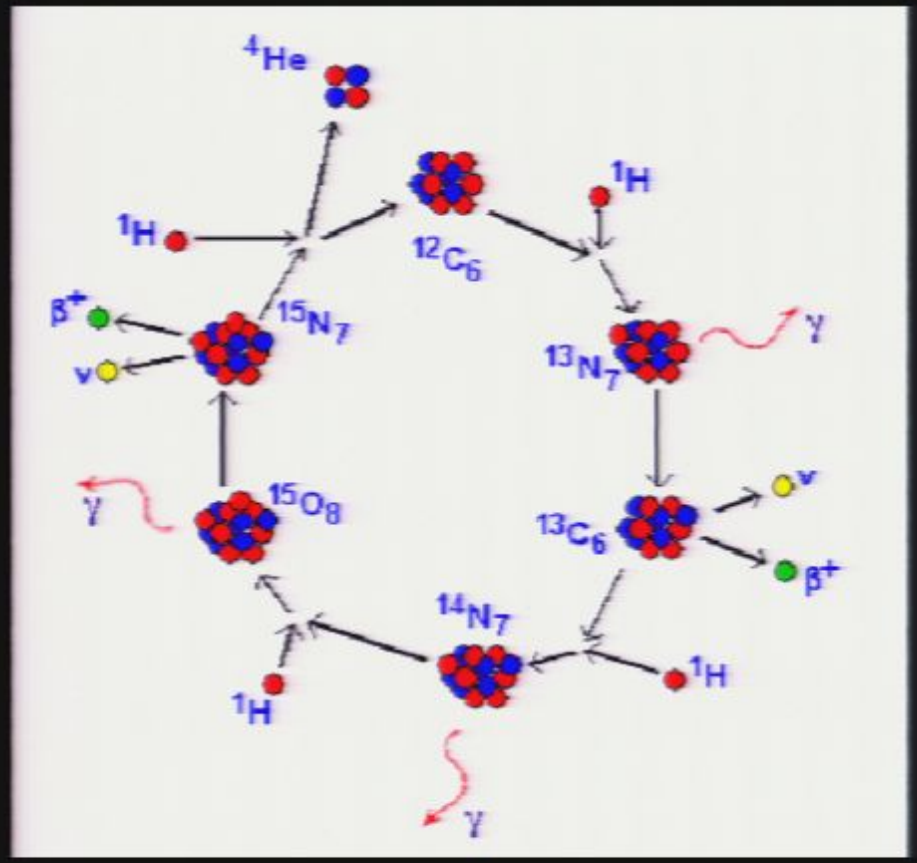
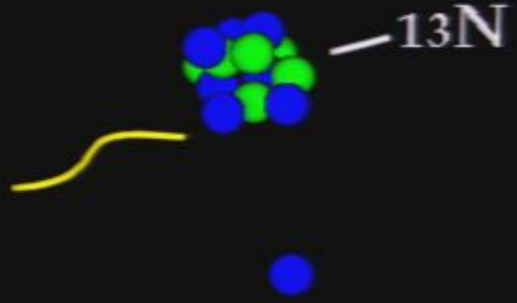


Gamma Ray Released

Neutron Proton



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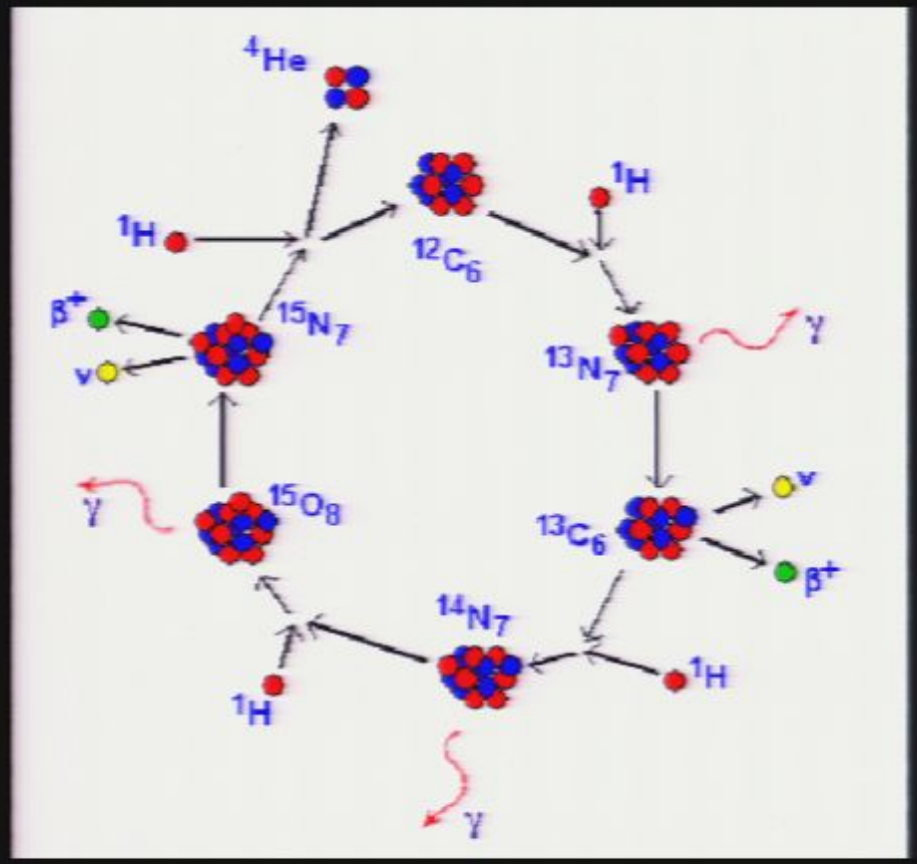
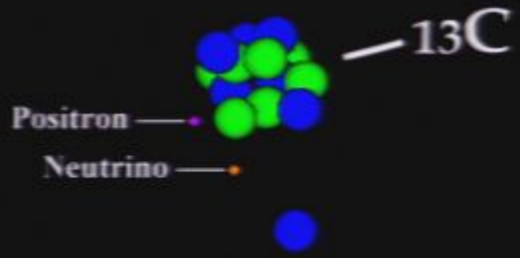


^{13}N ß$^+$ Decays Into ^{13}C

Neutron — Proton



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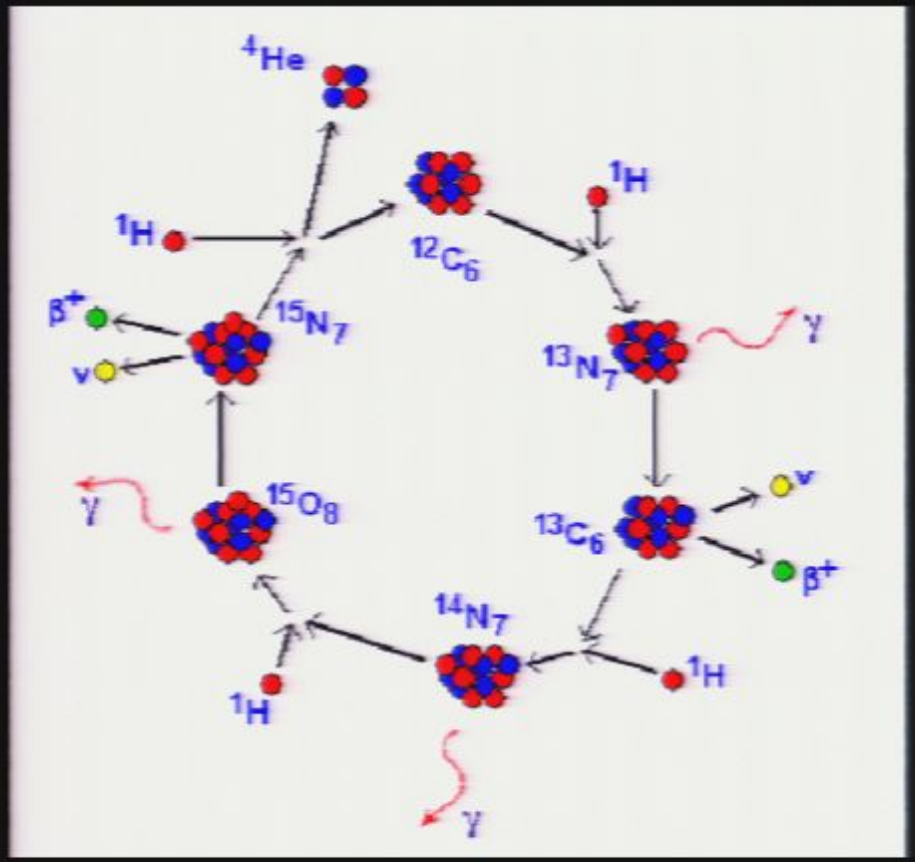

Stray 1H Absorbed Into 12C, Forming 14N

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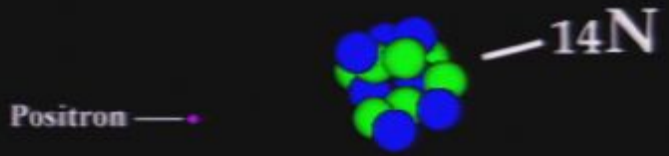

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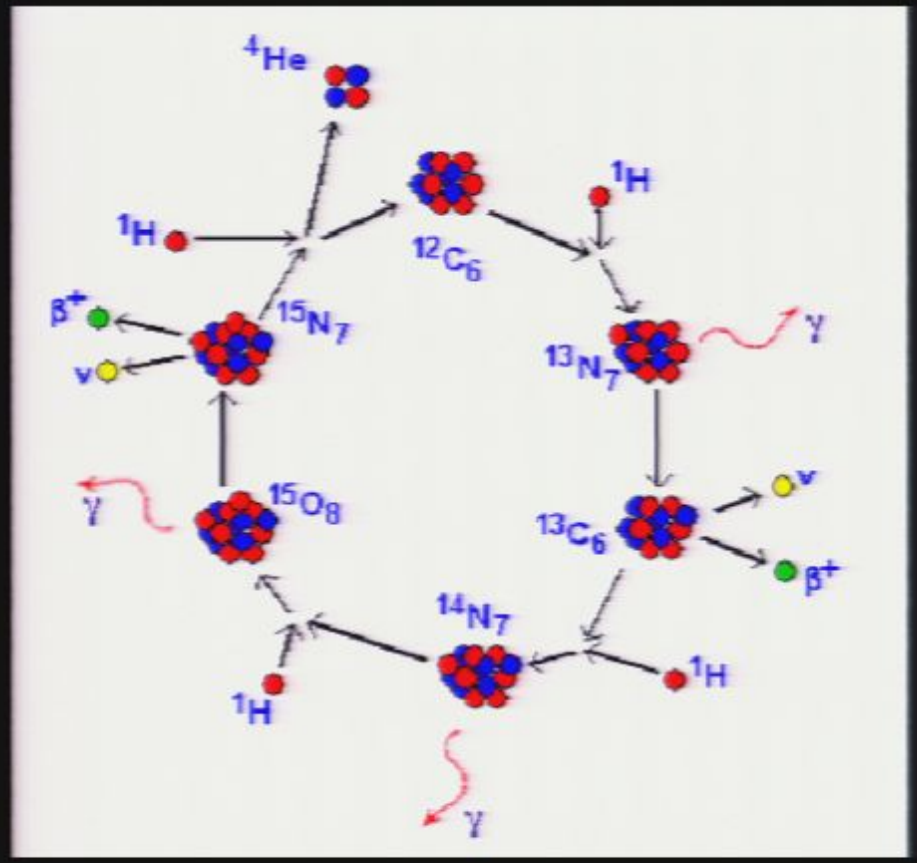
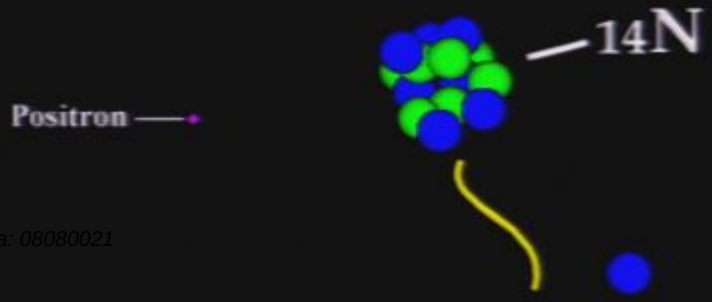


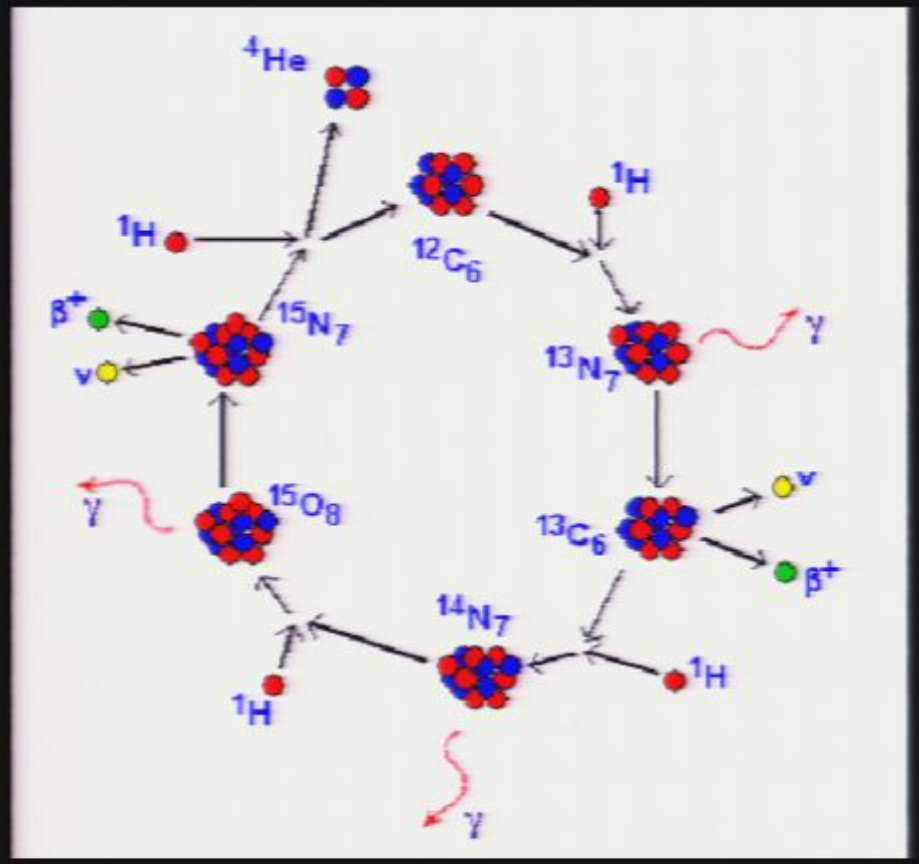
Gamma Ray Released

Neutron Proton



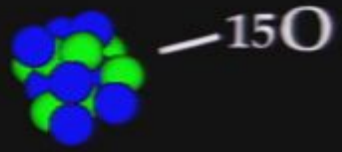
CNO Cycle

- *The higher the temperature, the more important the production of energy from the CNO.*
- *For stars less than 1 solar mass proton-proton cycle dominates.*



Stray 1H Absorbed Into 14N, Forming 15O

● = Neutron ● = Proton



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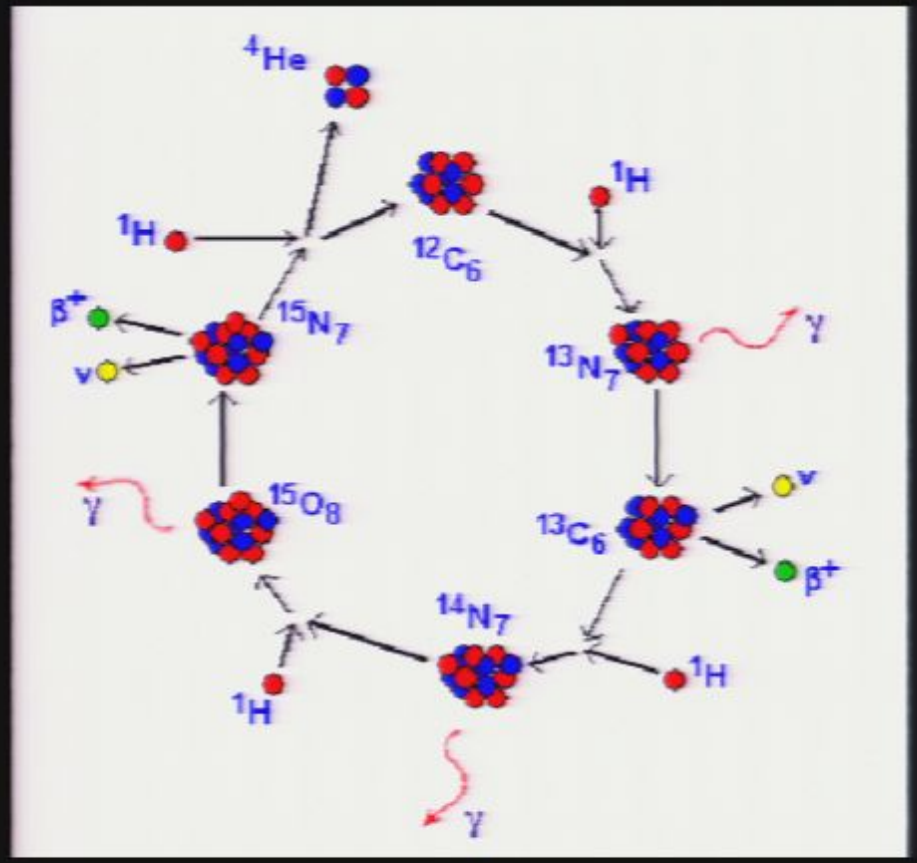

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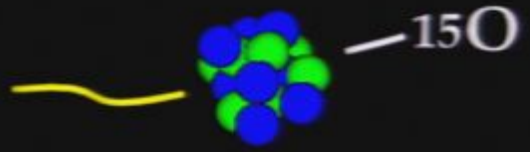
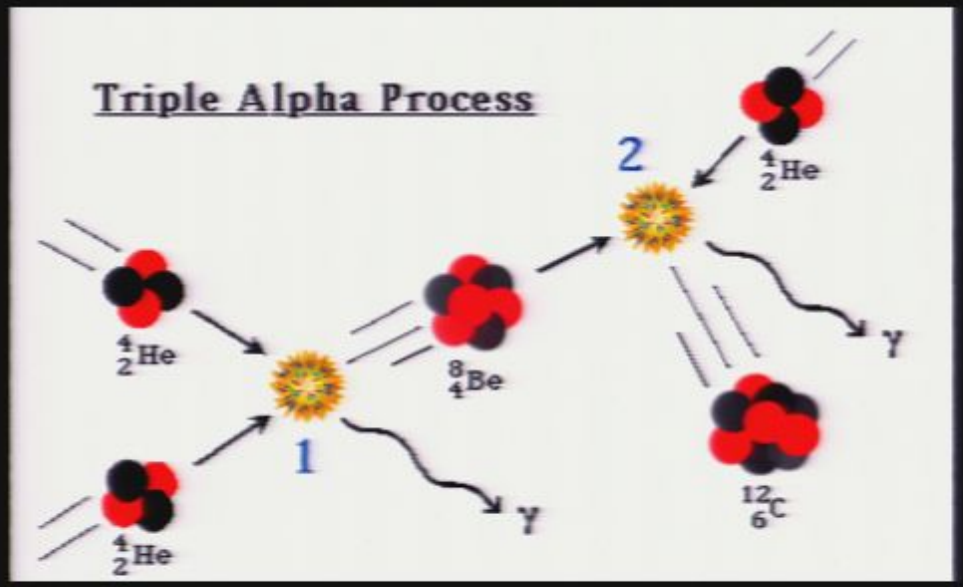


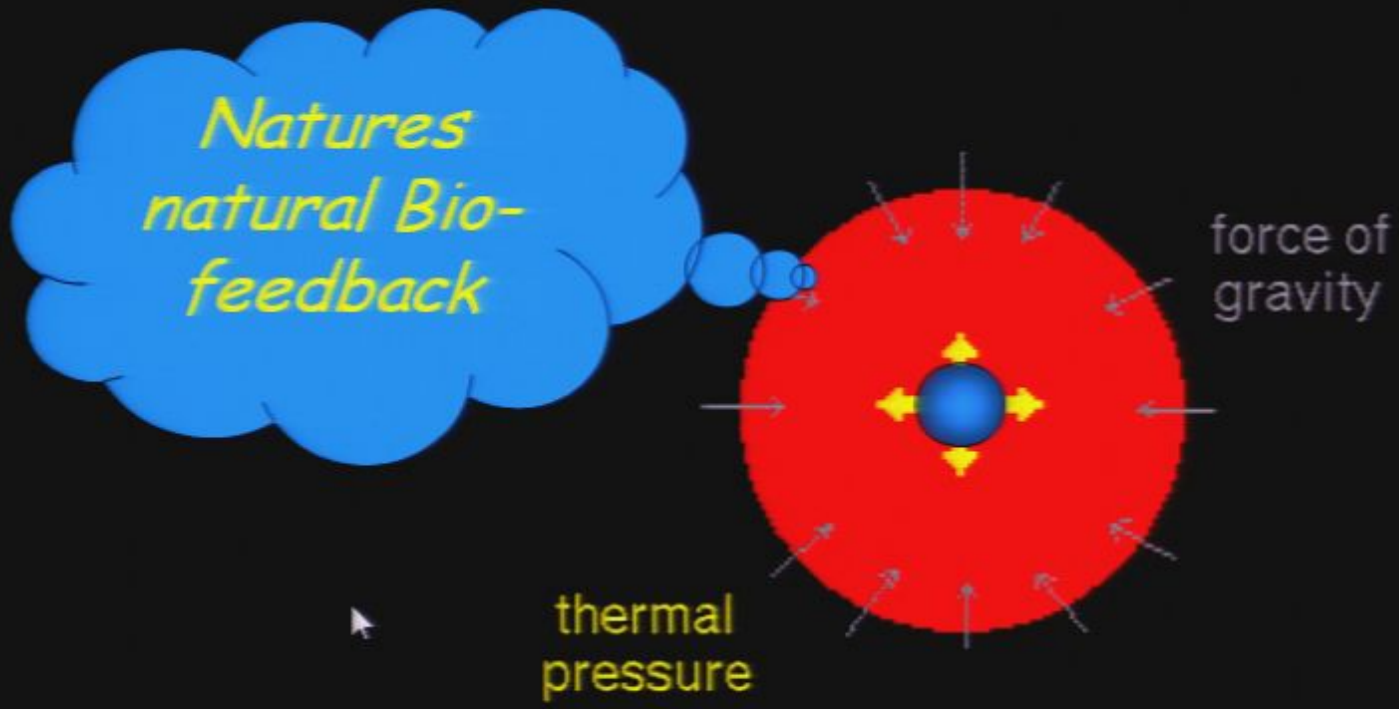
Beyond Helium

As Hydrogen is exhausted in the core of the star, Helium nuclei merge to create Beryllium with again fuses with another Helium nucleus to give Carbon and then to Oxygen then to Silicon until we finally end up with Iron.



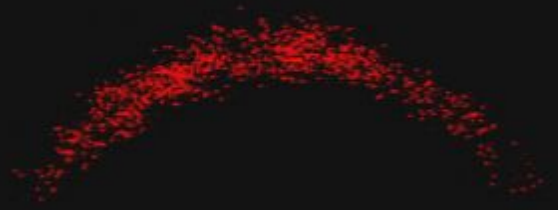
The Death of Stars

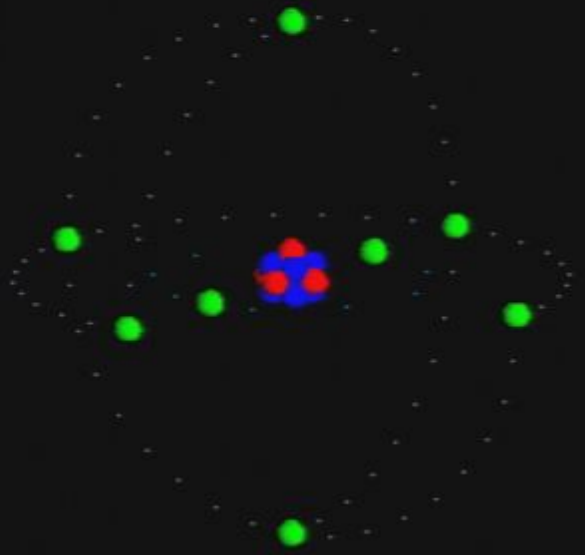
Pressure Balance in a Star



Thermal Pressure = Force of Gravity

Model of an Atom





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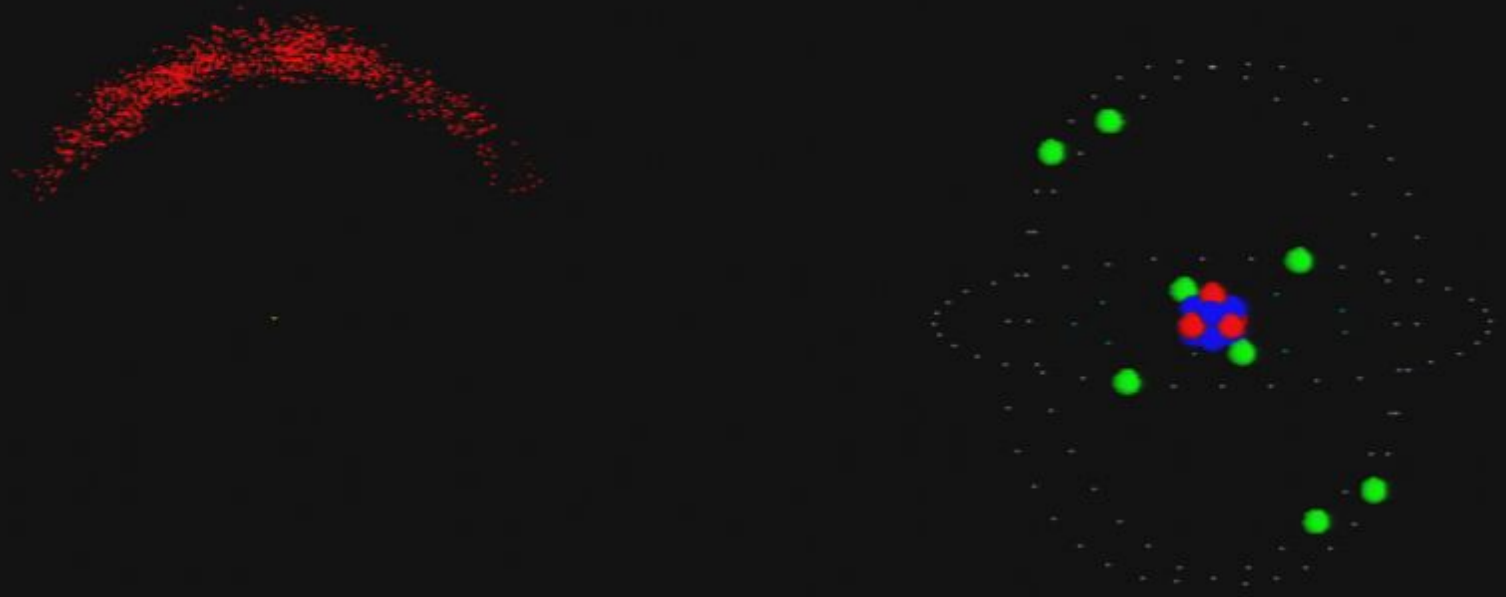

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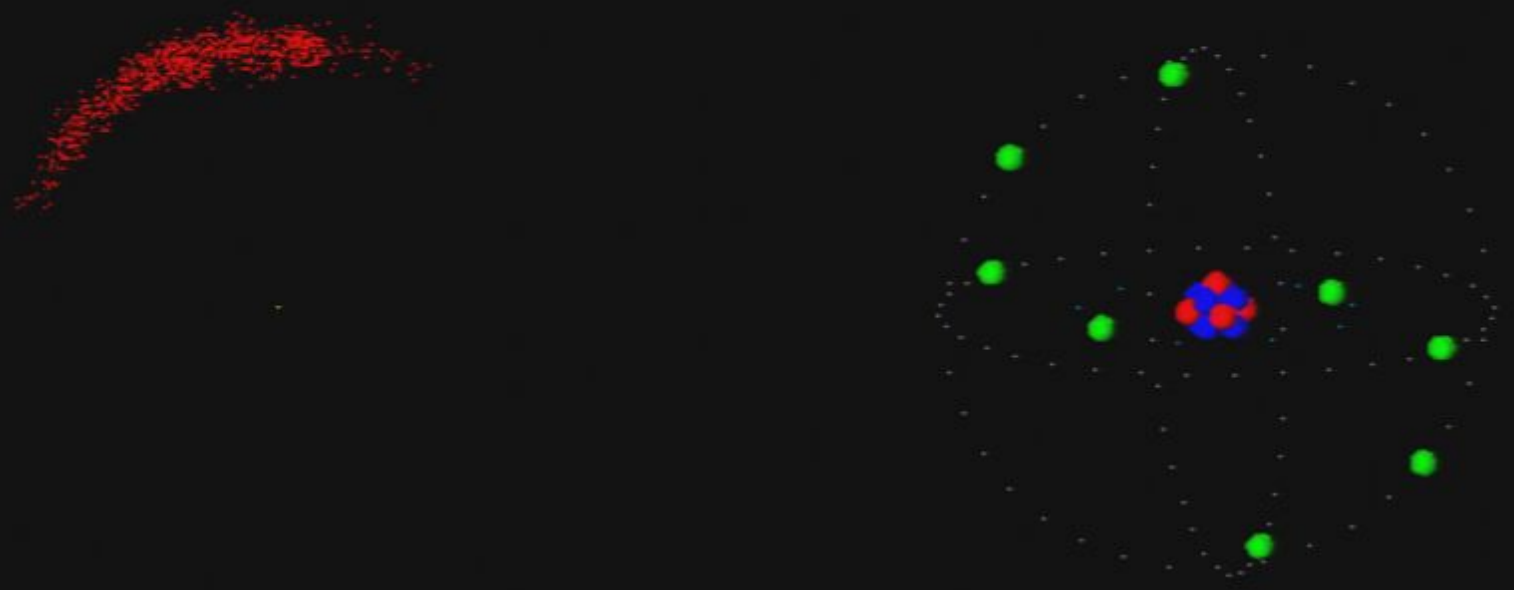

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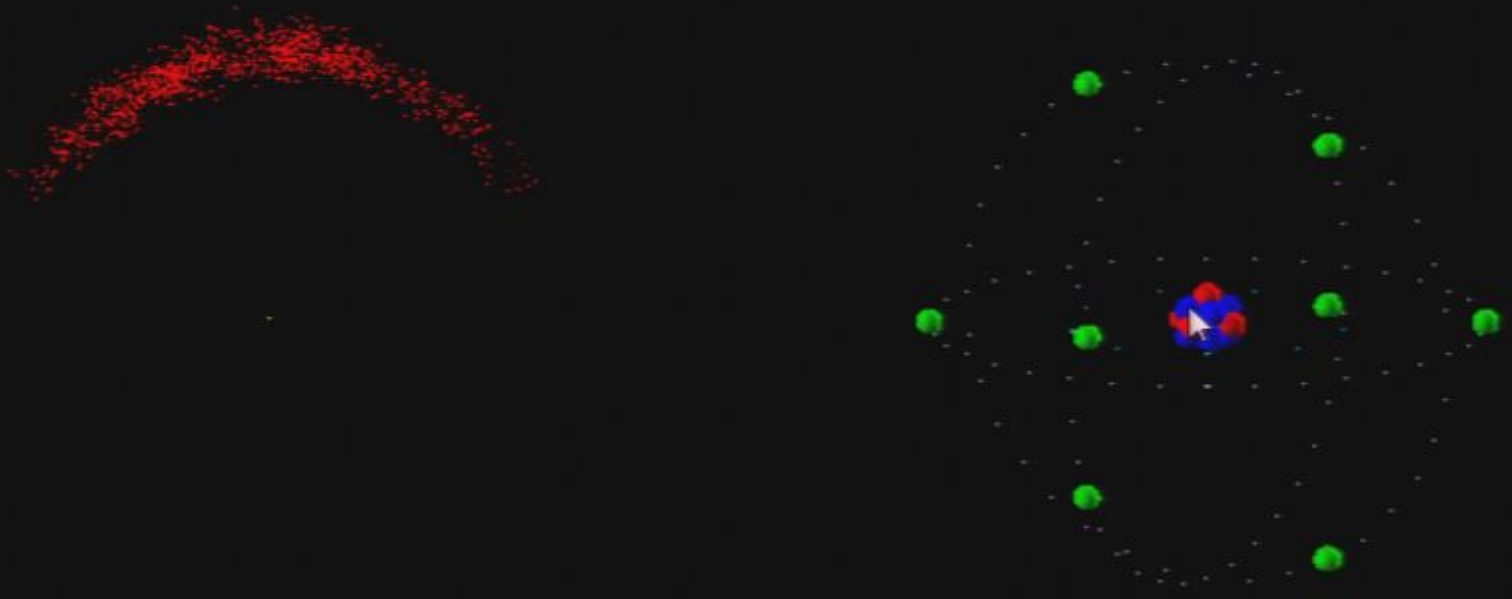

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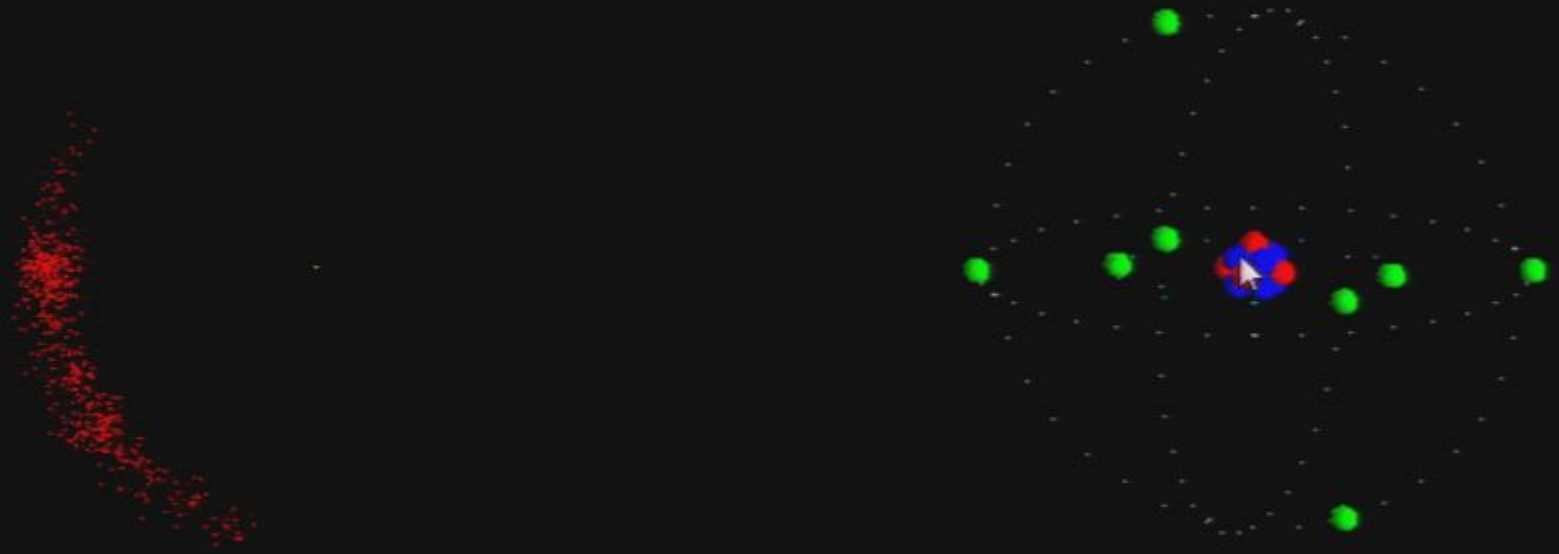

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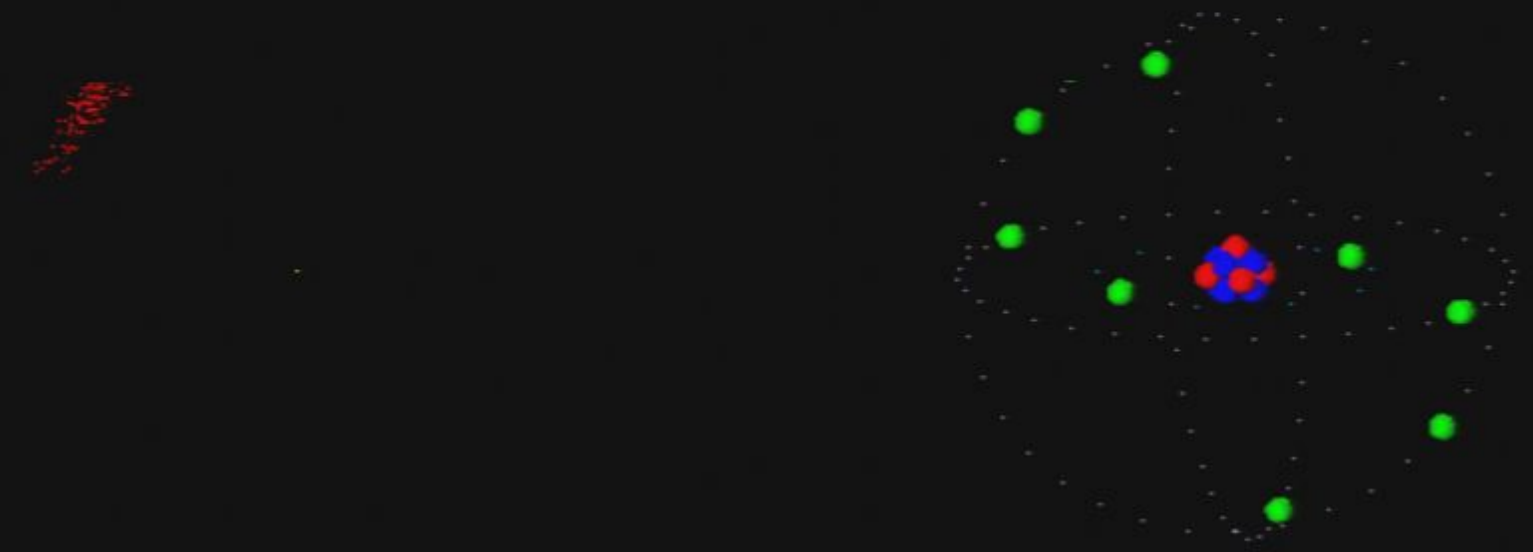

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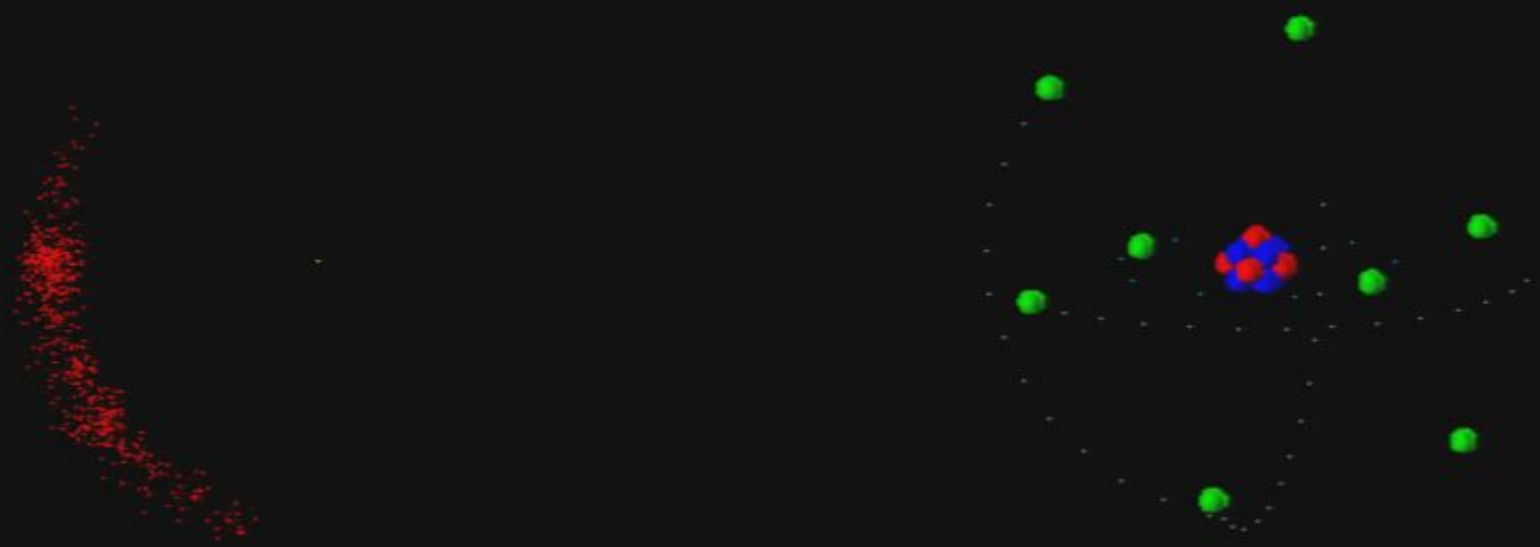

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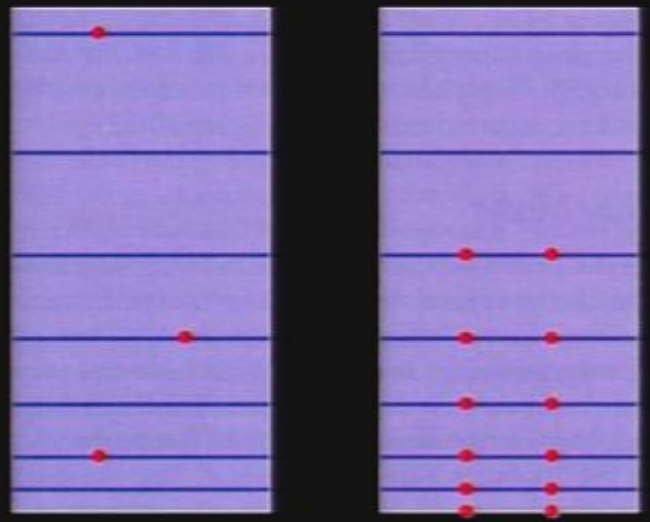
Electron Degeneracy Pressure

$$Radius = N_e^{\frac{2}{3}} \frac{h^2}{8Gm_e m_p M}$$

- Pauli Exclusion Principle:
  No two electrons (fermions) can occupy the same position in space at the same time doing the same thing.
- Electrons are packed side by side in a white dwarf
- This prevents it from collapsing any further



Calculate Magnitude of Radius

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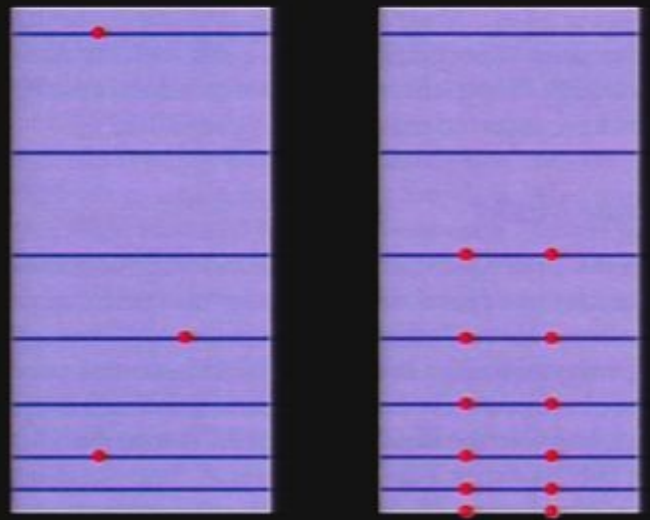

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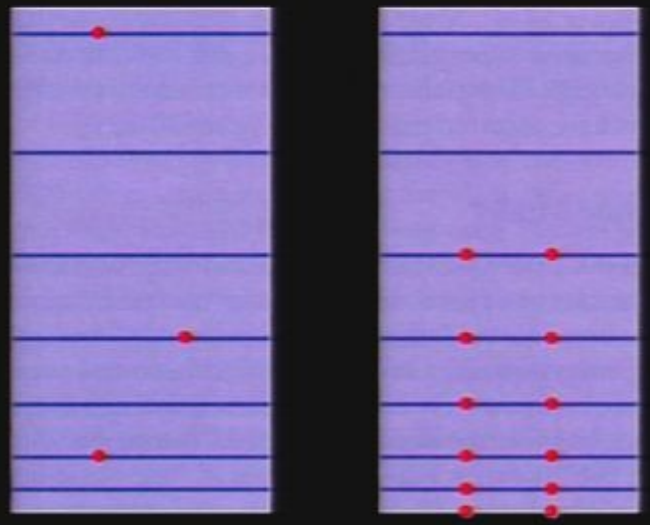

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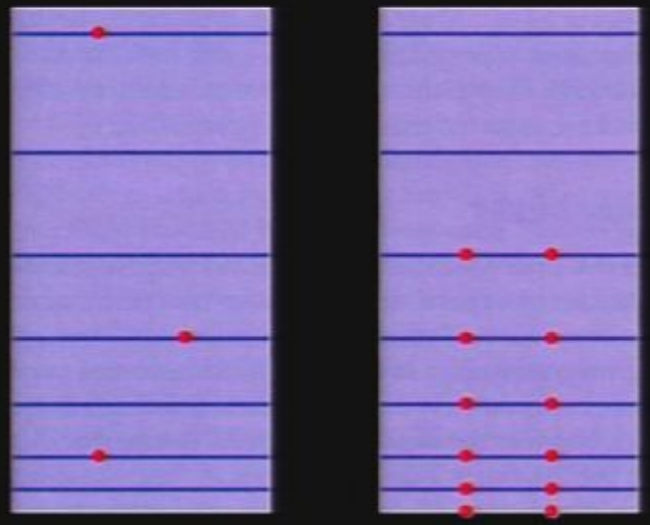
$$h = 6.6261 \times 10^{-34}$$

$$G = 6.6726 \times 10^{-11}$$

$$m_e = 9.1094 \times 10^{-31}$$

$$m_p = 1.6726 \times 10^{-27}$$

$$M = 1.989 \times 10^{30}$$



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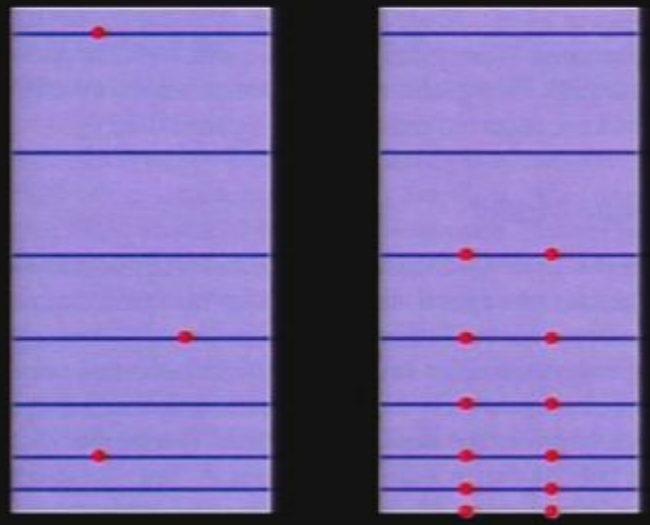
$$\left(5.95 \times 10^{56}\right)^{\frac{2}{3}}$$

$$2.7 \times 10^{-31} m$$



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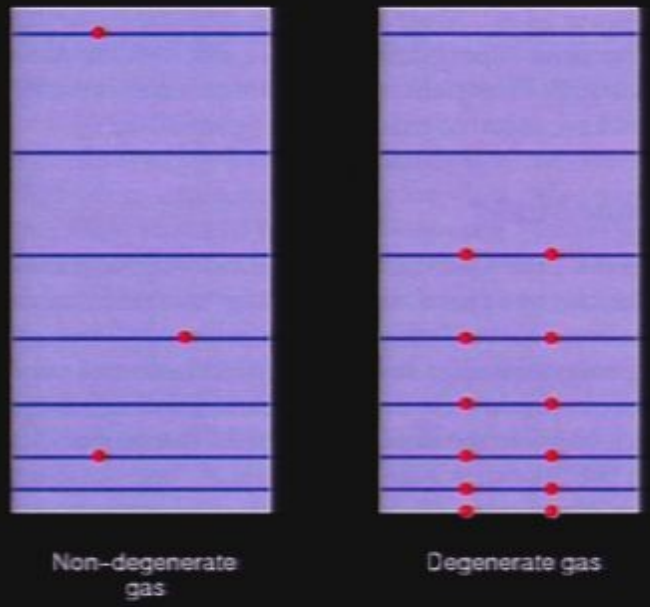
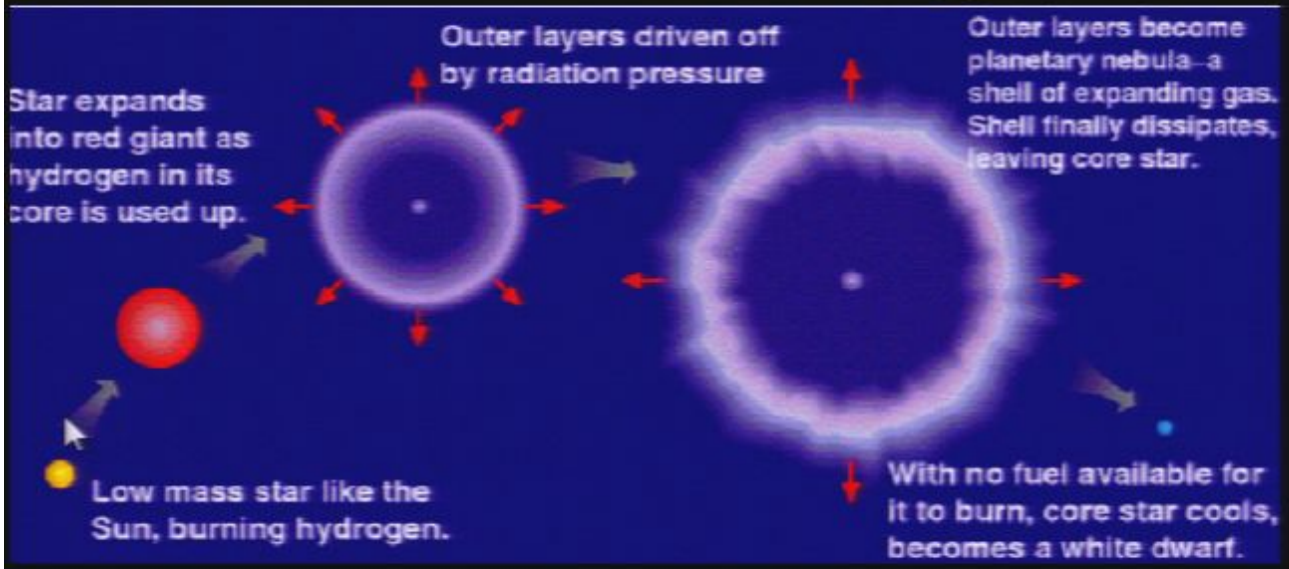
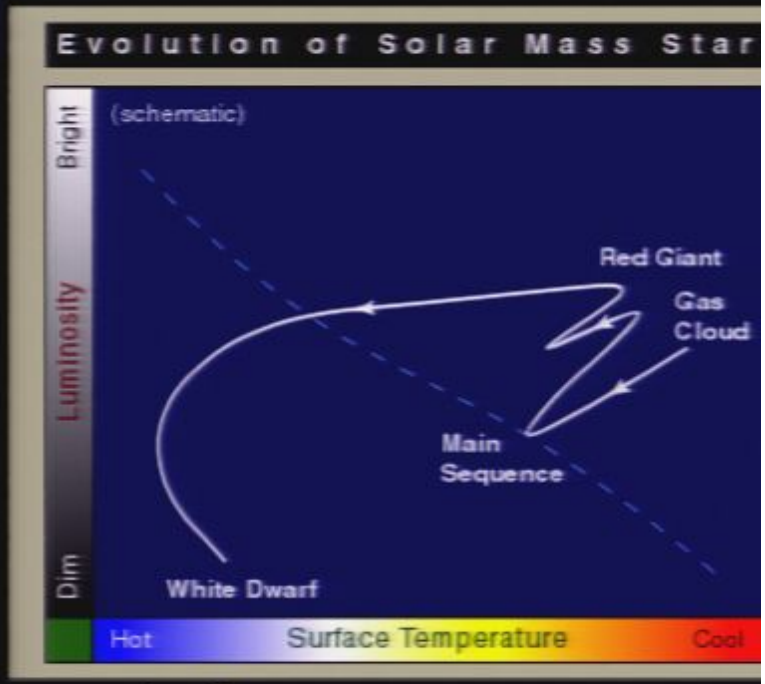
$$\approx 10^7 m$$



Path to being a White Dwarf





7 solar mass star now reduced to about 20% of its original mass

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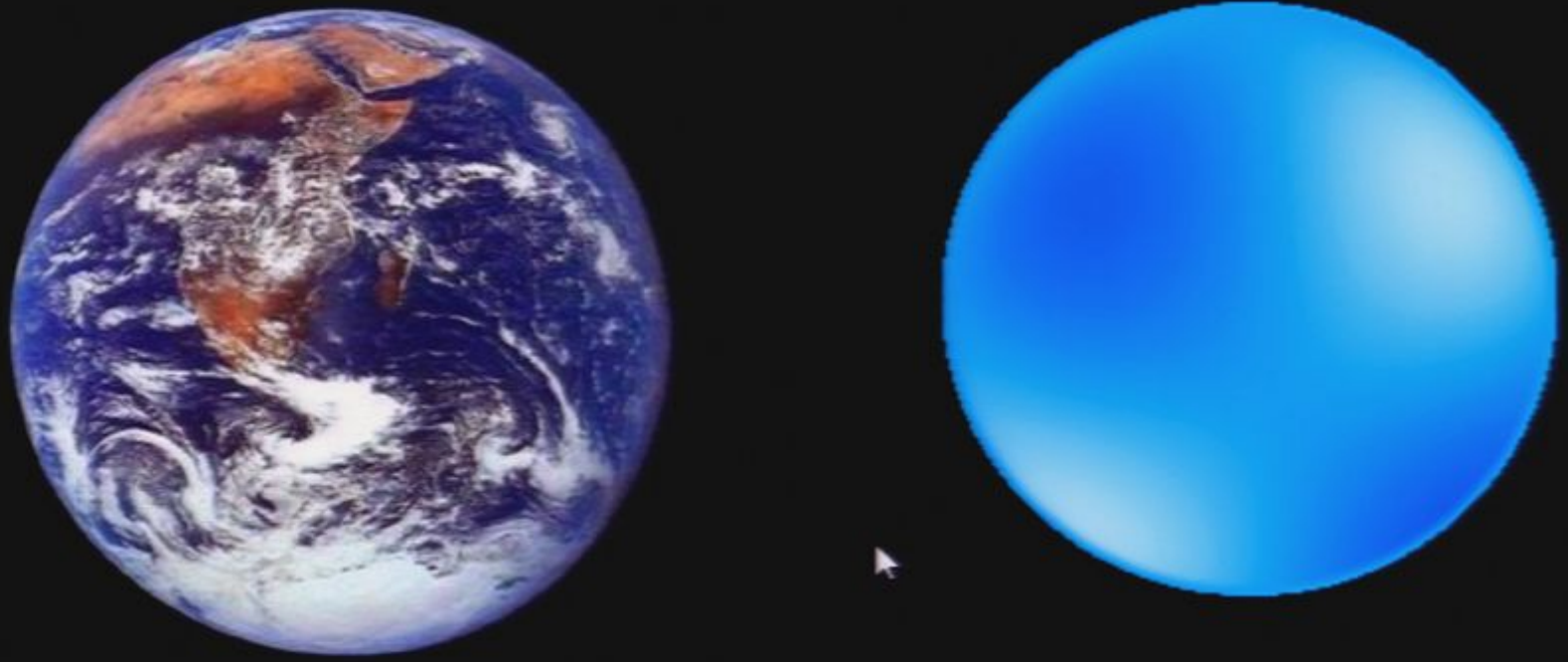
- ...are found in the centers of planetary nebula.
- ...have masses less than the Chandrasekhar mass (1.4 Solar Masses).

White Dwarf Properties

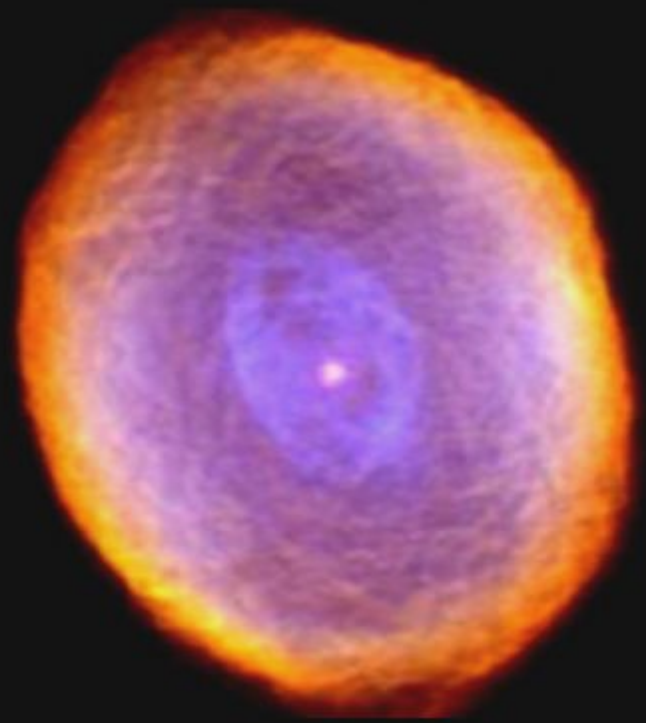
...have diameters about the same as the Earth's.

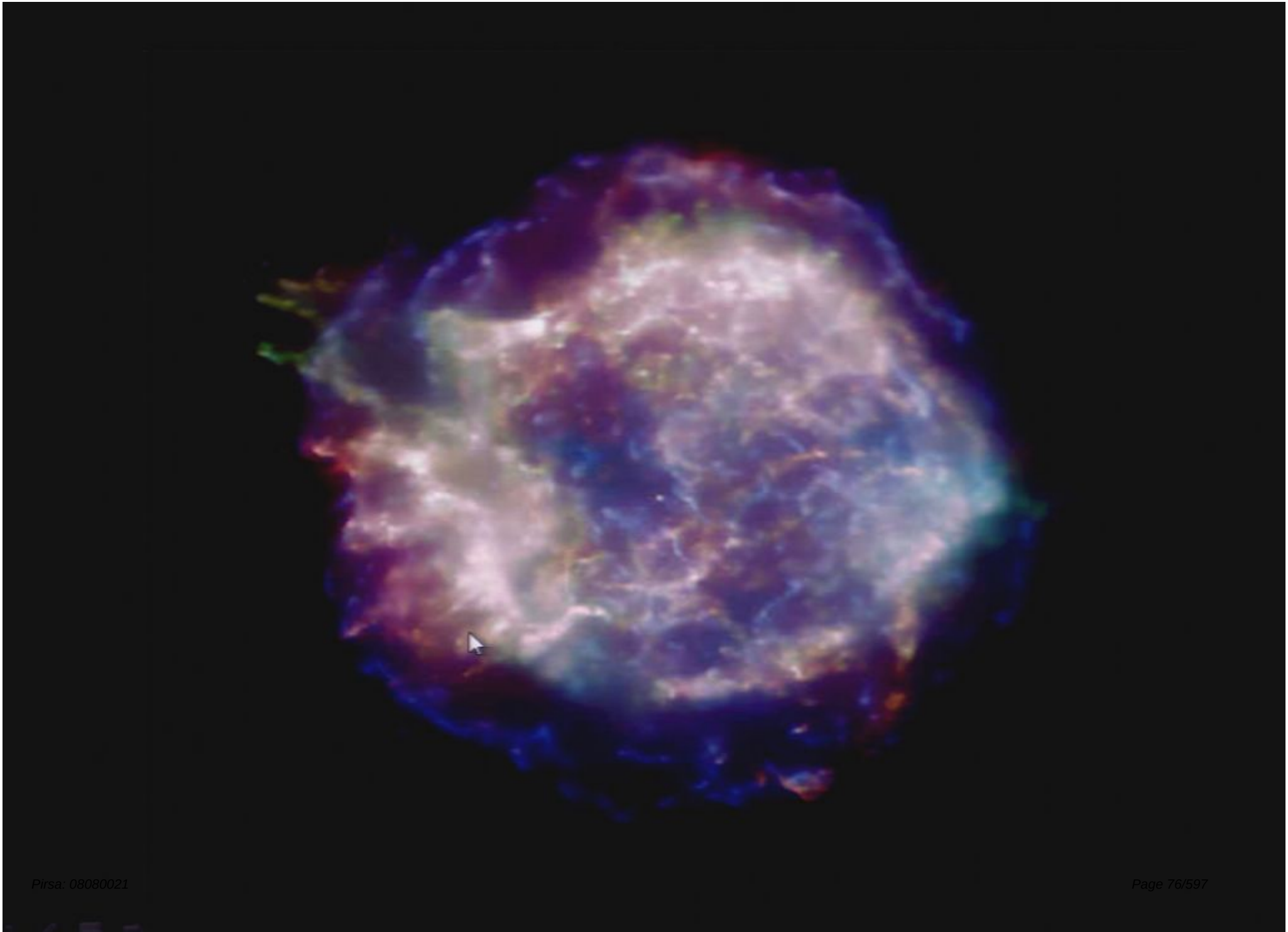


Look in the Middle

Cat’s eye nebula

Spirograph Nebula





Eskimo Nebula

Above the Chandrasekhar Limit

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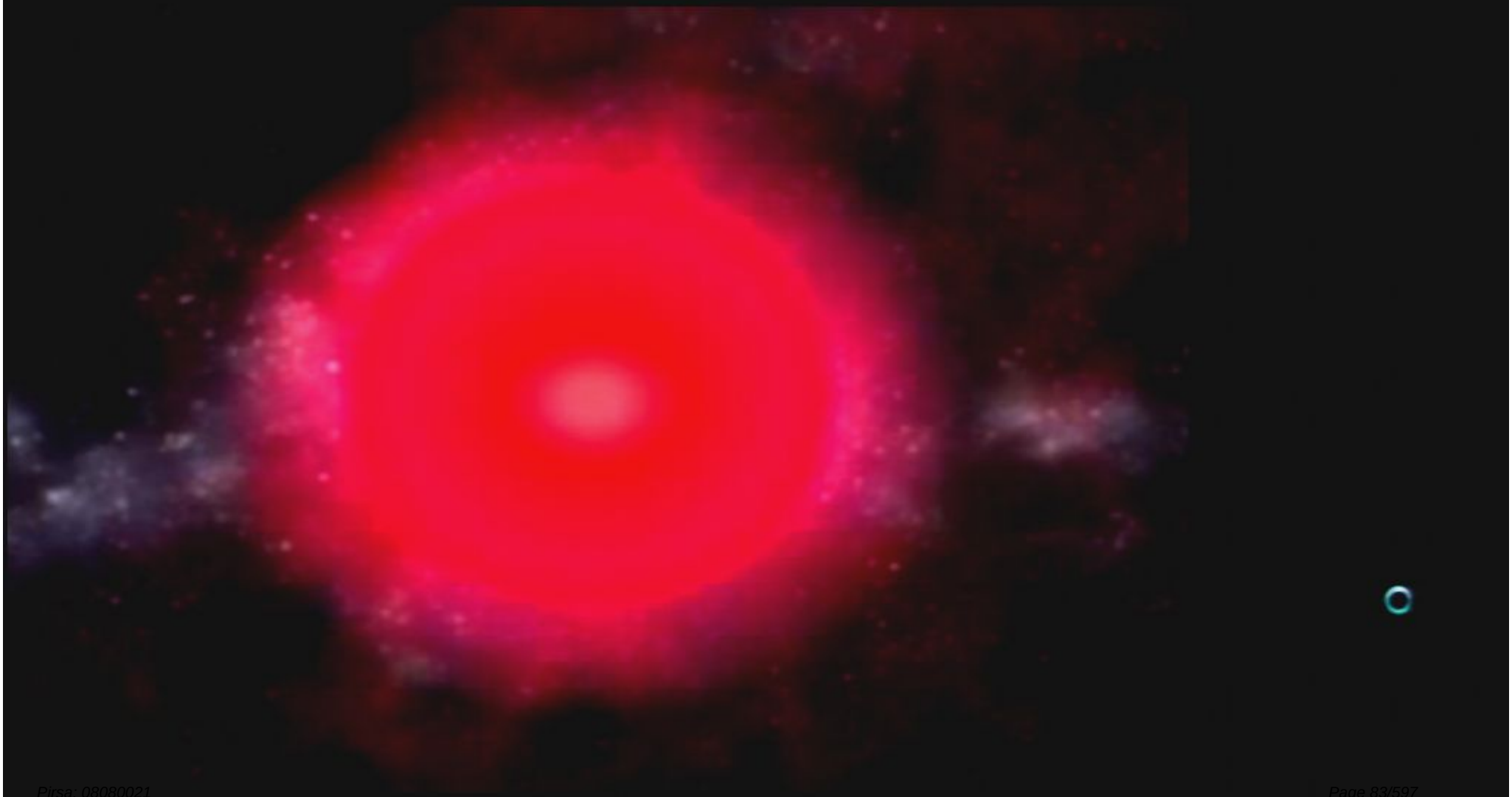
A Super Nova



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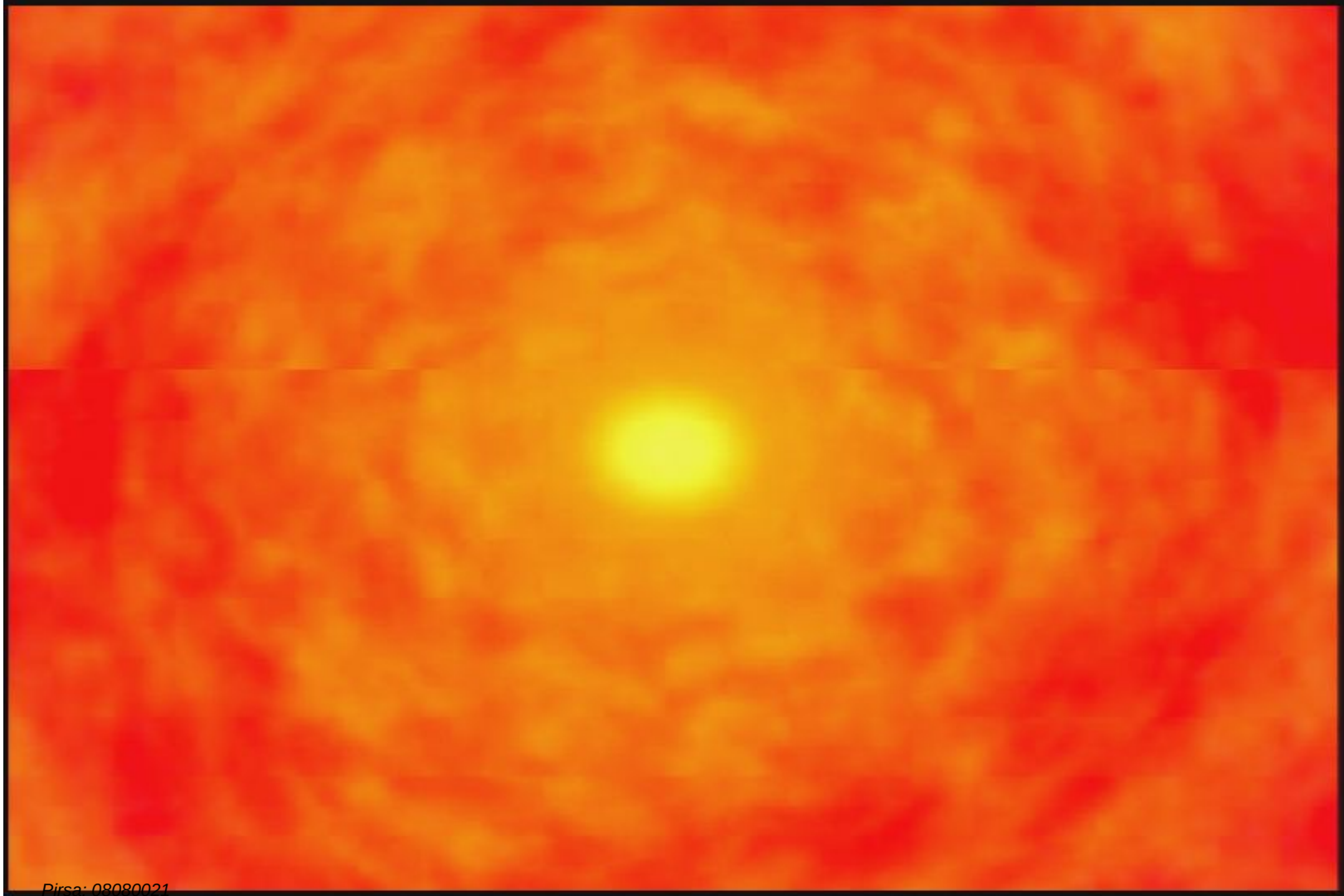

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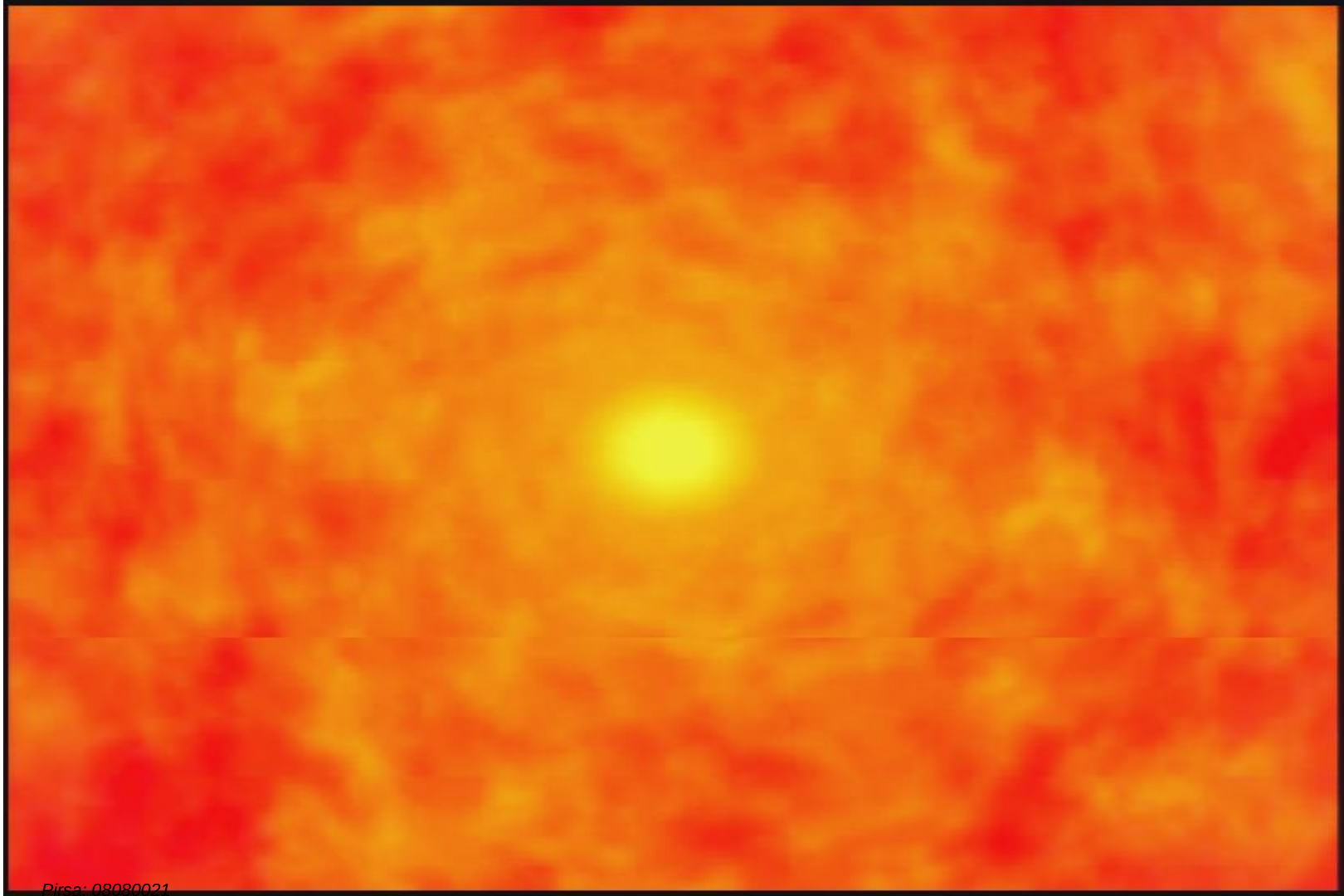

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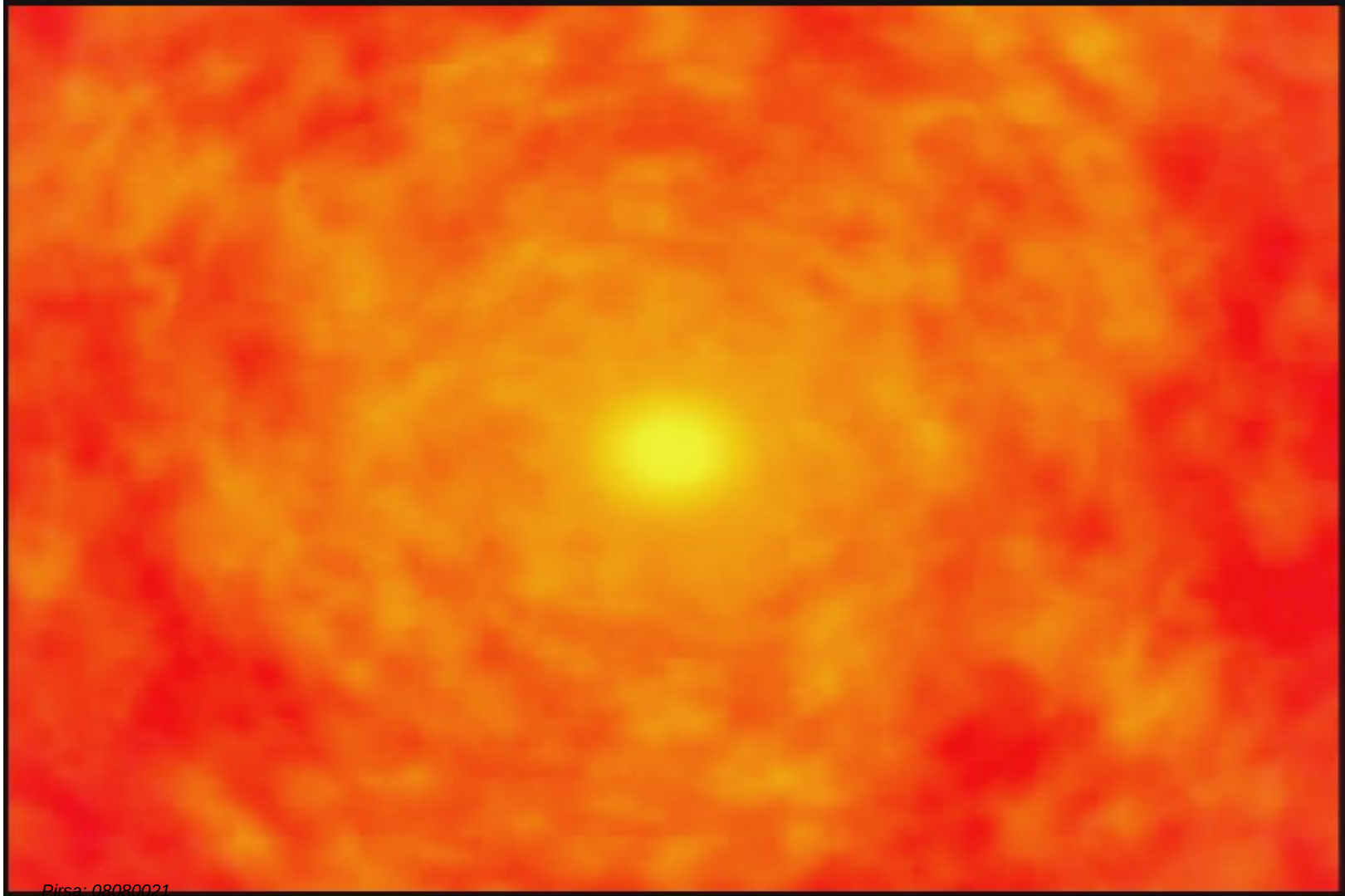

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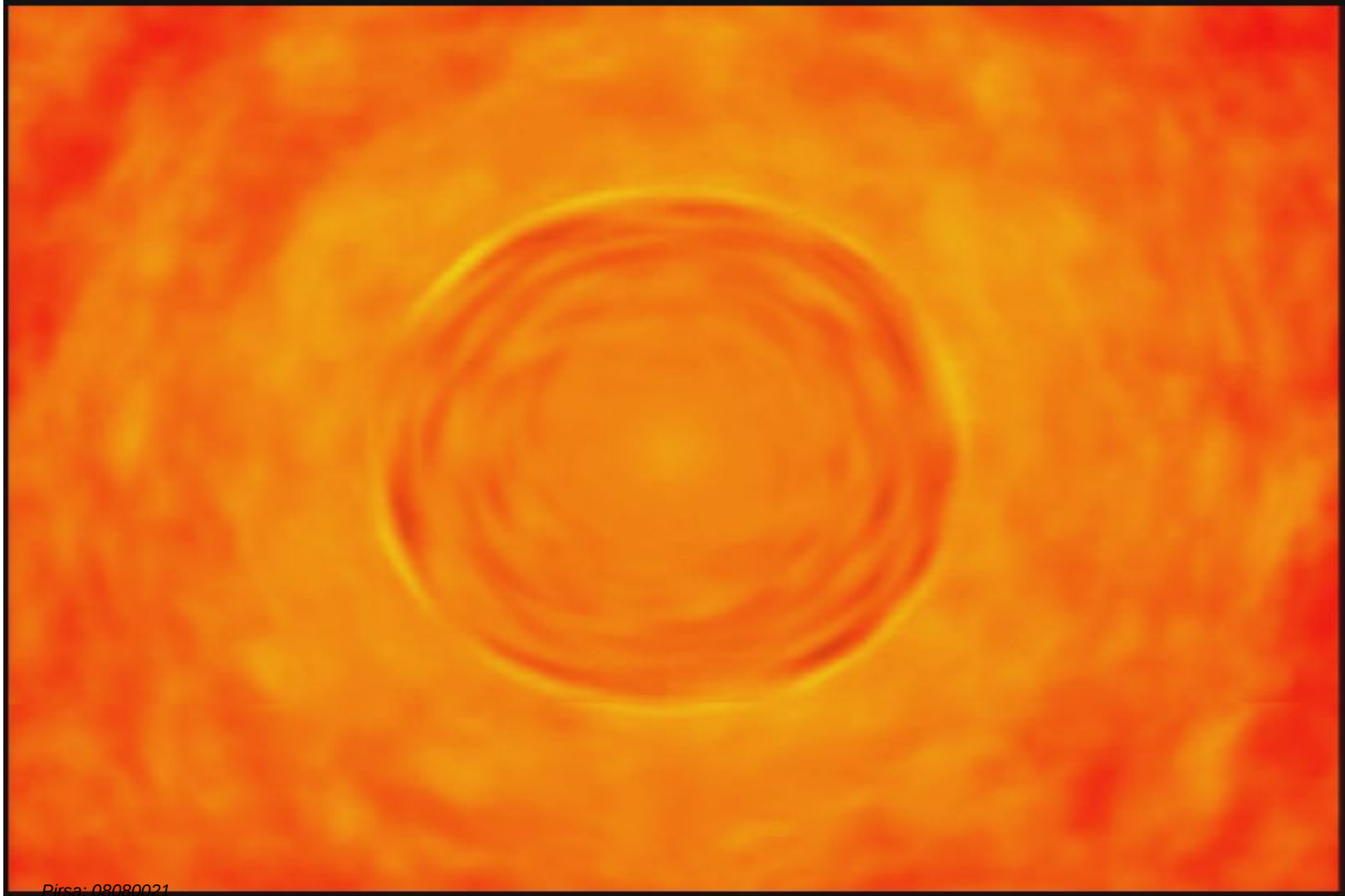

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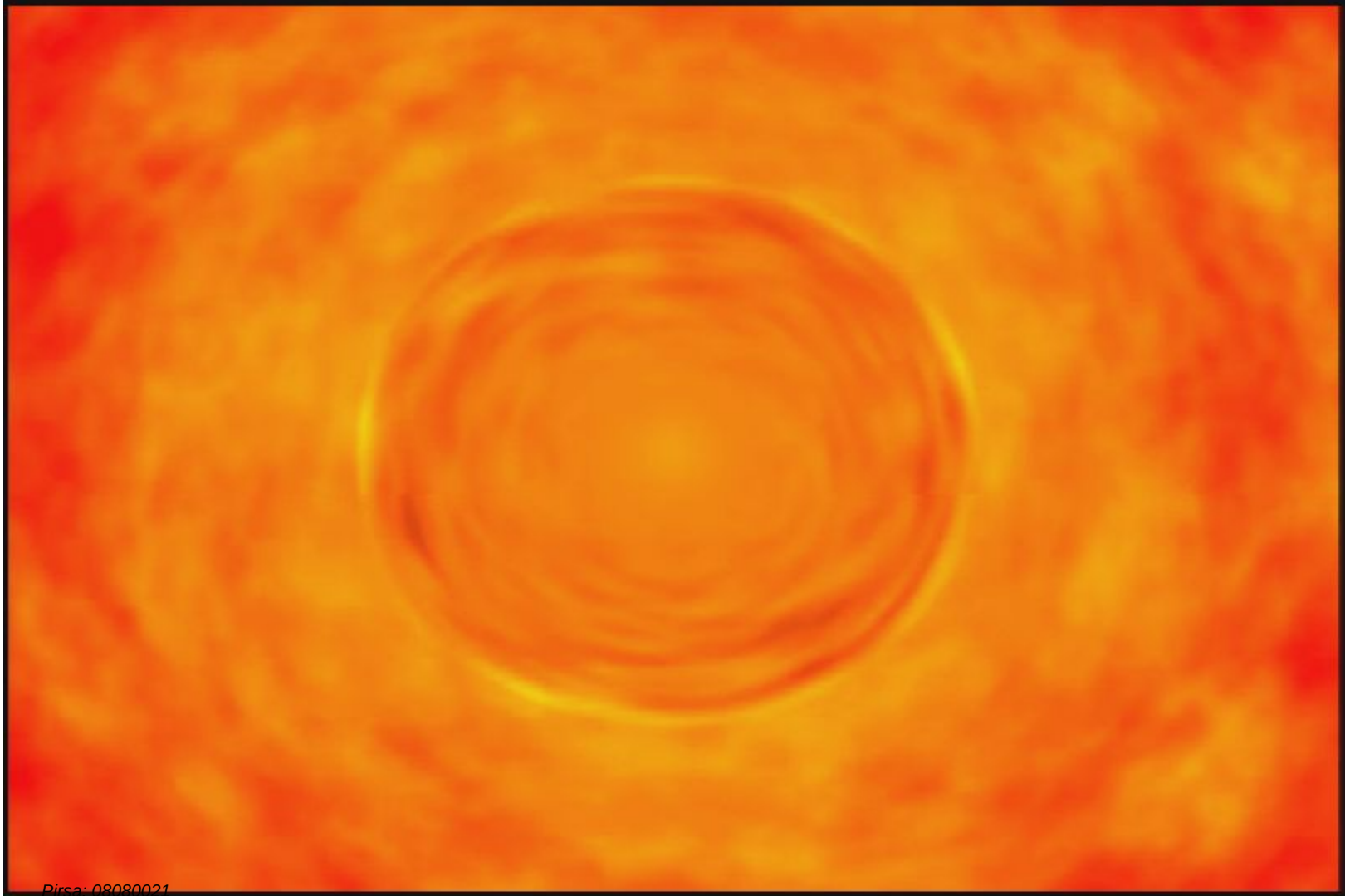

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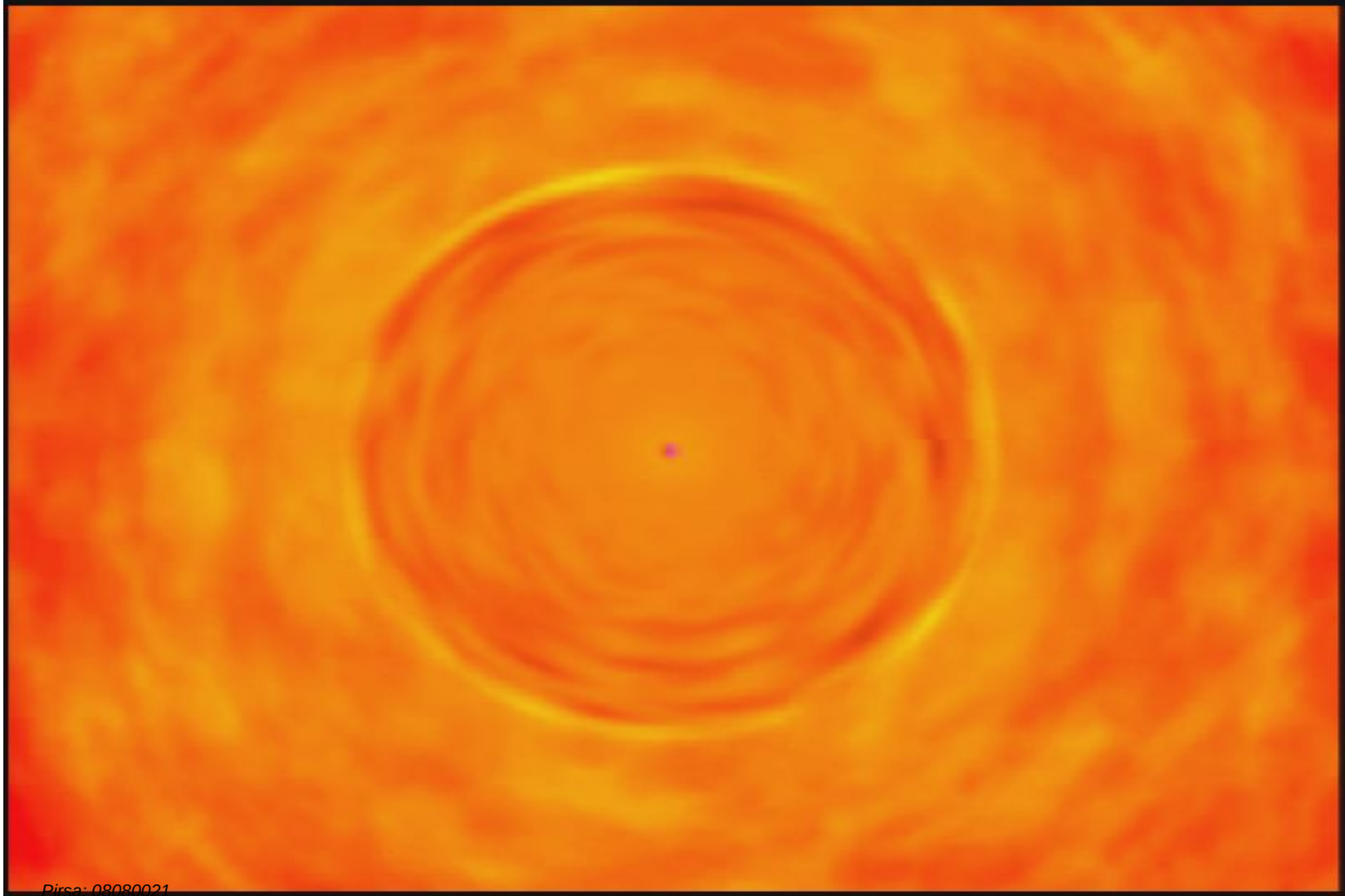

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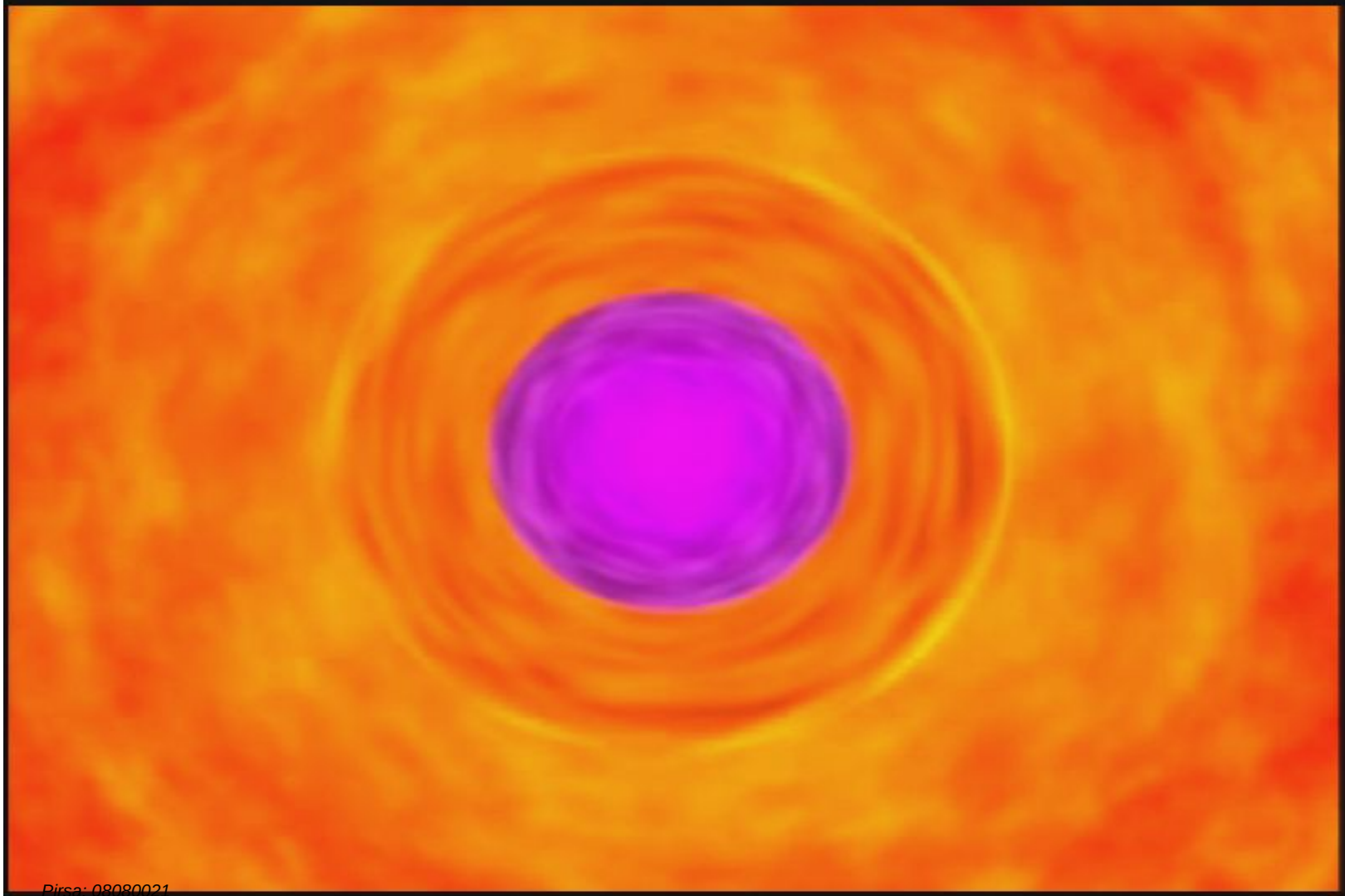

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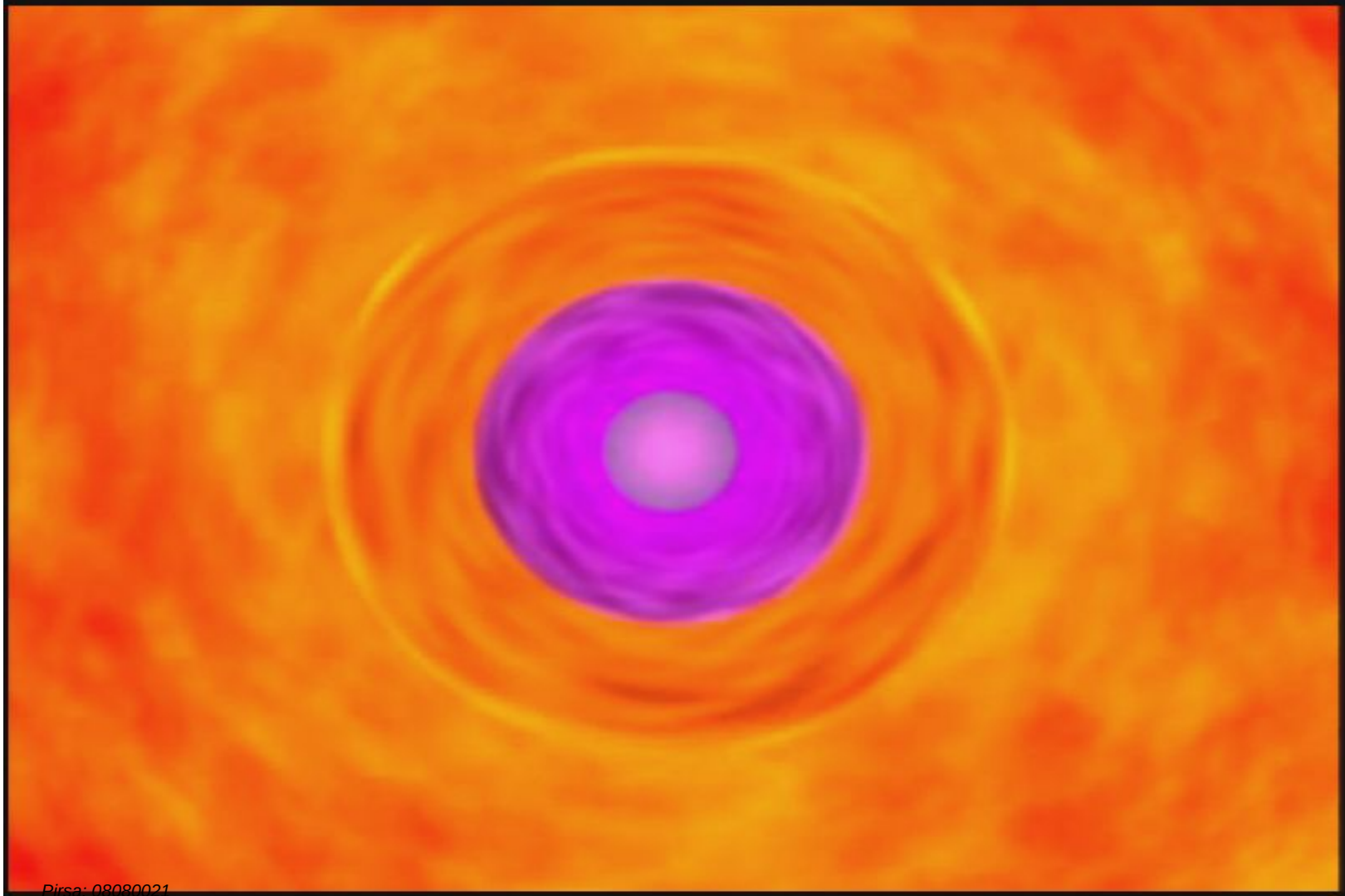

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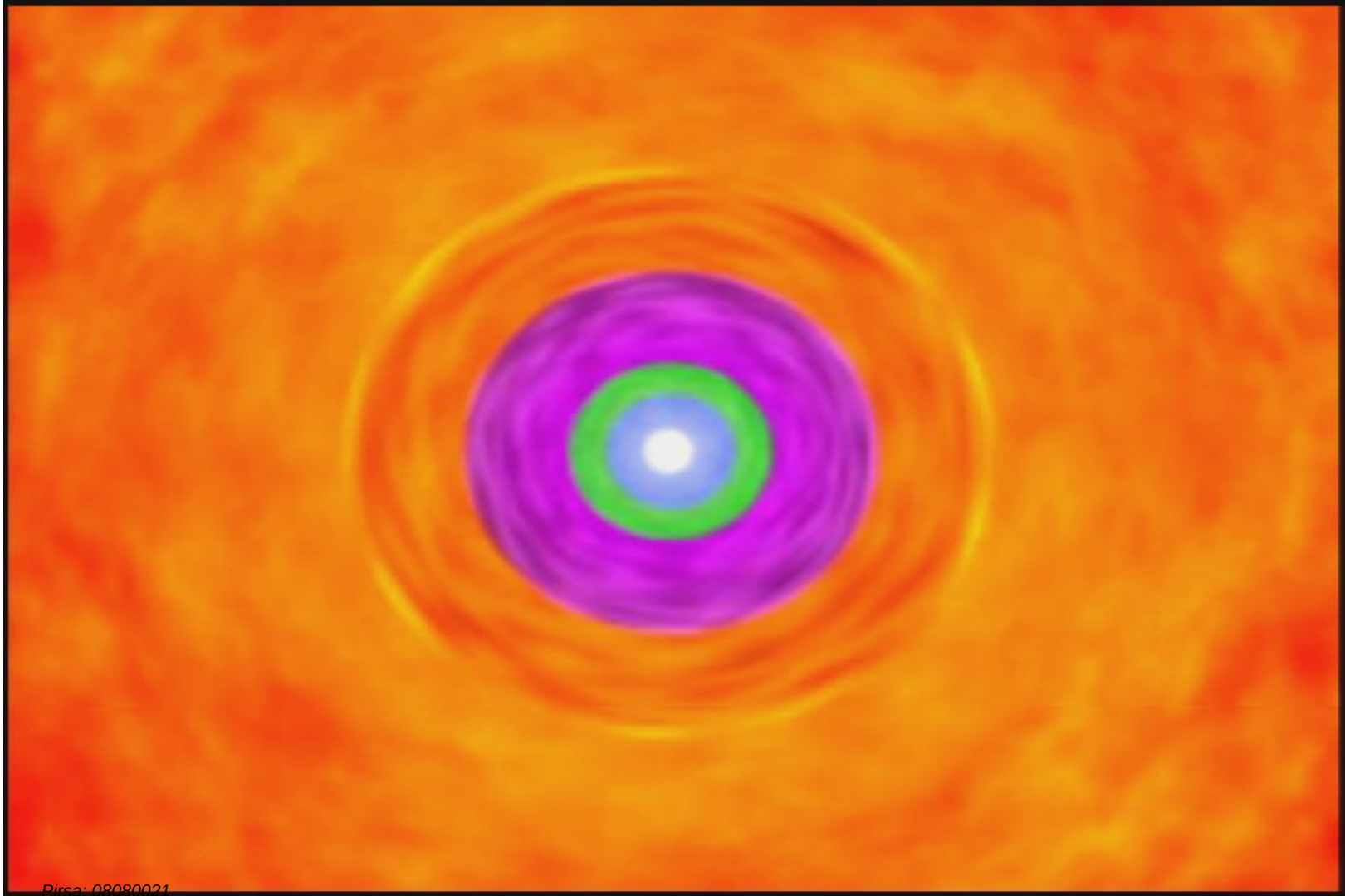

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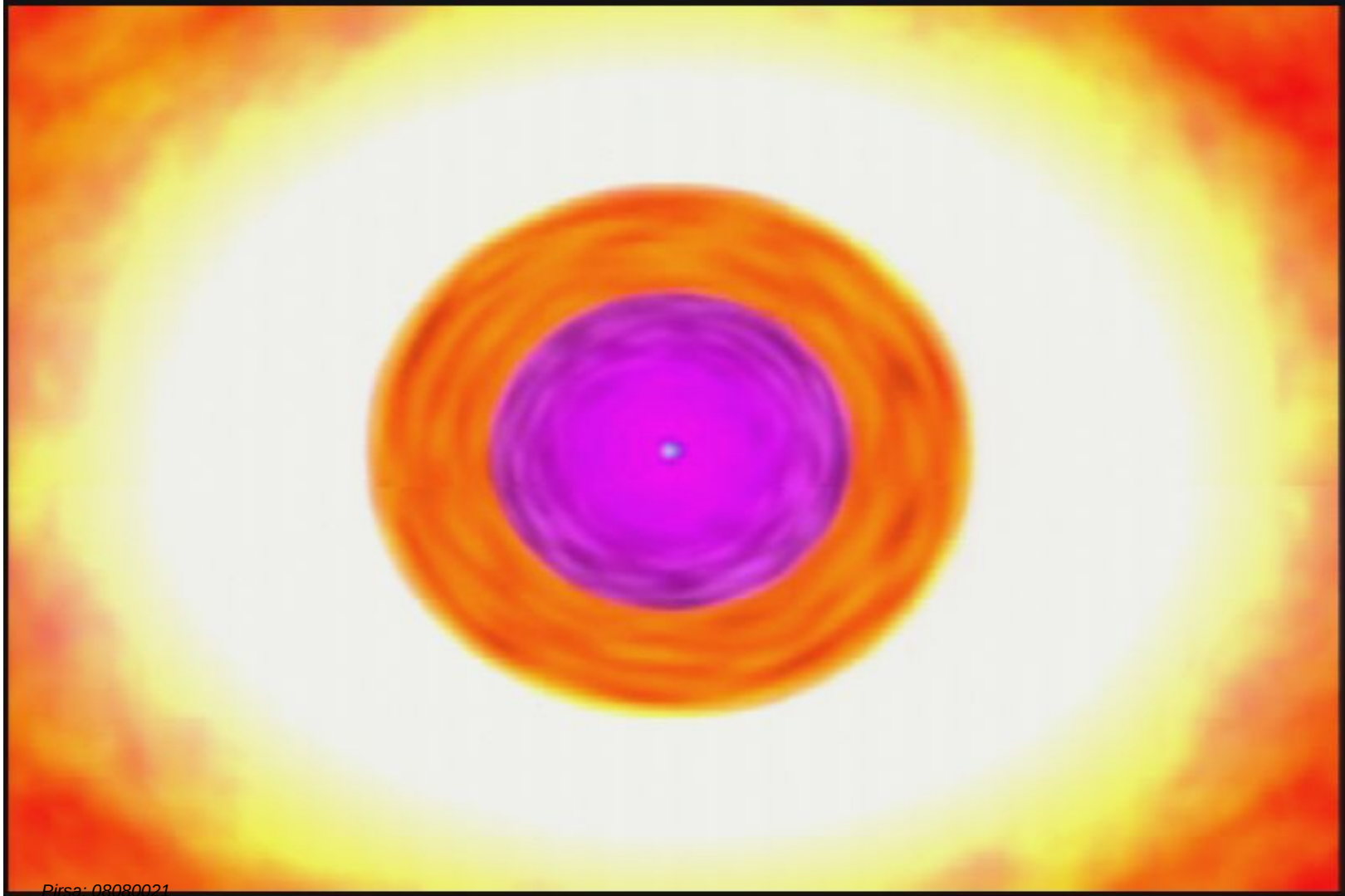

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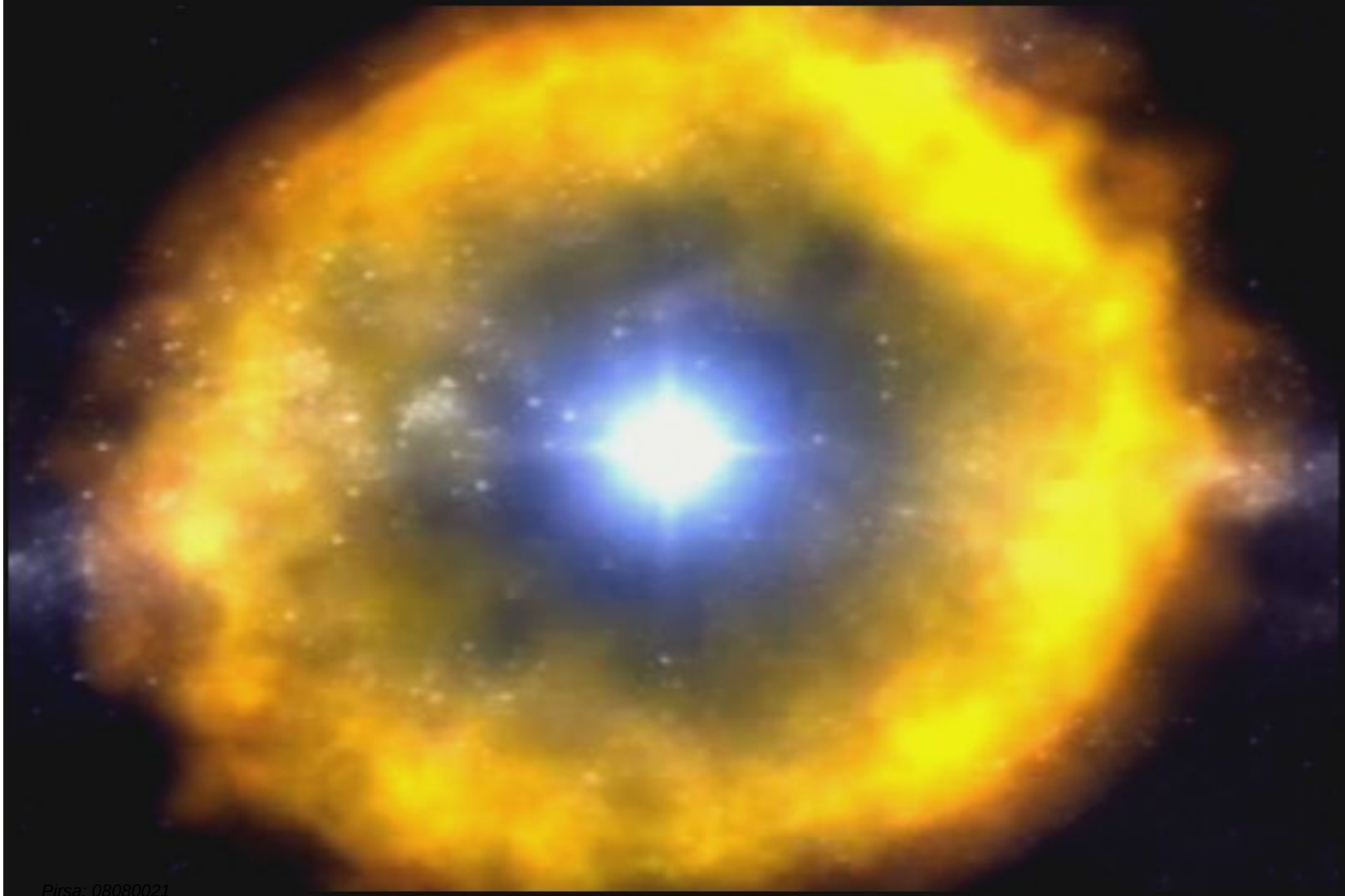

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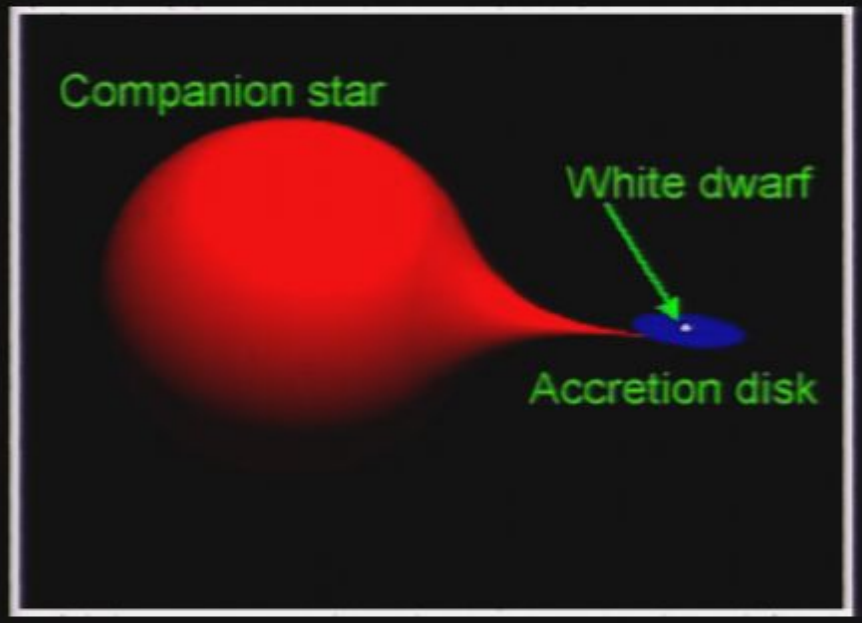
Type 1a Super Nova



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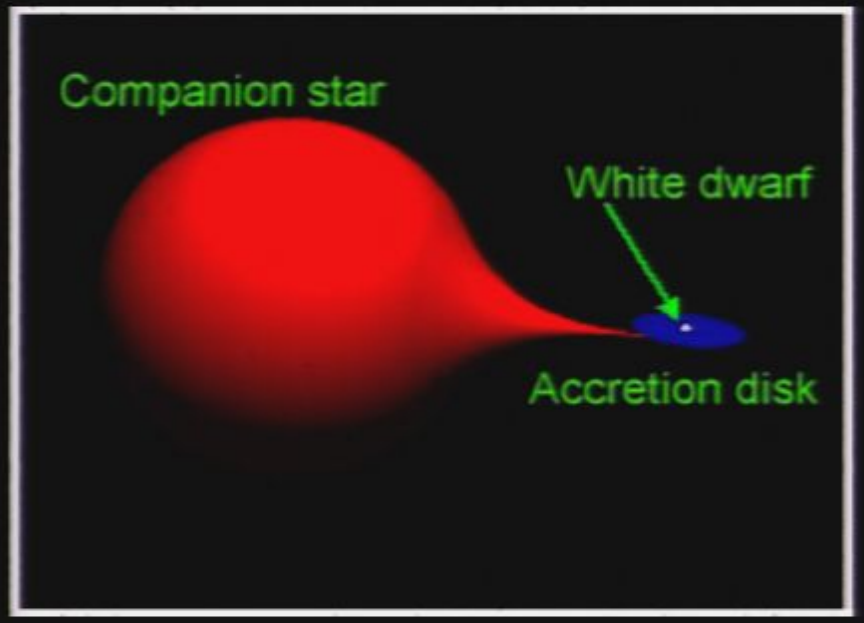

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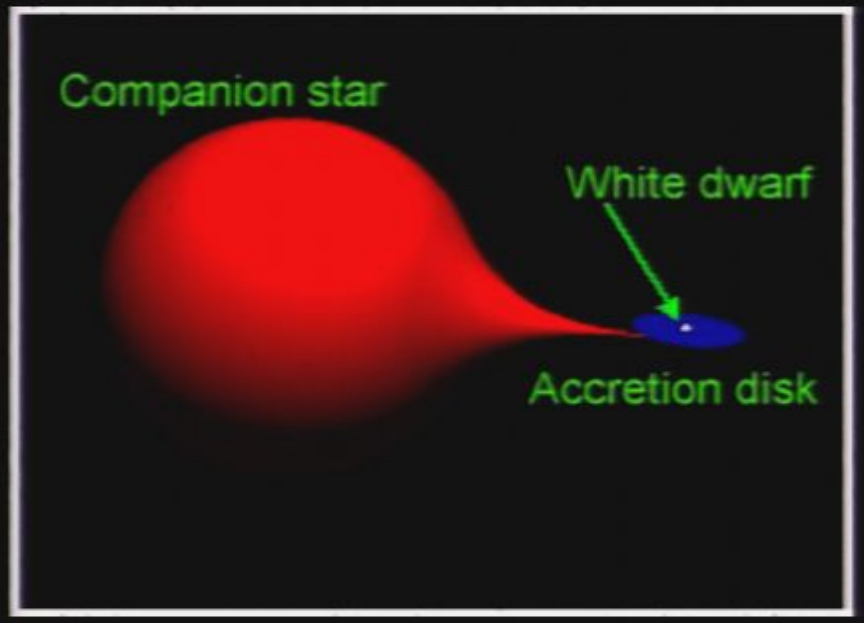

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The more massive
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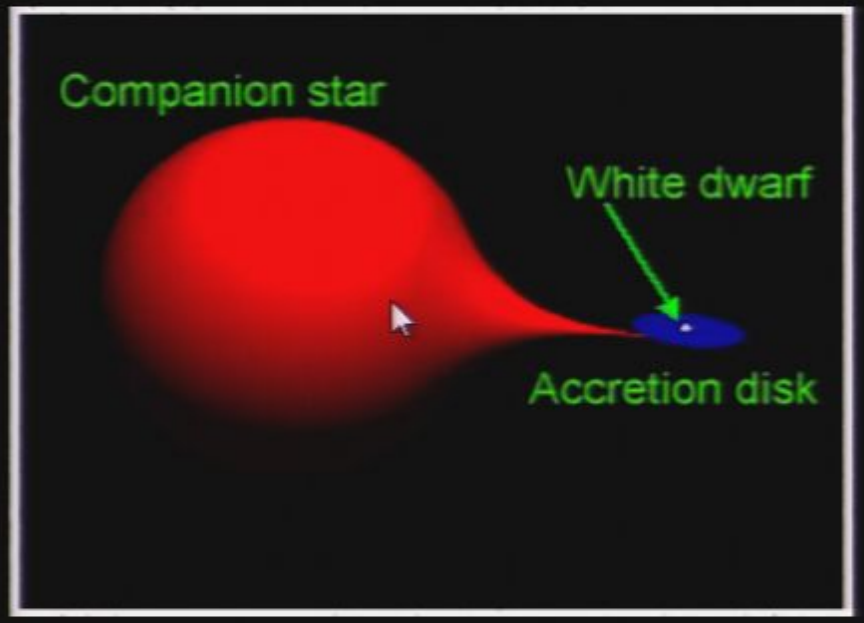

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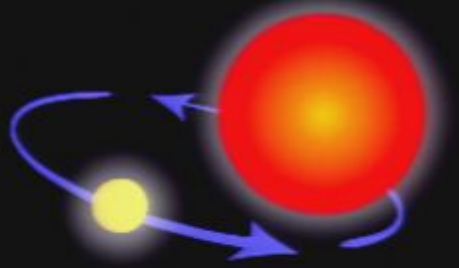

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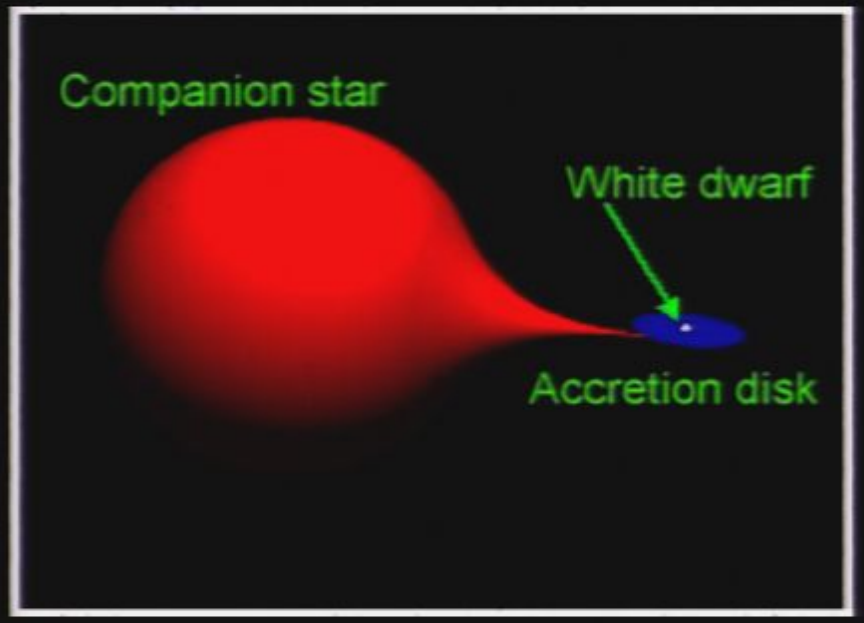

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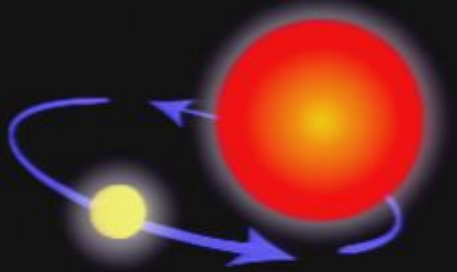

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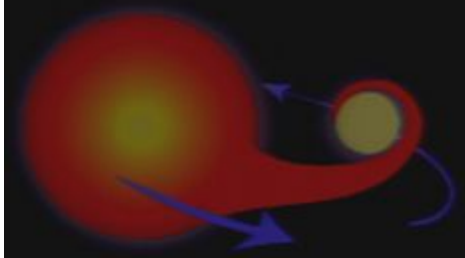
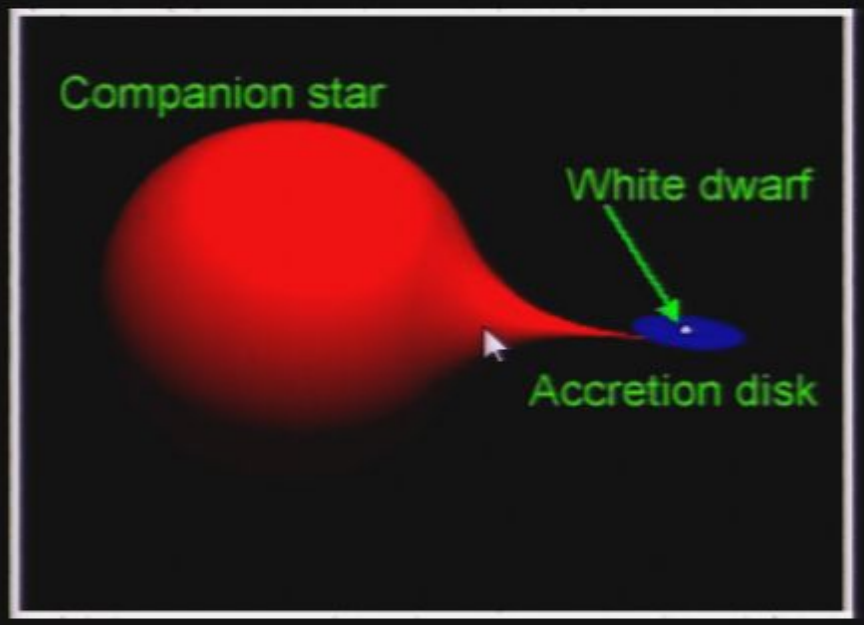
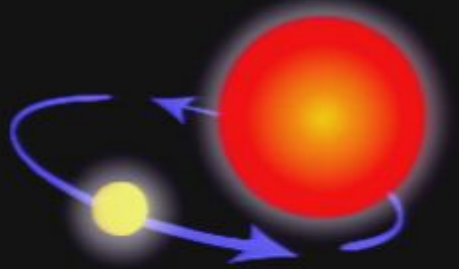


...which spills gas onto the
econdary star, causing it to
pand and become engulfed.

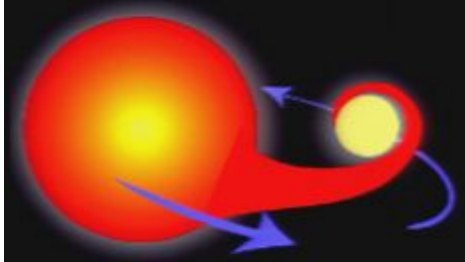


Type 1a Super Nova

Two normal stars
are in a binary pair.



The more massive
star becomes a giant...



...which spills gas onto the
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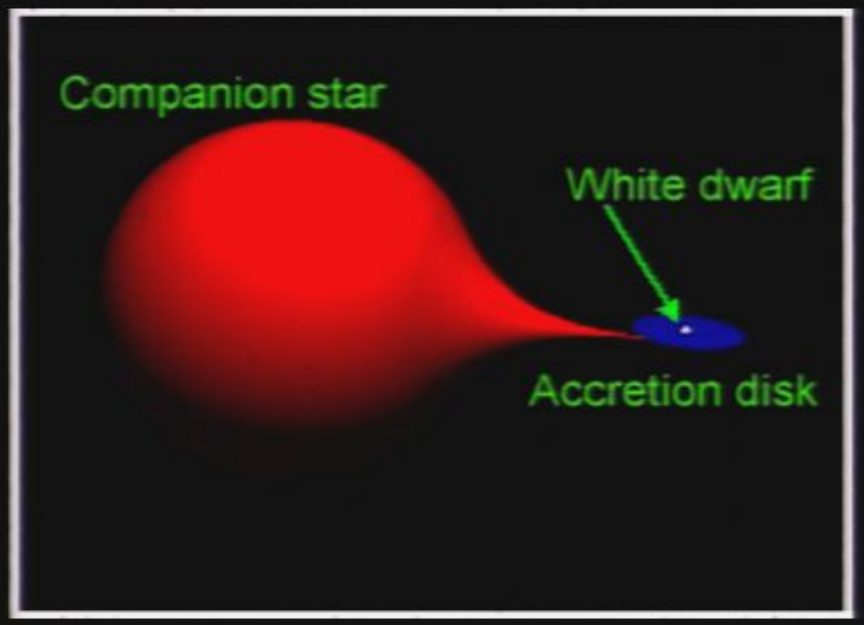

Type 1a Super Nova

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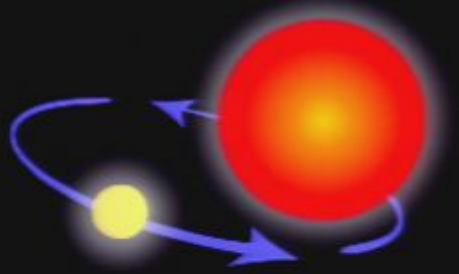

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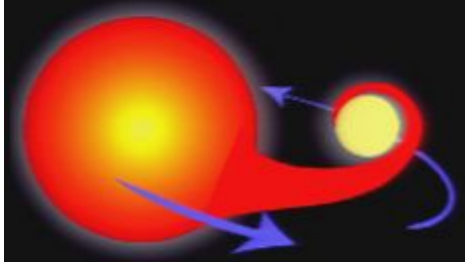

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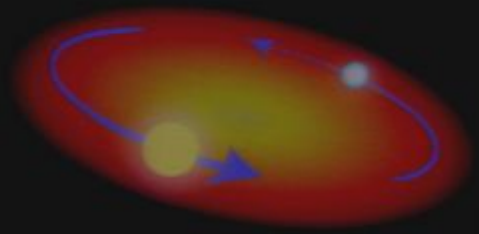
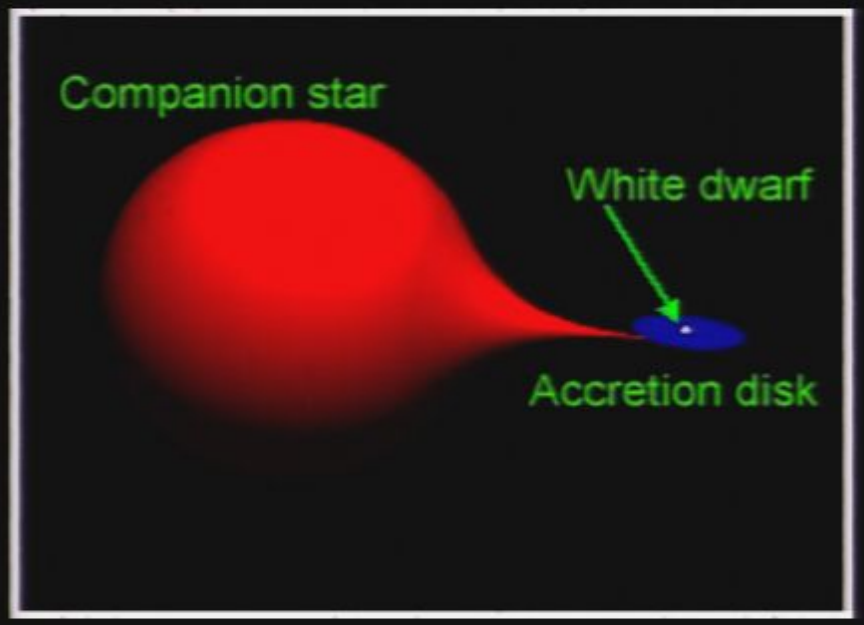


The secondary, lighter star and the core of the giant star spiral inward within a common envelope



Type 1a Super Nova

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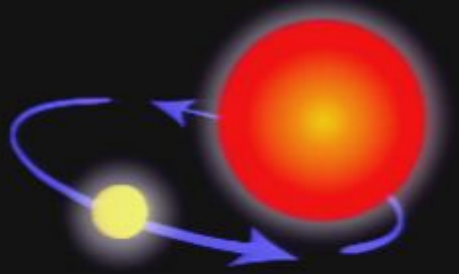

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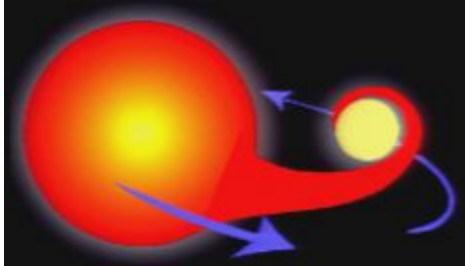

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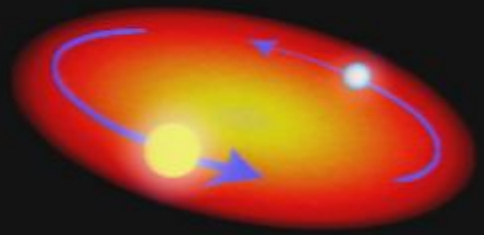

The secondary, lighter star
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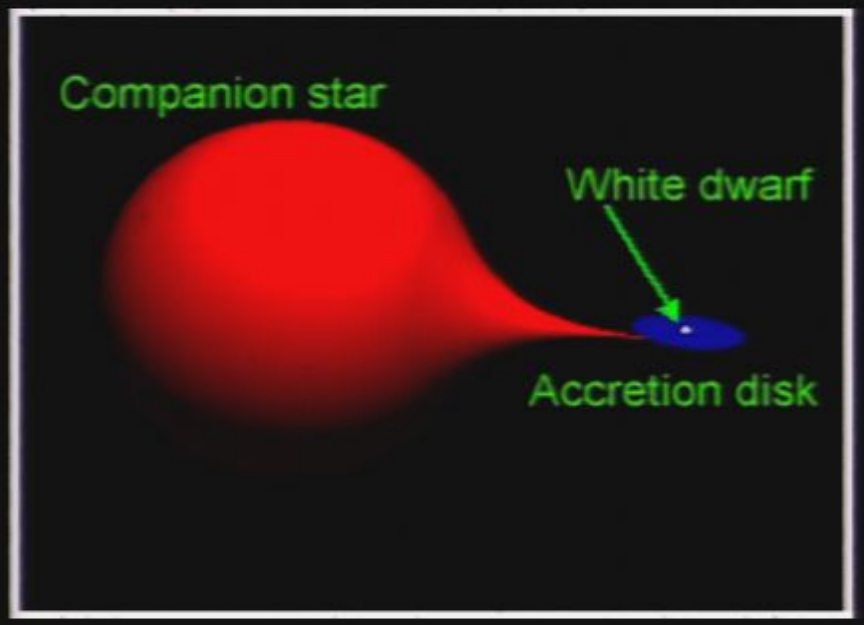
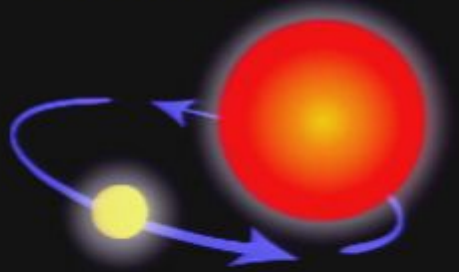


Type 1a Super Nova

Two normal stars are in a binary pair.



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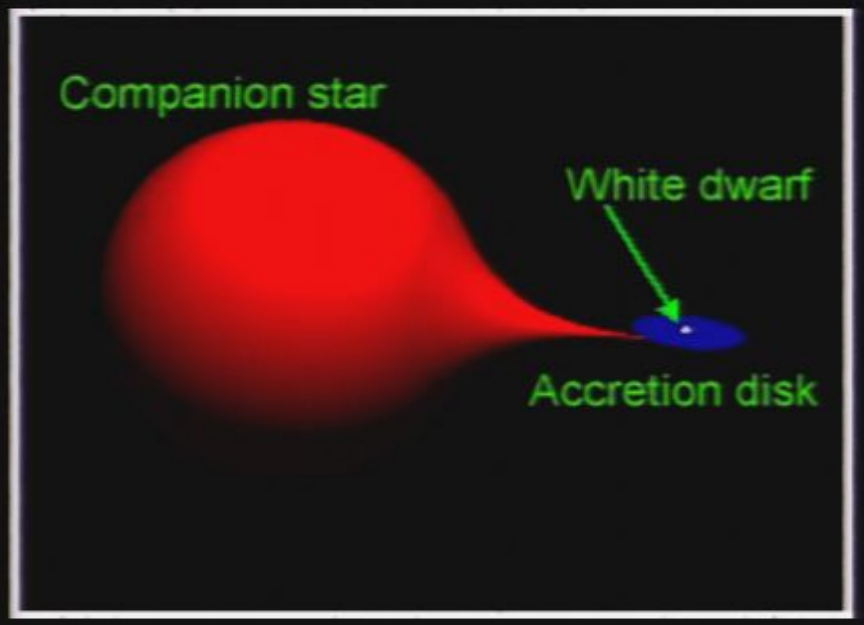

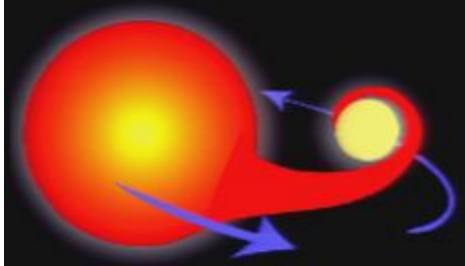

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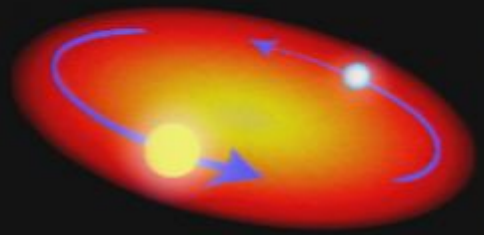
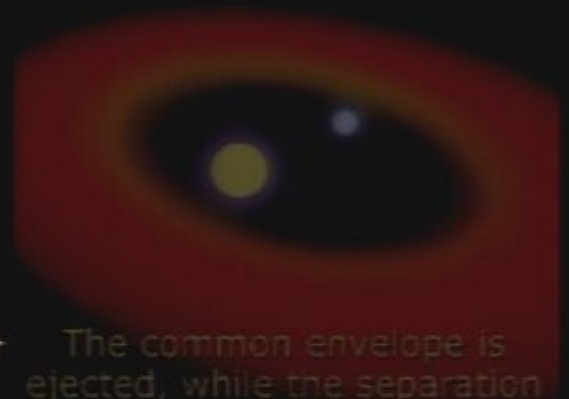


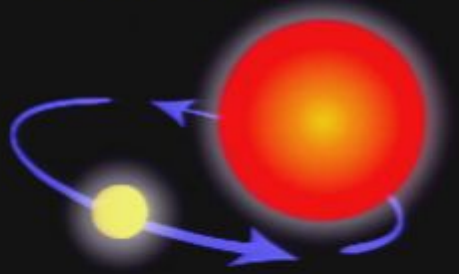
The secondary, lighter star and the core of the giant star spiral inward within a common envelope

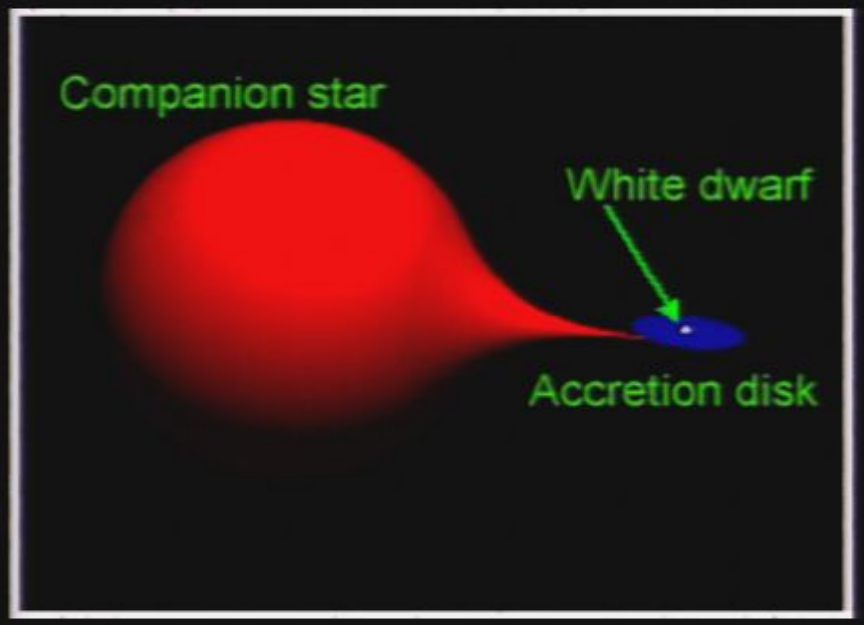


The common envelope is ejected, while the separation between the core and the secondary star decreases

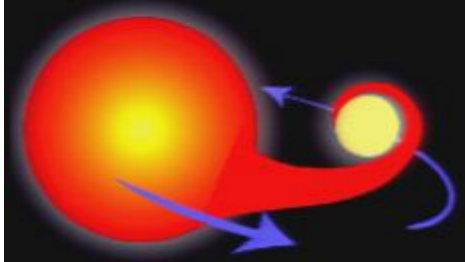
Type 1a Super Nova

Two normal stars are in a binary pair.





The more massive star becomes a giant...



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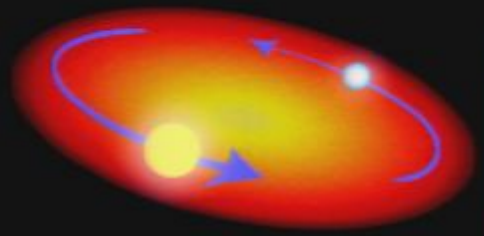
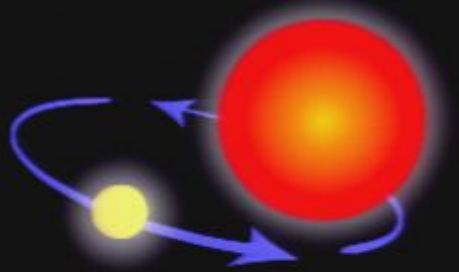


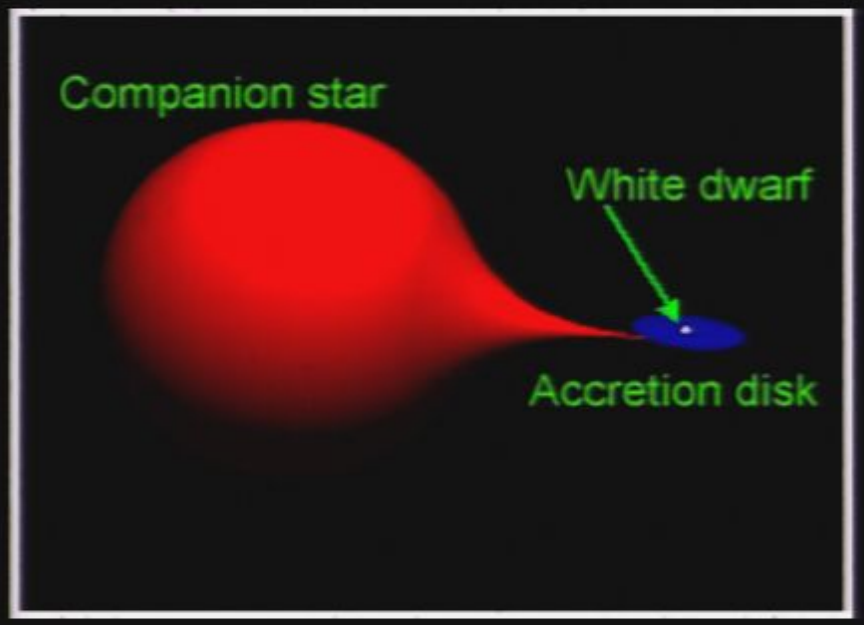
The secondary, lighter star and the core of the giant star spiral inward within a common envelope

The common envelope is ejected, while the separation between the core and the secondary star decreases

Type 1a Super Nova

Two normal stars are in a binary pair.





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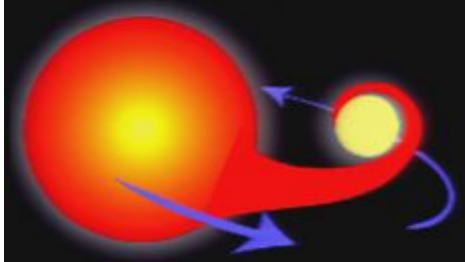

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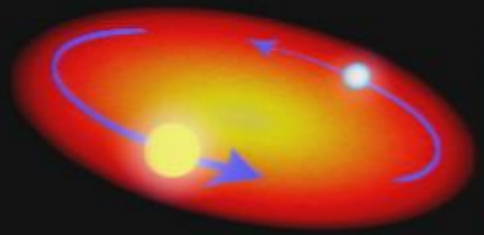


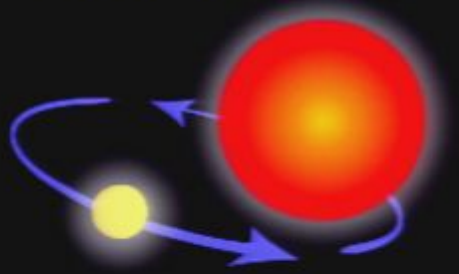
The secondary, lighter star and the core of the giant star spiral inward within a common envelope

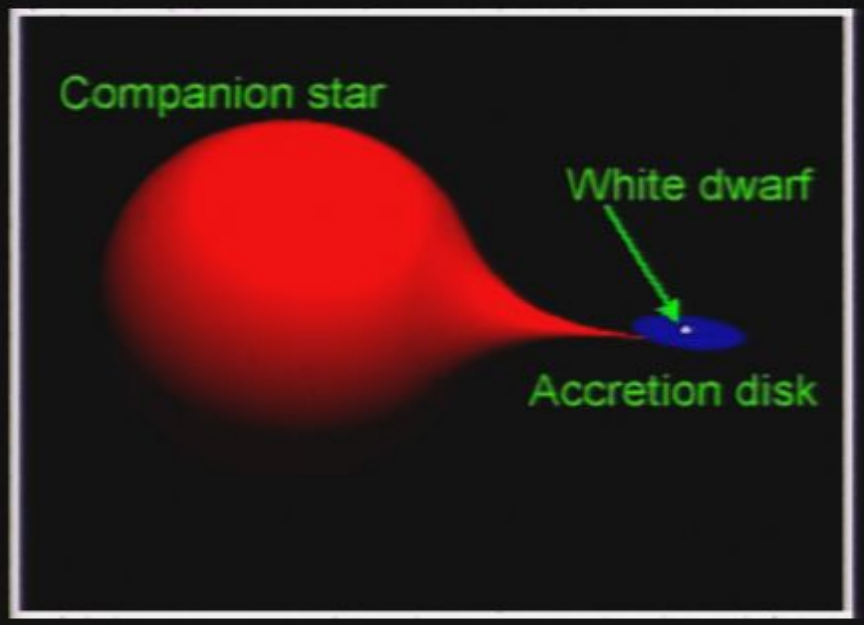
The common envelope is ejected, while the separation between the core and the secondary star decreases

The remaining core of the giant collapses and becomes a white dwarf

Type 1a Super Nova

Two normal stars are in a binary pair.





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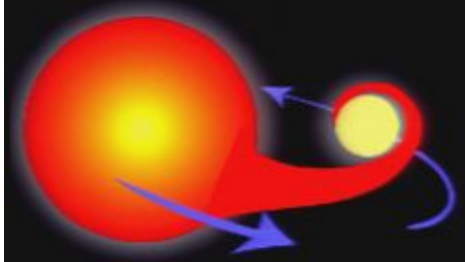

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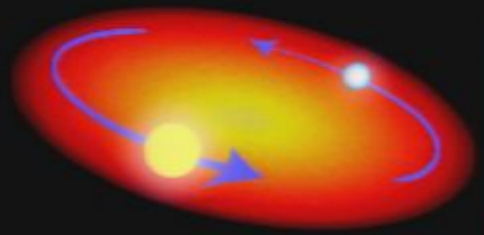
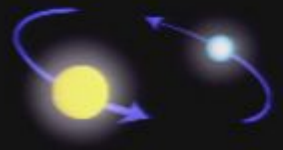


The secondary, lighter star and the core of the giant star spiral inward within a common envelope

The common envelope is ejected, while the separation between the core and the secondary star decreases



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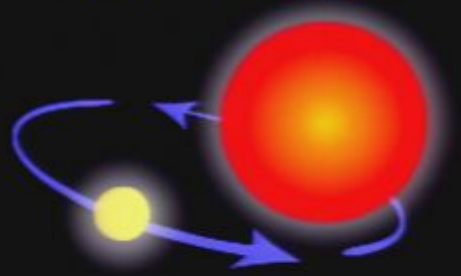

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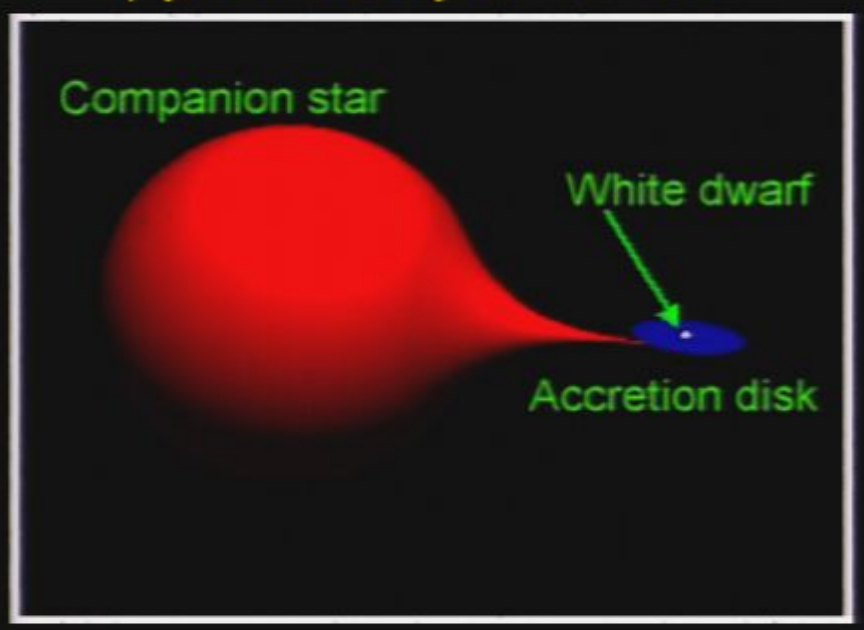
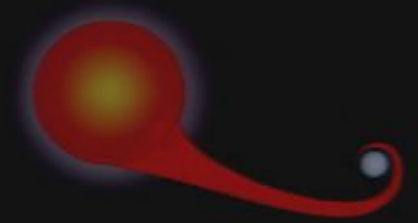
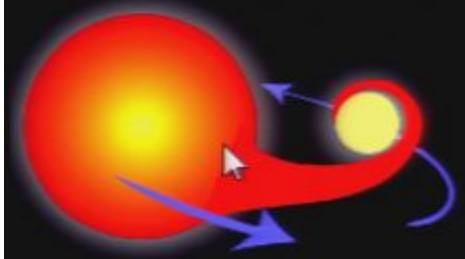
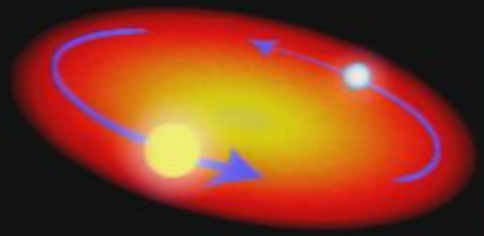




The aging companion star starts swelling, spilling gas onto the white dwarf.

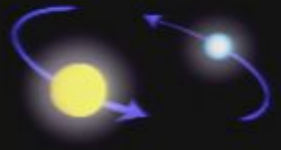


...which spills gas onto the econdary star, causing it to pand and become engulfed



The secondary, lighter star and the core of the giant star spiral inward within a common envelope

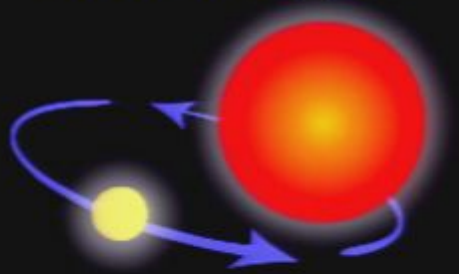
The common envelope is ejected, while the separation between the core and the secondary star decreases



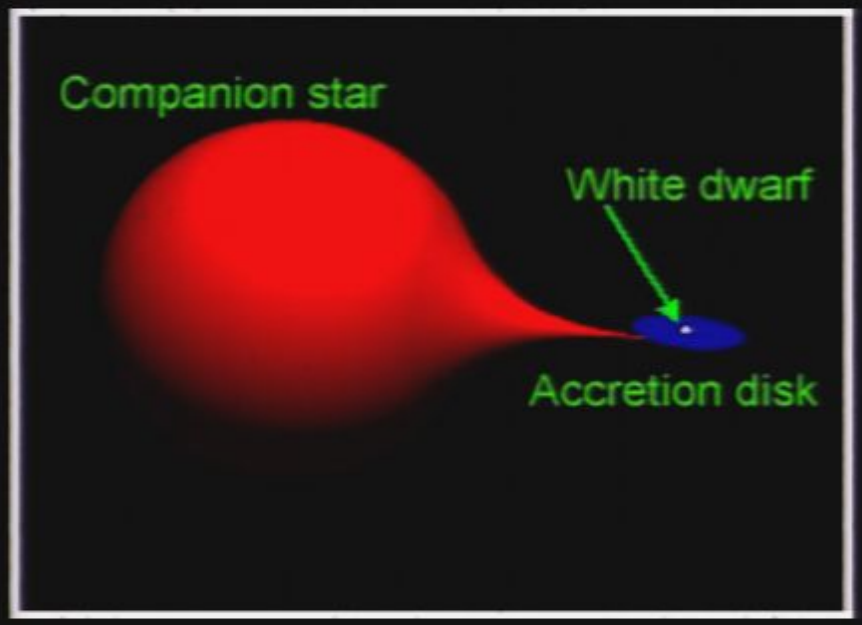
The remaining core of the giant collapses and becomes a white dwarf

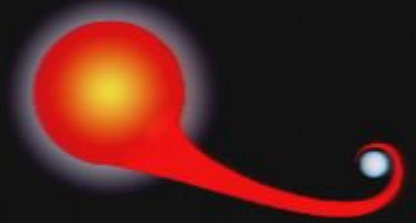
Type 1a Super Nova

Two normal stars are in a binary pair.

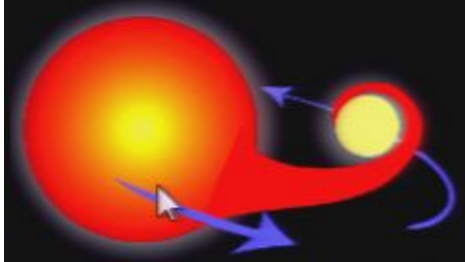


The more massive star becomes a giant...





The aging companion star starts swelling, spilling gas onto the white dwarf.



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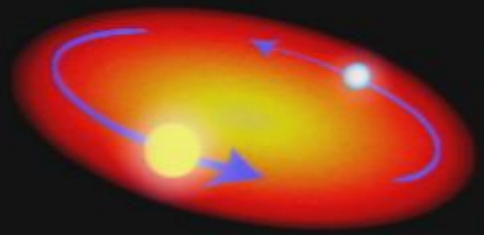
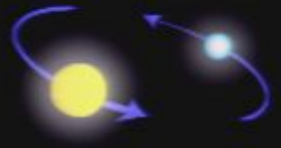
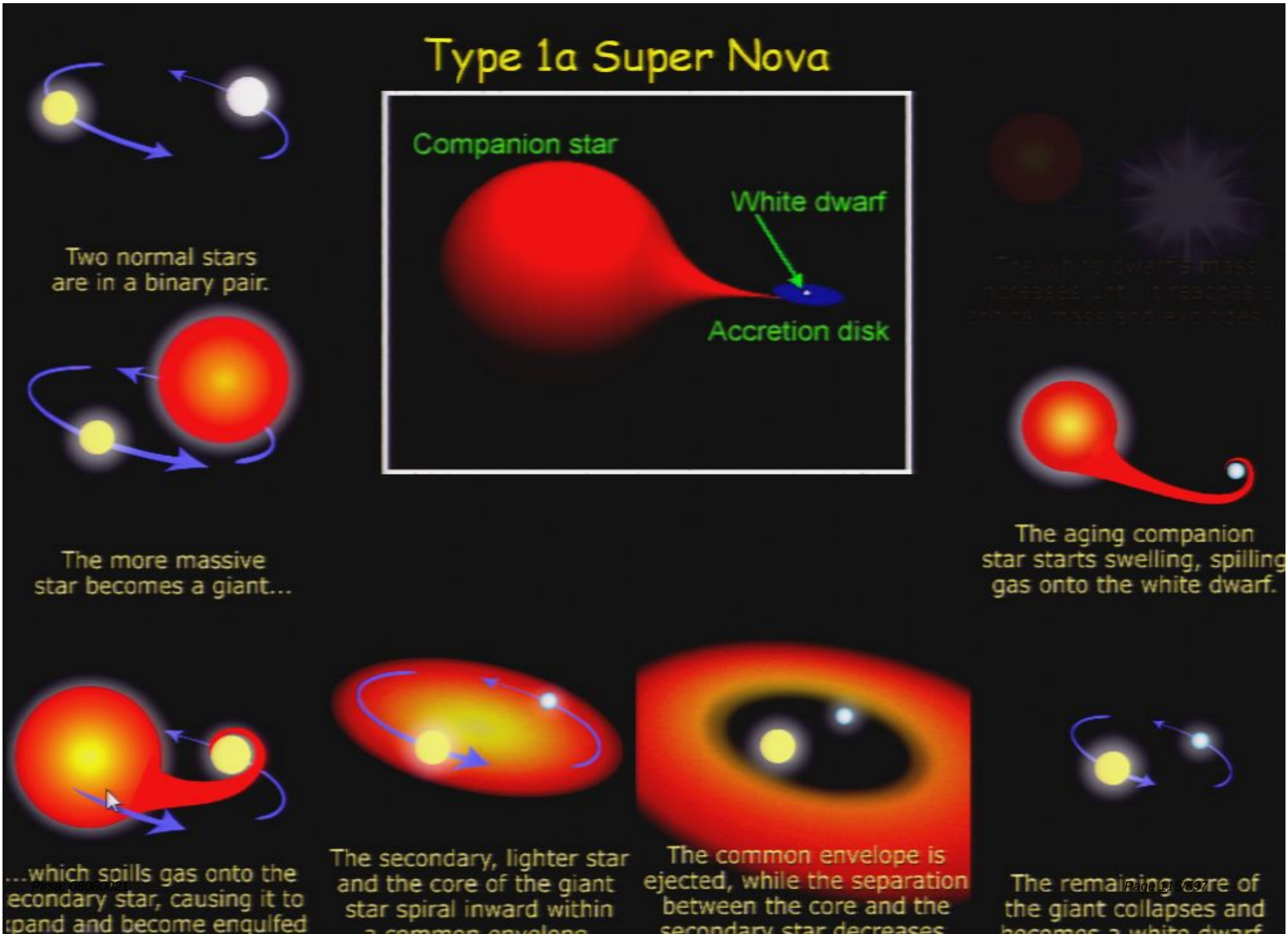


The secondary, lighter star and the core of the giant star spiral inward within

The common envelope is ejected, while the separation between the core and the



The remaining core of the giant collapses and


Type 1a Super Nova
Companion star
White dwarf
Accretion disk
Two normal stars are in a binary pair.
The more massive star becomes a giant...
The aging companion star starts swelling, spilling gas onto the white dwarf.
...which spills gas onto the
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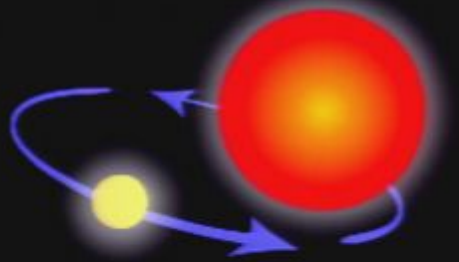

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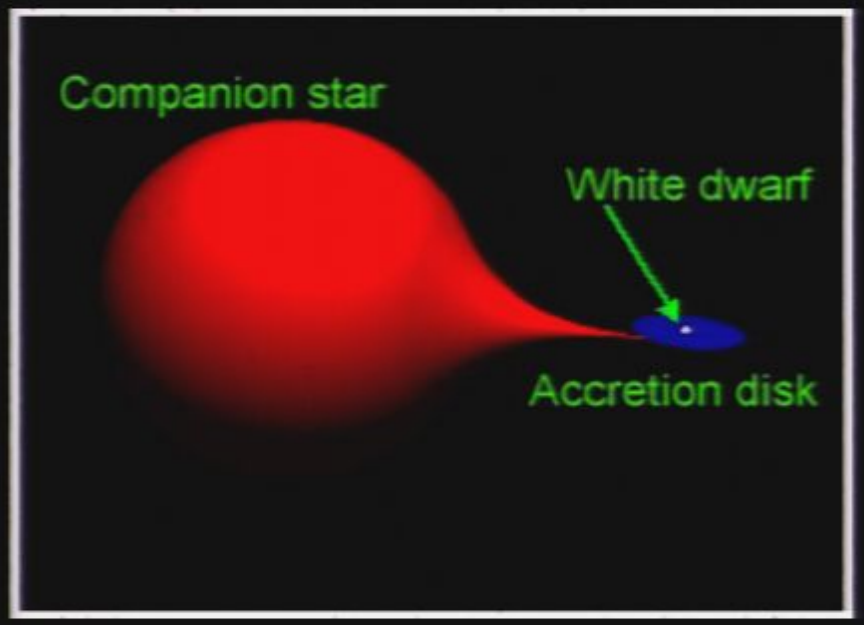
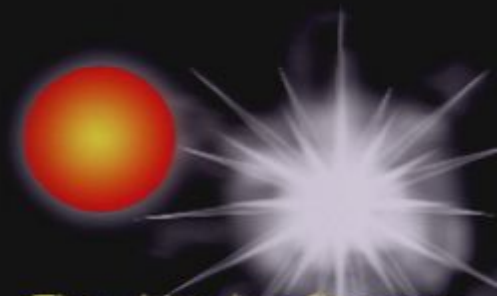
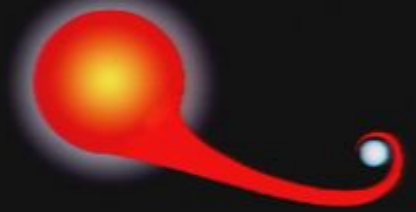
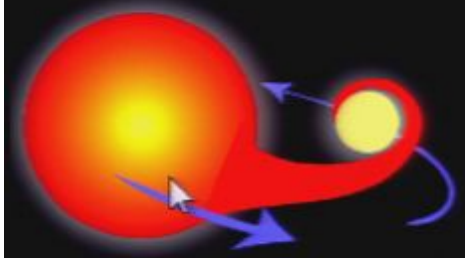




The white dwarf's mass increases until it reaches a critical mass and explodes...



The aging companion star starts swelling, spilling gas onto the white dwarf.



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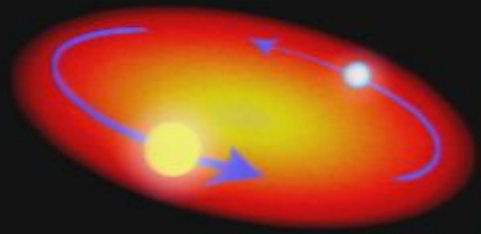

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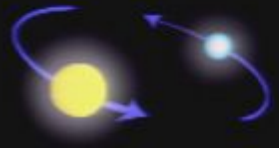
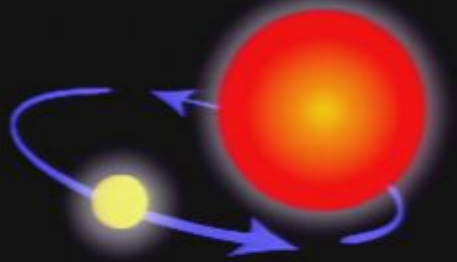


The remaining core of the giant collapses and

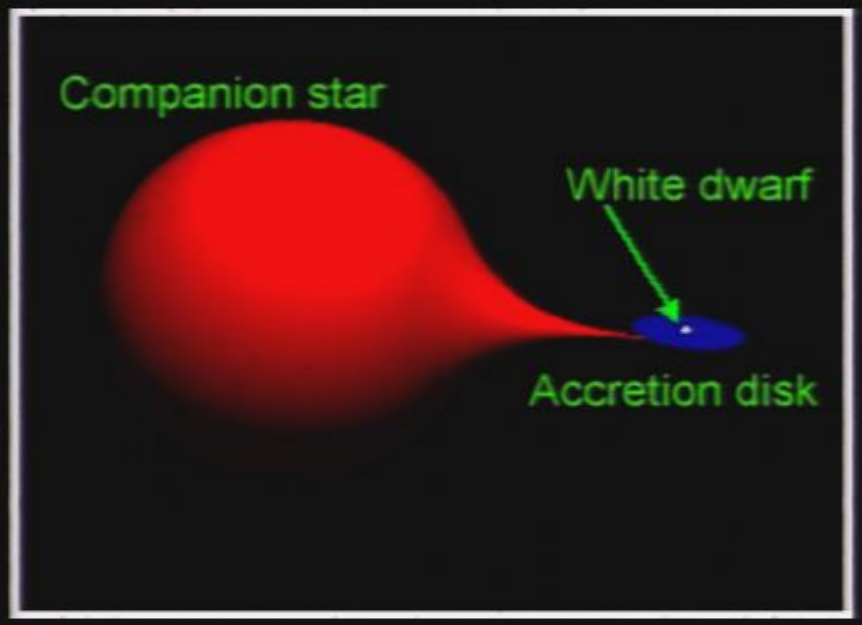
Pirsa: 08080021

Type 1a Super Nova

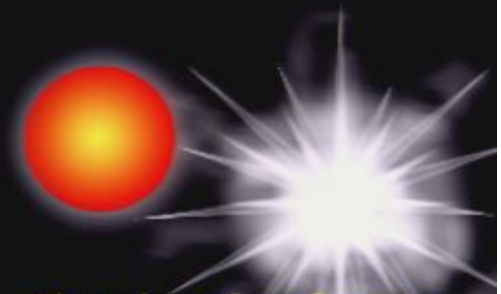
Two normal stars are in a binary pair.



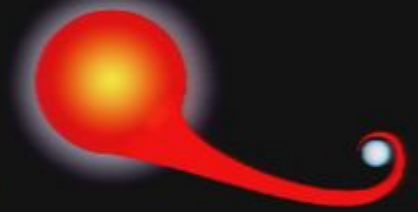
The more massive star becomes a giant...



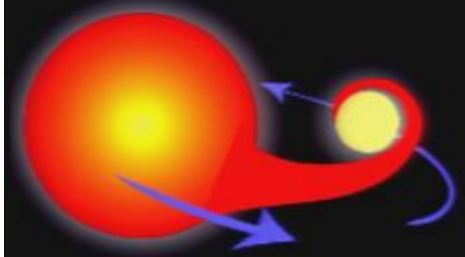
Not of interest to black hole cosmologists, but type 1a's are great yard sticks in determining distances



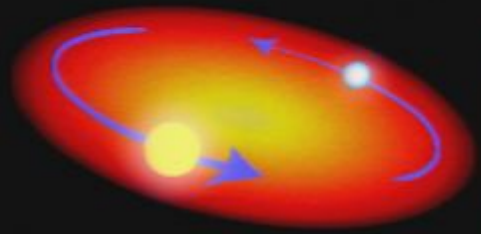
The white dwarf's mass increases until it reaches a critical mass and explodes...



The aging companion star starts swelling, spilling gas onto the white dwarf.



...which spills gas onto the econdary star, causing it to pand and become engulfed



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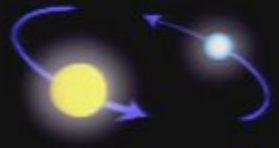

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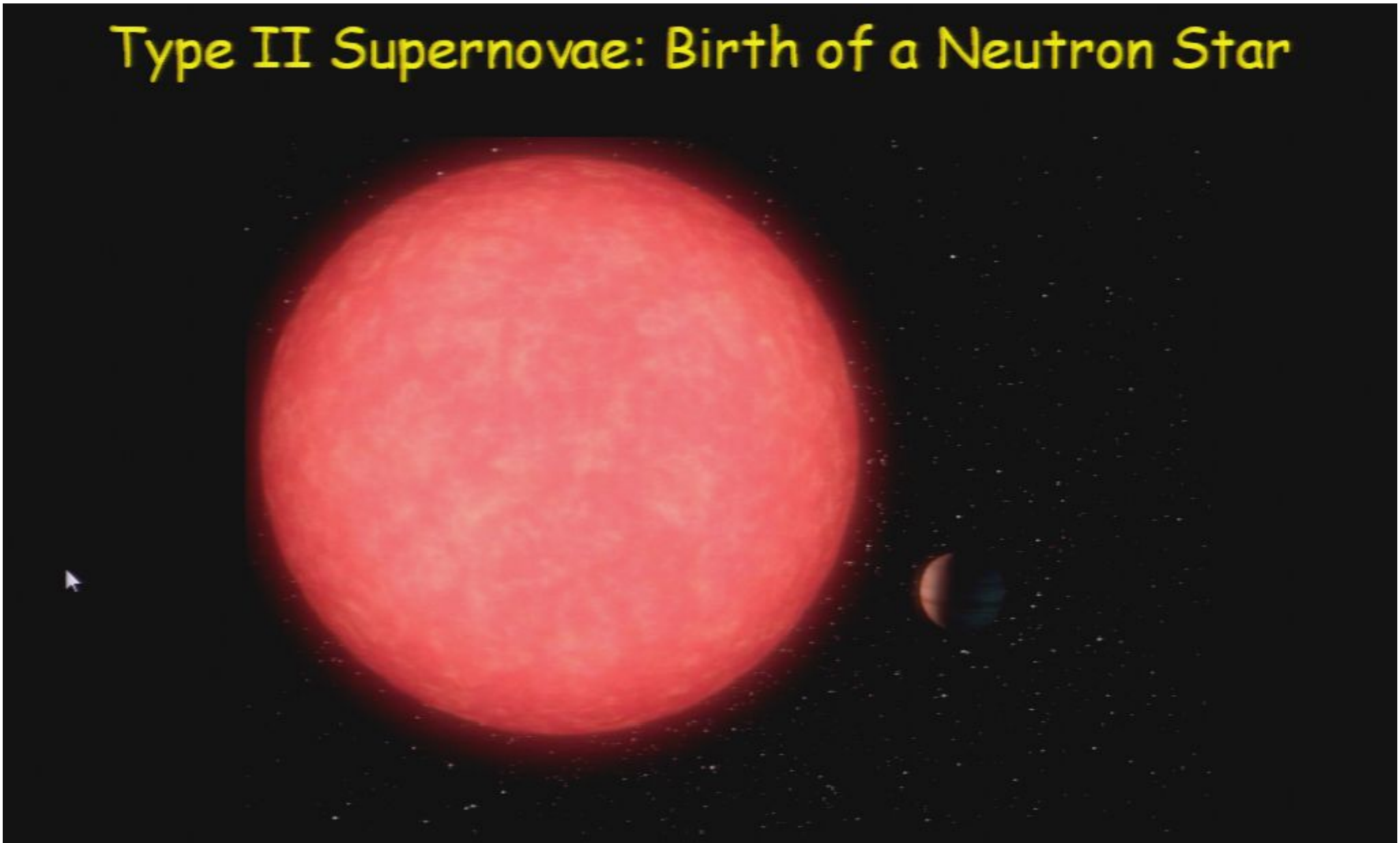
Type II Supernovae: Birth of a Neutron Star



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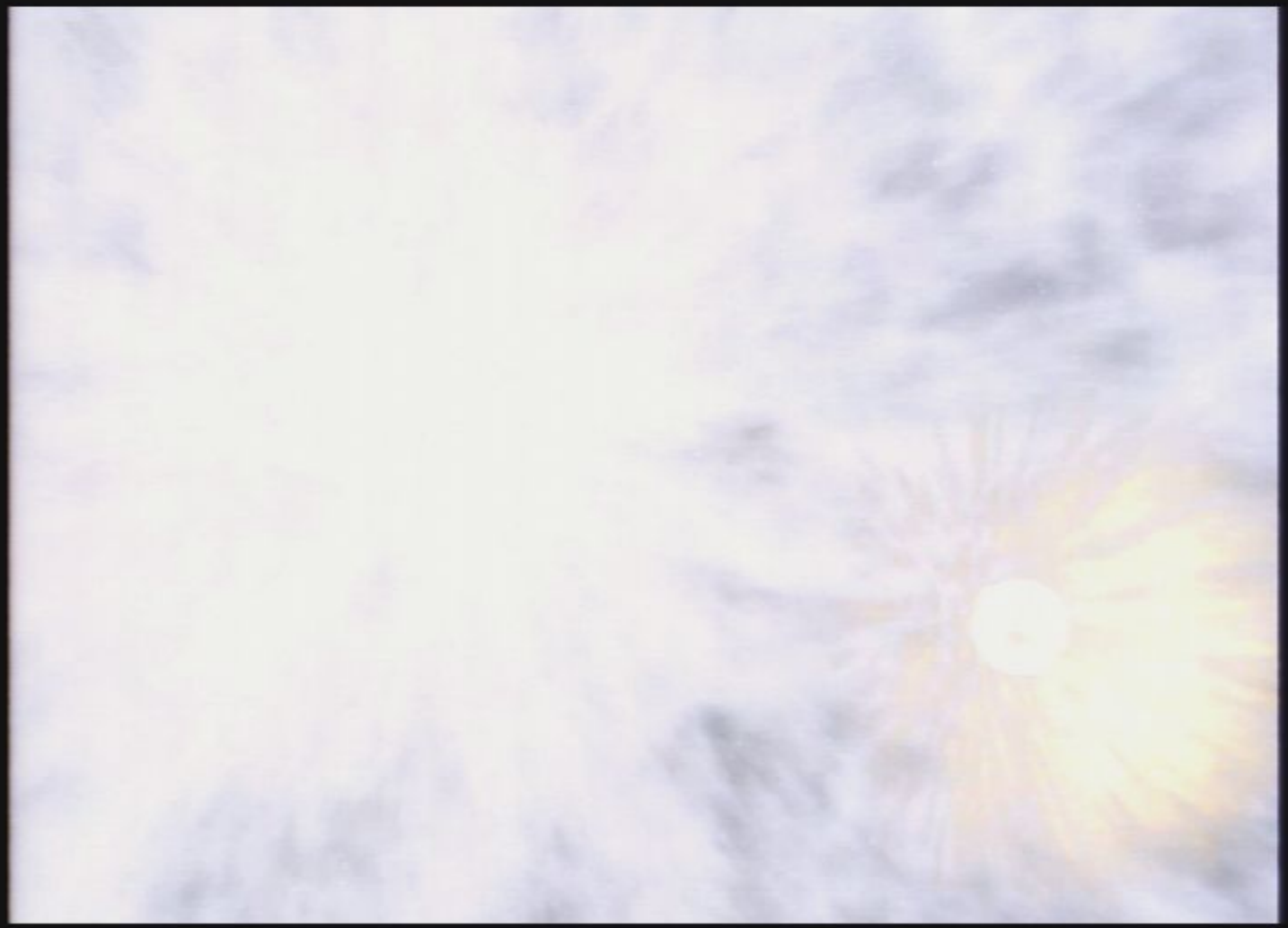

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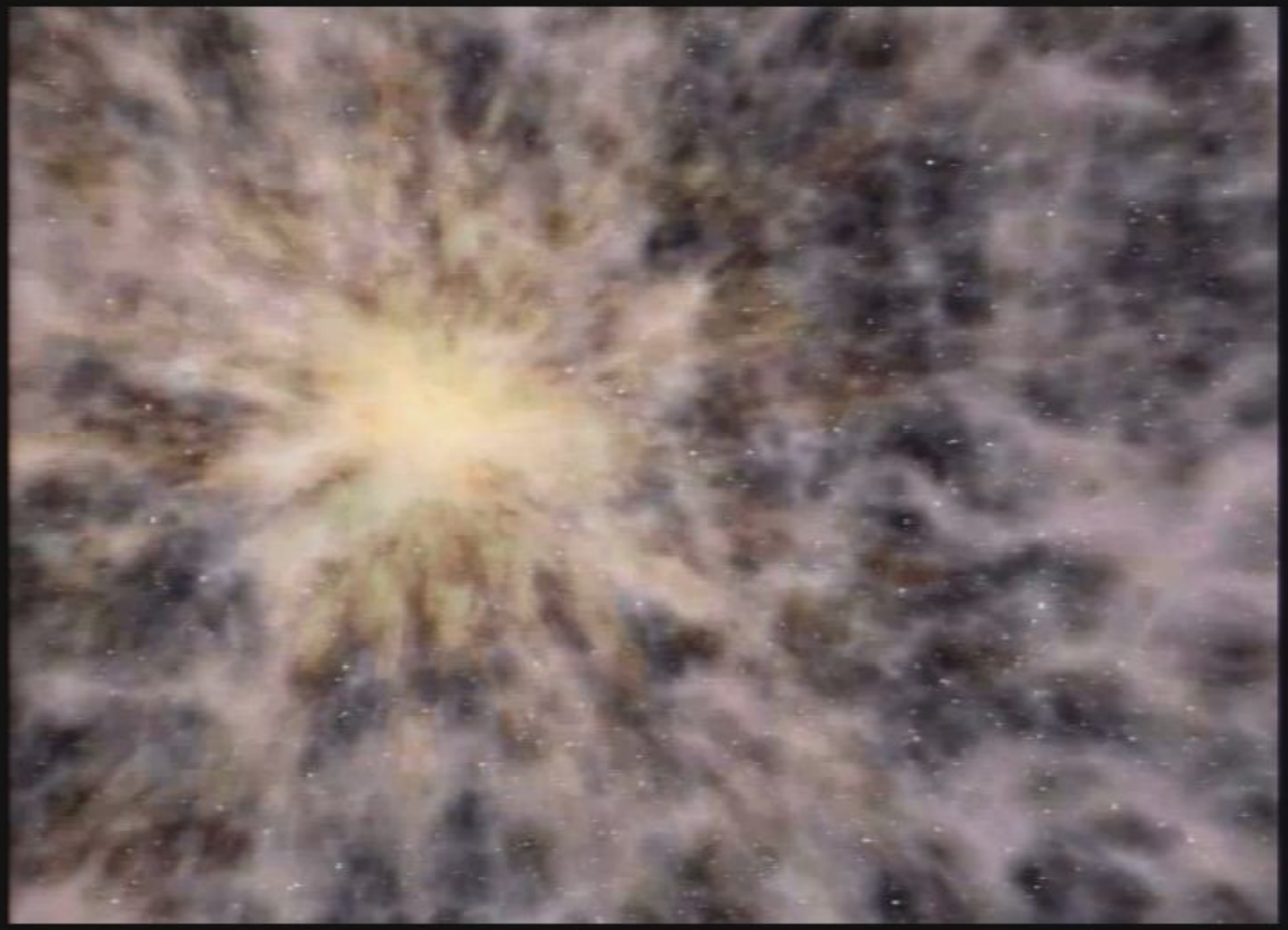

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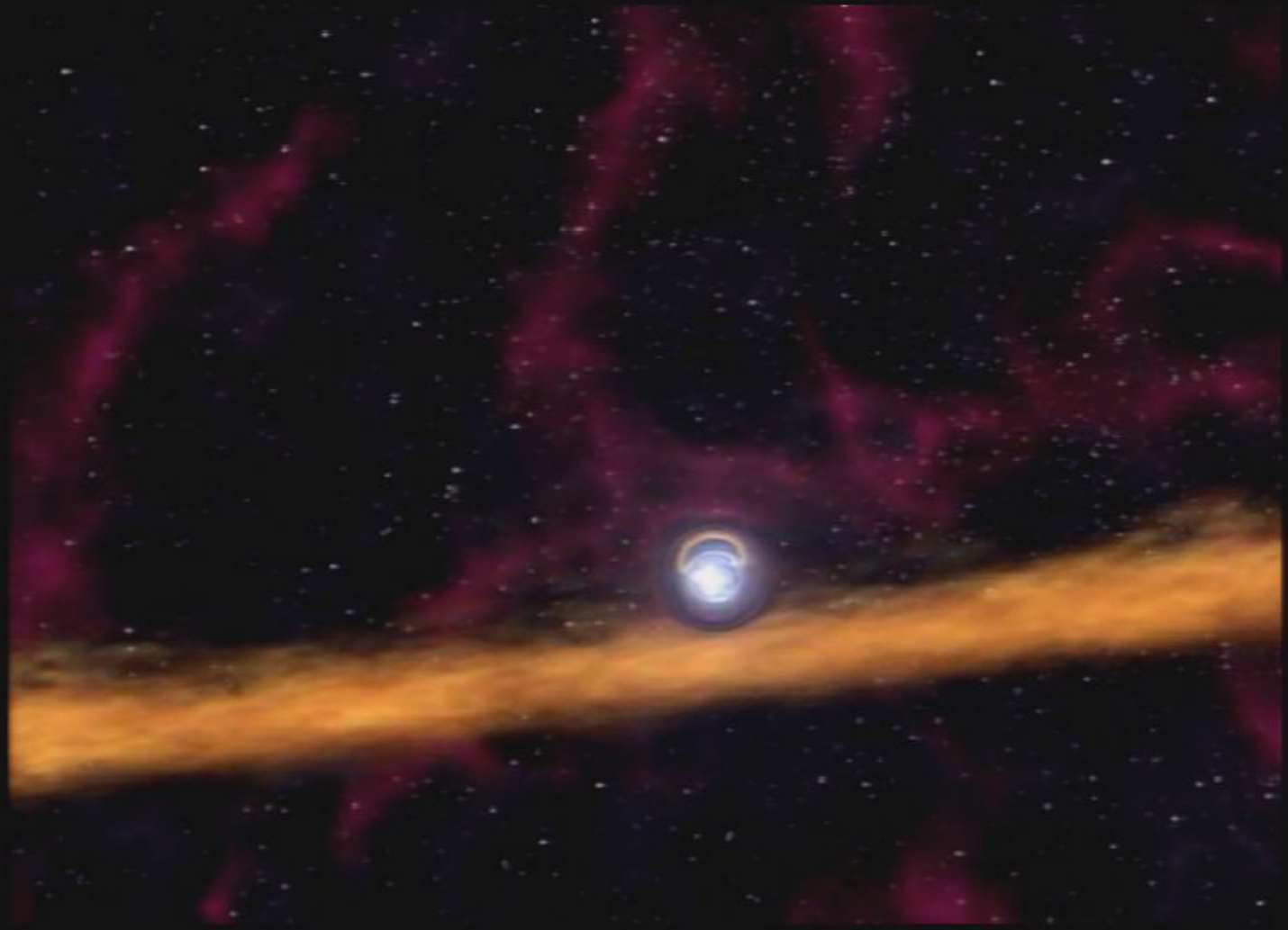

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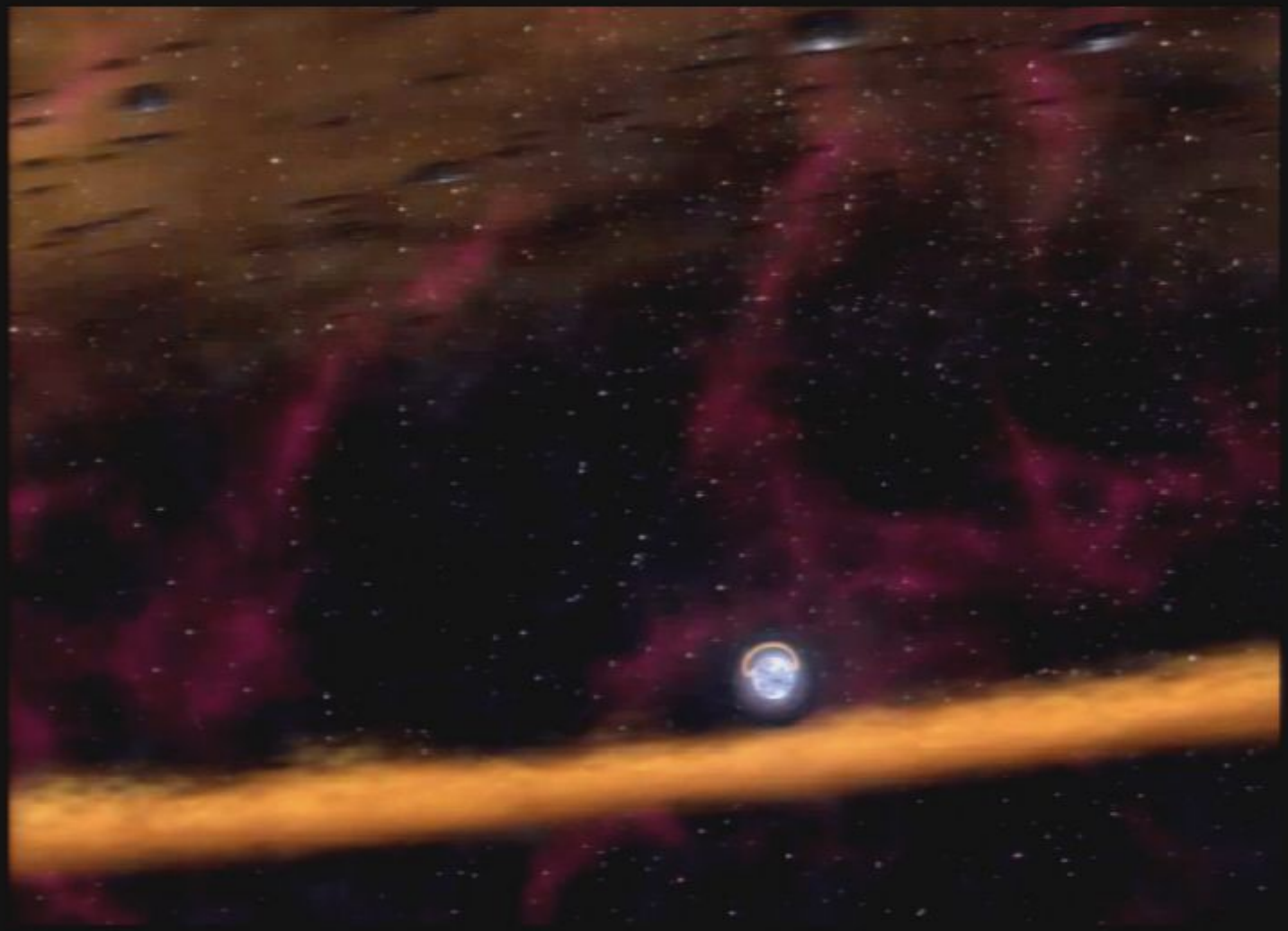

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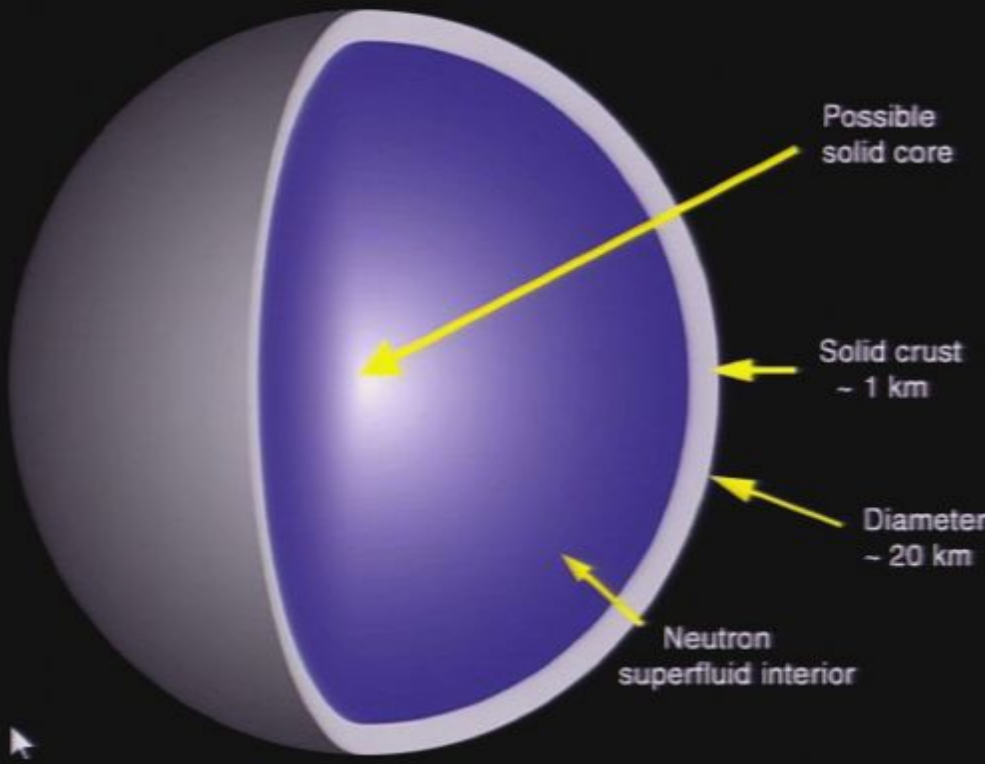
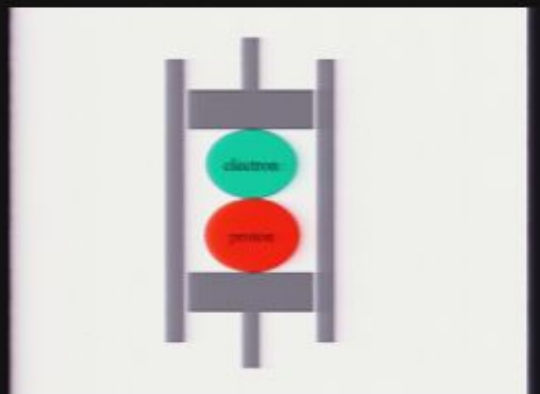
Neutron Star Facts

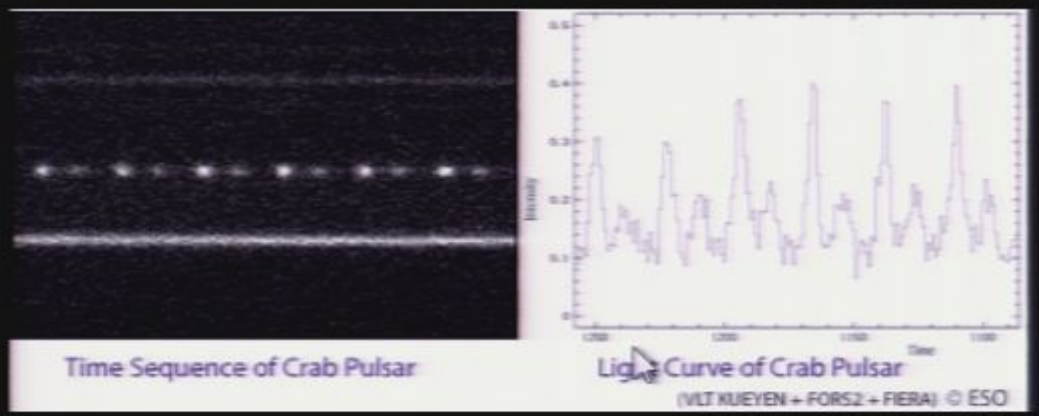
- A giant ball of neutrons.
- Mass : at least 1.4 x mass of the Sun to maximum of about 3 solar masses.
- Temperature 1 million degrees and cooling.
- Diameter: 20 km!
- Density: 10^{18} kg/m^3
  - A sugar cube of this matter weighs 400 billion tons
- Day: 1 - 0.001 seconds!
- Magnetic fields as strong as the Sun, but in the space of a city.
- But just a theory until 1968

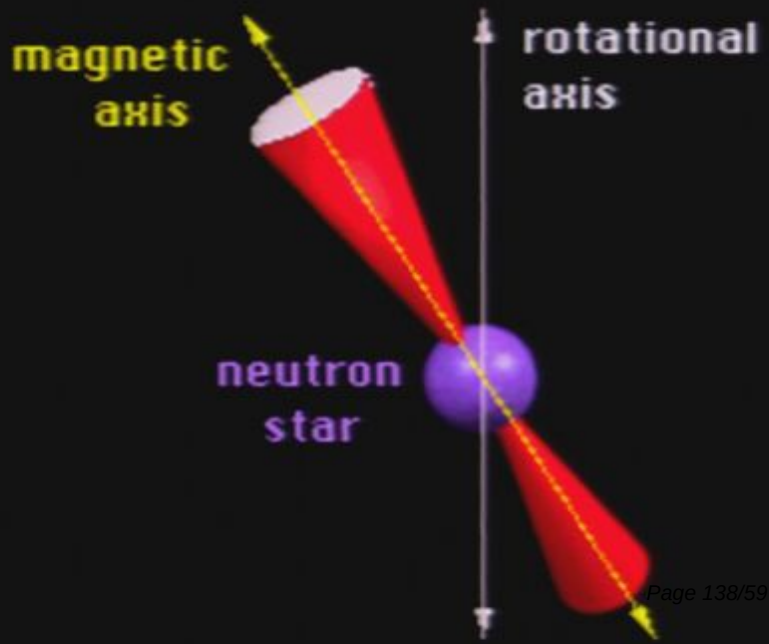




Pulsars

- Discovered by Bell and Hewish in 1968
- Stands for pulsating stars, since they emit regular pulses
- Now known to be spinning neutron stars





Crab Nebula Pulsar

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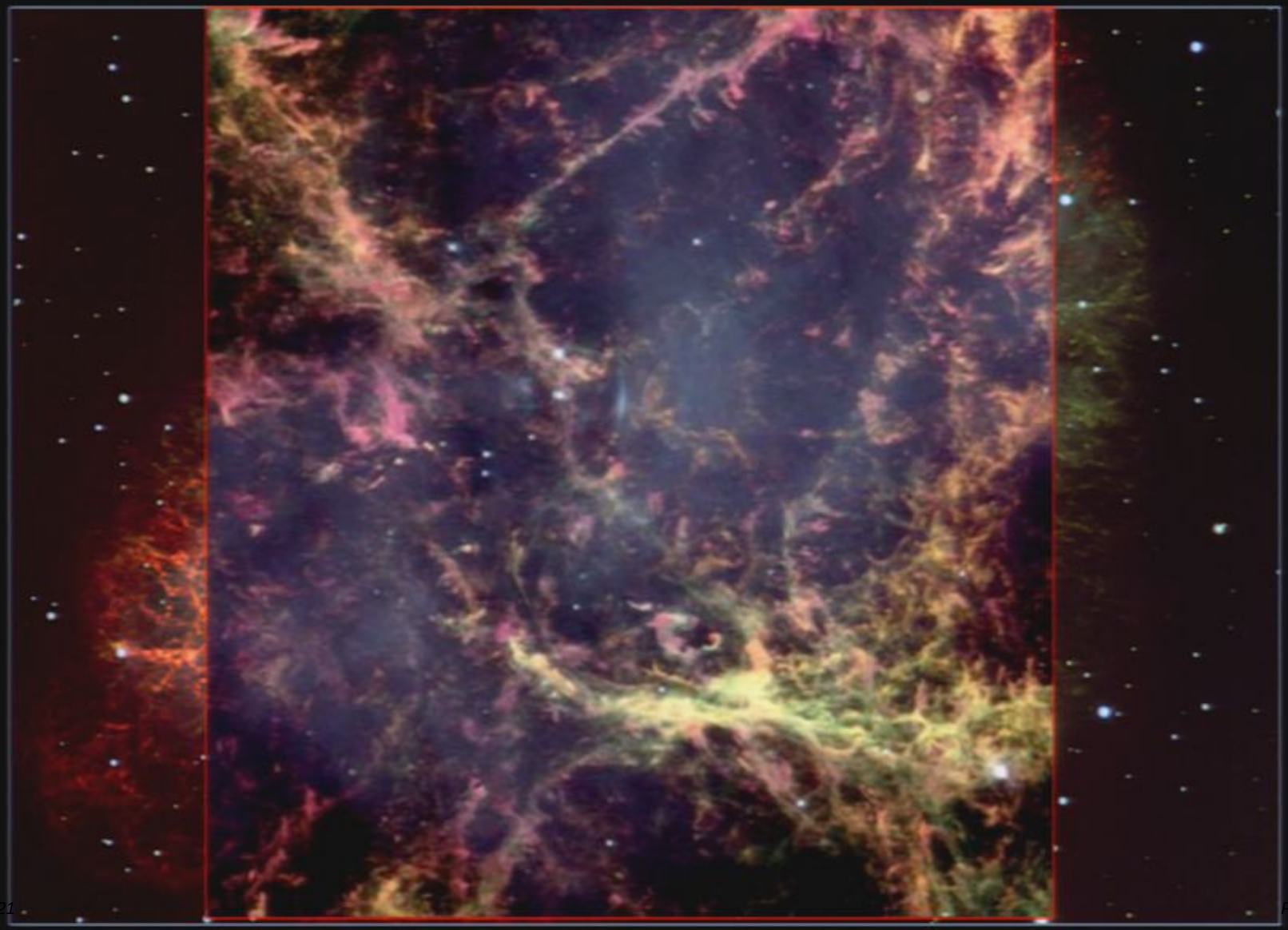

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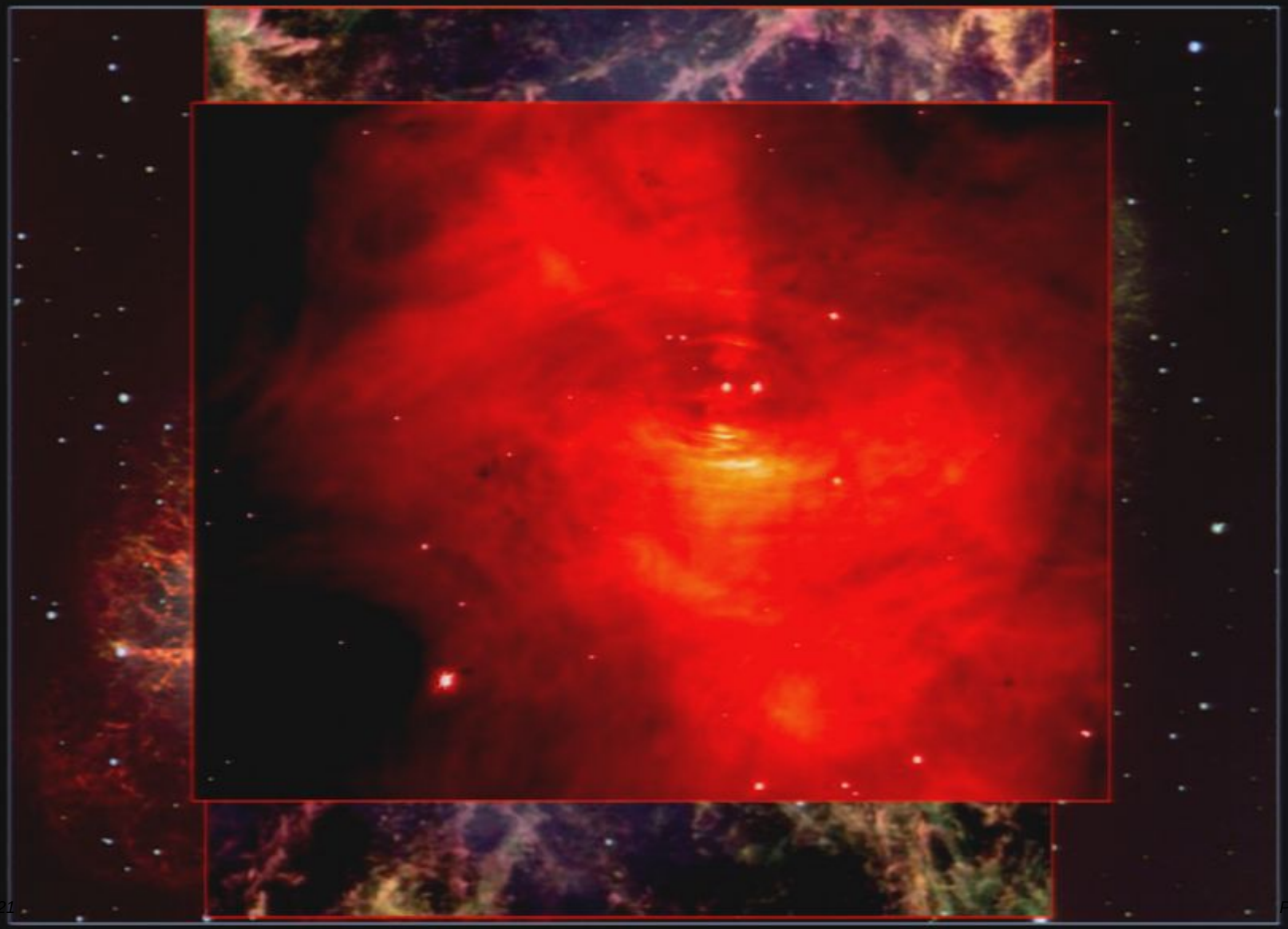

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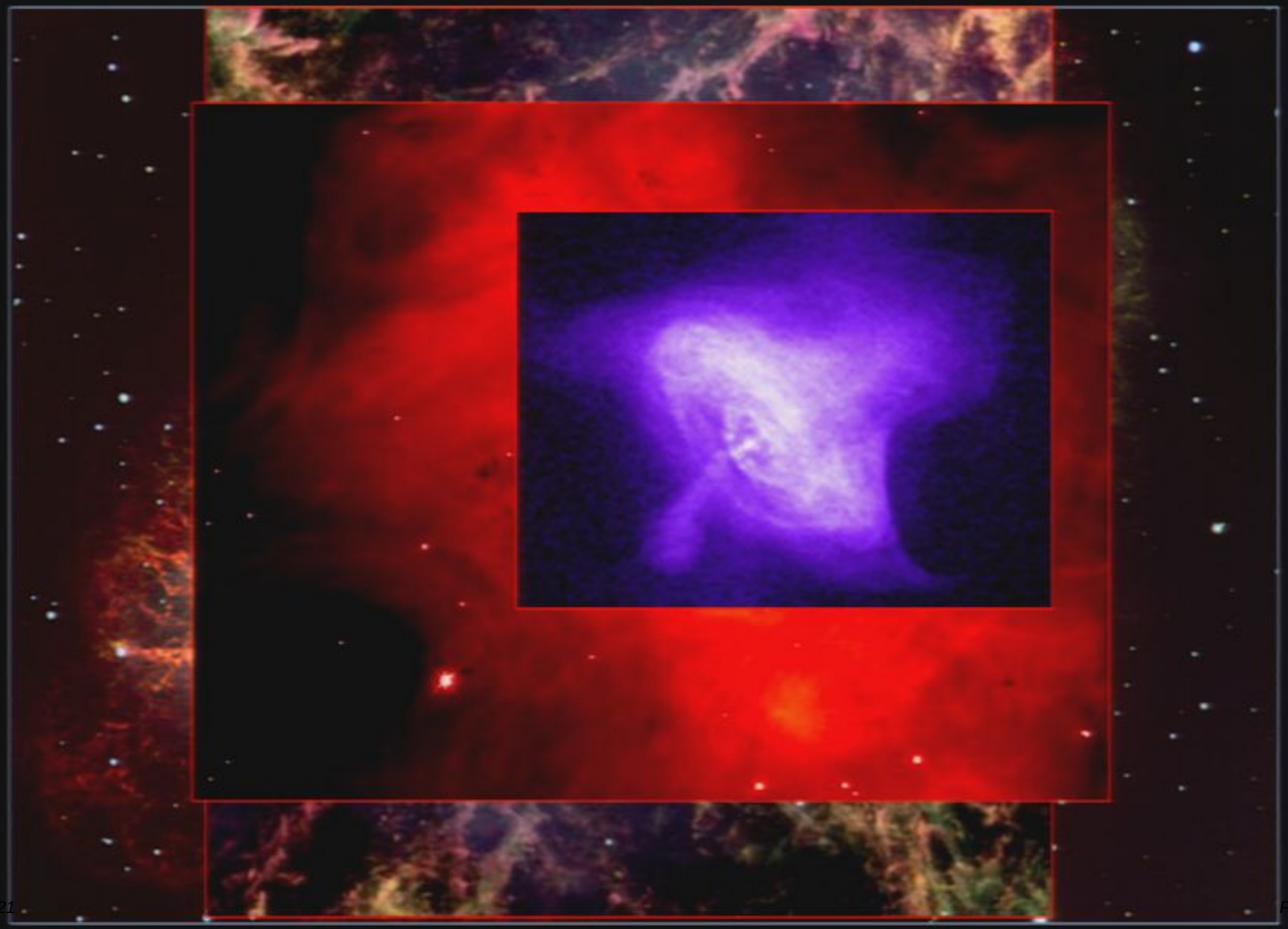

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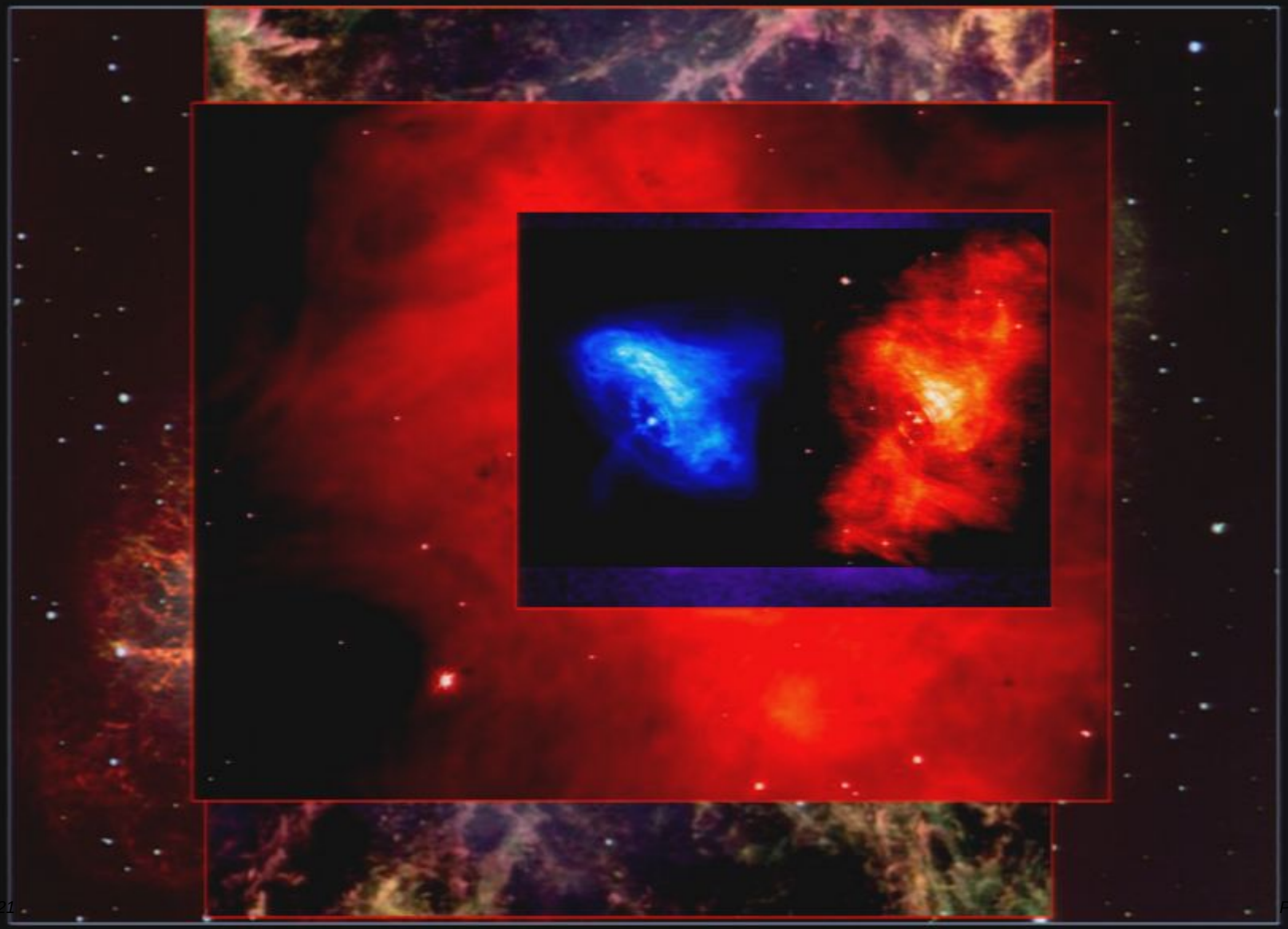

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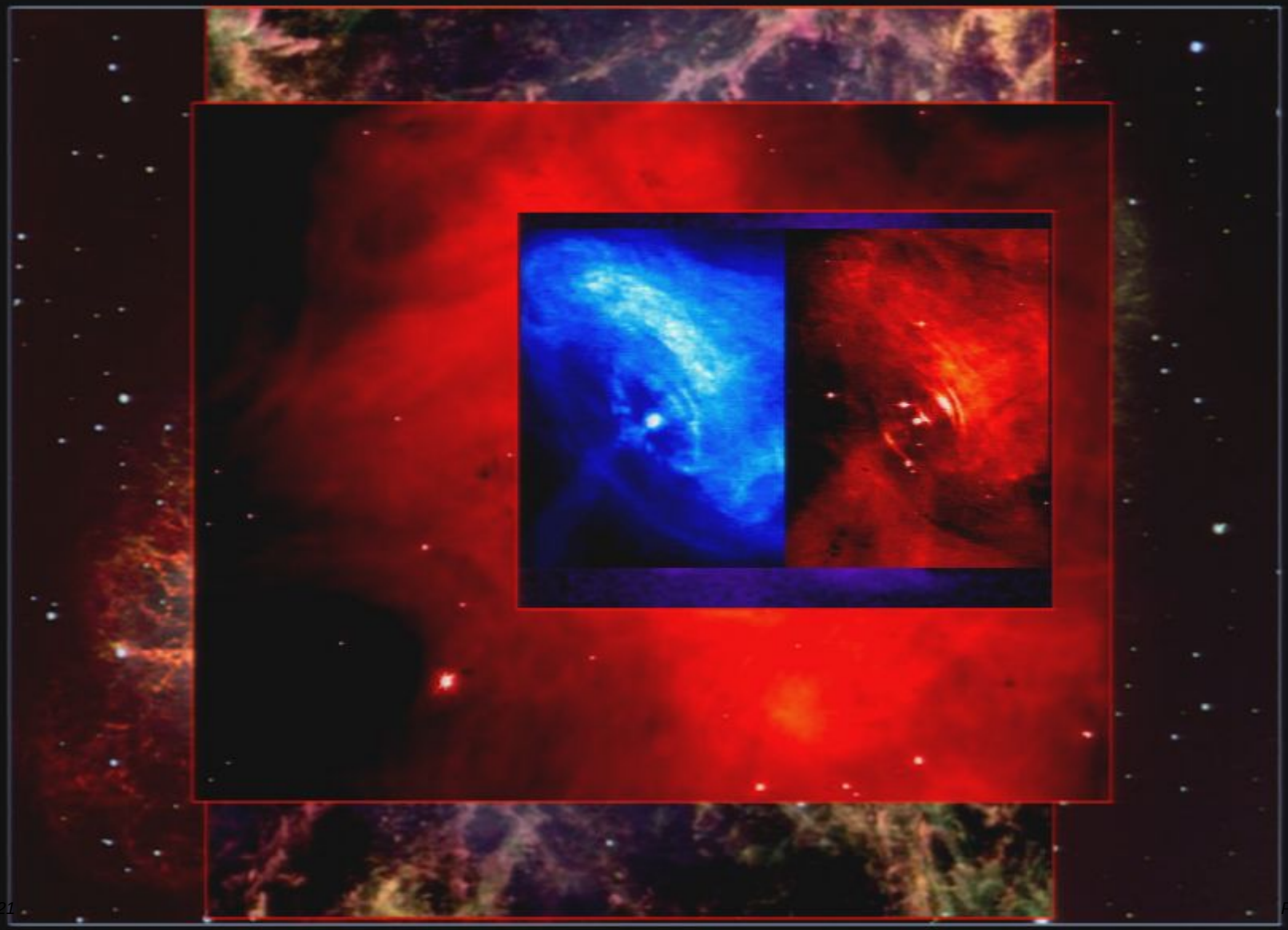

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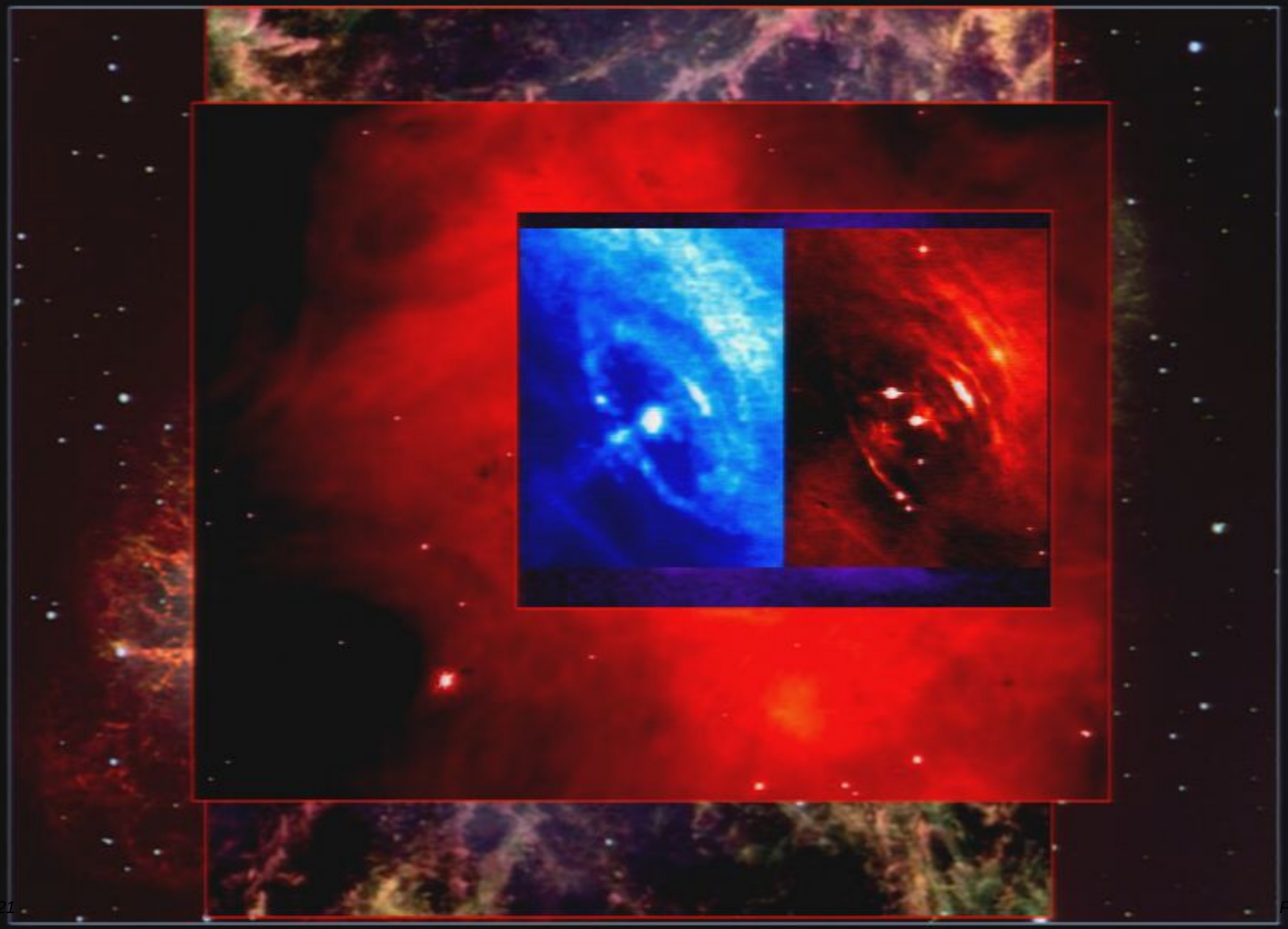

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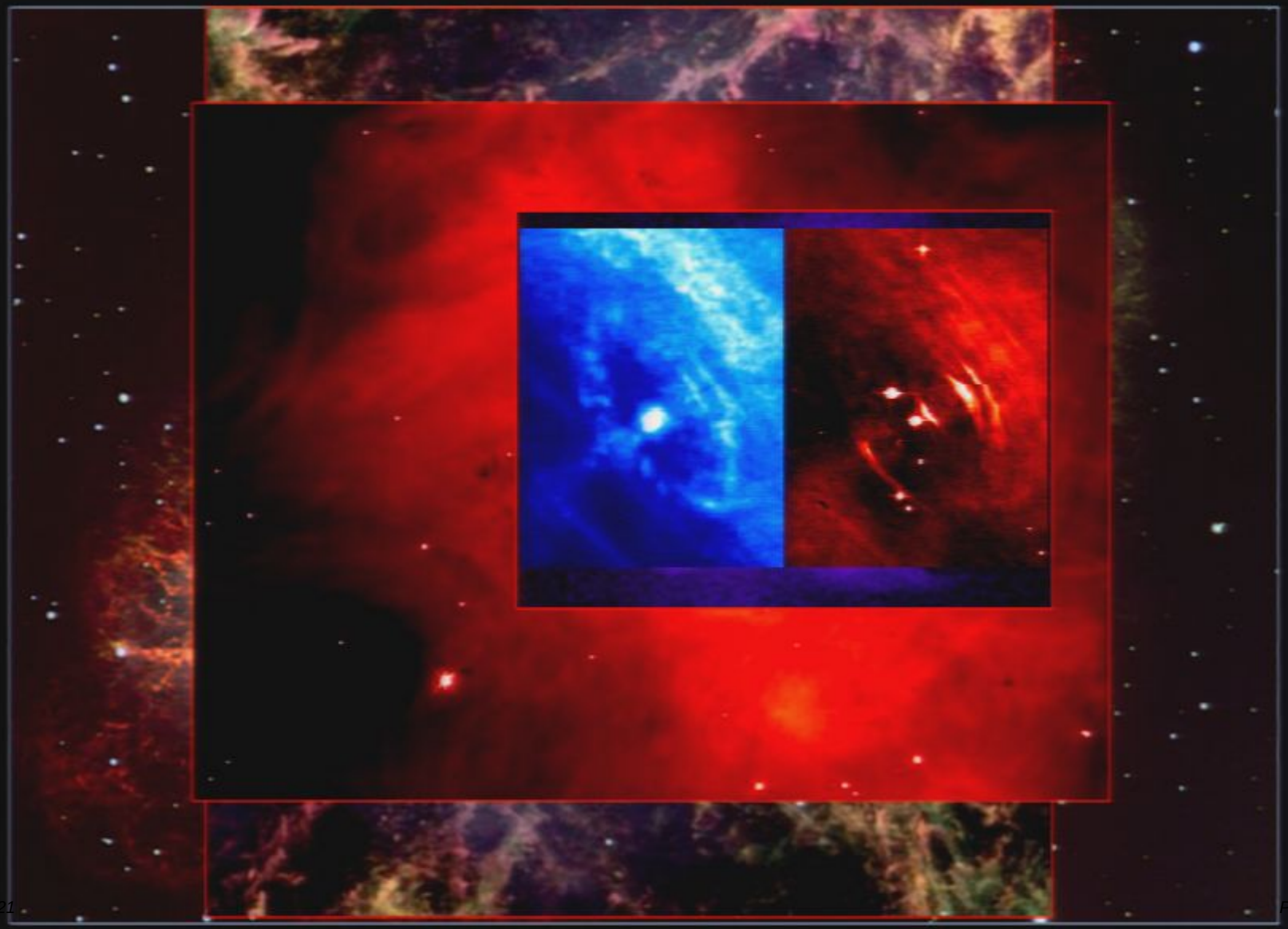

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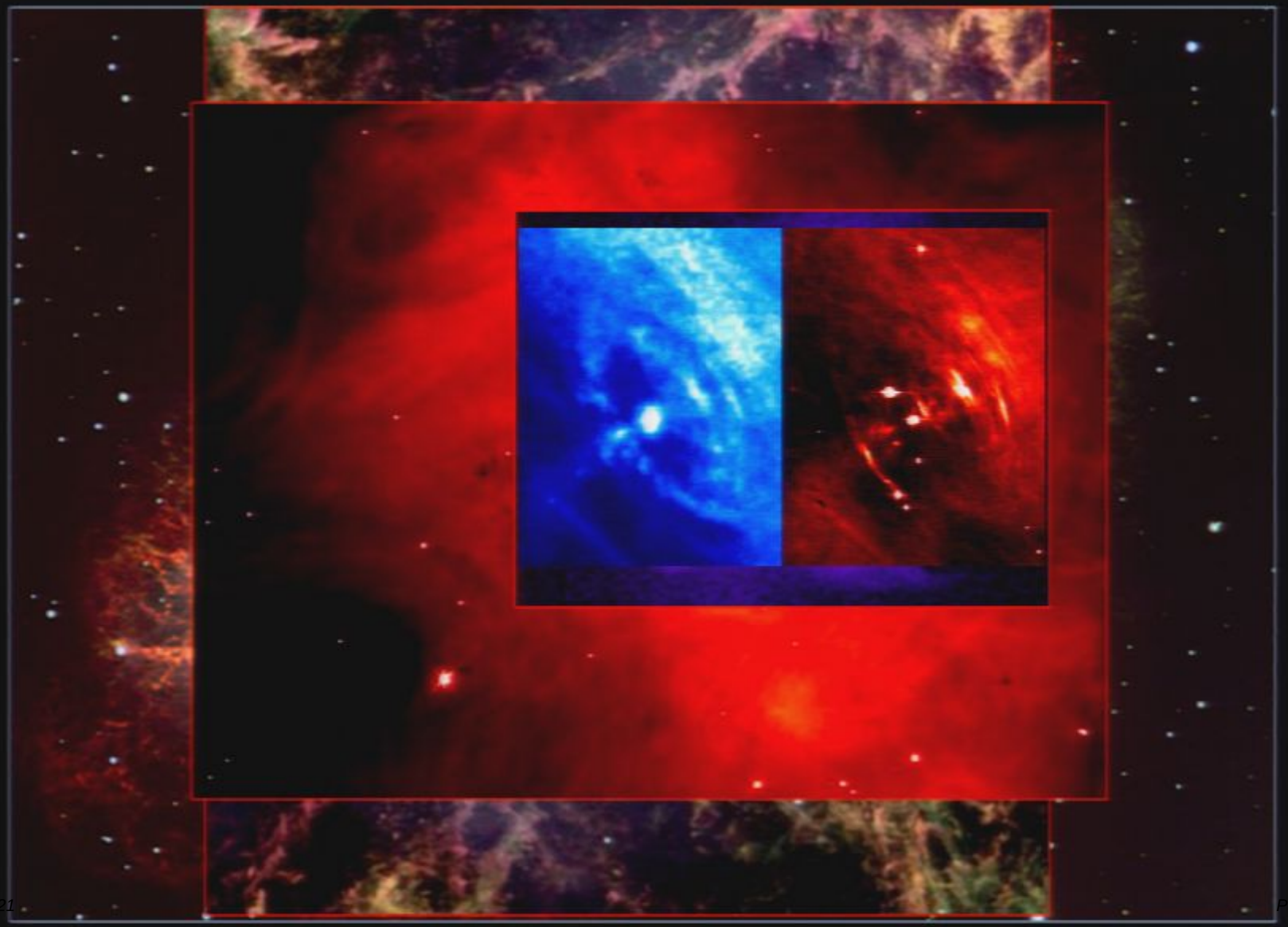

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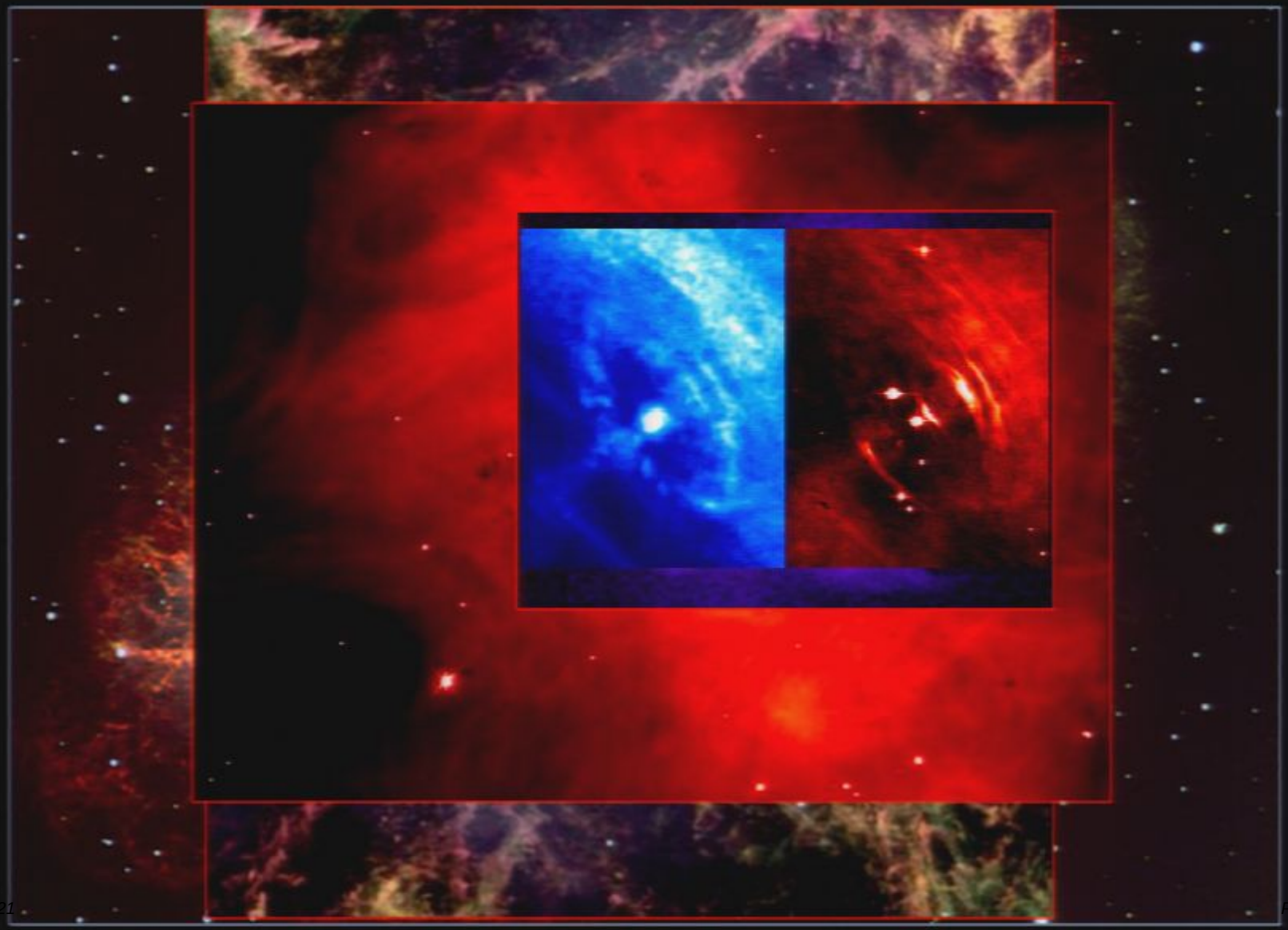

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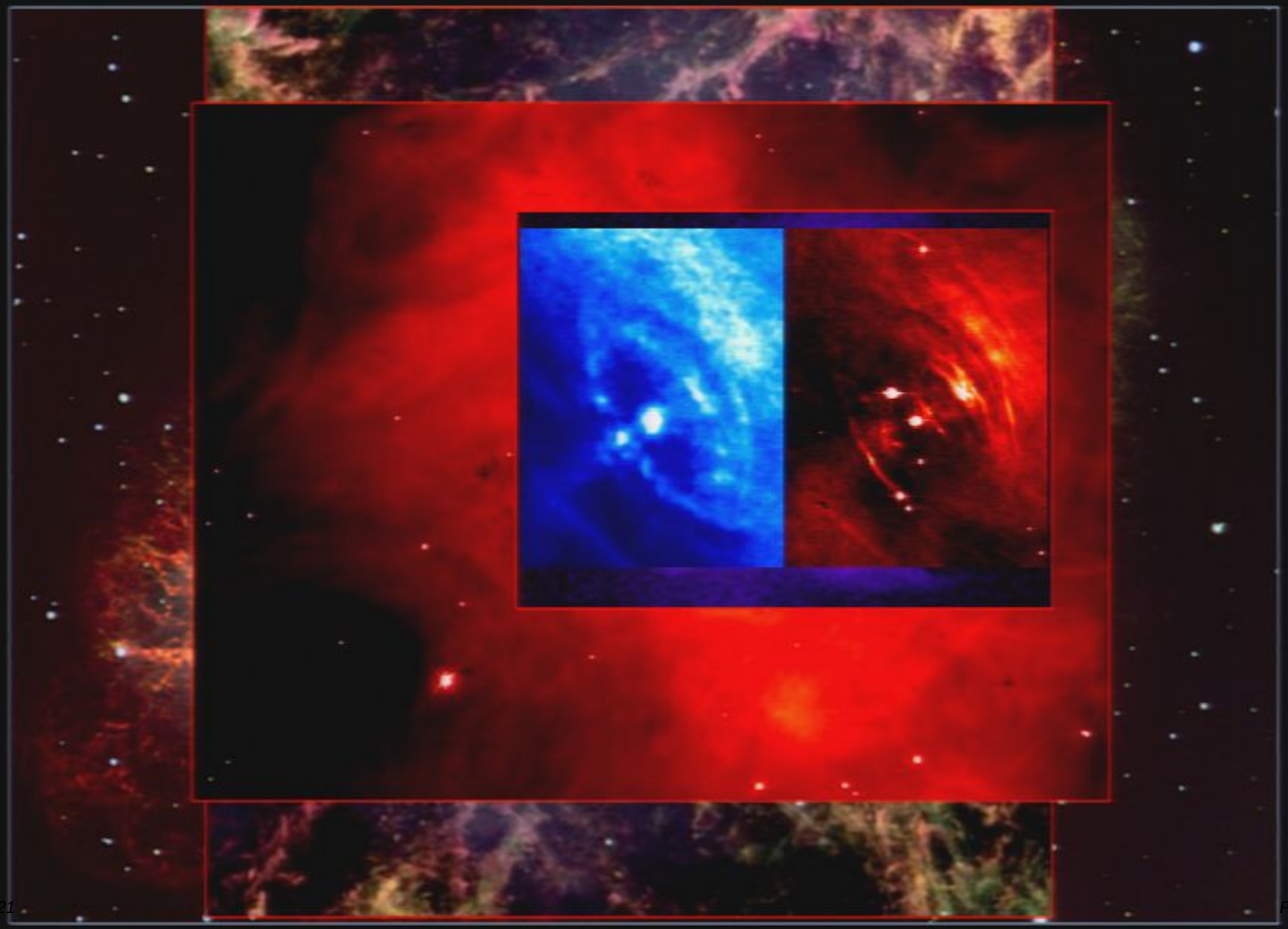

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Black Hole

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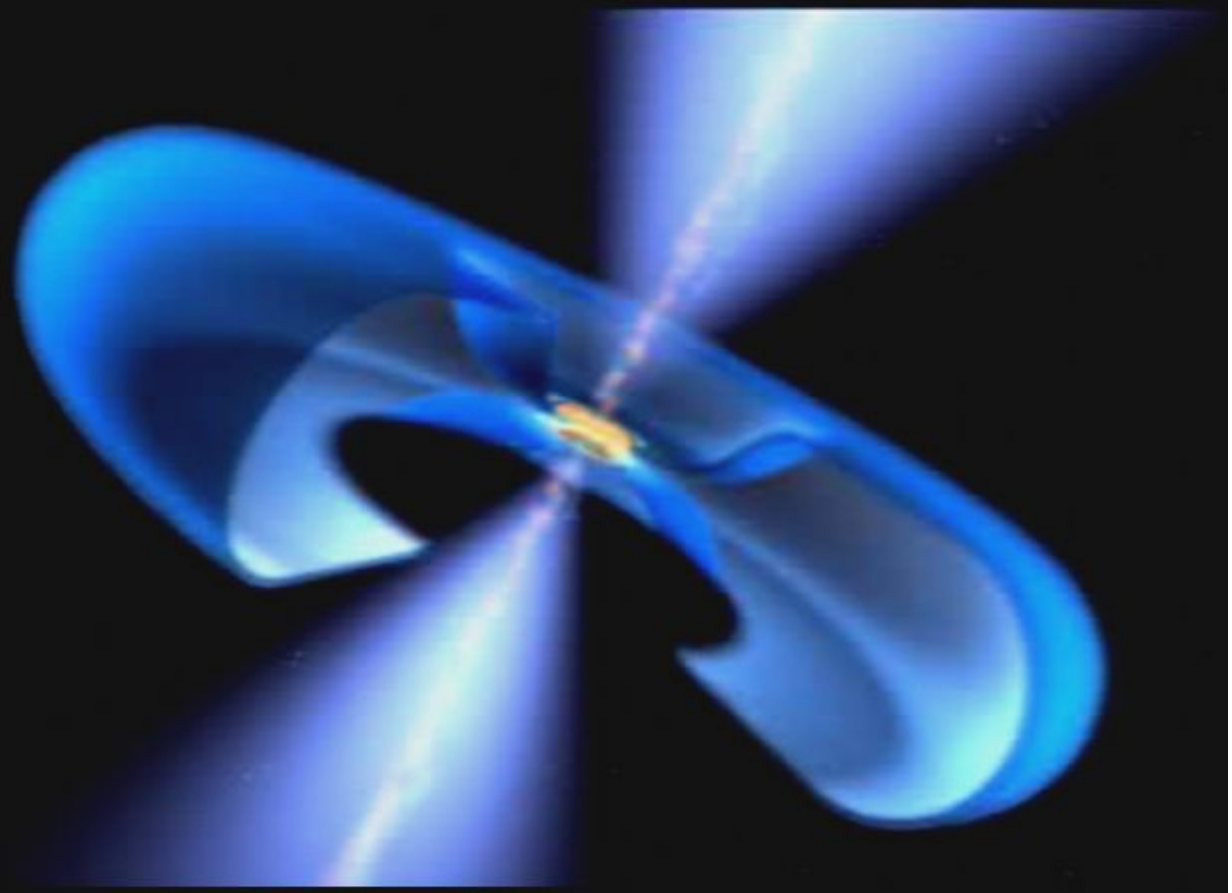

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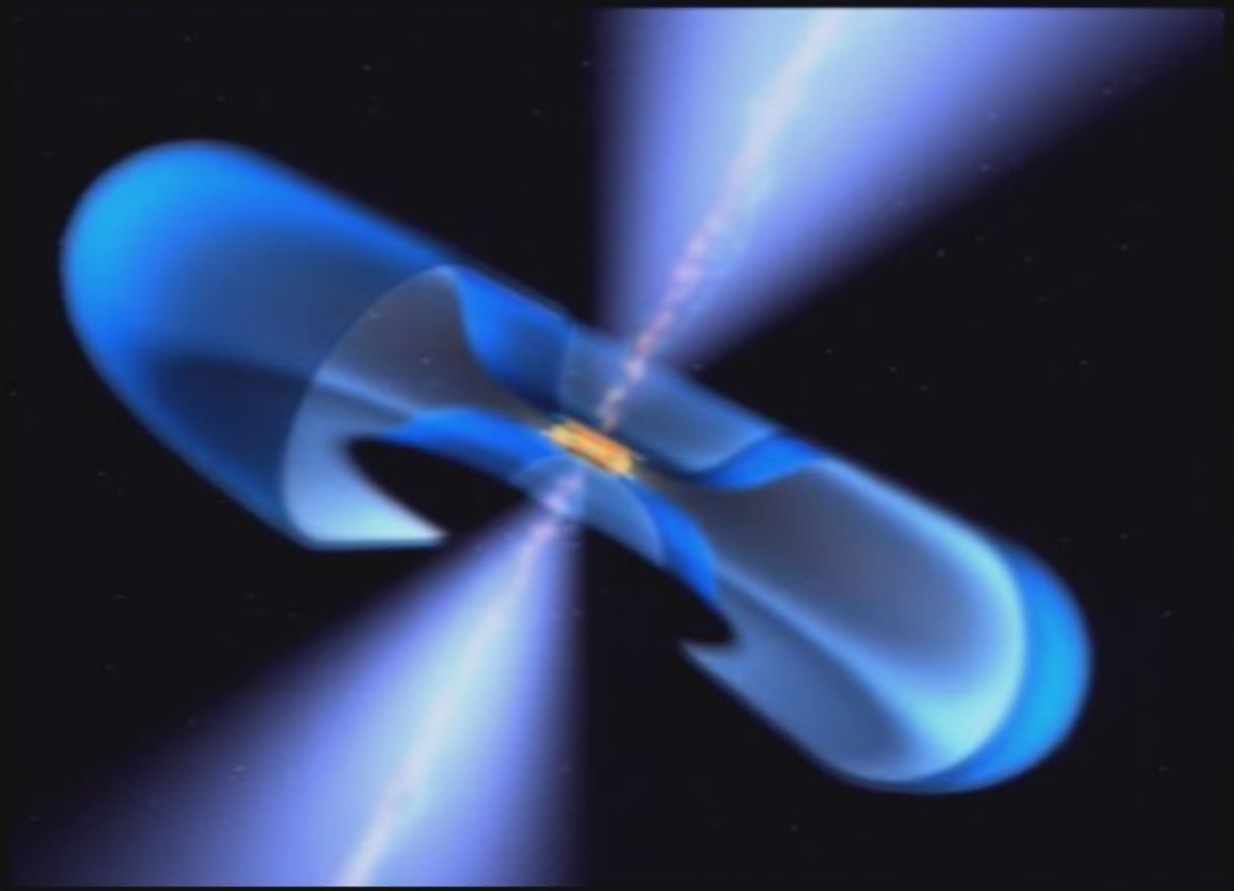

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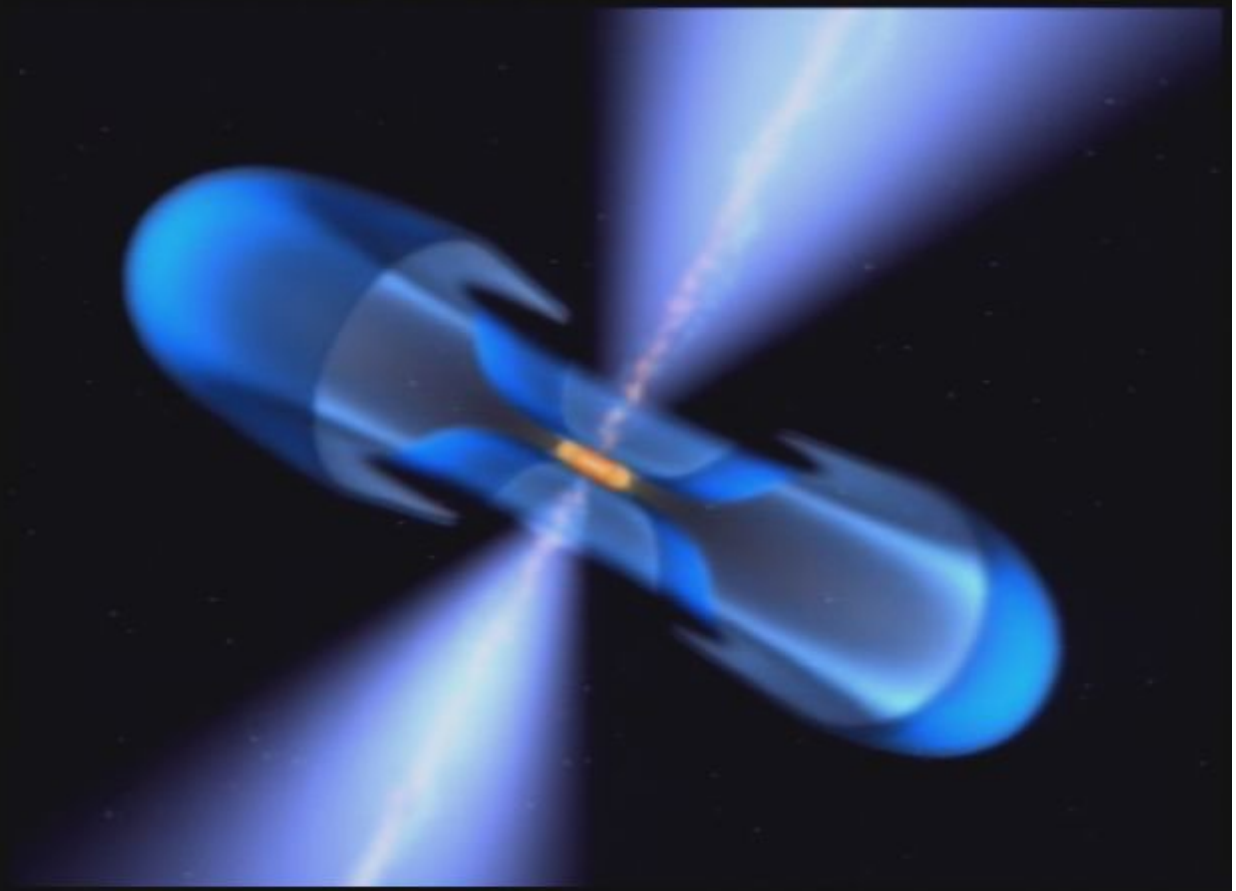

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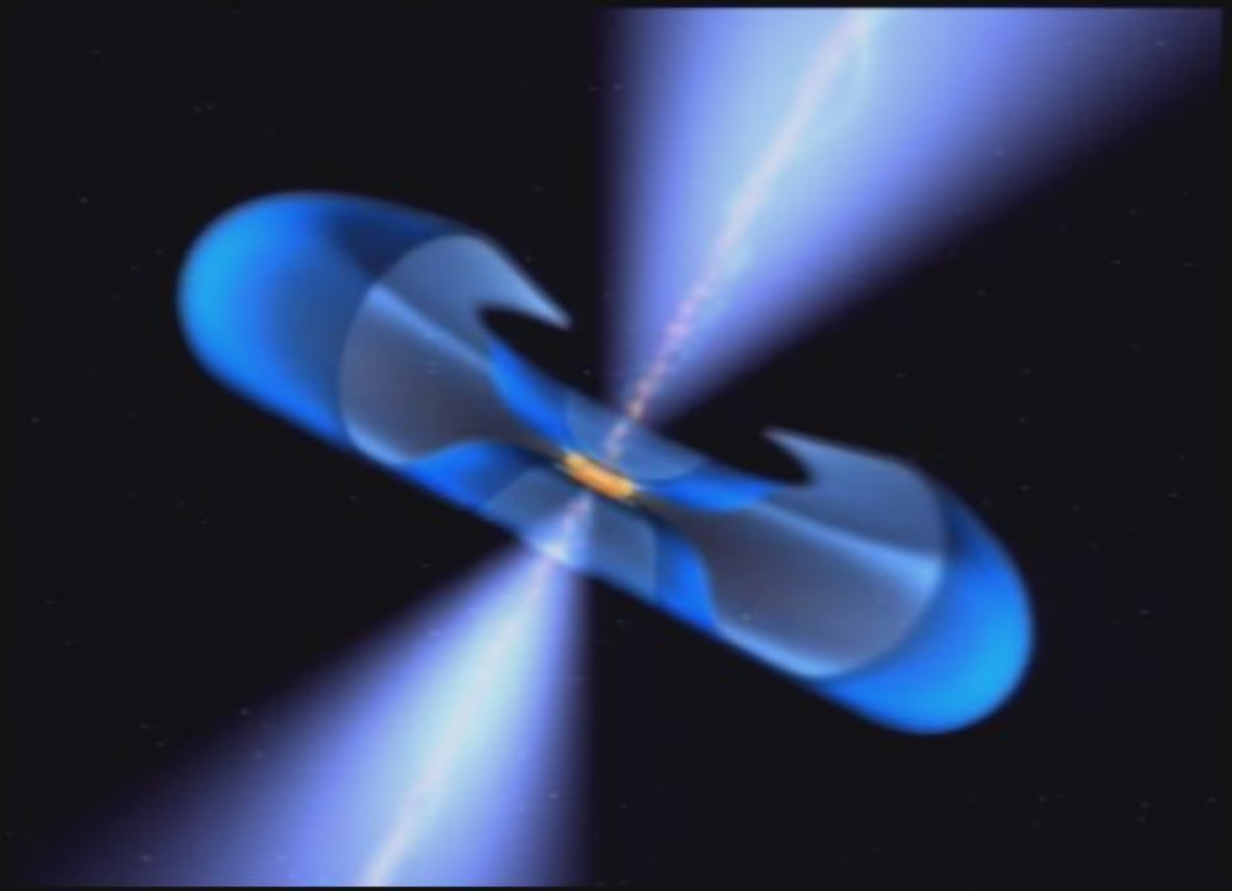

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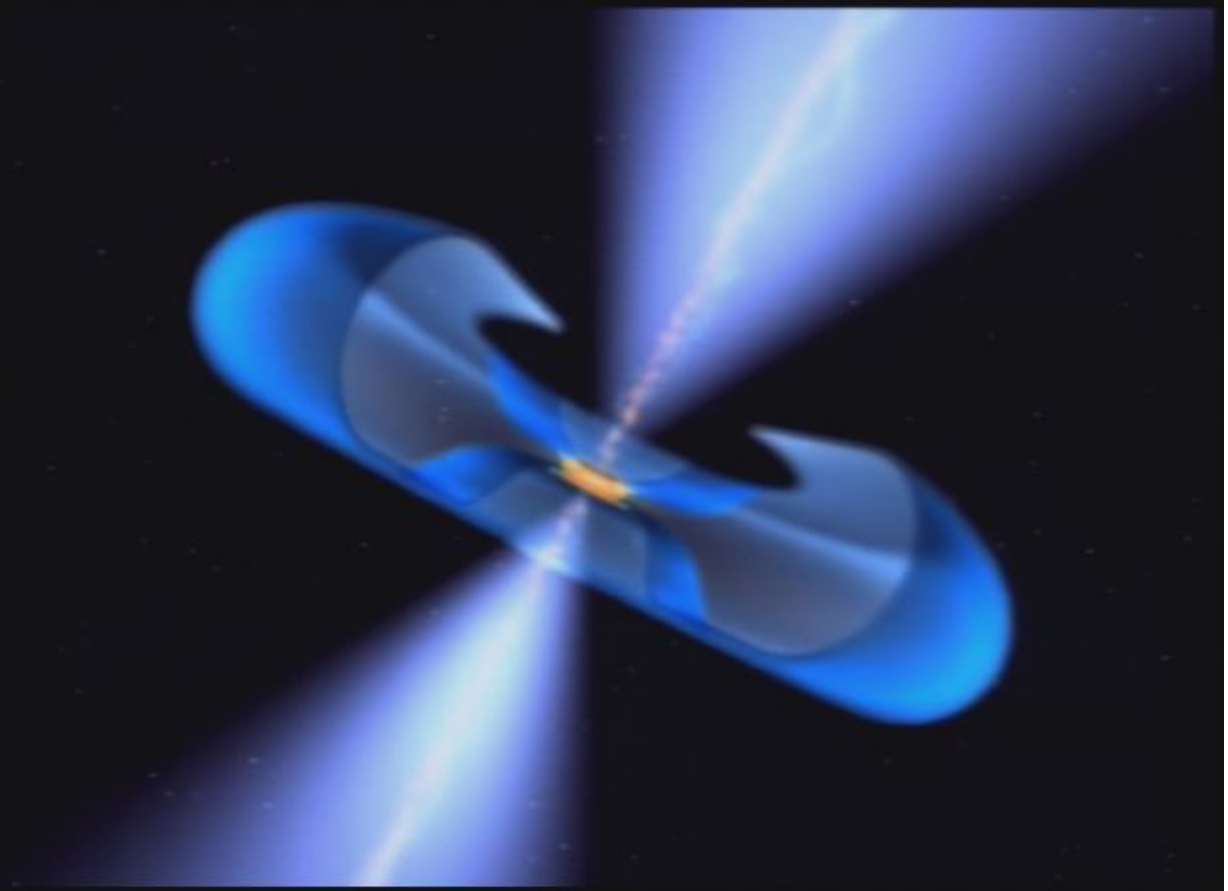

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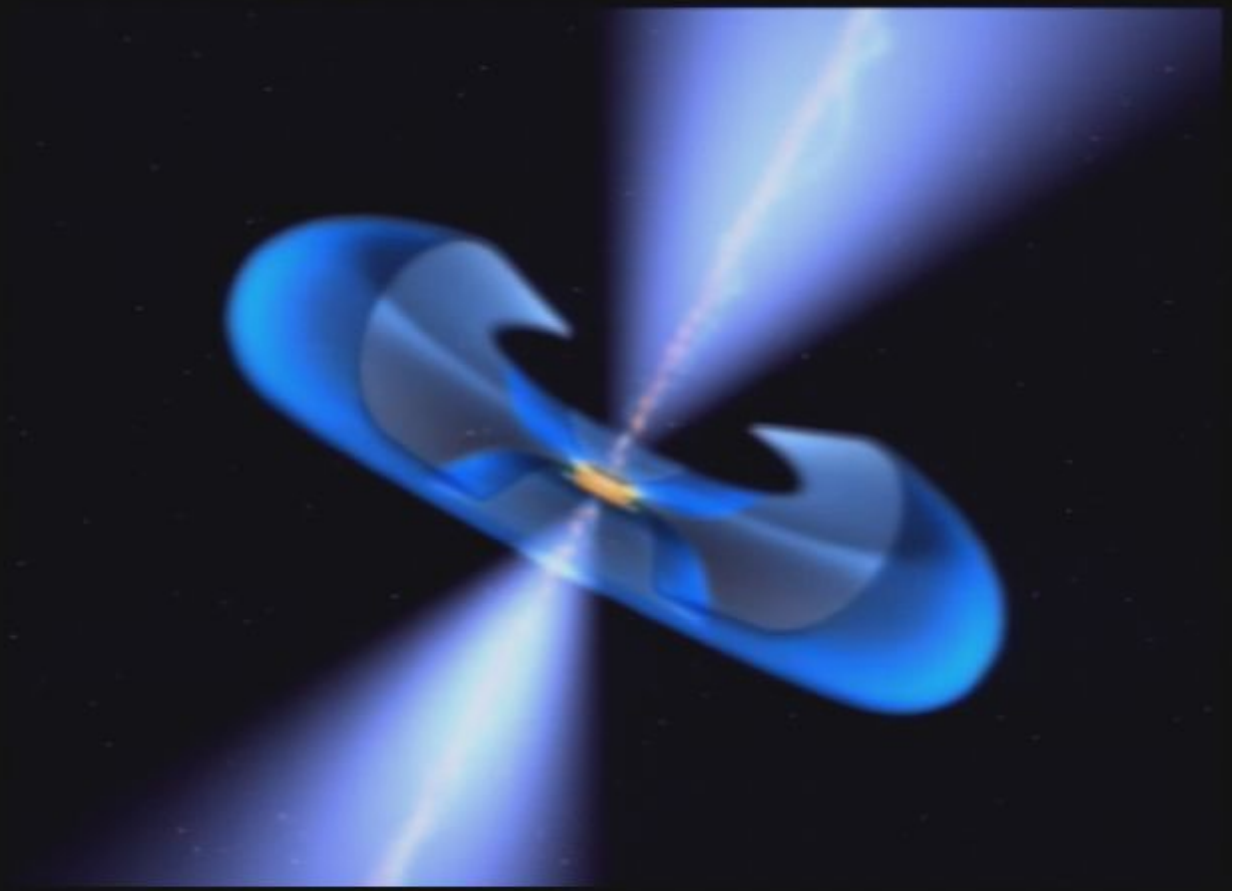

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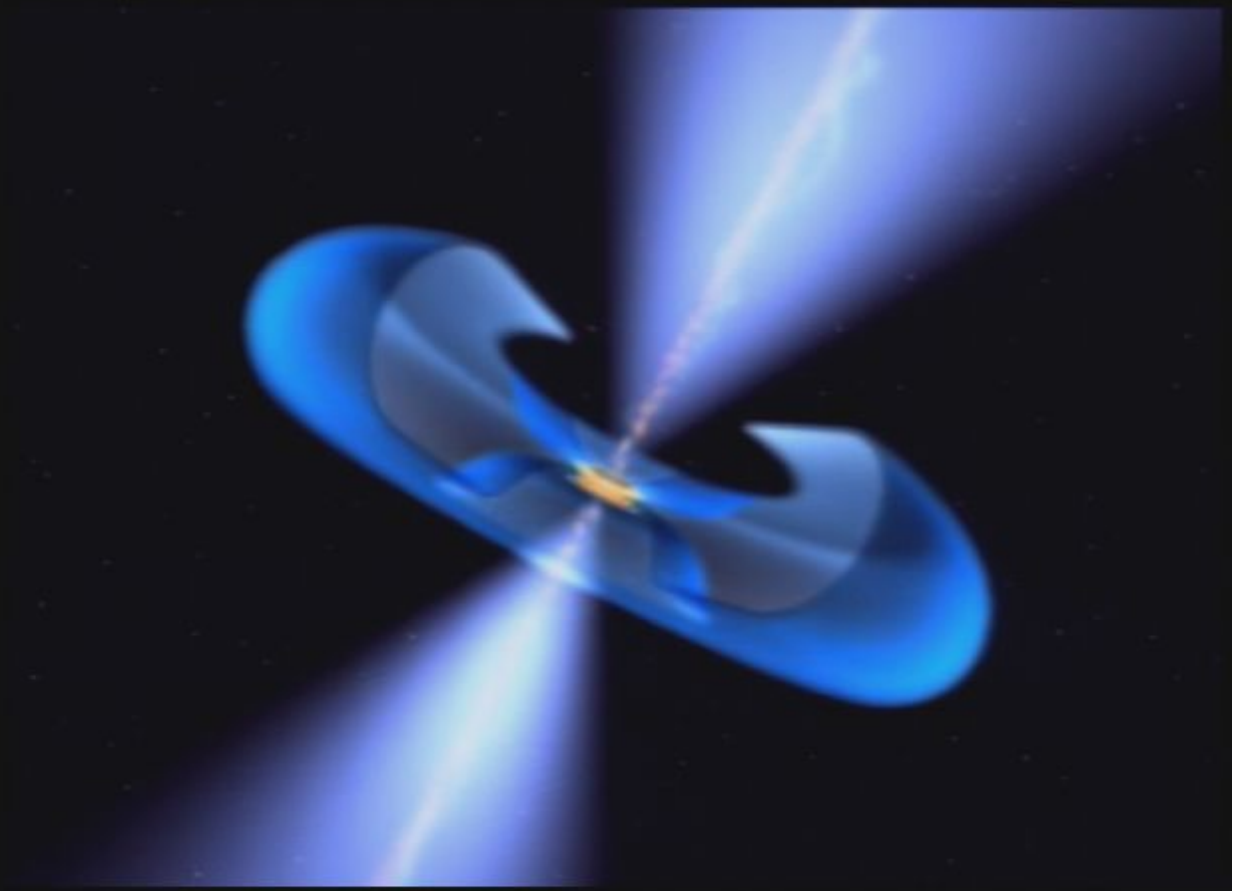

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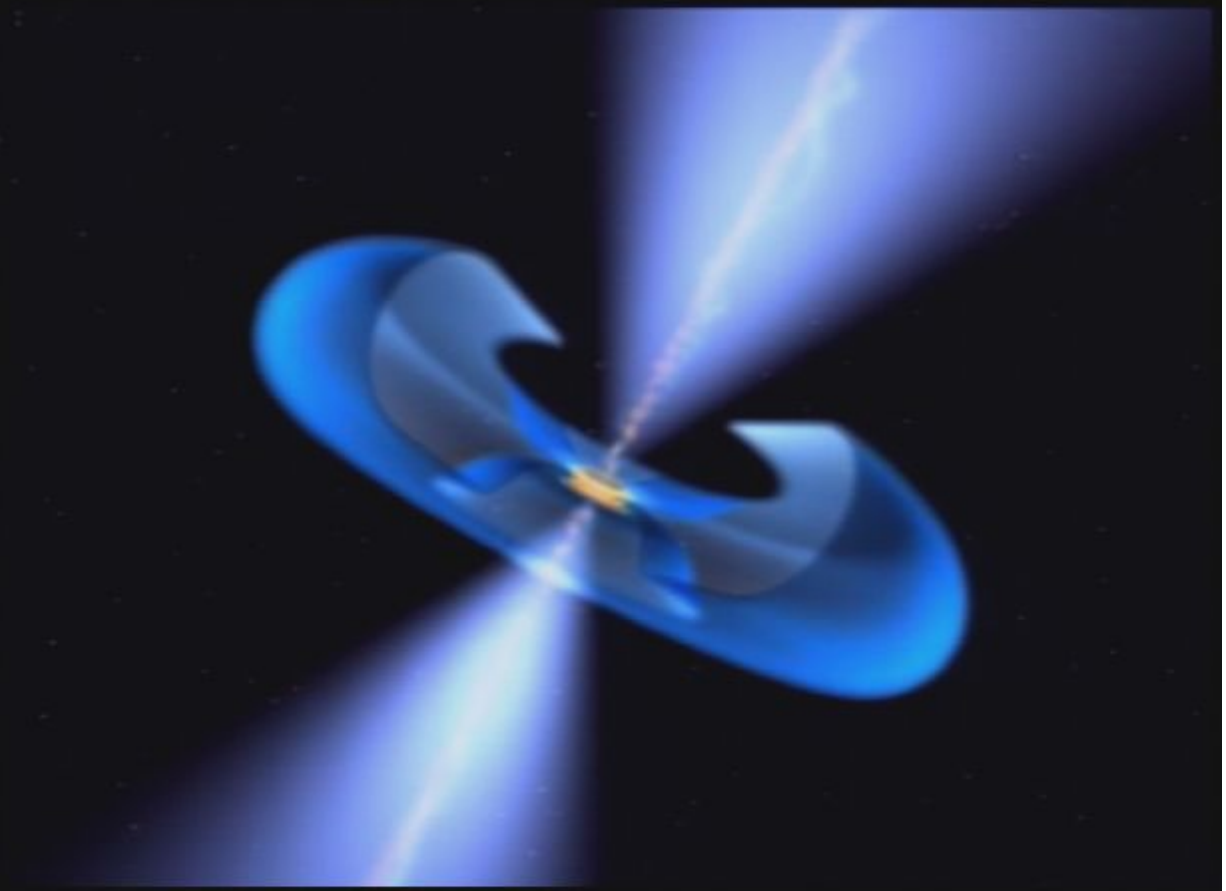

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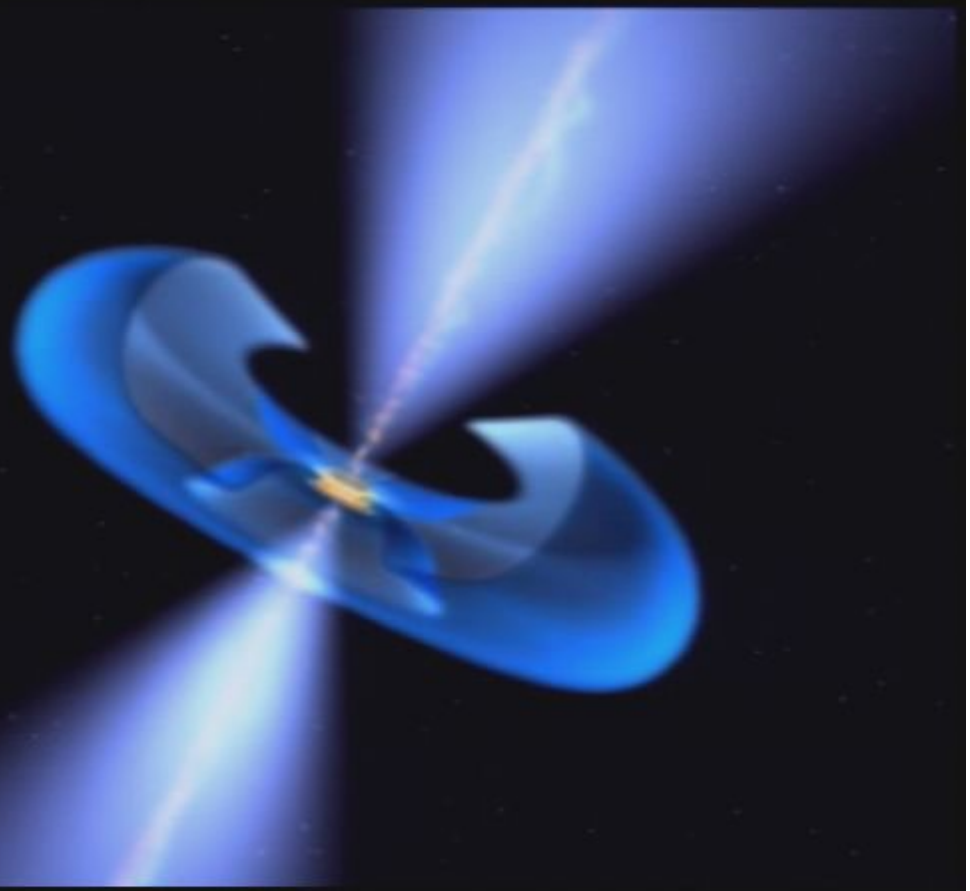

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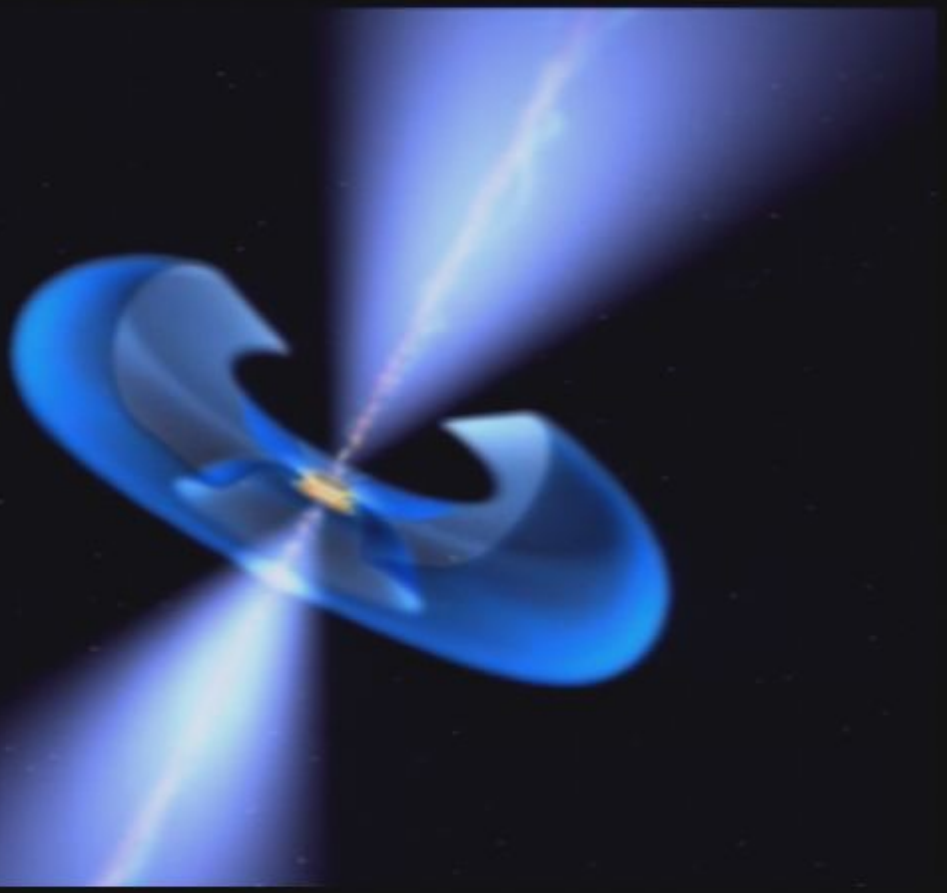

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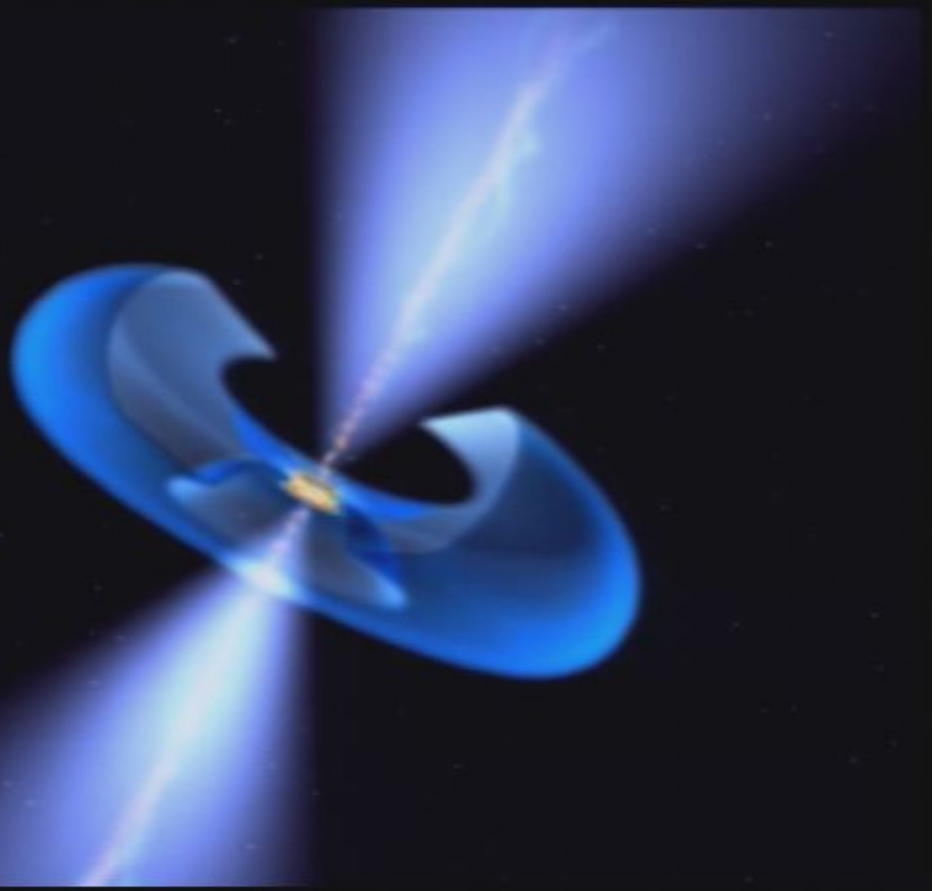

The Birth of a Black Hole

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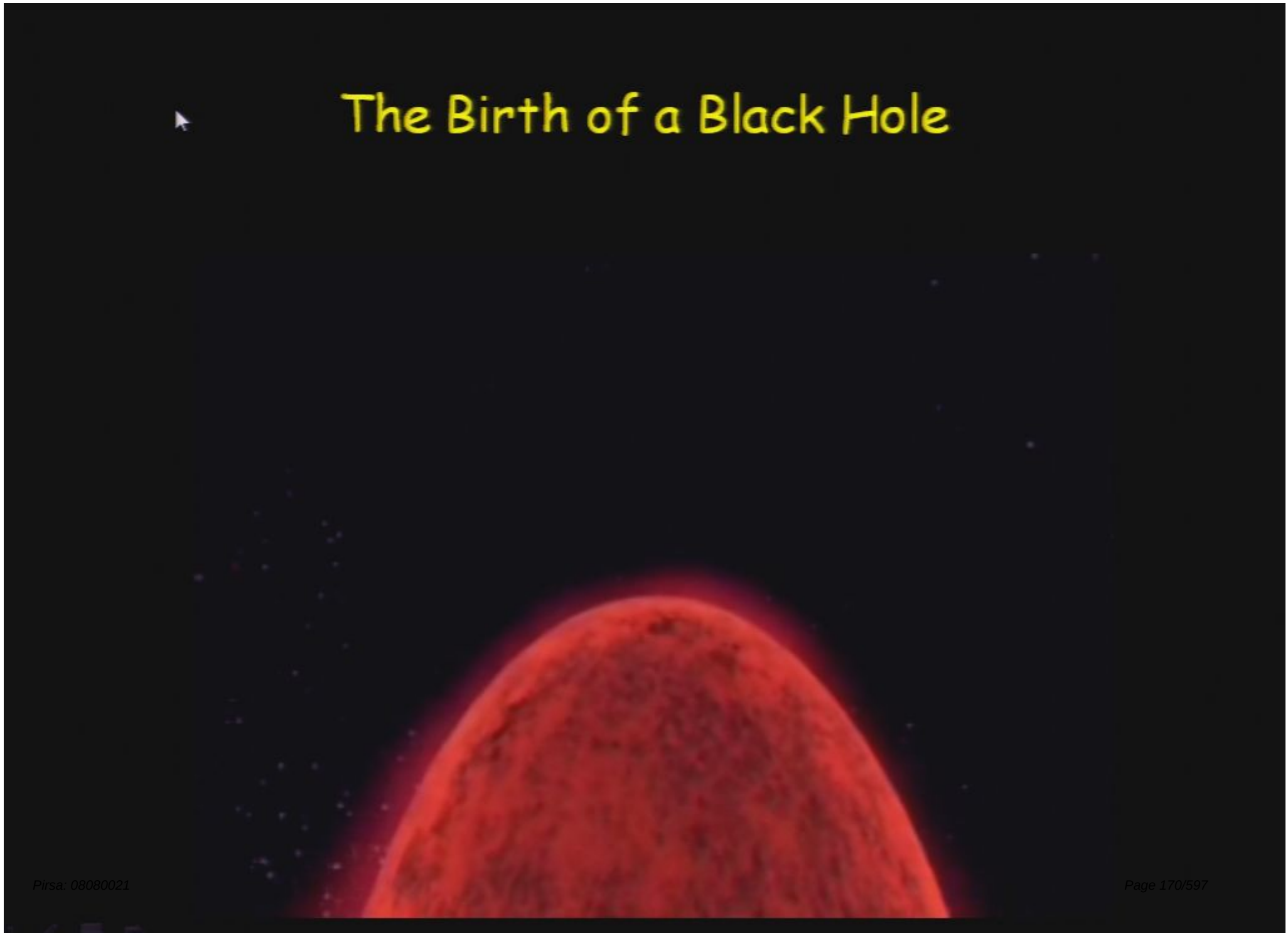

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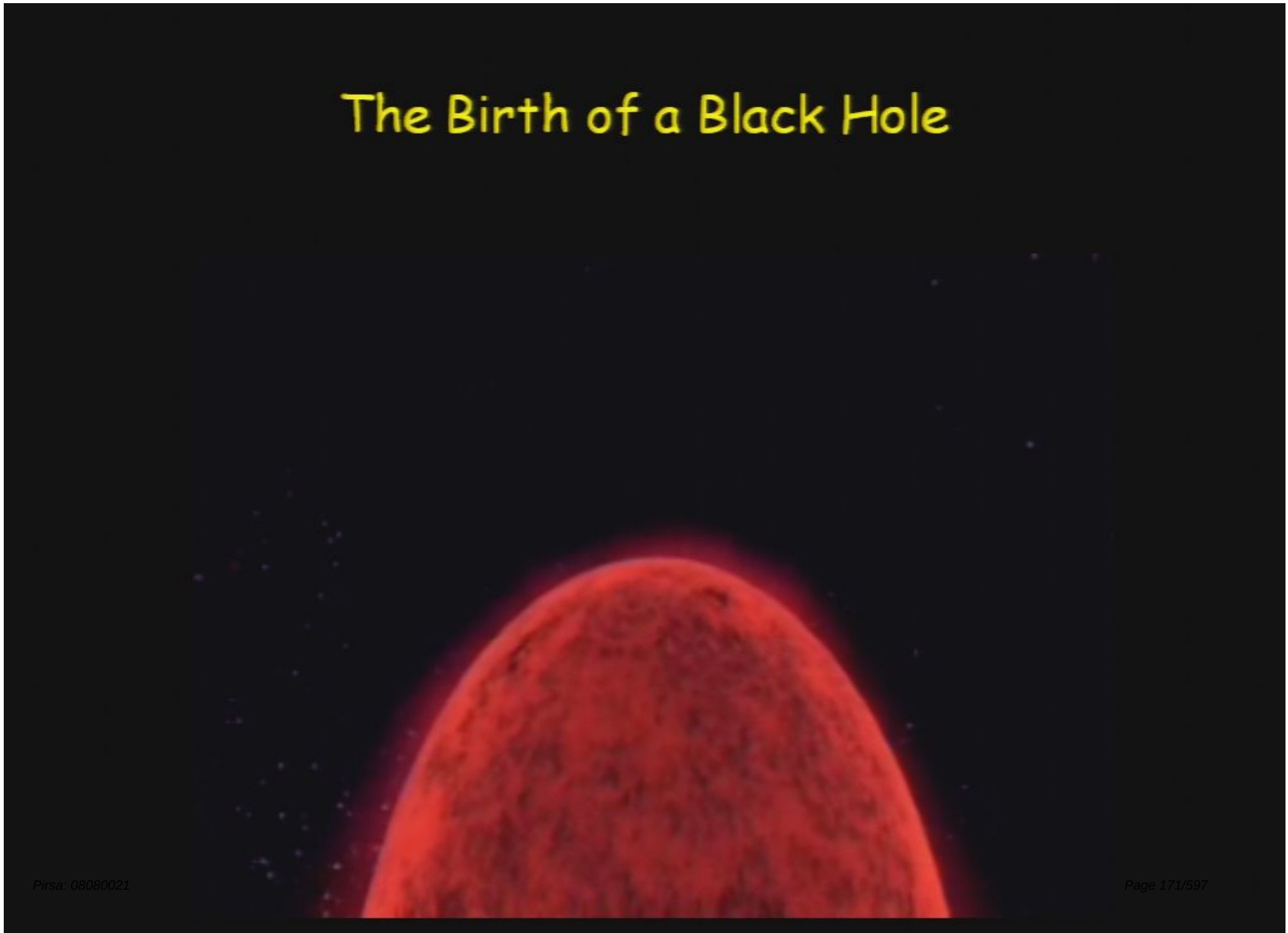

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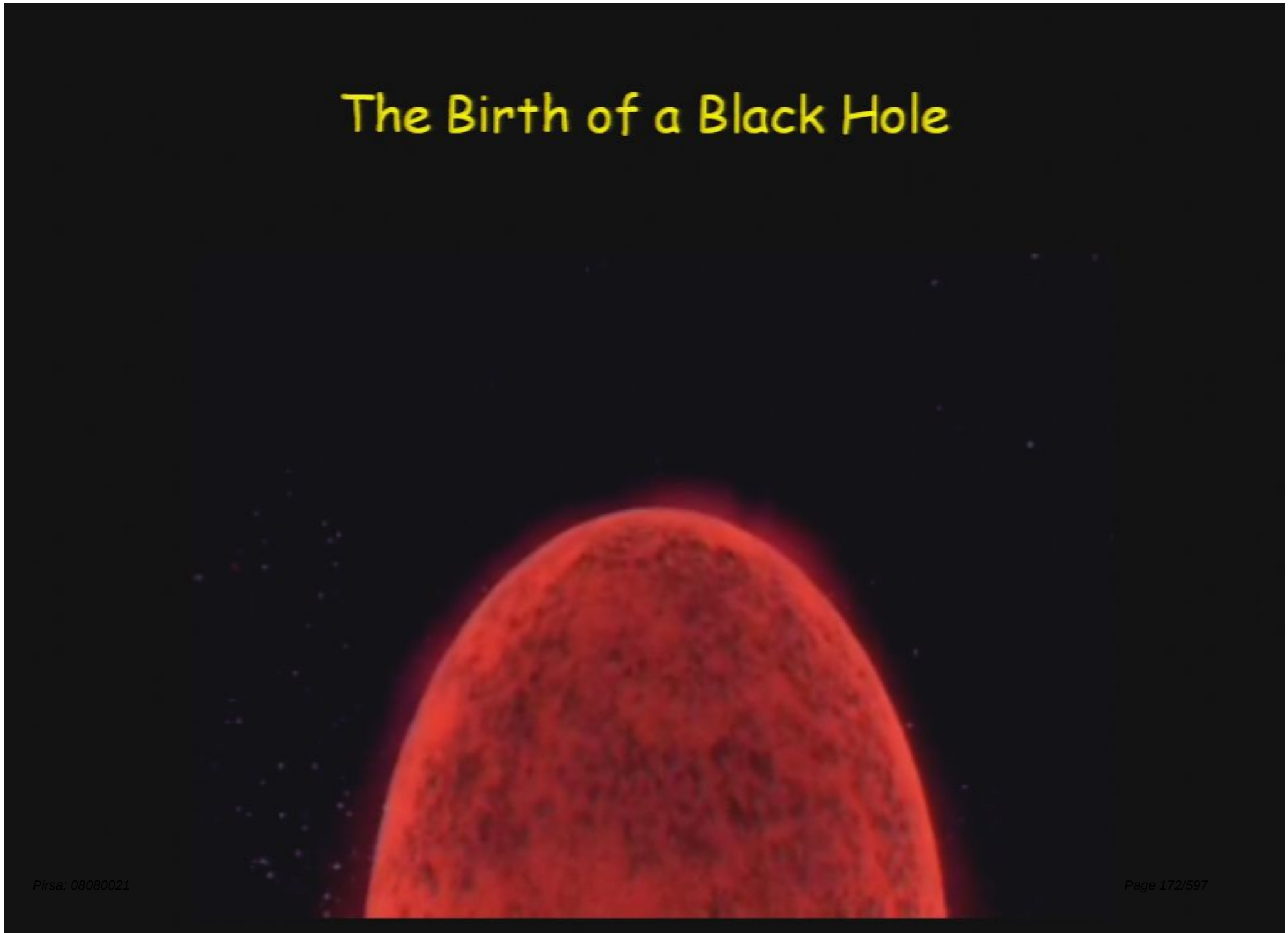

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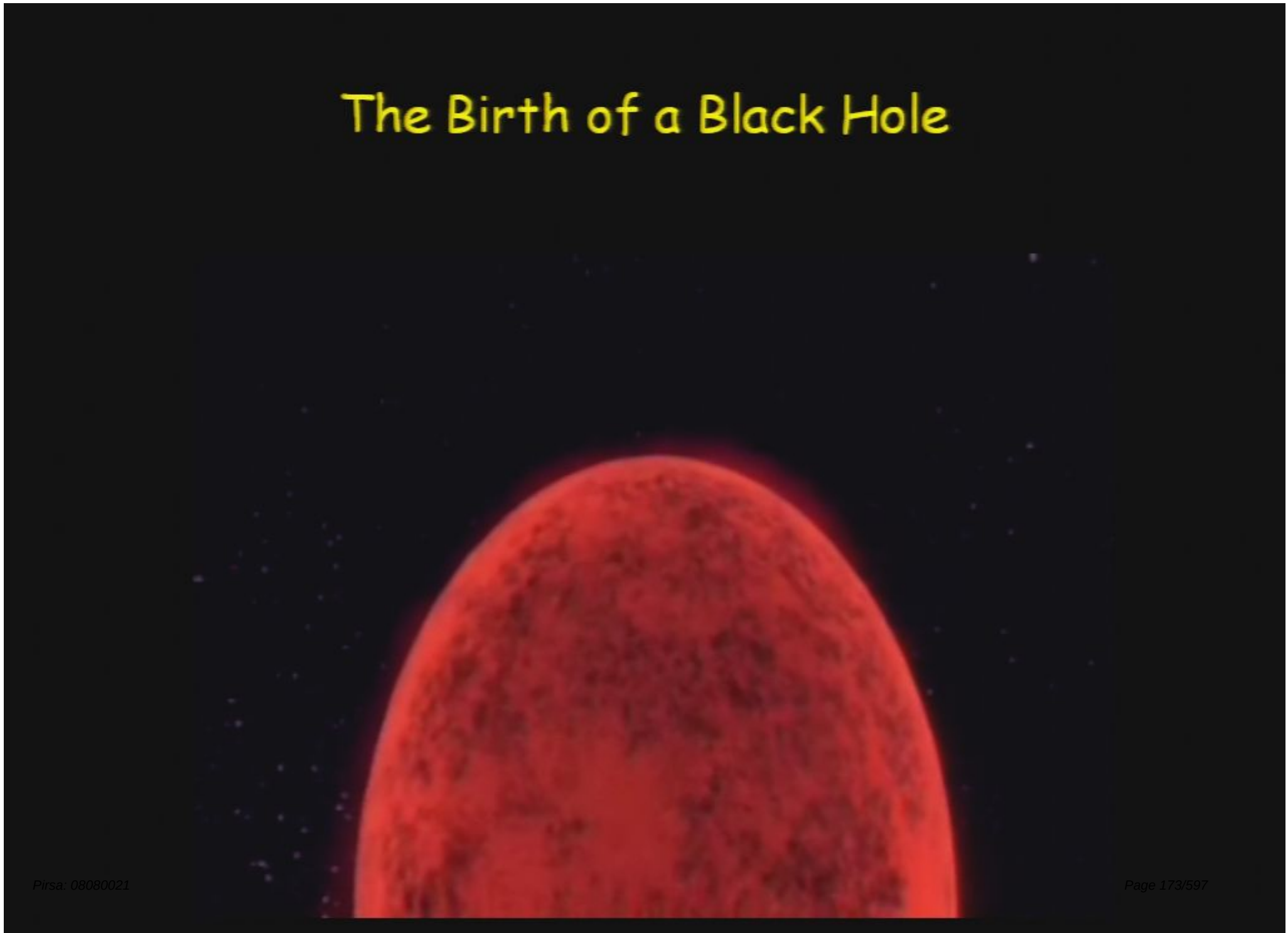

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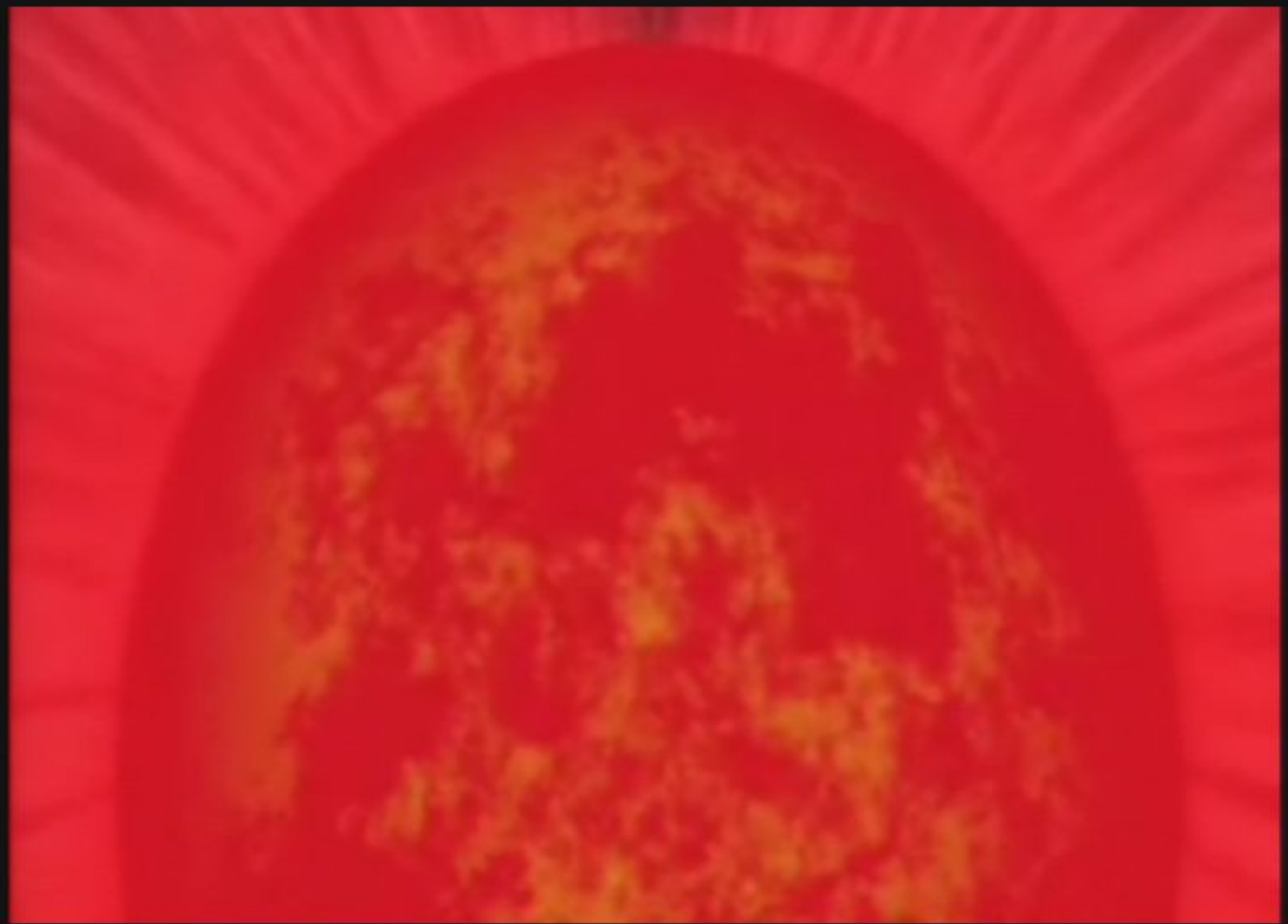

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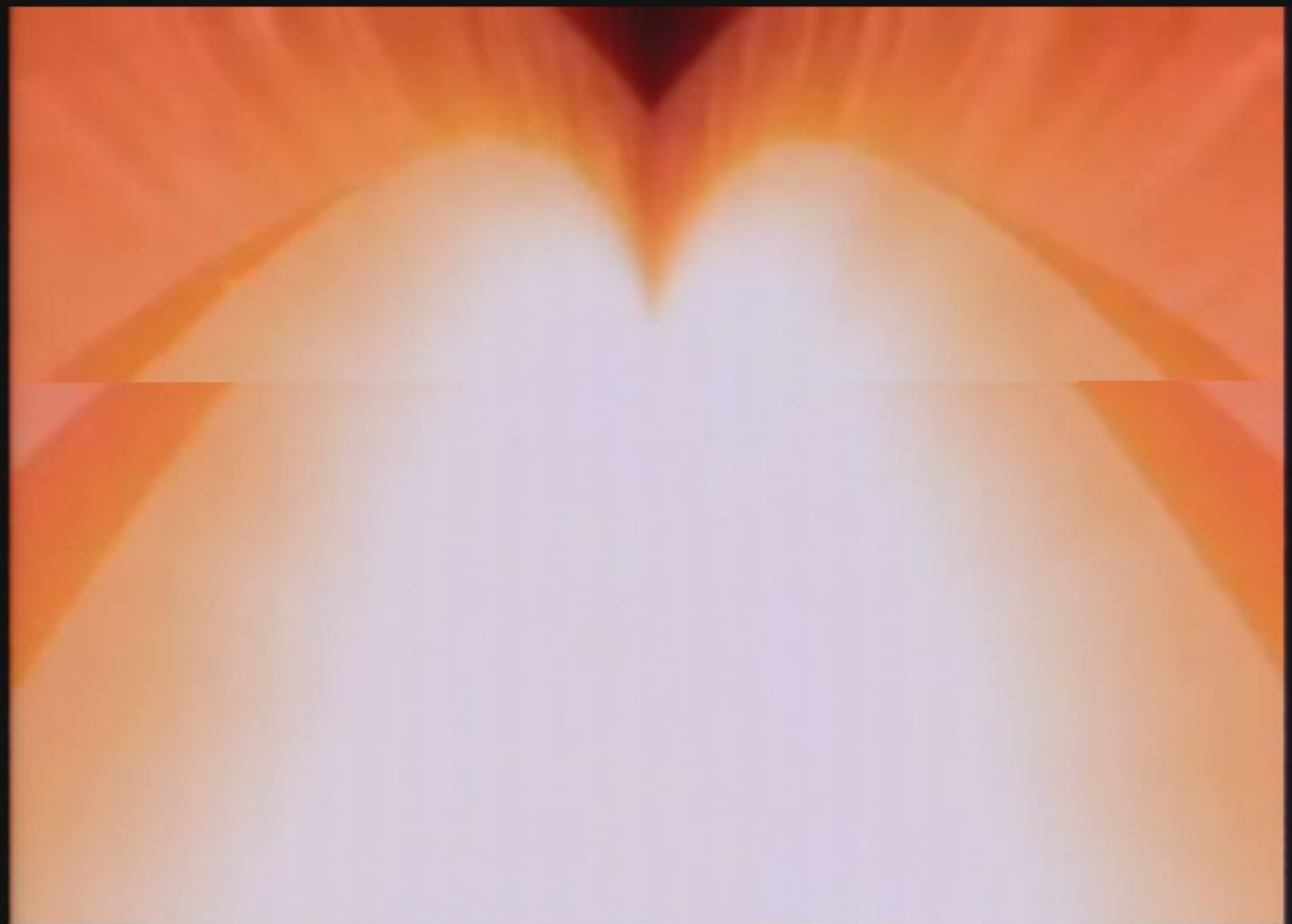

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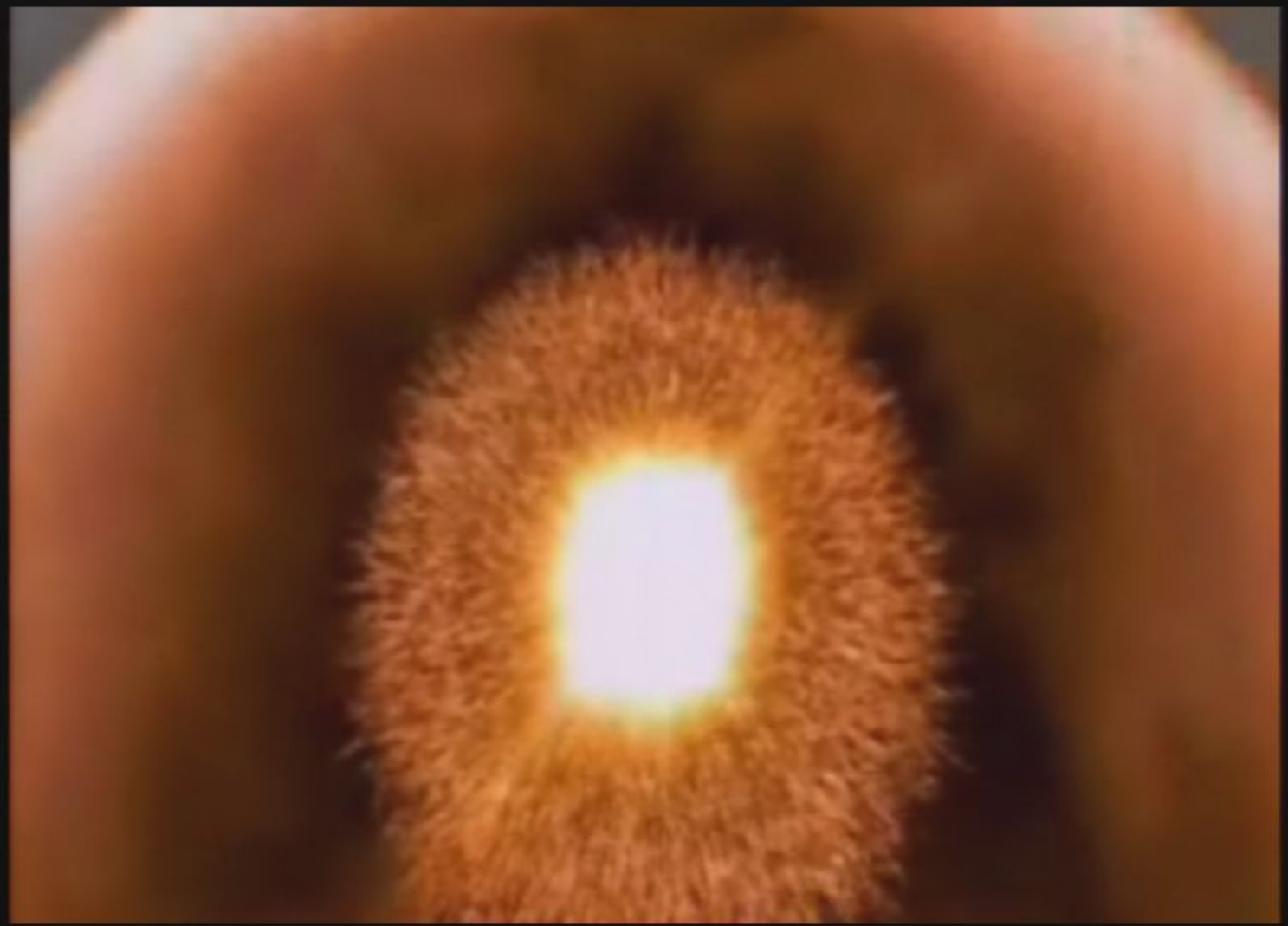

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If we could eliminate the radiation and light, what would it be like to watch the collapsing of a star into a Black Hole? What would it be light to fall into a Black Hole?

Watching a Star Collapse from a Safe Distance

If you watched a star collapsing into a Black Hole, the light emitted from the star would be red-shifted and as a result would get dimmer by a factor of 2 every 20 micro-seconds per solar mass. At the same time the surface would appear to slow down and become frozen

This is not too Exciting... what about visiting the Black Hole?

$$L \propto e^{-\frac{t}{3\sqrt{3}M}}$$

$$t = 10^{-3}\left(\frac{M_{star}}{M_{\odot}}\right)$$

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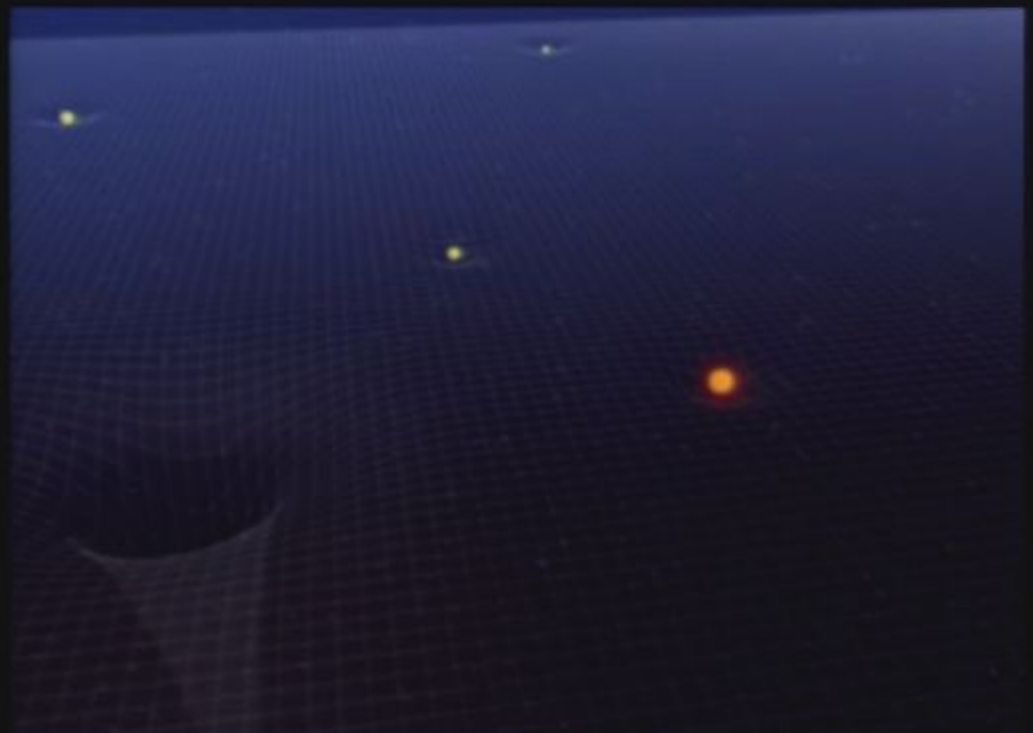

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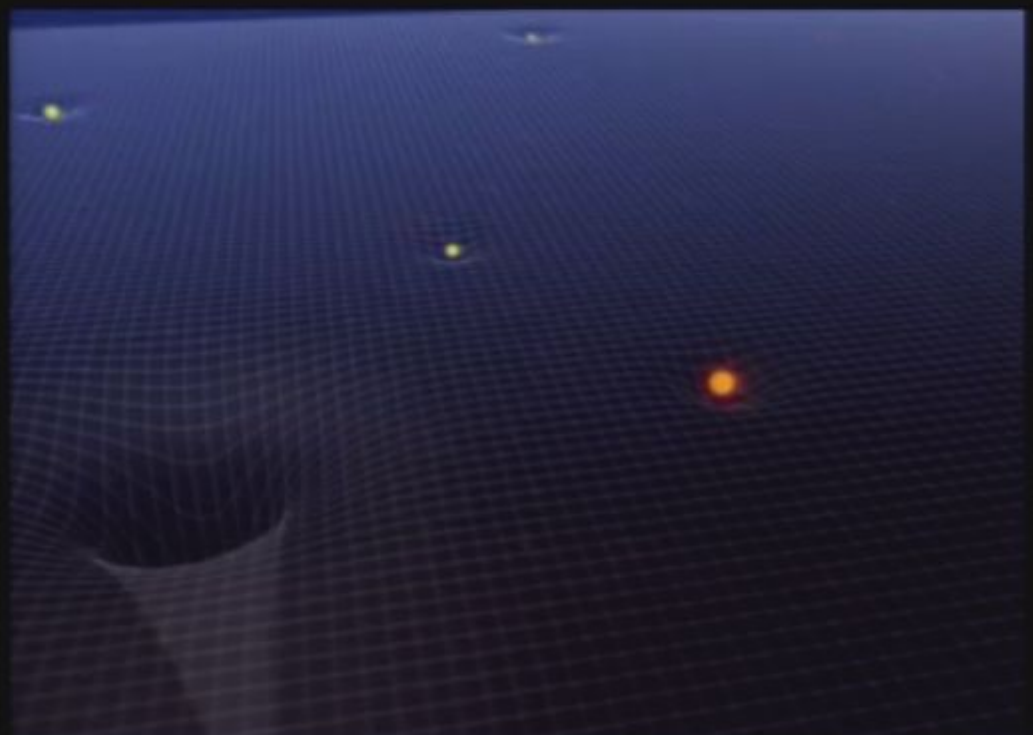

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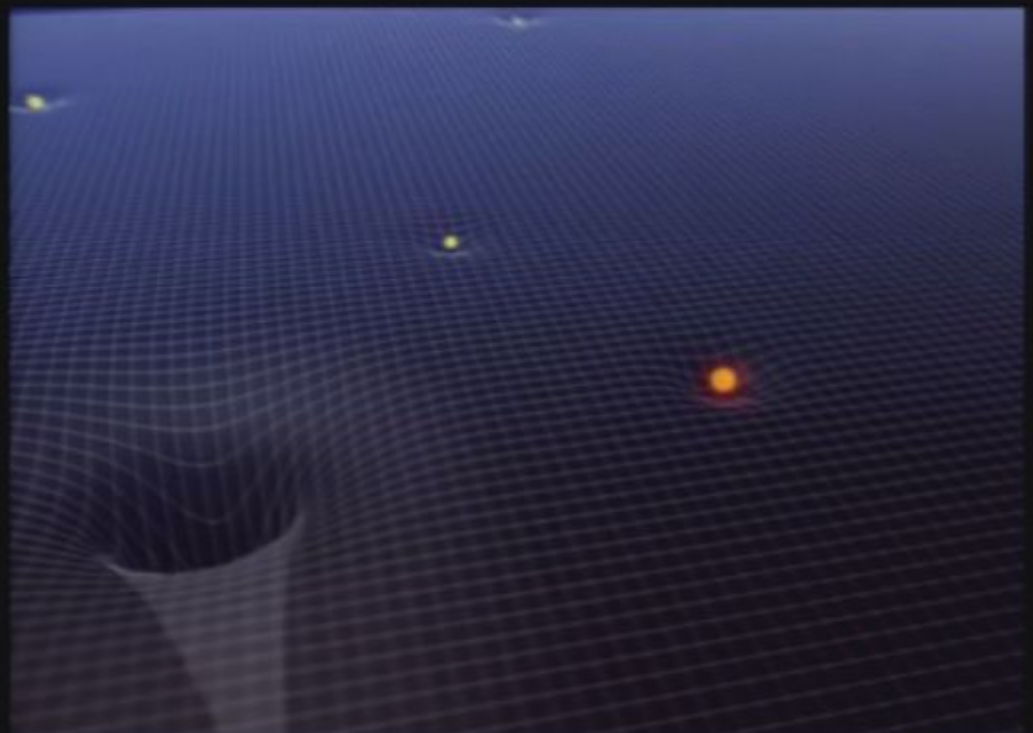

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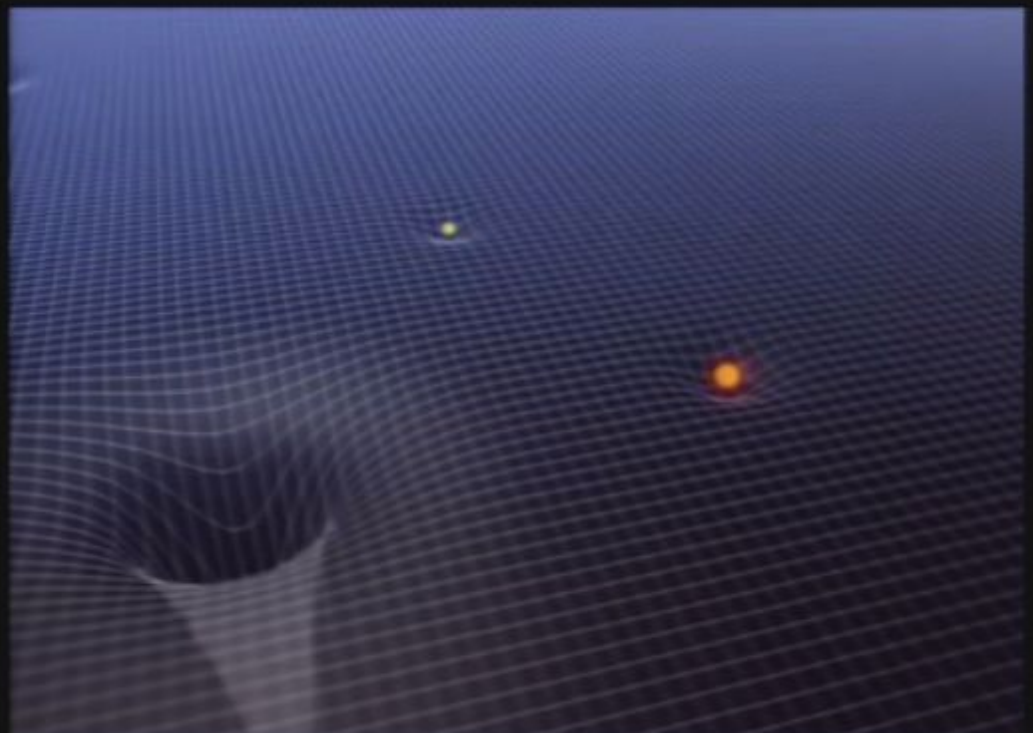

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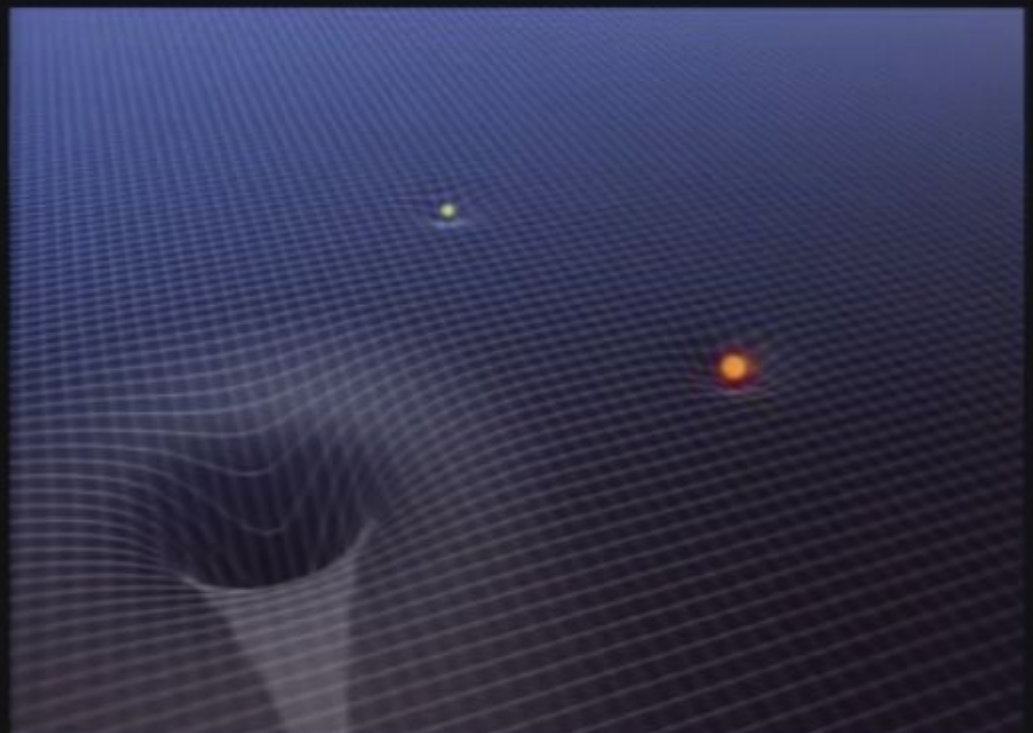

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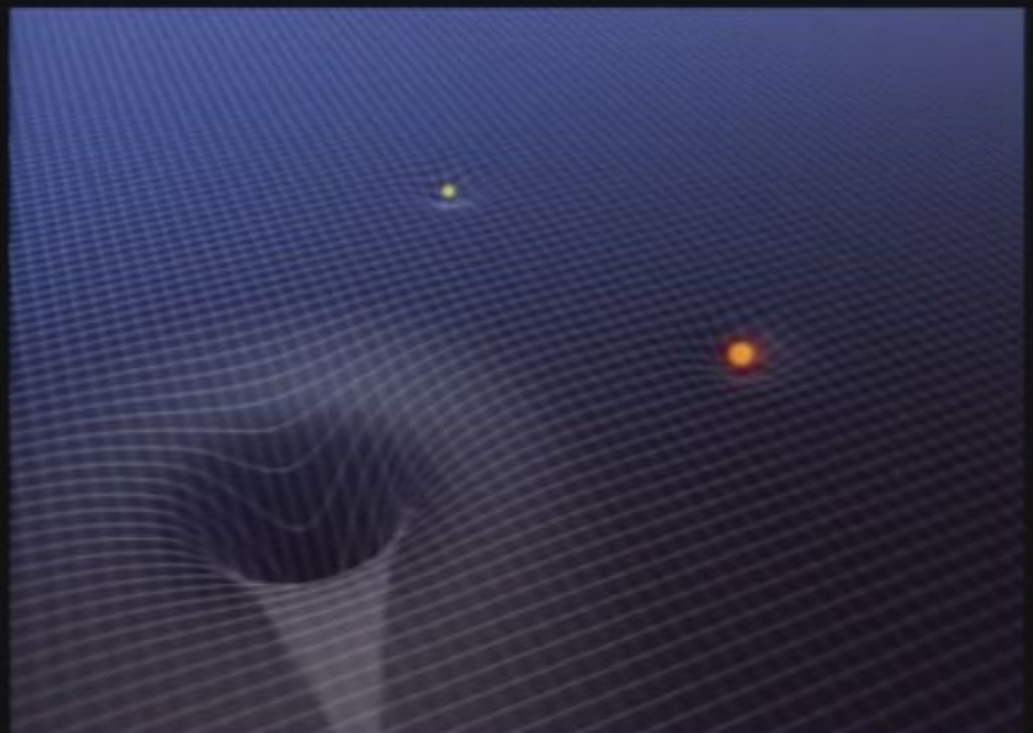

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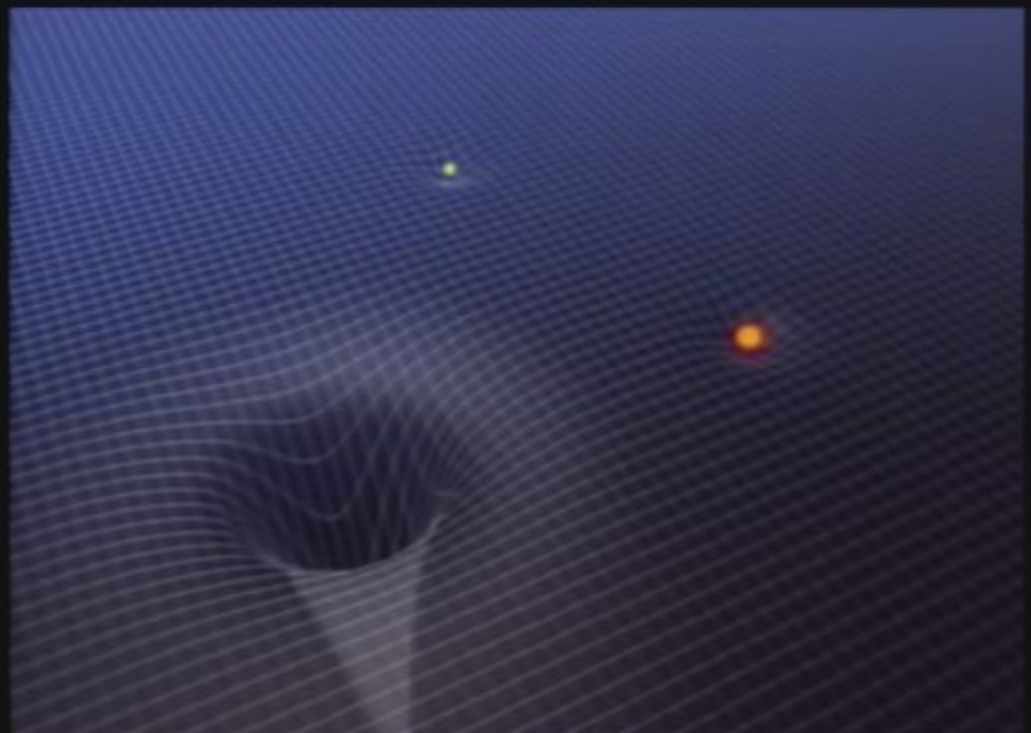

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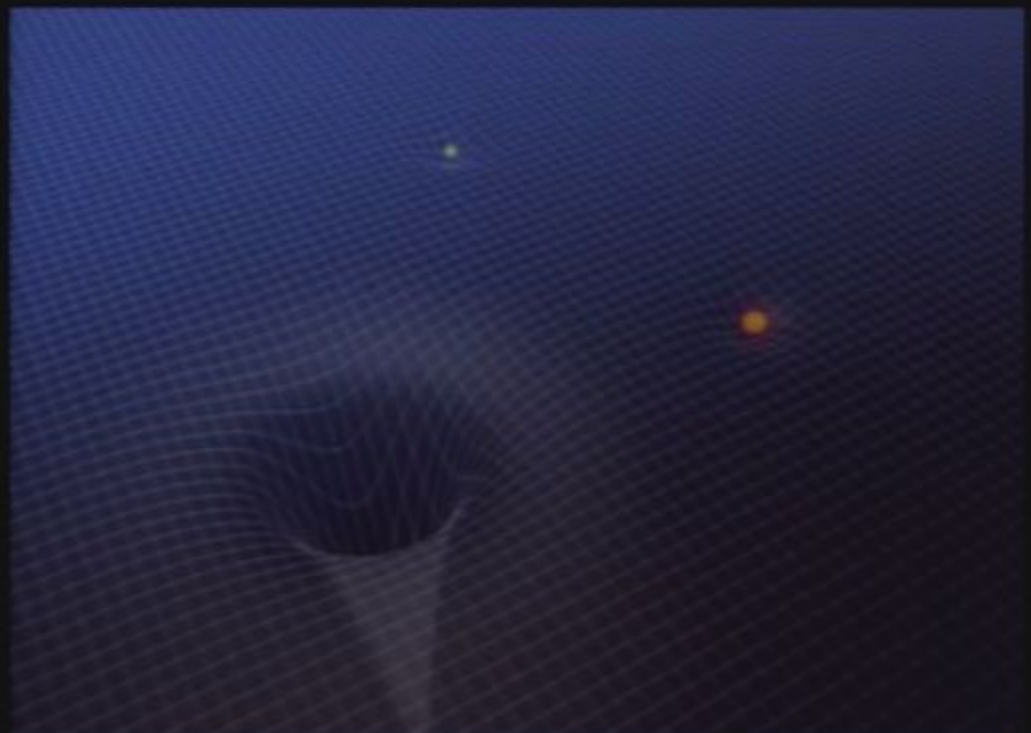

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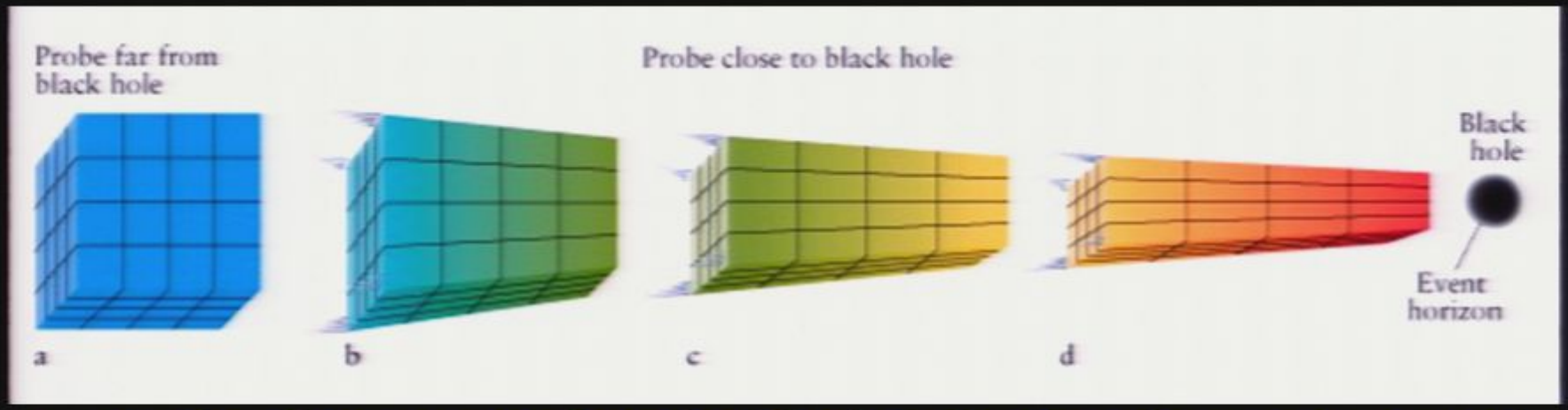
Traveling into a Black Hole



- As the ship approaches the black hole, the ship is elongated by the variation in gravity
- The ship is also gravitationally red shifted at the end closer to the black hole
- From the outside, the ship will appear to hover forever at the edge of the hole to us - an effect of the time dilation, yet in the ship, the occupant do enter into the black hole. Never to be heard from again.

Watching a clock fall into a black hole

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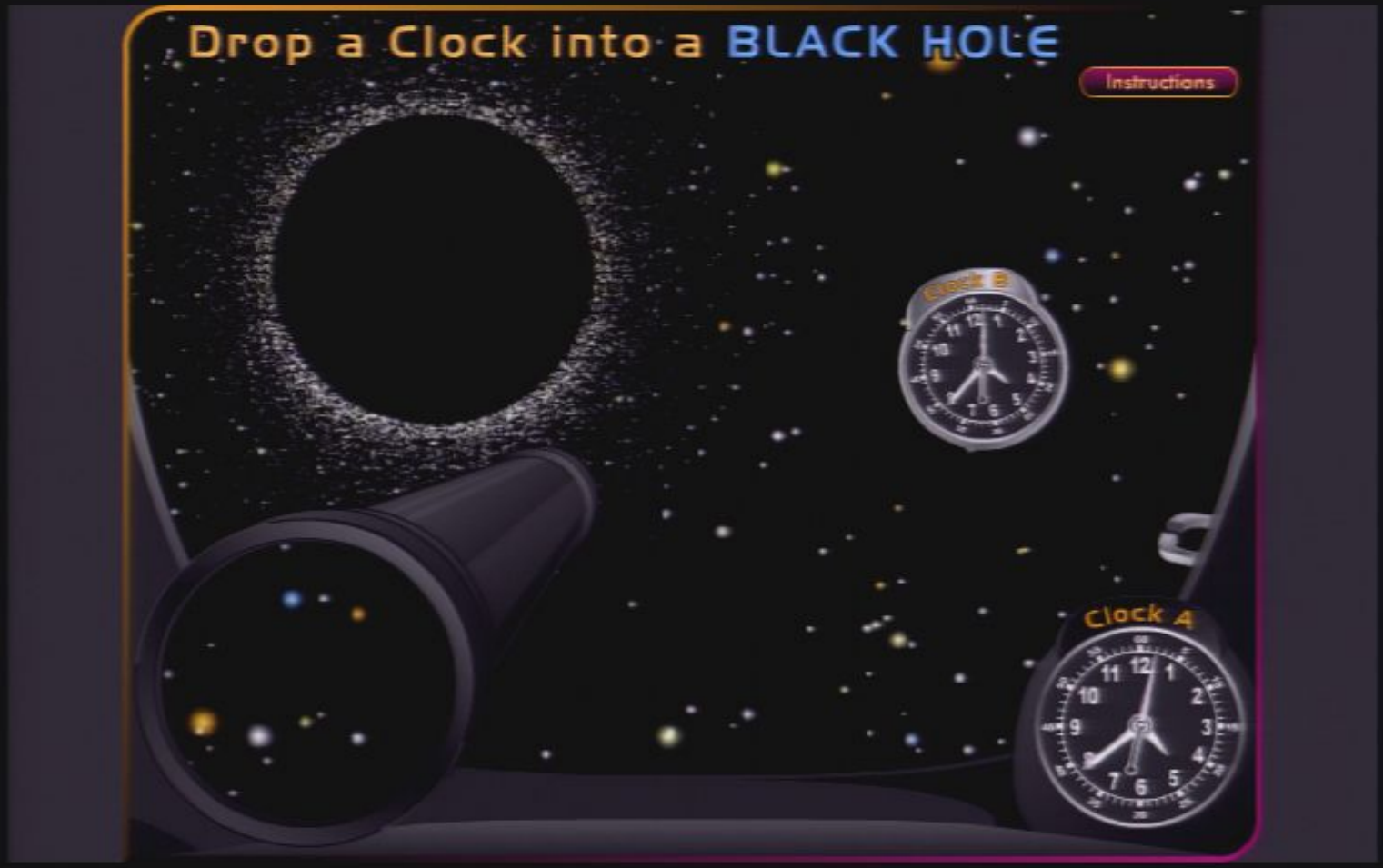

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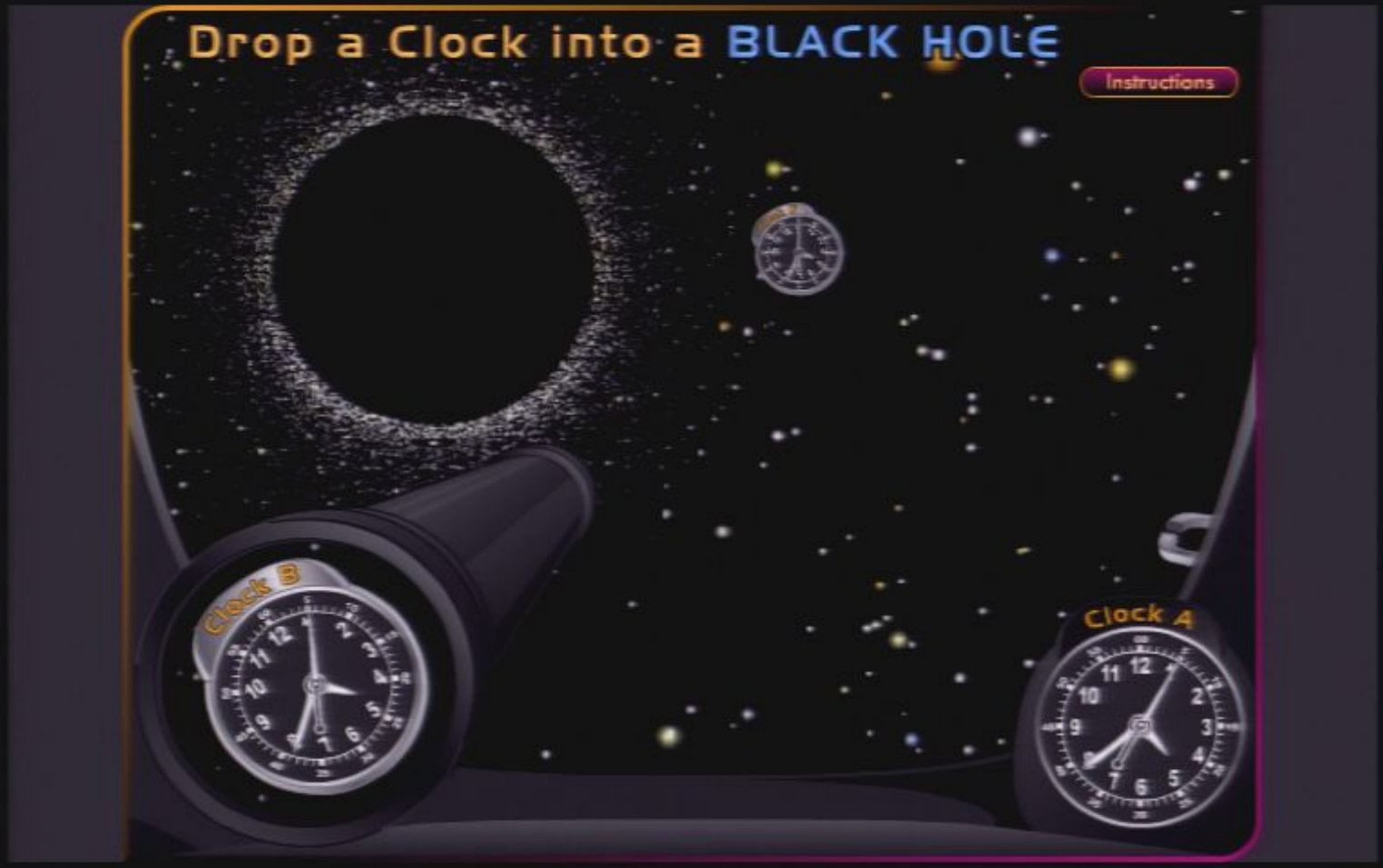

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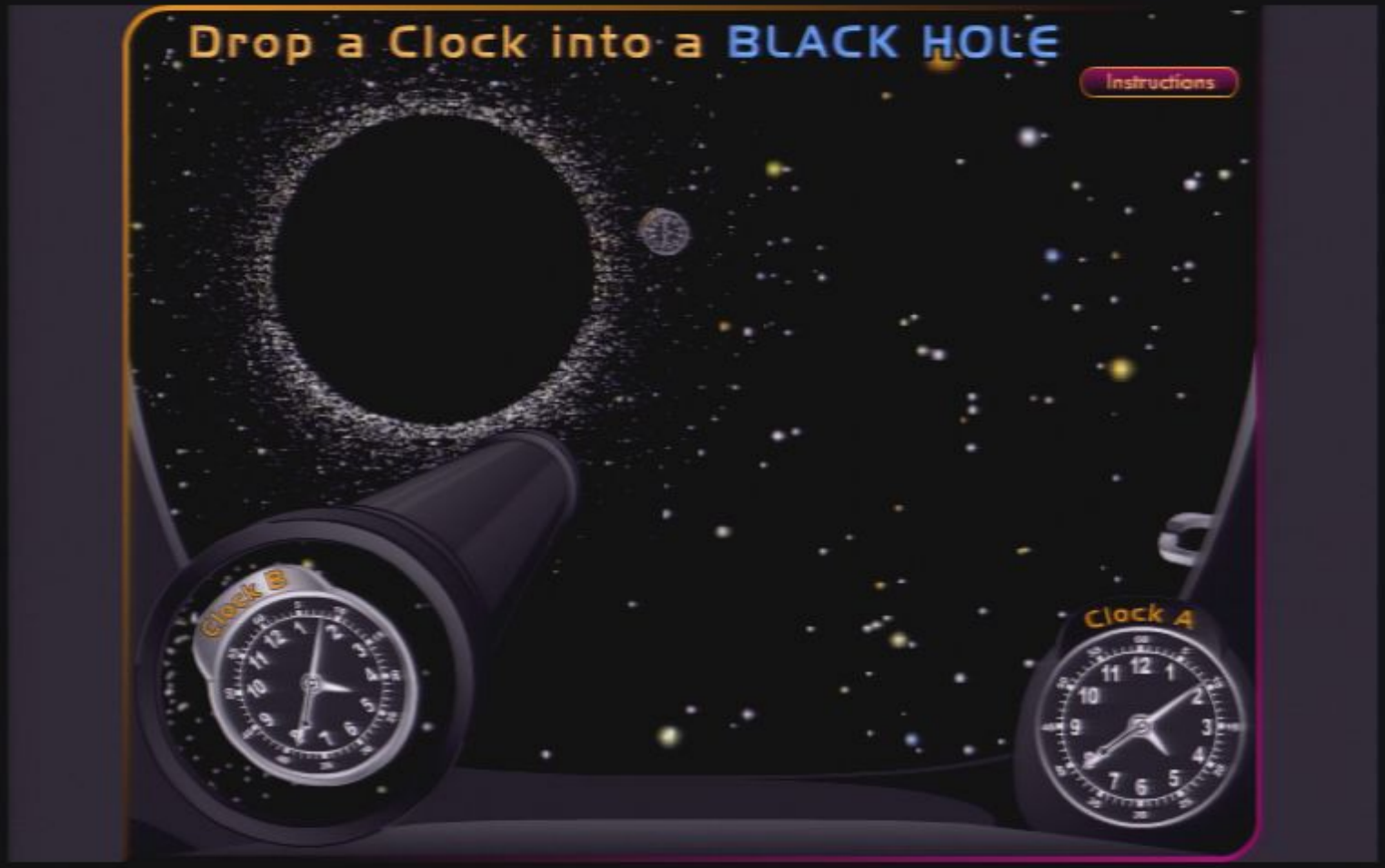

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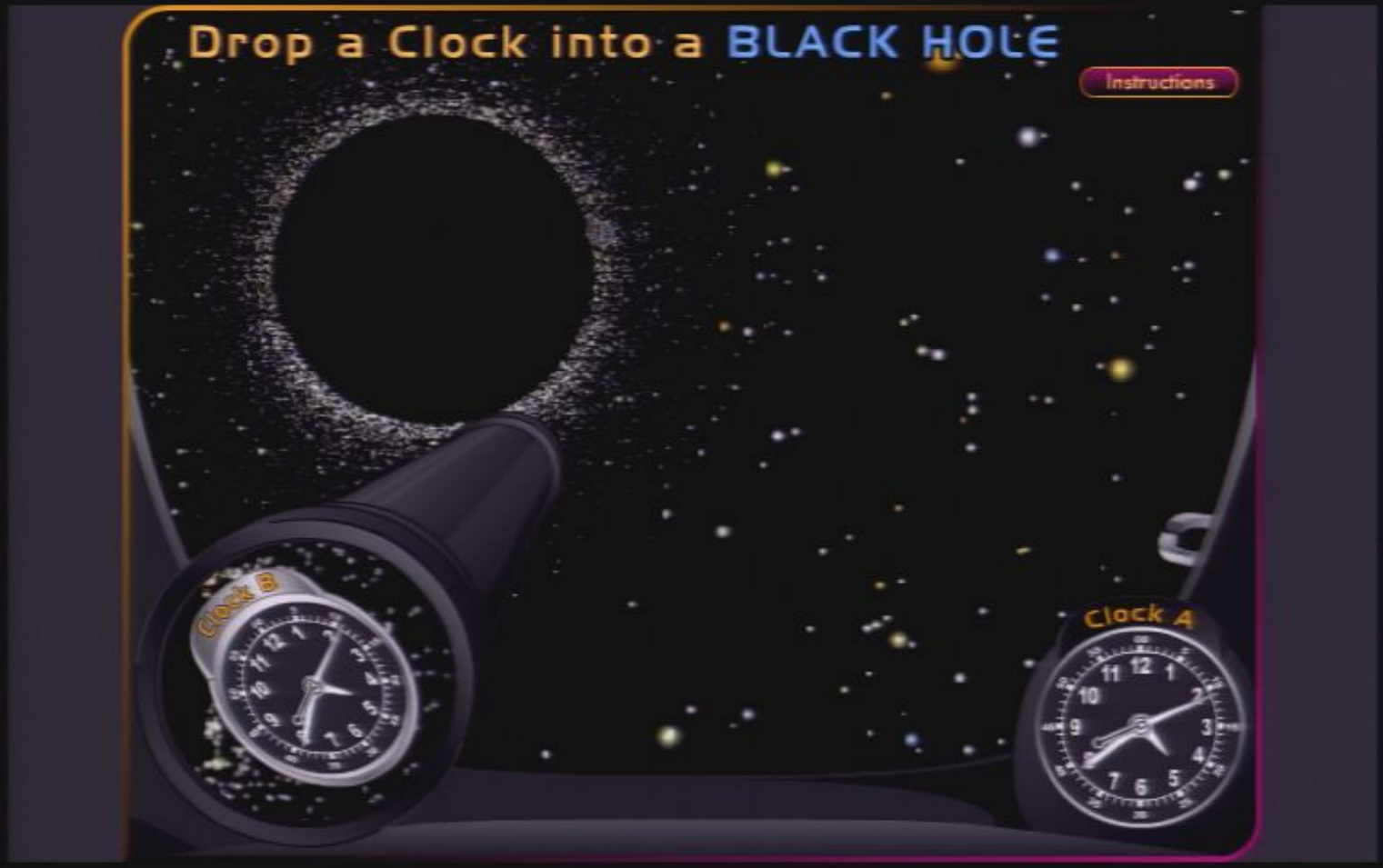

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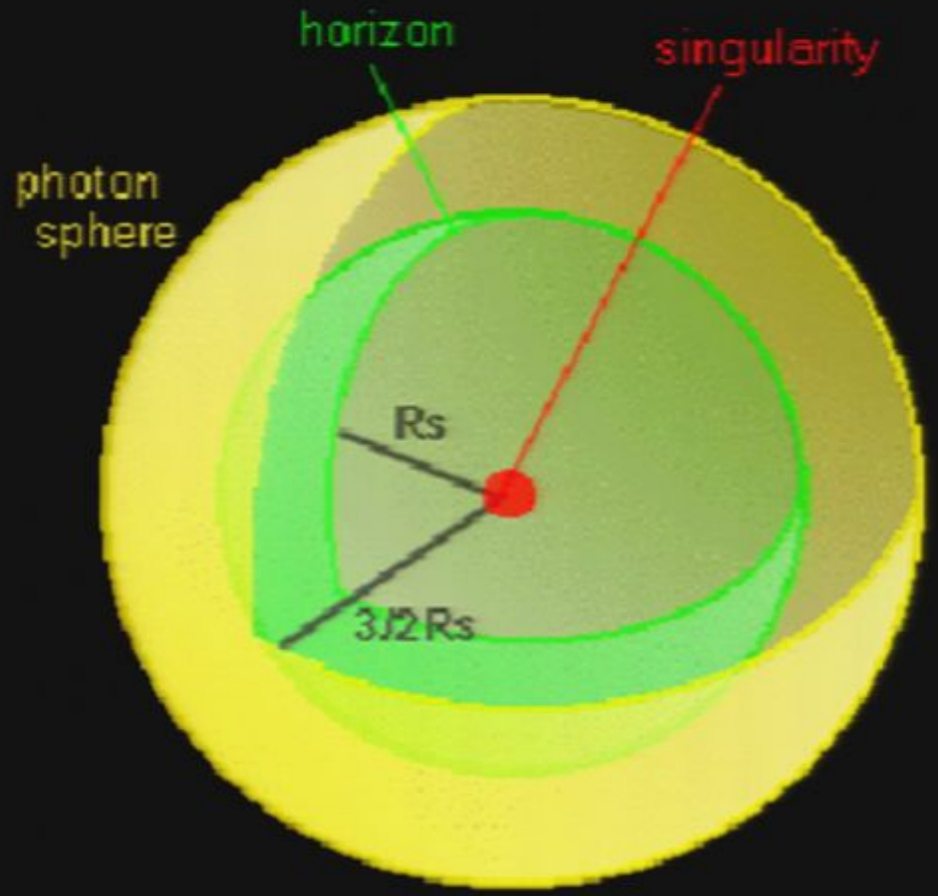
To get a better understanding of what is happening, and more specifically where it is happening. Let's look at the anatomy of a Black Hole

Structure of a Schwarzschild Black Hole



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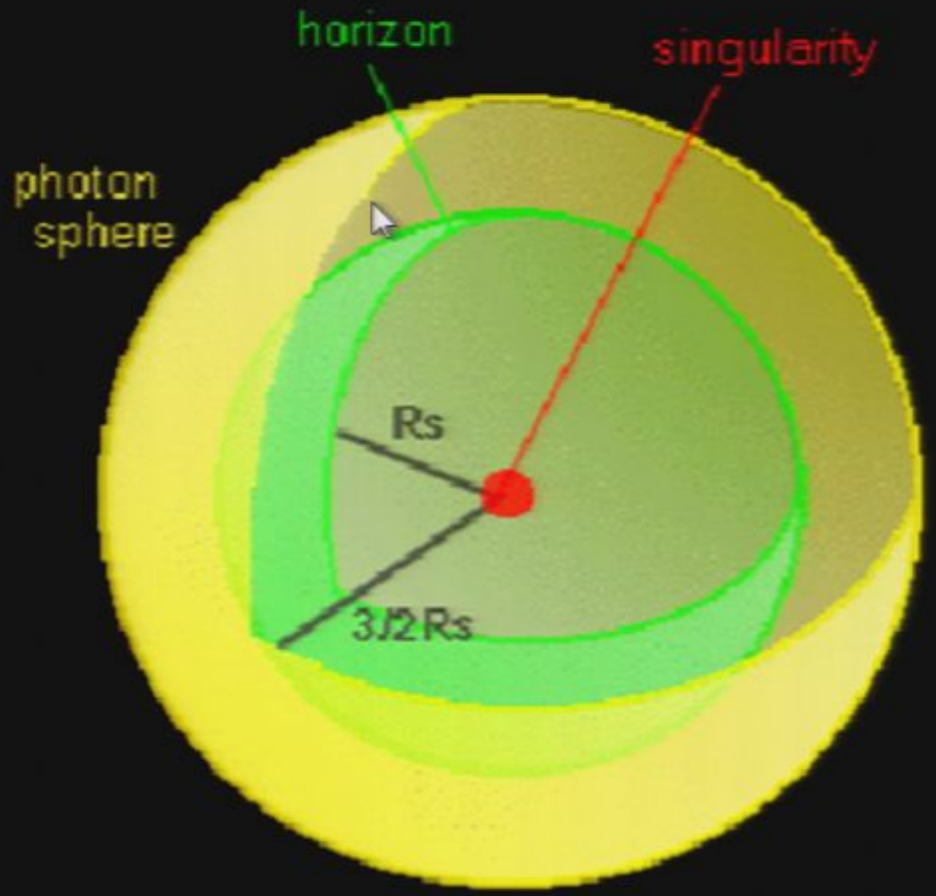

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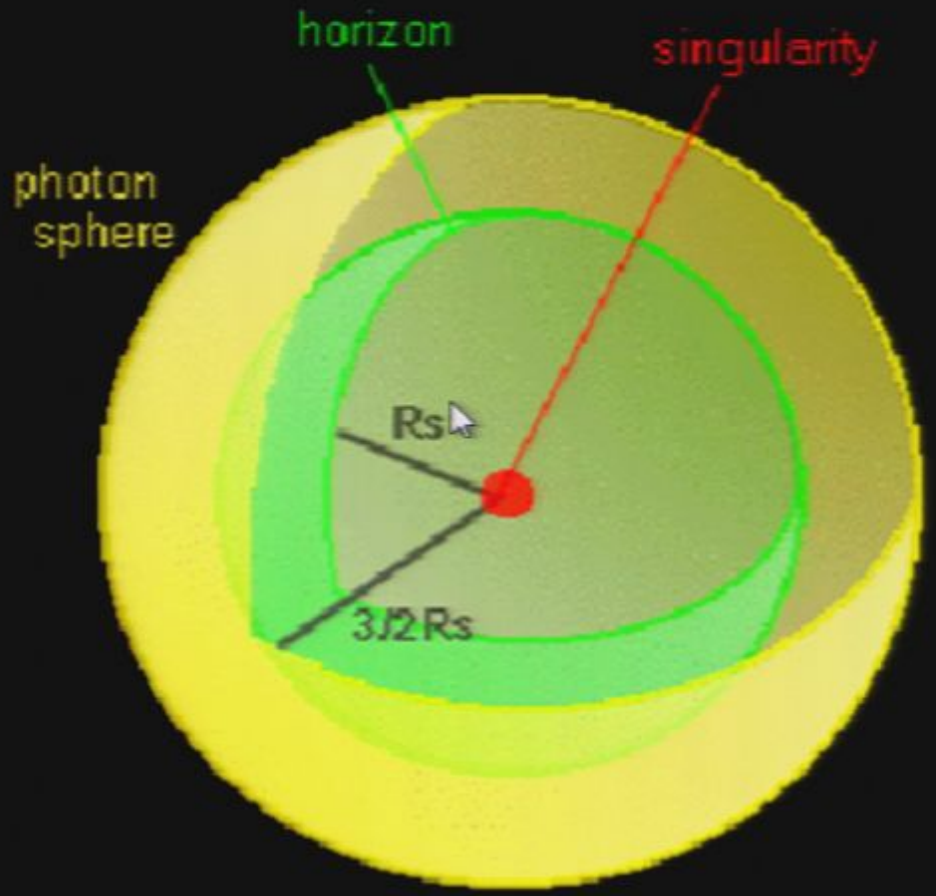

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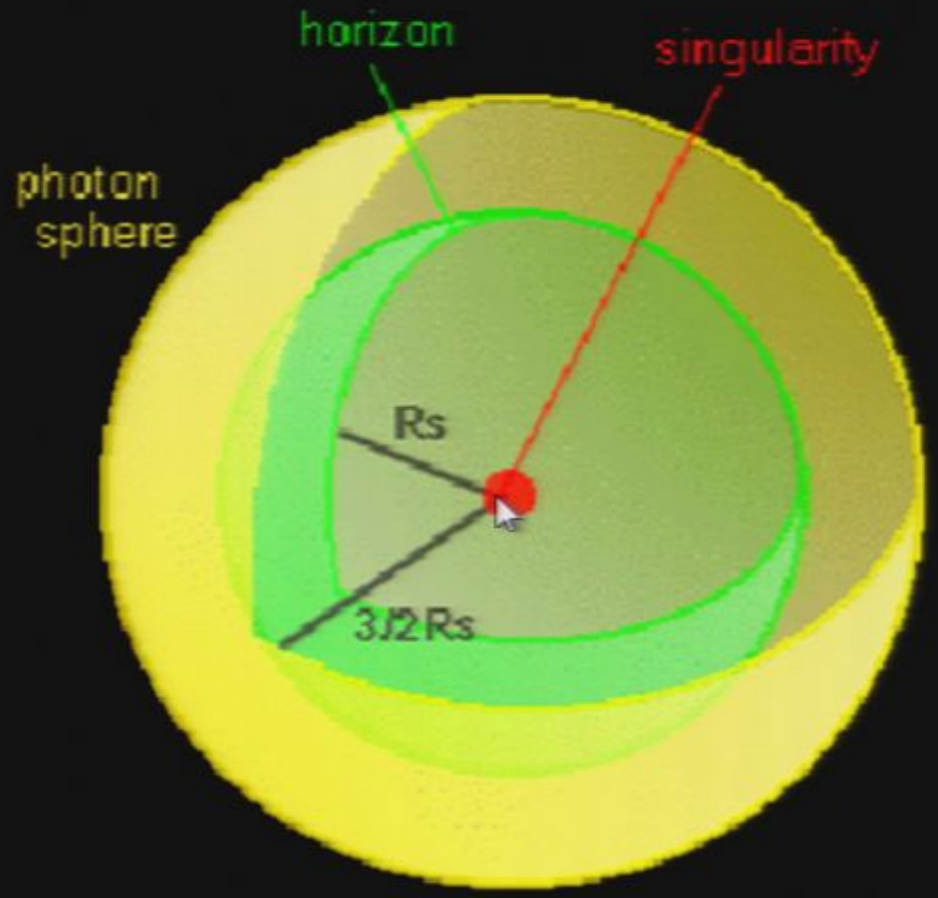

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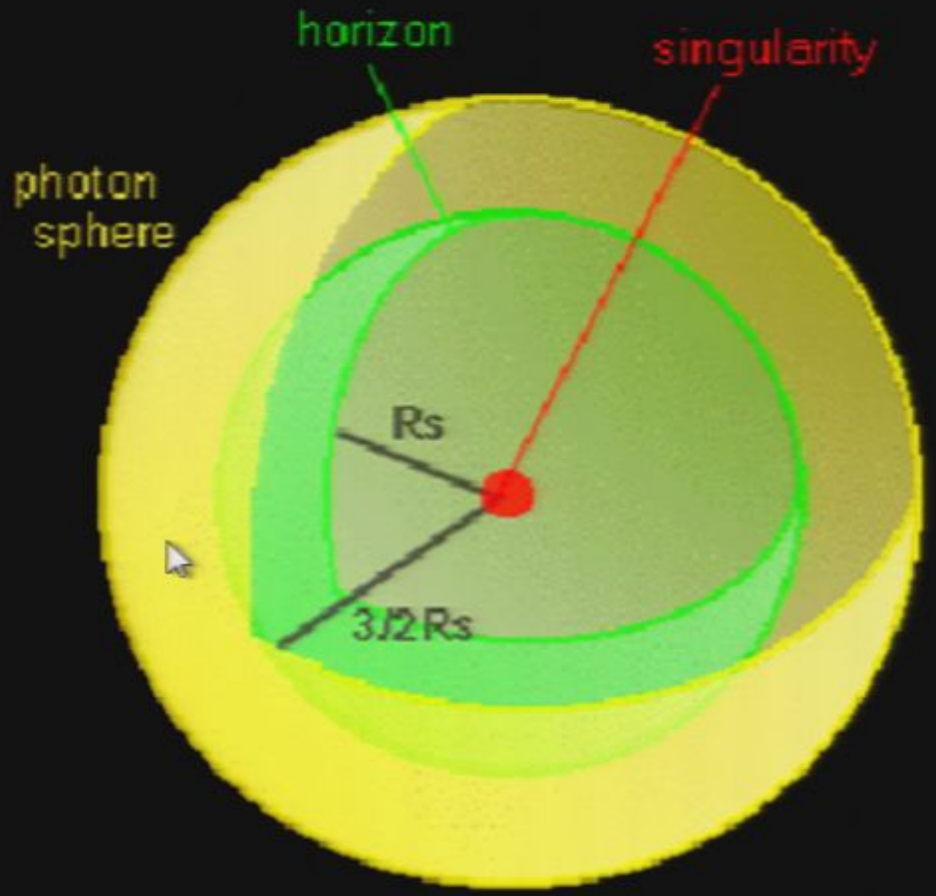
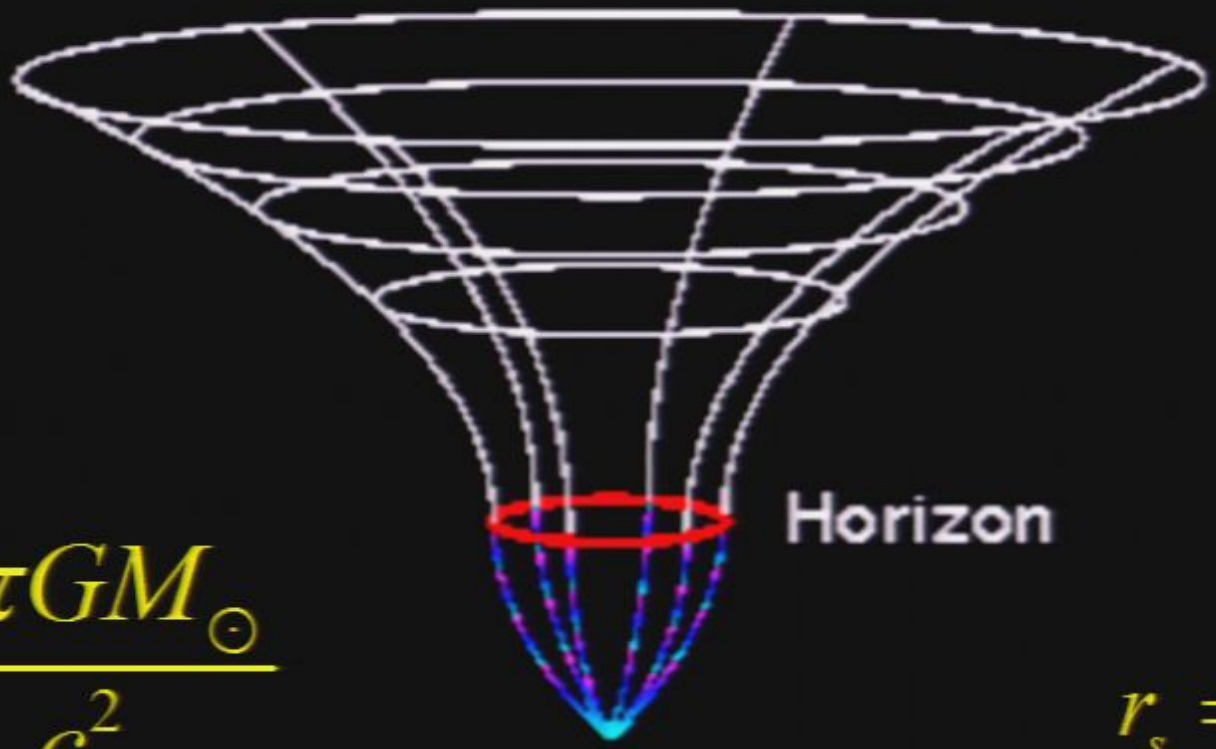


Singularity

- Within the singularity, matter is infinitely compressed into a region of infinite density. At the singularity, gravity is infinite. Space-time has become infinitely curved. At the present time, science has no tools to describe conditions within the singularity. All laws of physics lose meaning in such a region.
- At a singularity, space and time cease to exist as we know them. The laws of physics as we know them break down at a singularity, so it's not really possible to envision something with infinite density and zero volume.

Embedding Structure



$$C_b = \frac{4\pi GM_\odot}{c^2}$$

$$r_s = \frac{2GM_\odot}{c^2}$$

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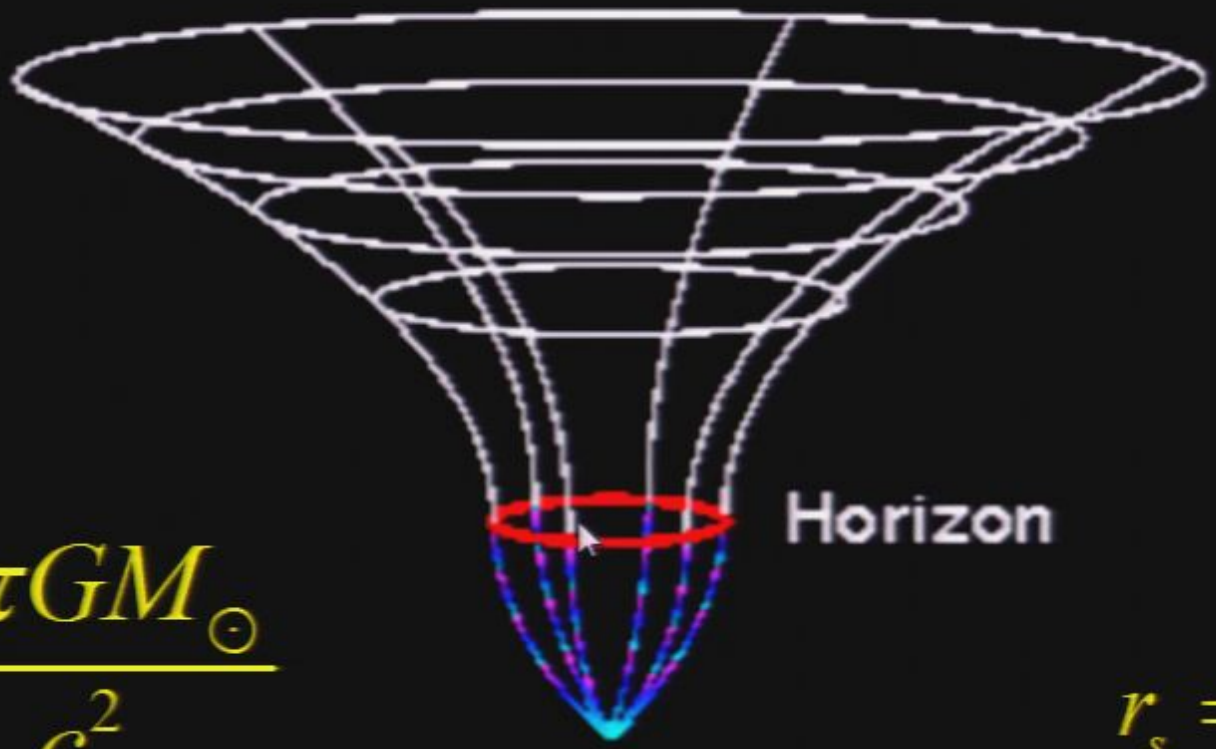

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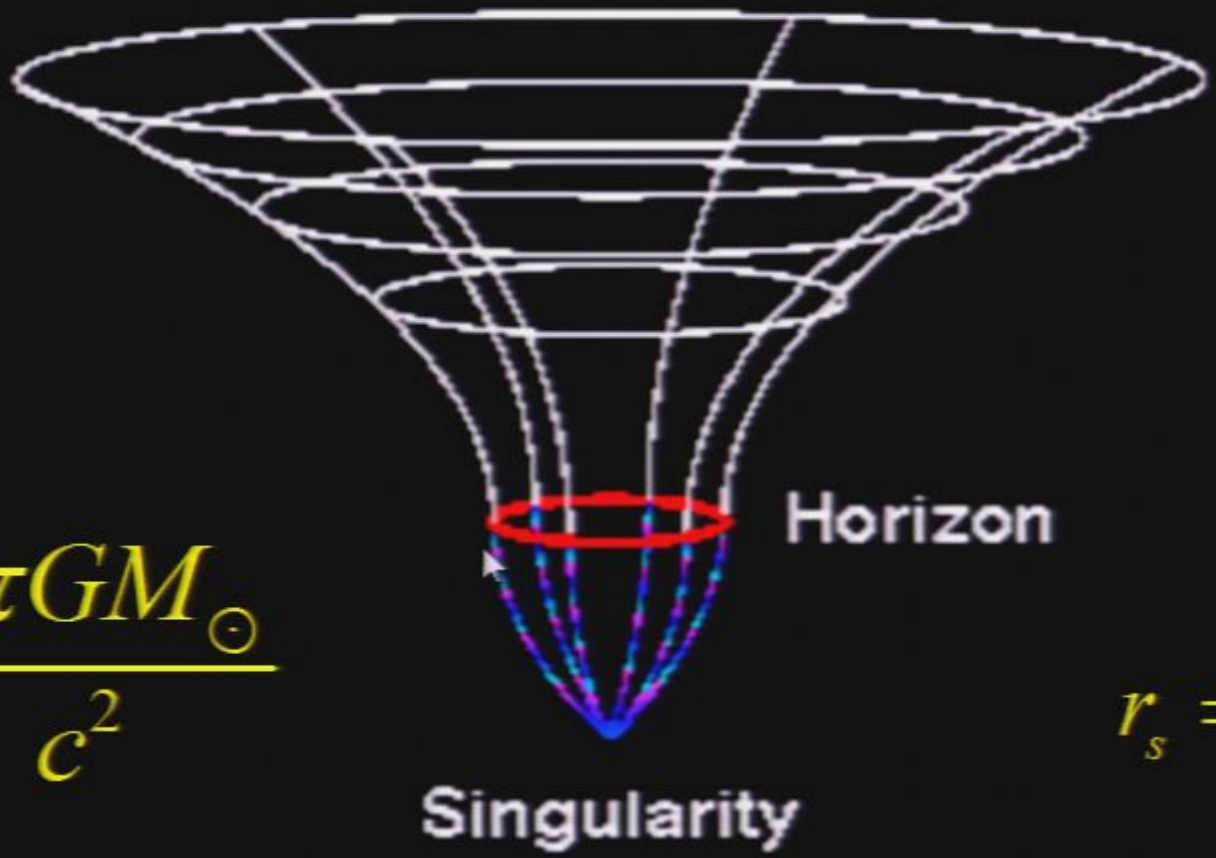

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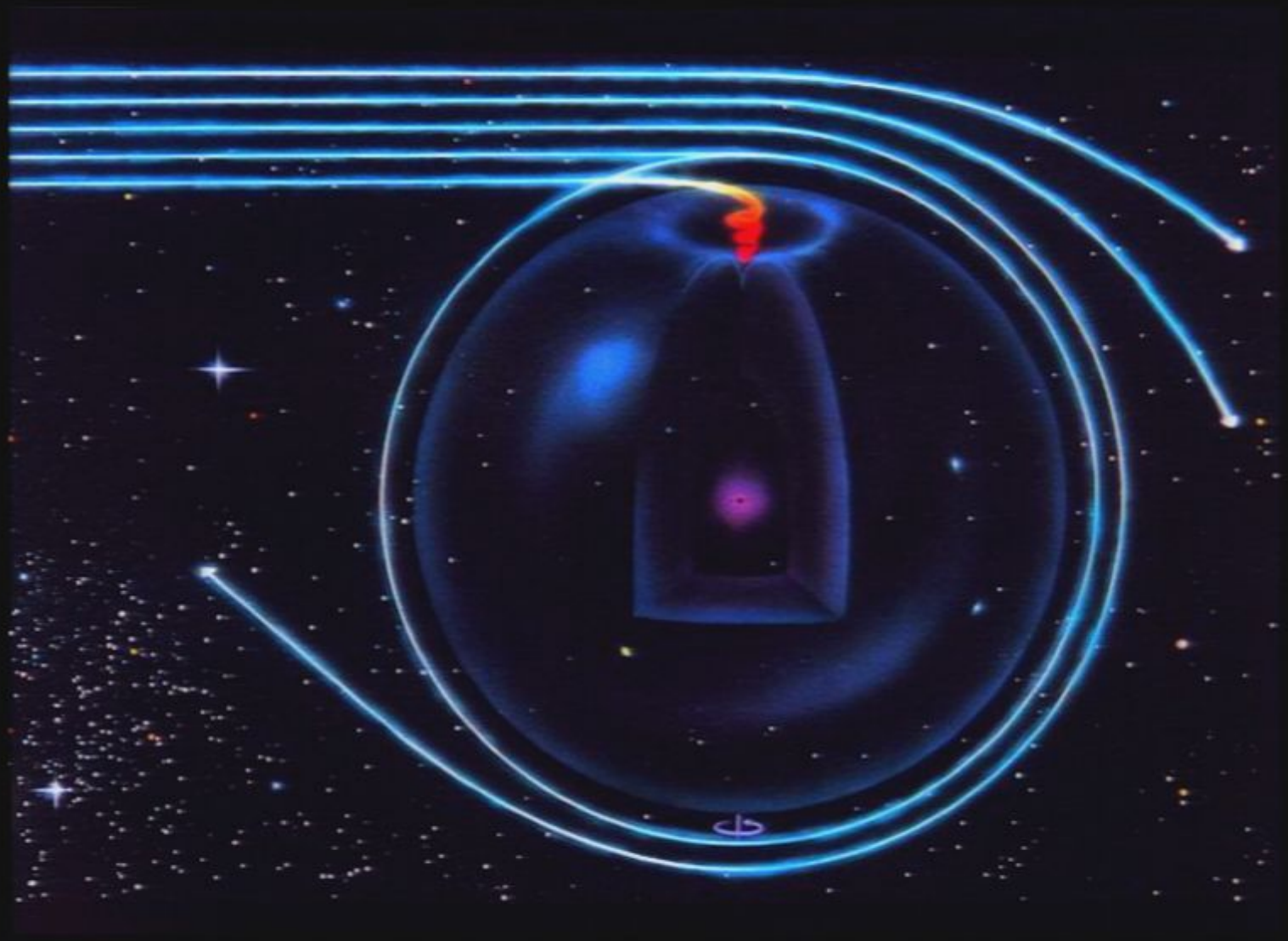
Photon orbits around a black hole



Time Dilation and Blueshift

$$t_2 = \frac{t_1}{\sqrt{1 - \frac{C_b}{C}}}$$

If you hovered at 1.00 000 1 times the event horizon circumference, then one day for you would mean ...

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If you hovered at 1.00 000 1 times the event horizon circumference, then one day for you would mean ...

1024 days for the rest of the universe.

$$\lambda_r = \lambda_e \sqrt{1 - \frac{C_b}{C}}$$

If you hovered at 1.00 000 8 times the event horizon circumference, visible light (5.8 x 10^{-7} m) from the stars would appear at wavelength ...

1.6×10^{-9} m (X-ray)

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The Effects

No matter how powerful your starship, once you enter the Event Horizon, you might as well enjoy the trip, because you are going in.

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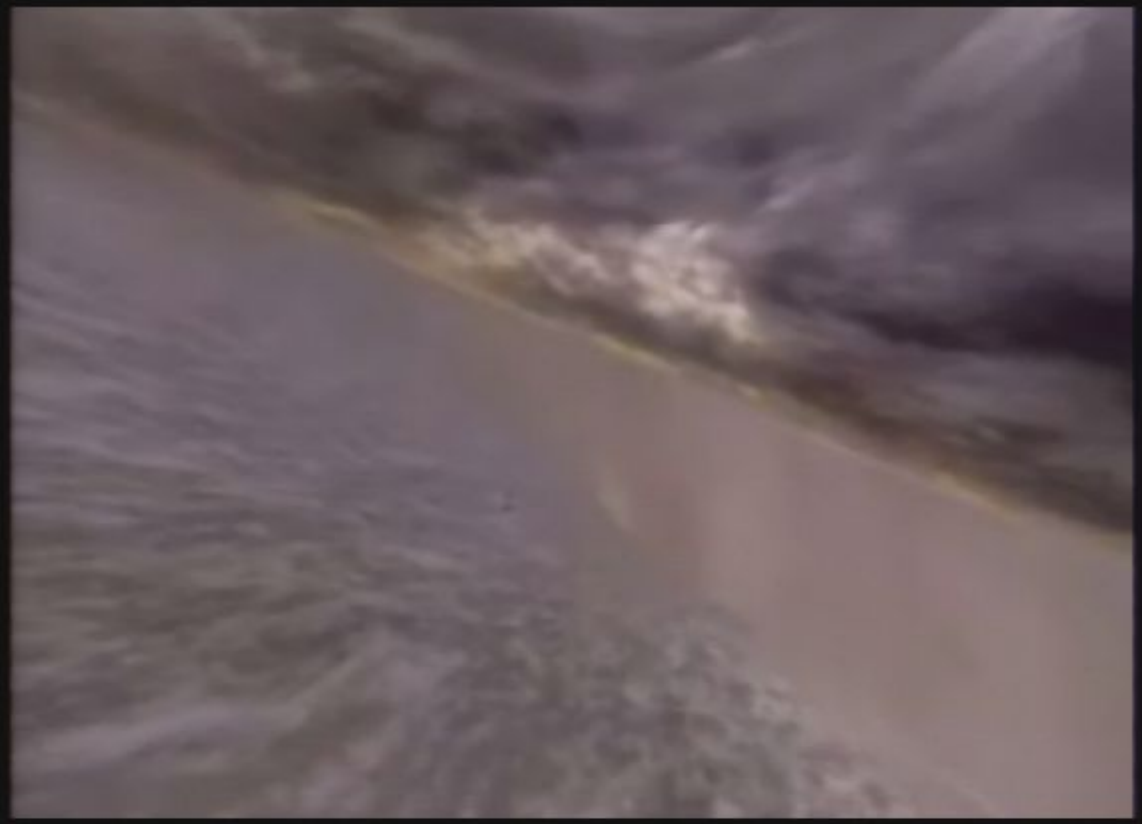

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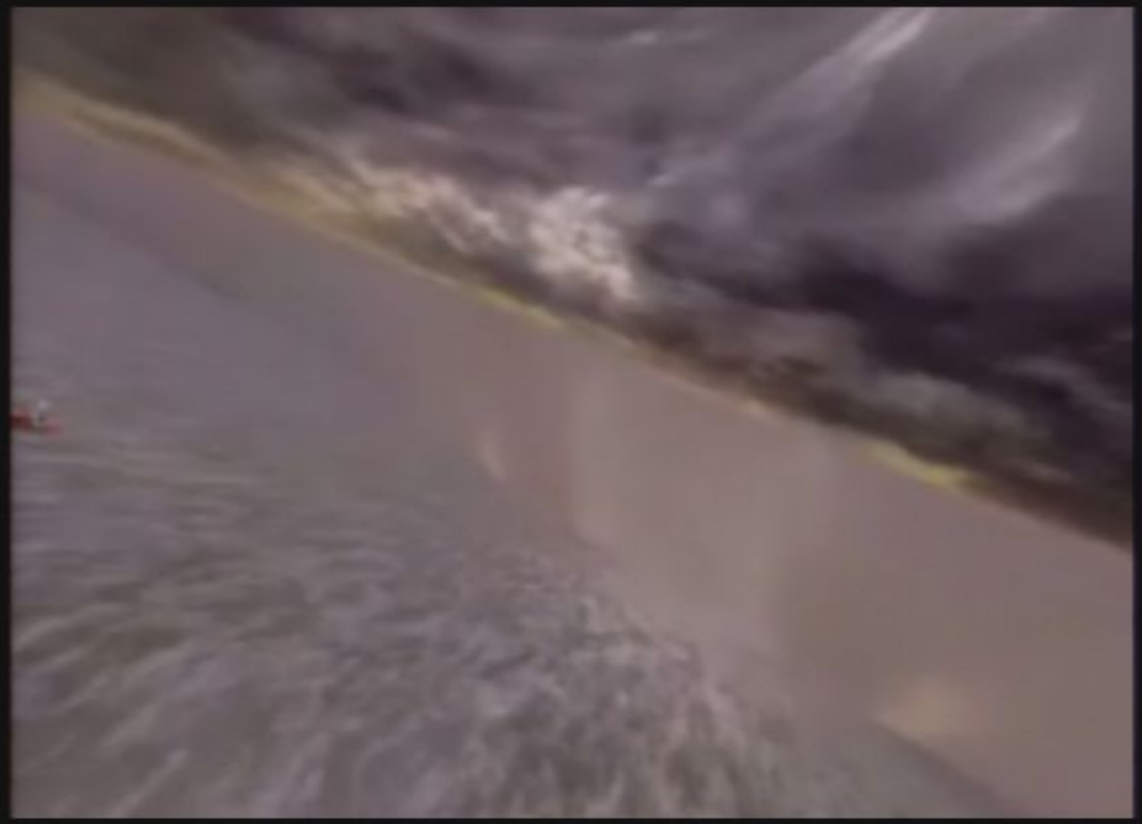

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Visiting a Black Hole

Spaghettification!

$$\Delta a = \frac{16\pi^3 GLM_b}{C^3}$$

$$\Delta a \propto \frac{1}{M_b{}^2}$$

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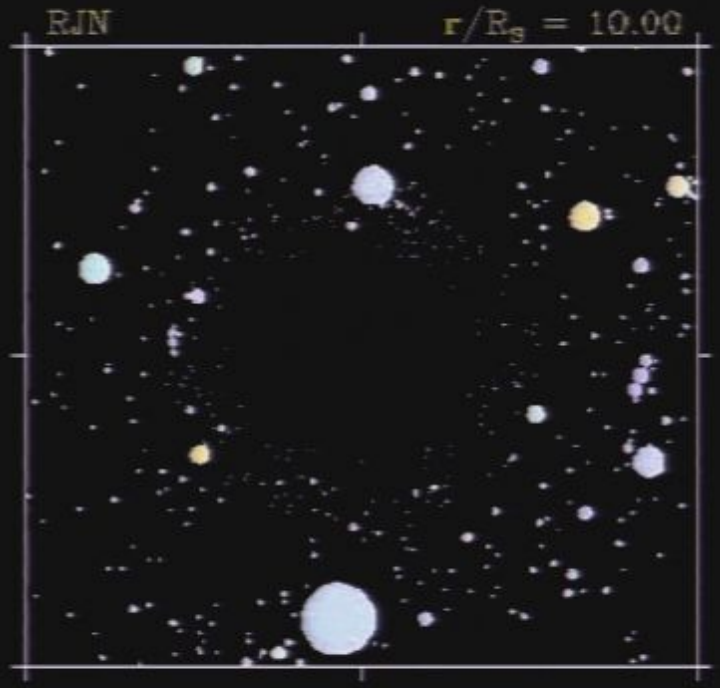

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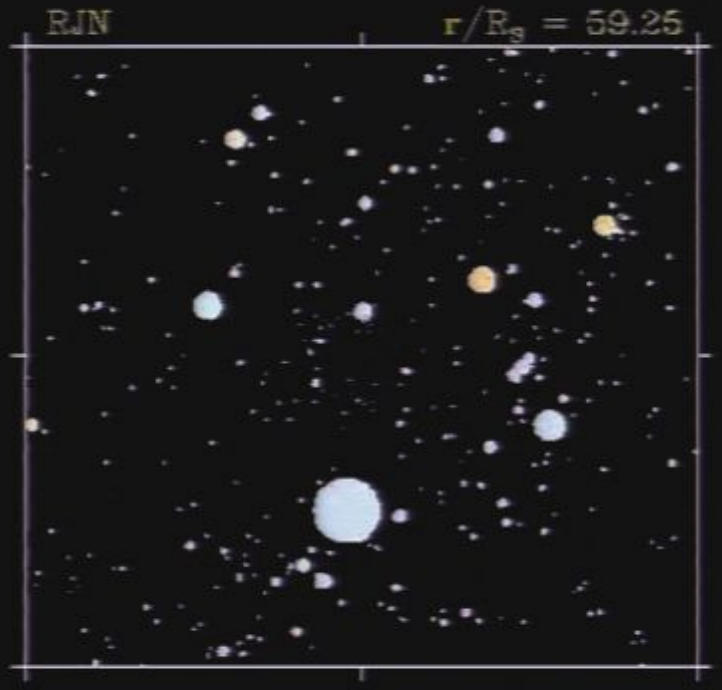
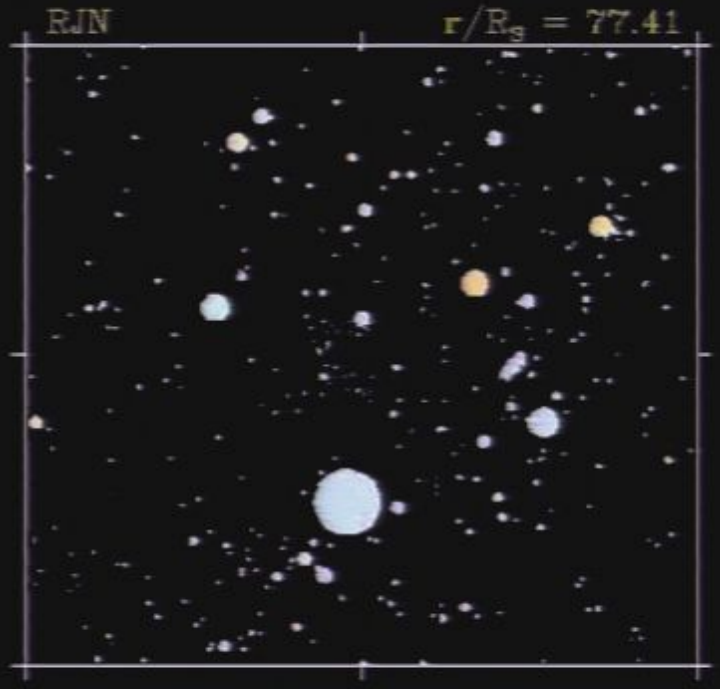


Approaching



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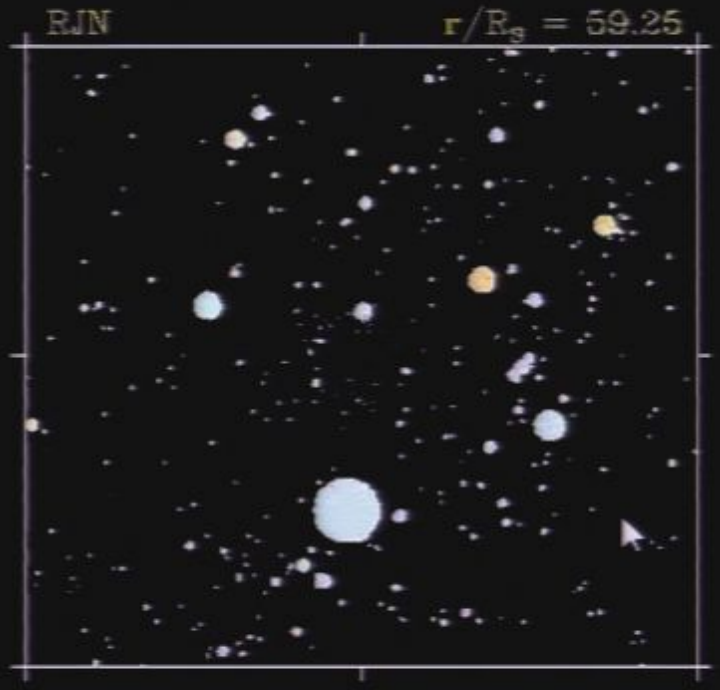

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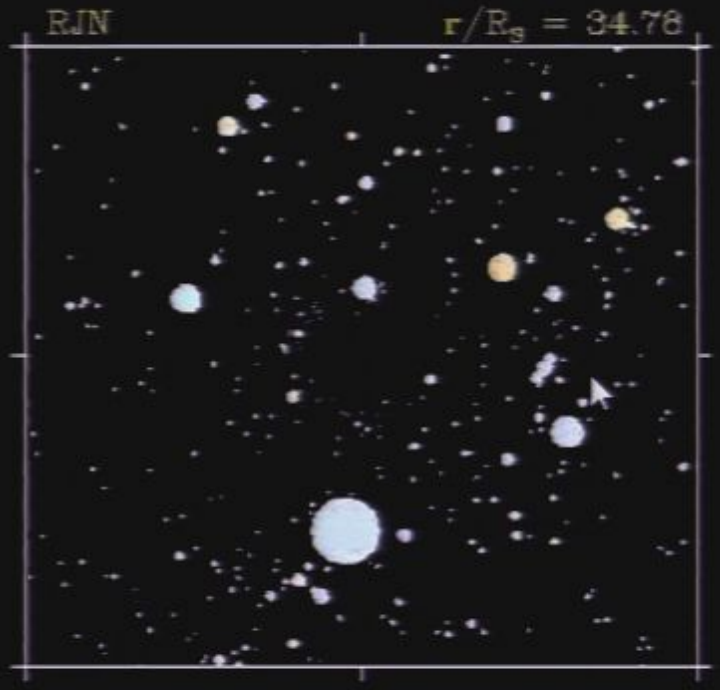

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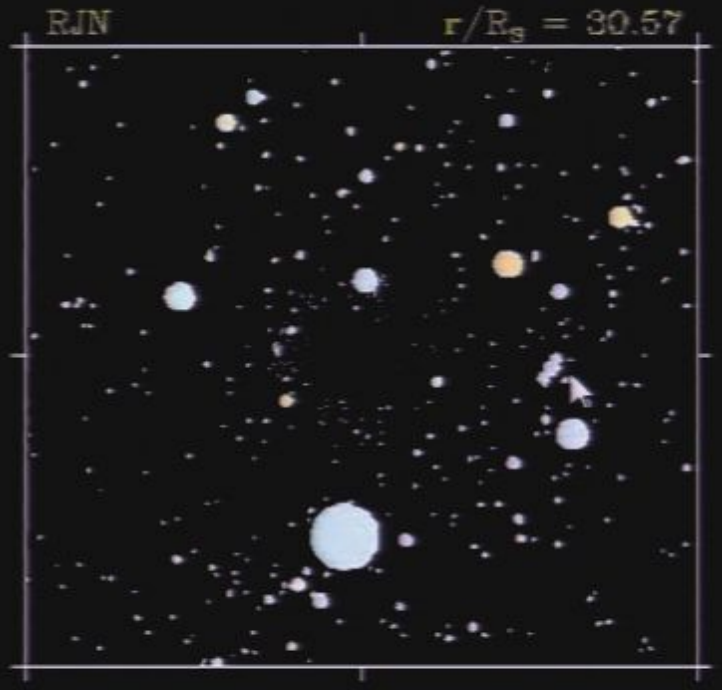

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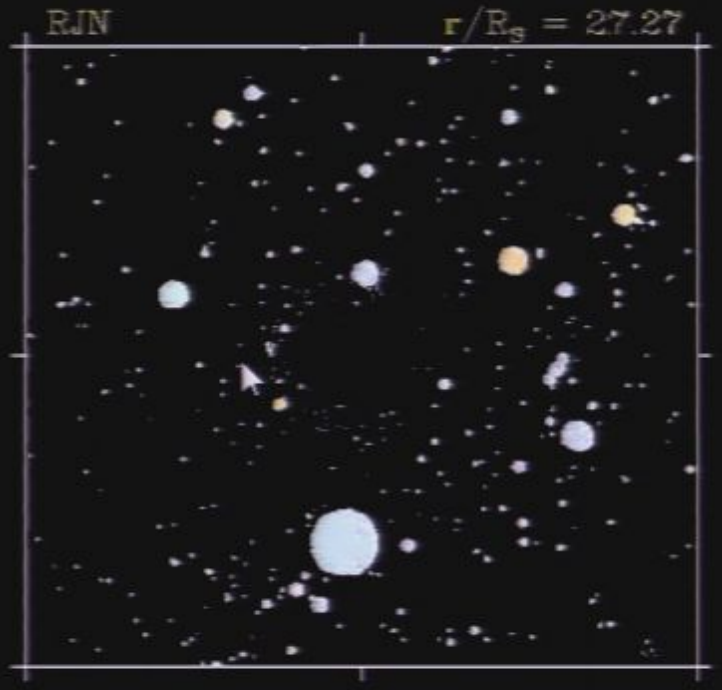

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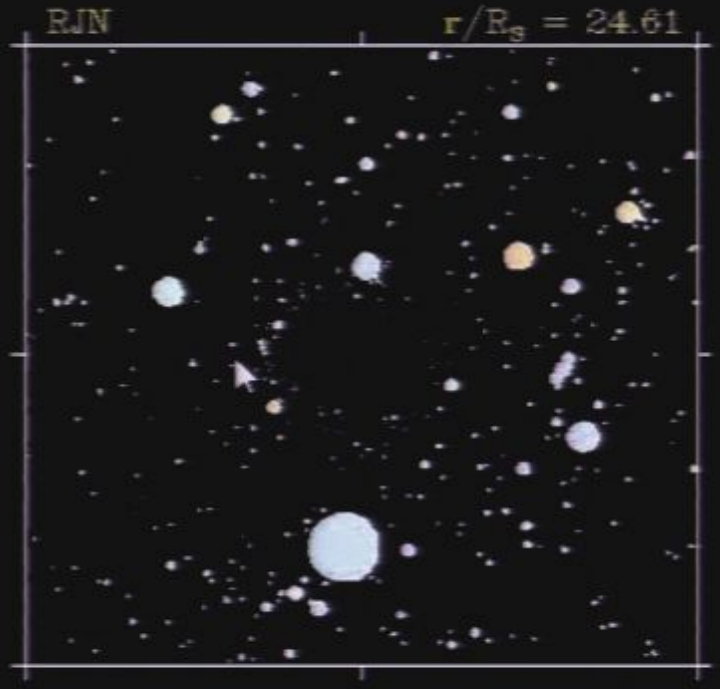

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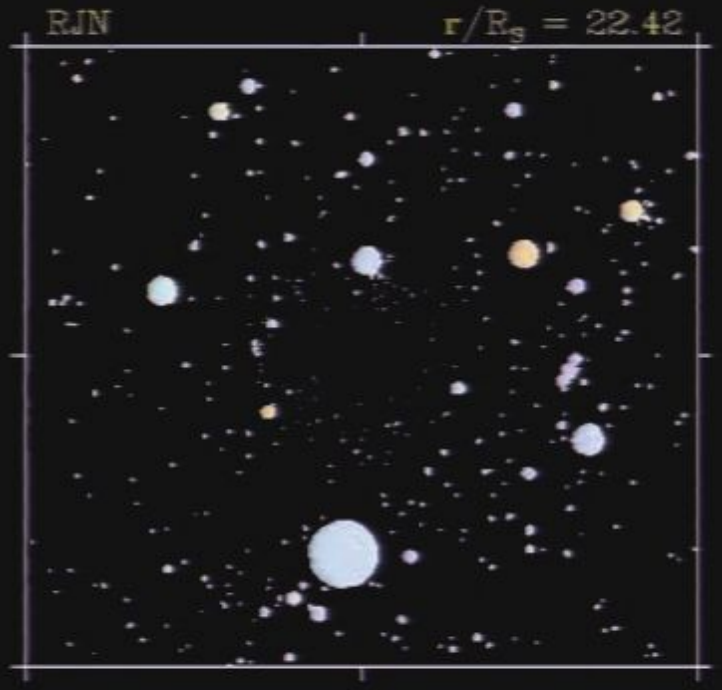

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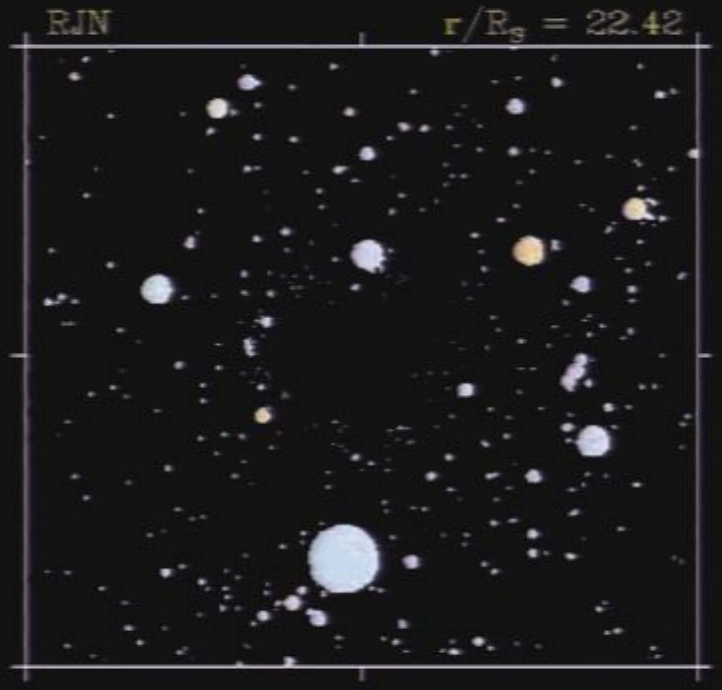

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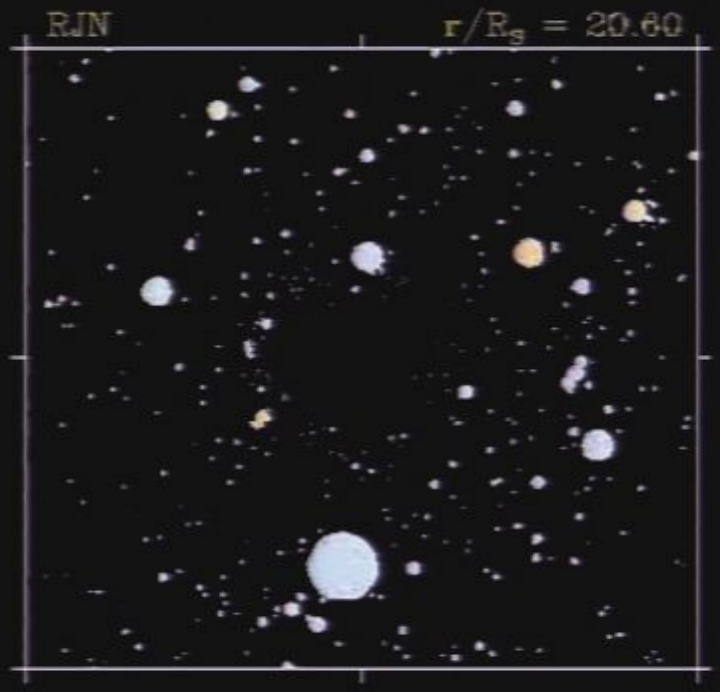
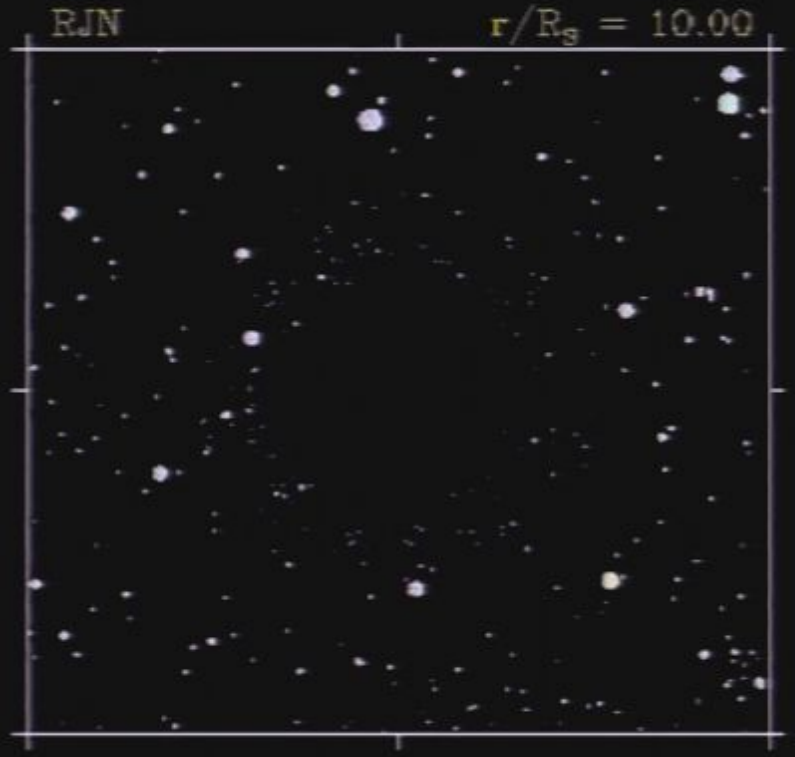
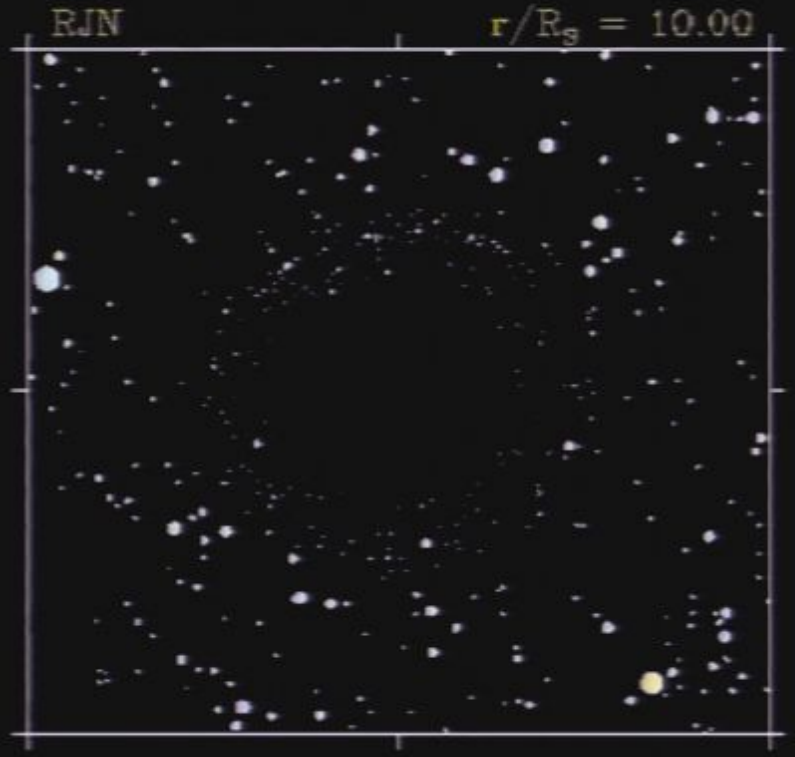


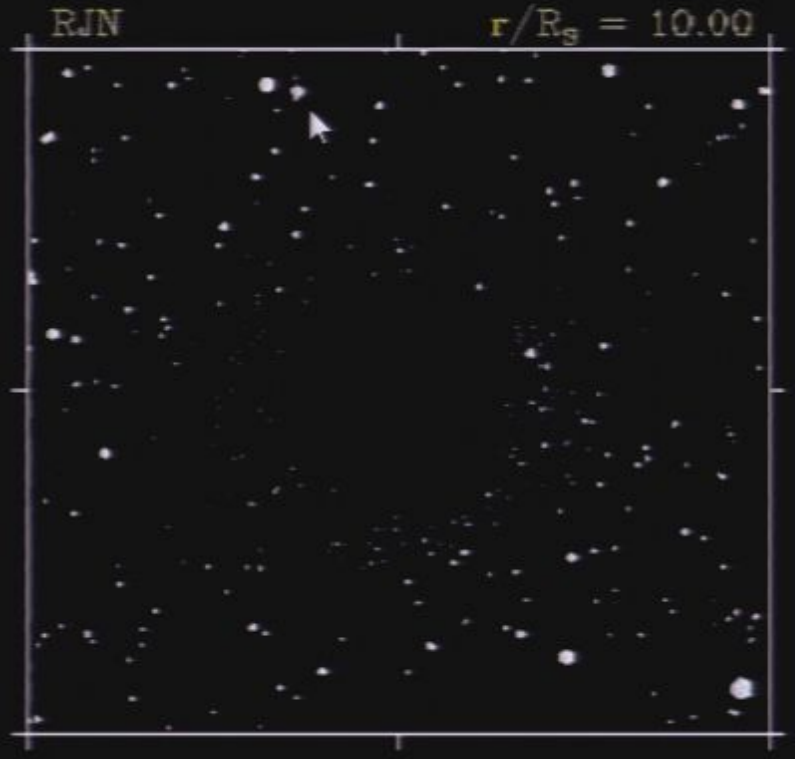
Orbiting Black Hole Looking Down



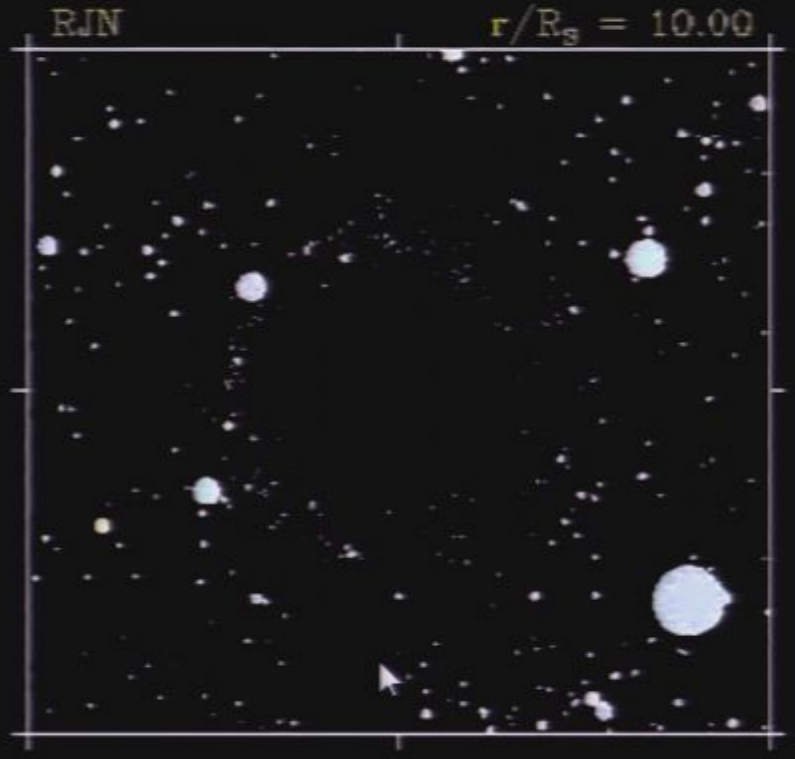
Orbiting Black Hole Looking Down



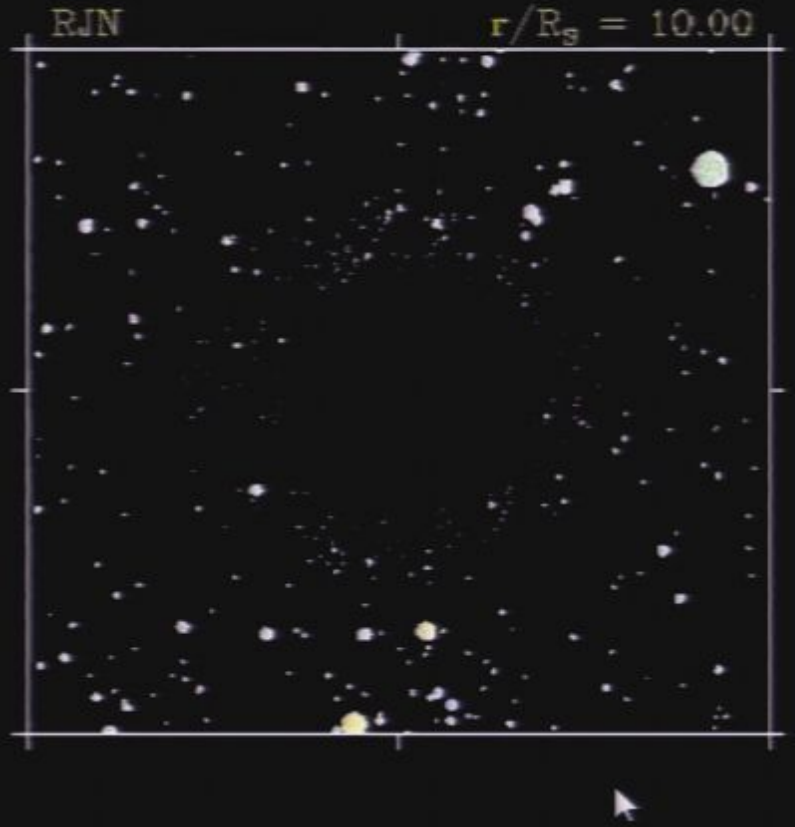
Orbiting Black Hole Looking Down



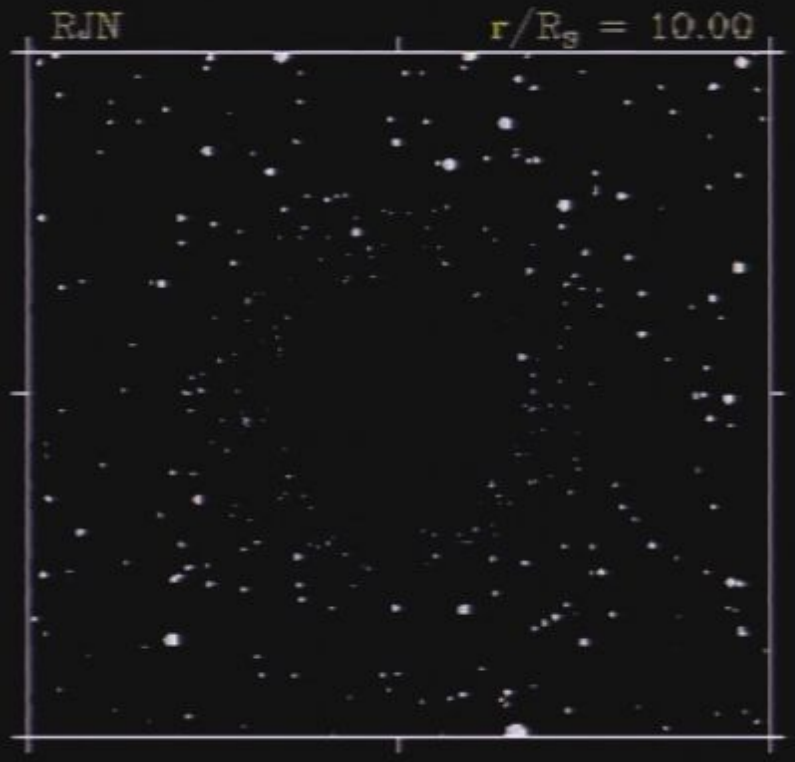
Orbiting Black Hole Looking Down



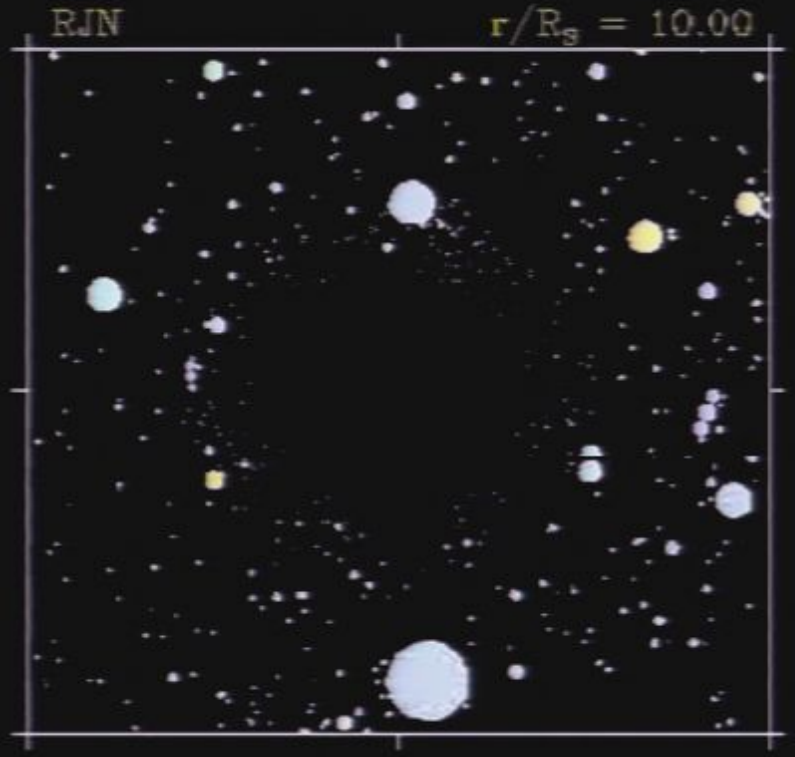
Orbiting Black Hole Looking Down



Orbiting Black Hole Looking Down



Orbiting Black Hole Looking Down



Orbiting Black Hole Looking Down

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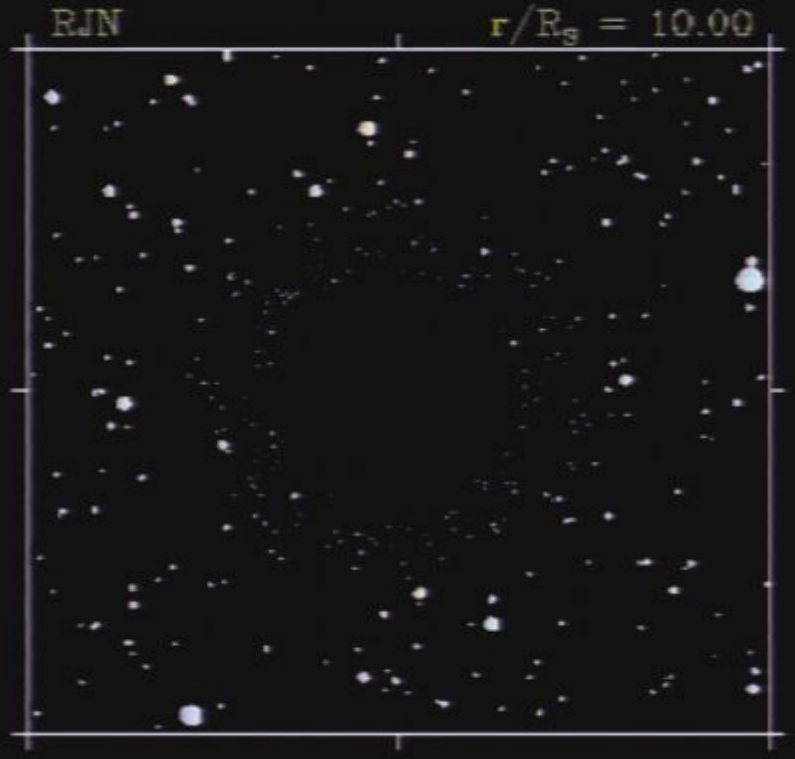
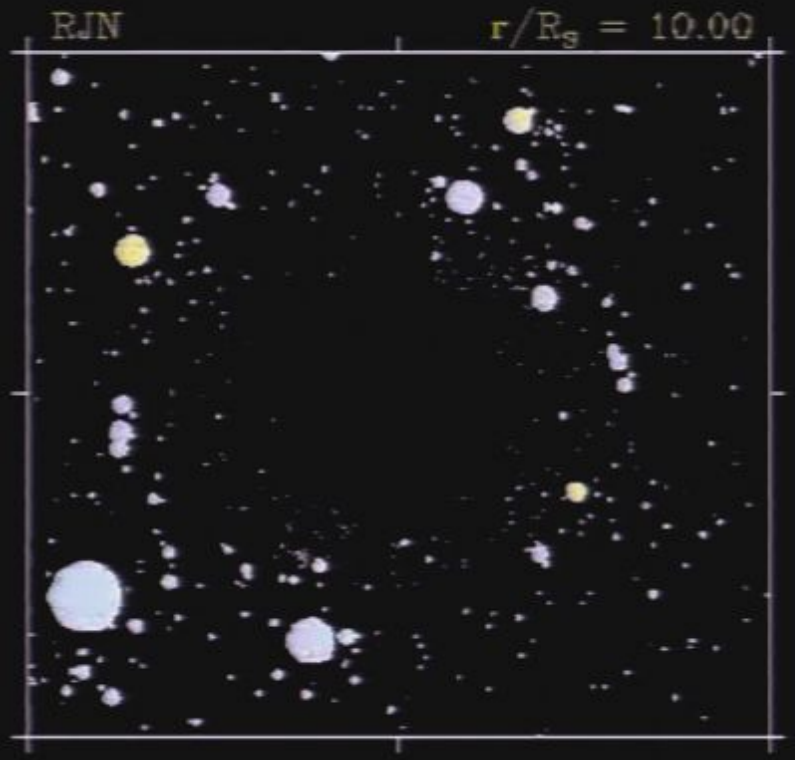


Orbiting Black Hole Looking Down



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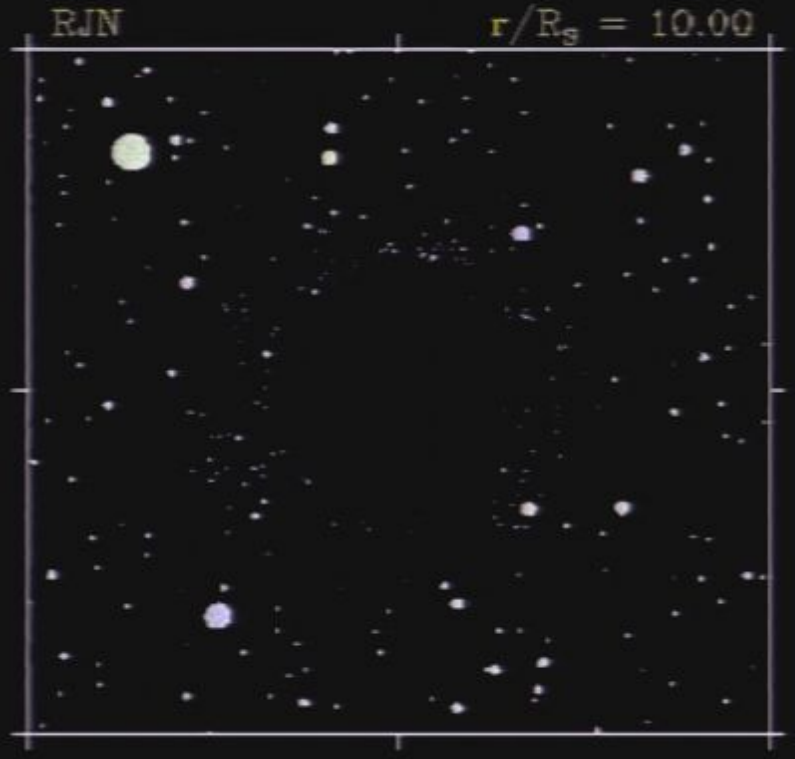

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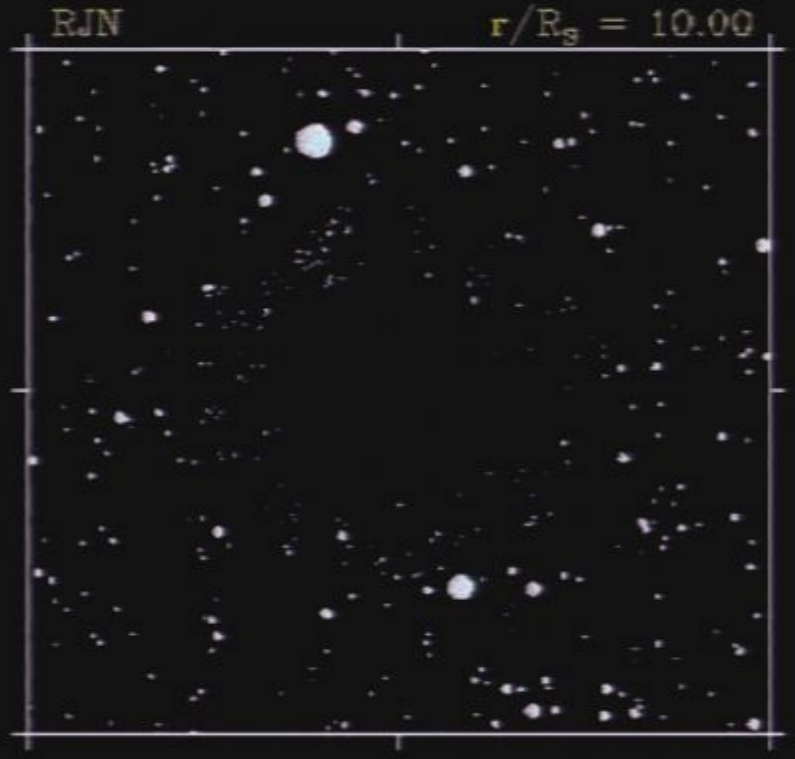
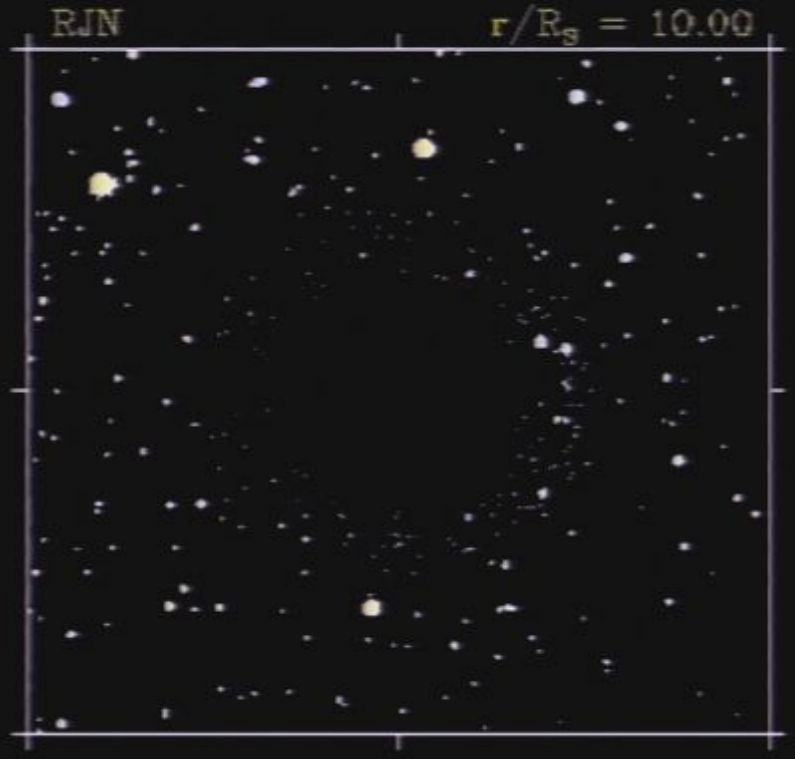
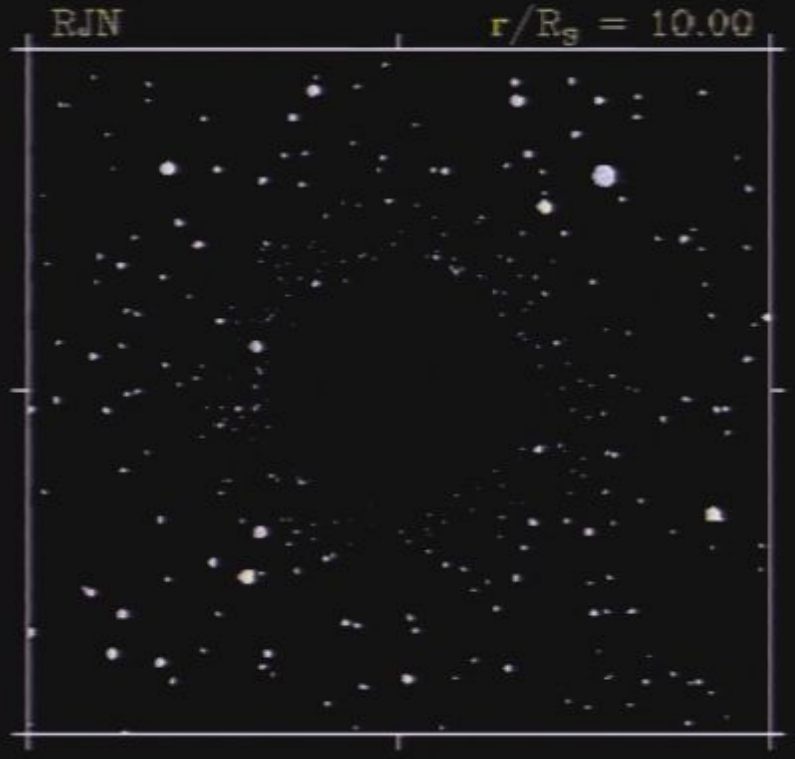


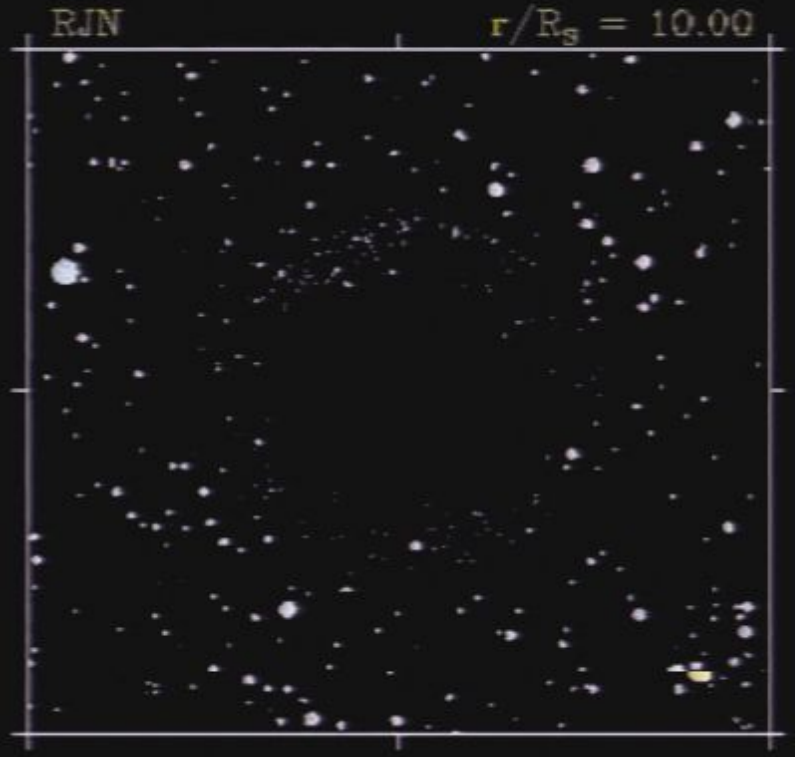
Orbiting Black Hole Looking Down



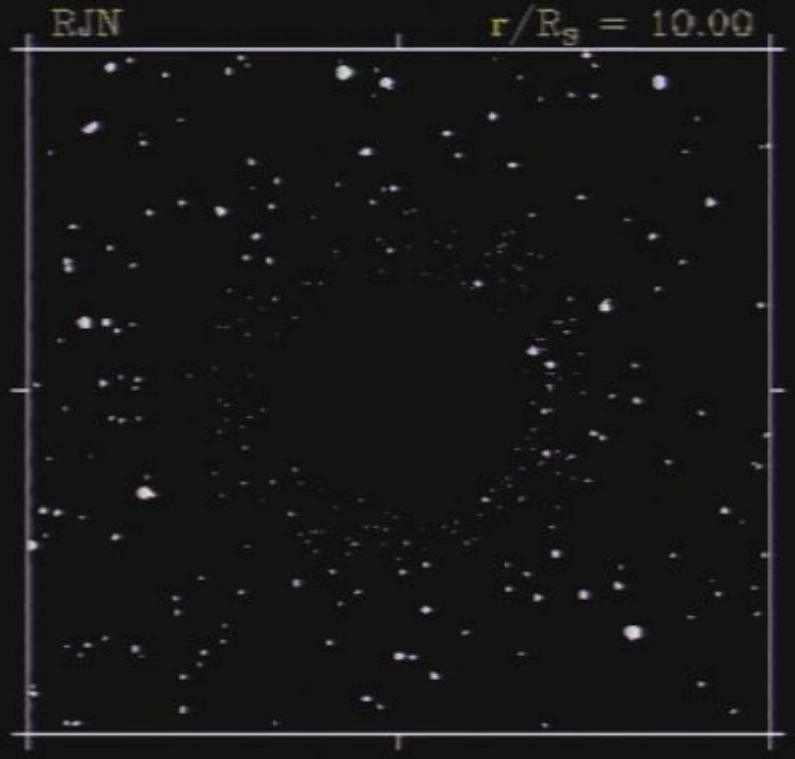
Orbiting Black Hole Looking Down



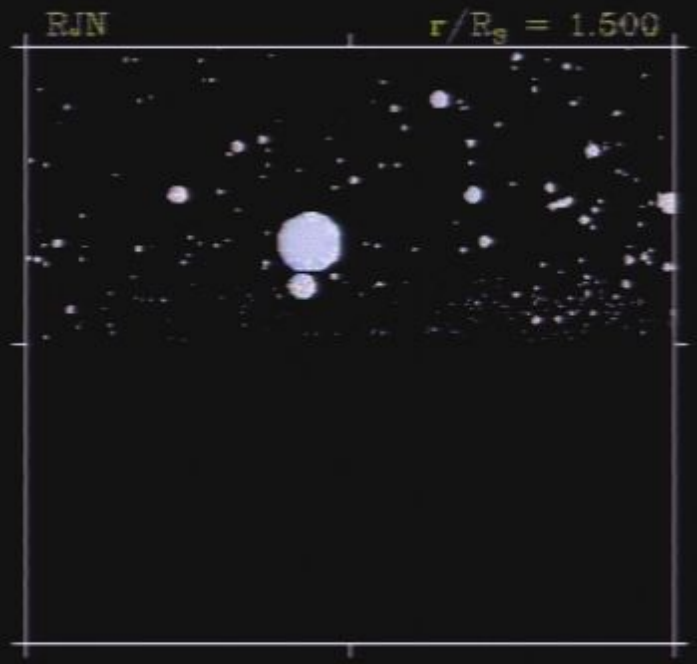
Orbiting Black Hole Looking Down



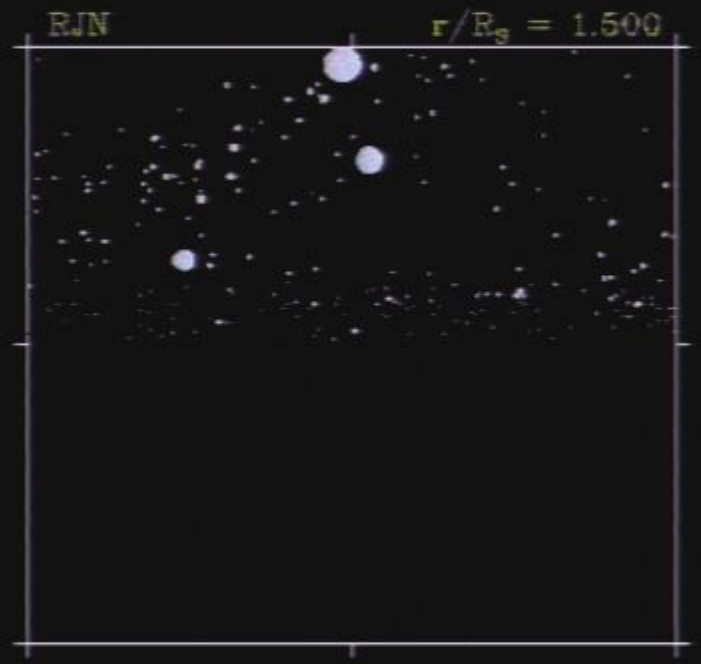
Orbiting Black Hole Looking Down



Orbiting Looking Horizontally at Photon Sphere



Orbiting Looking Horizontally at Photon Sphere



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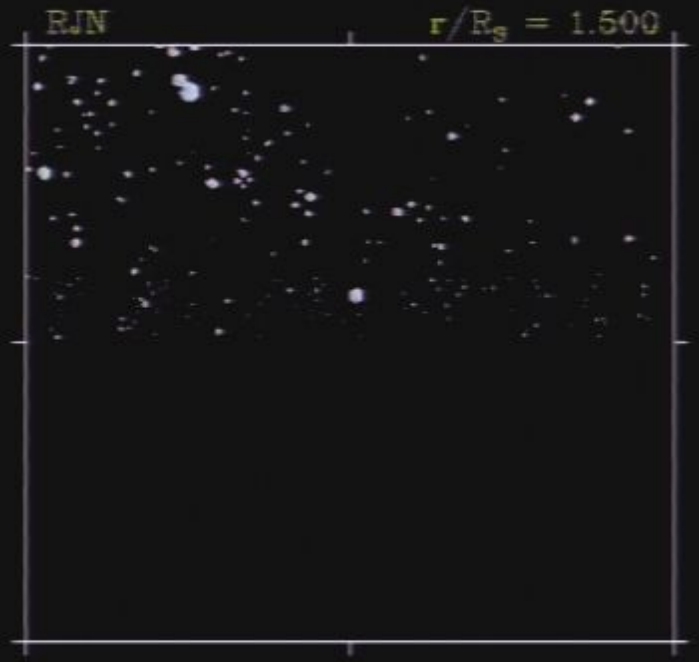

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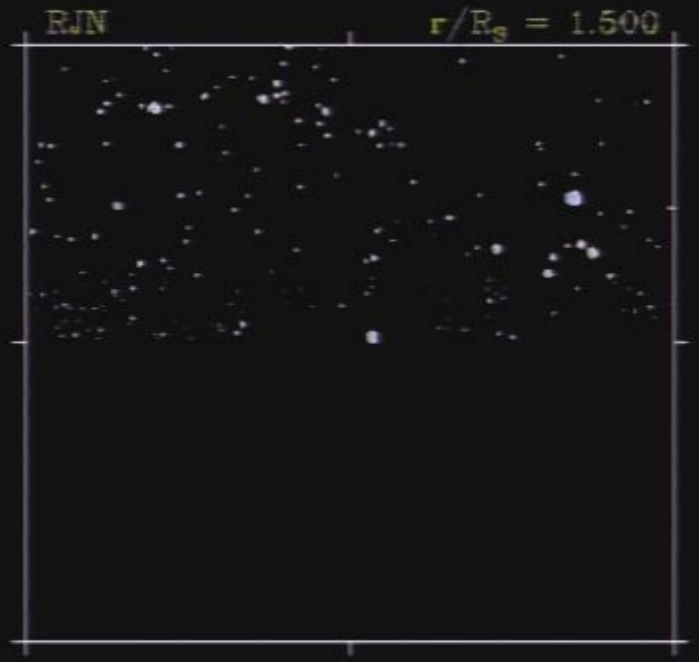

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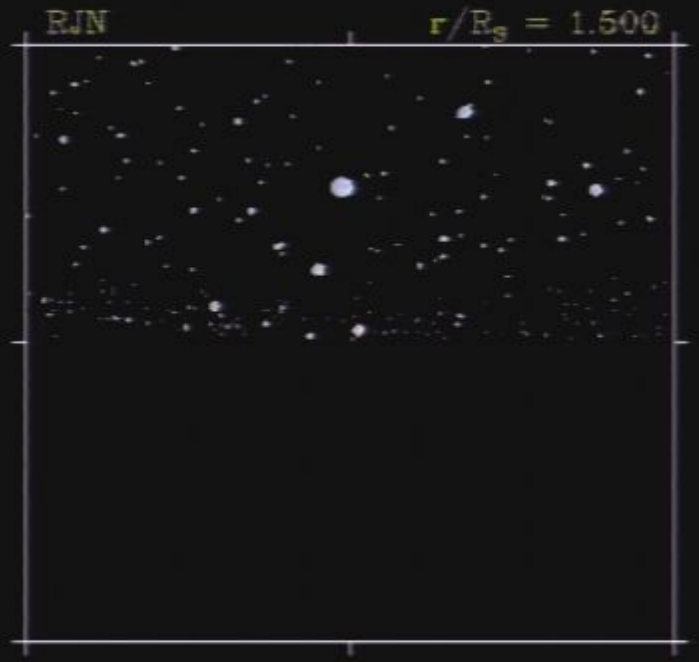

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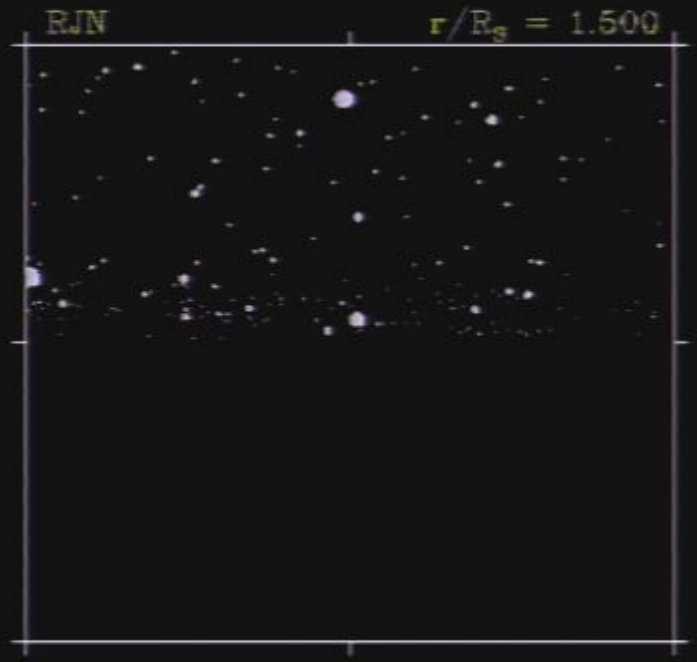

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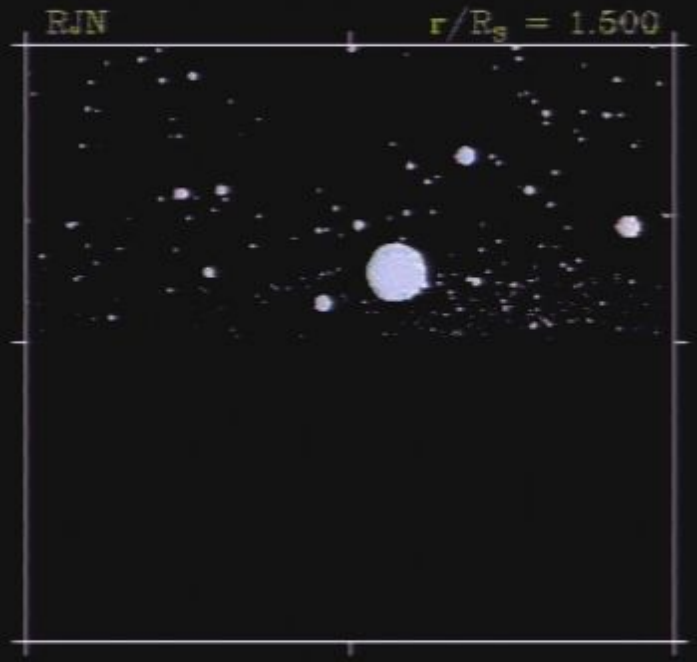

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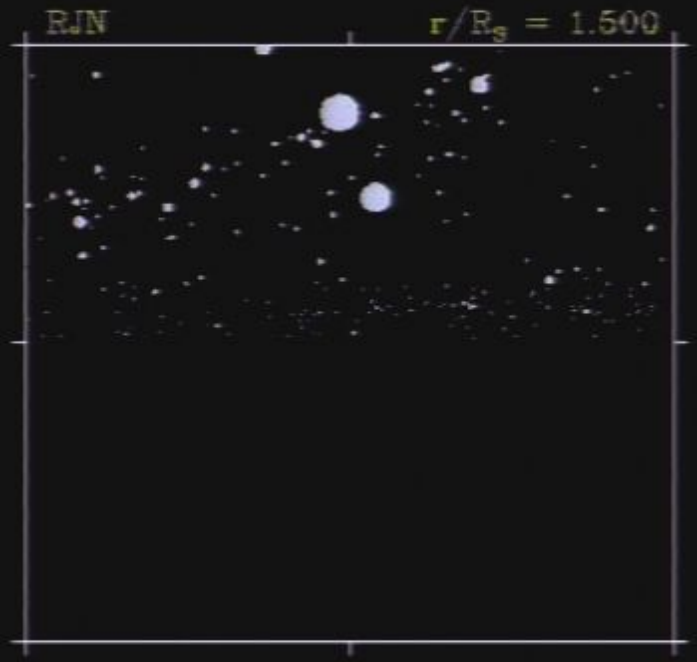

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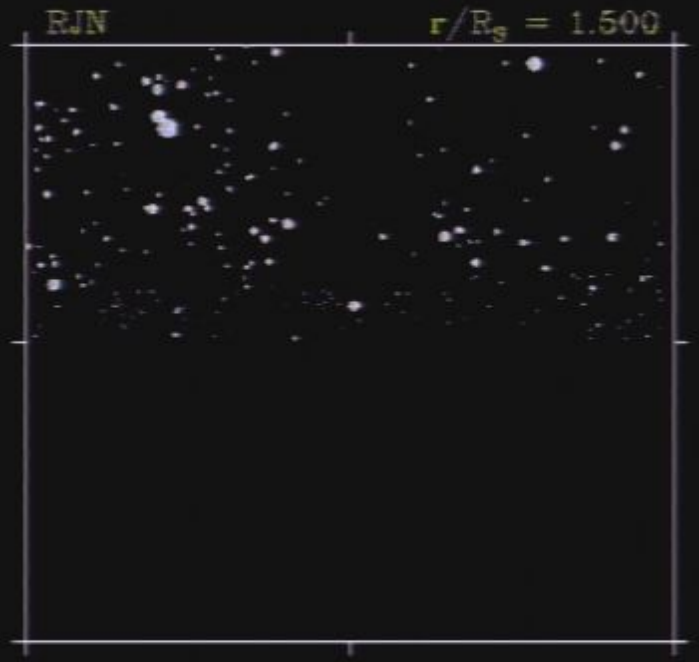

Orbiting Looking Horizontally at Photon Sphere

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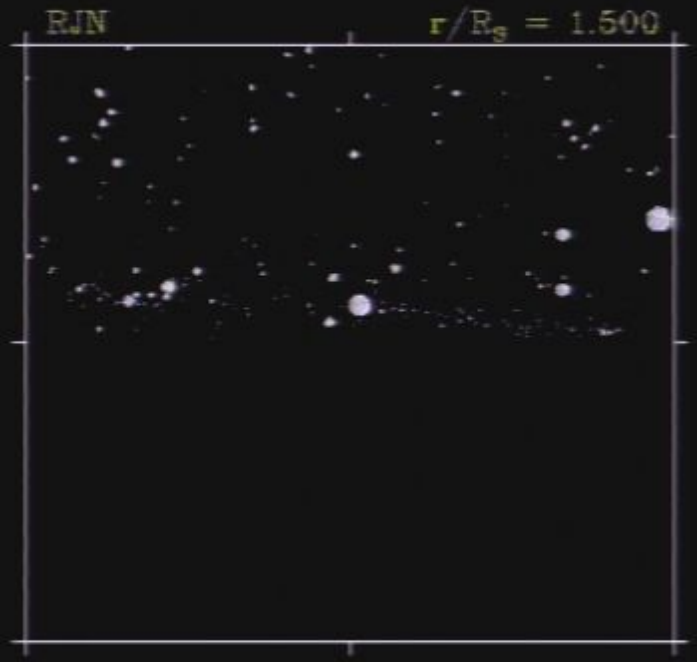

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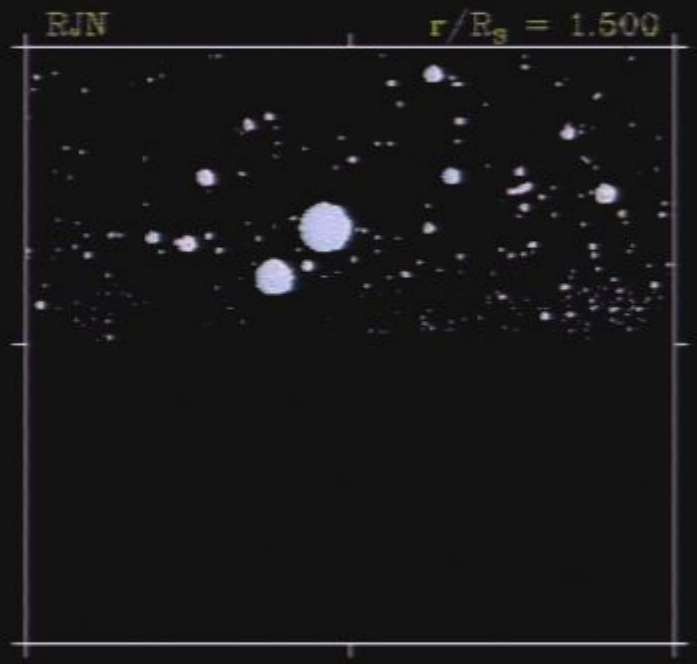

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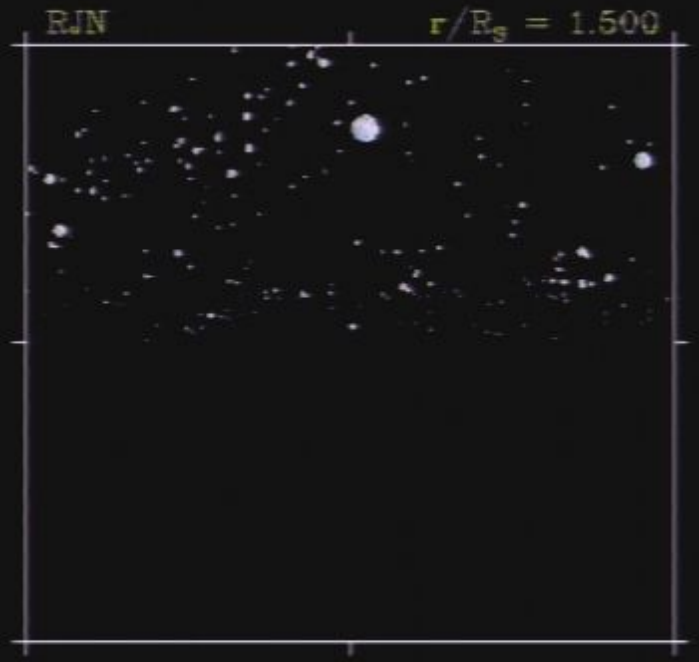

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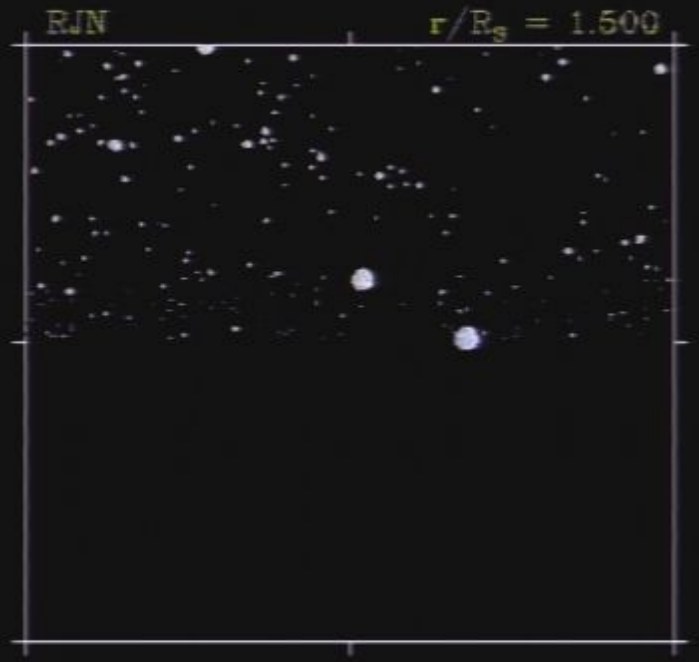

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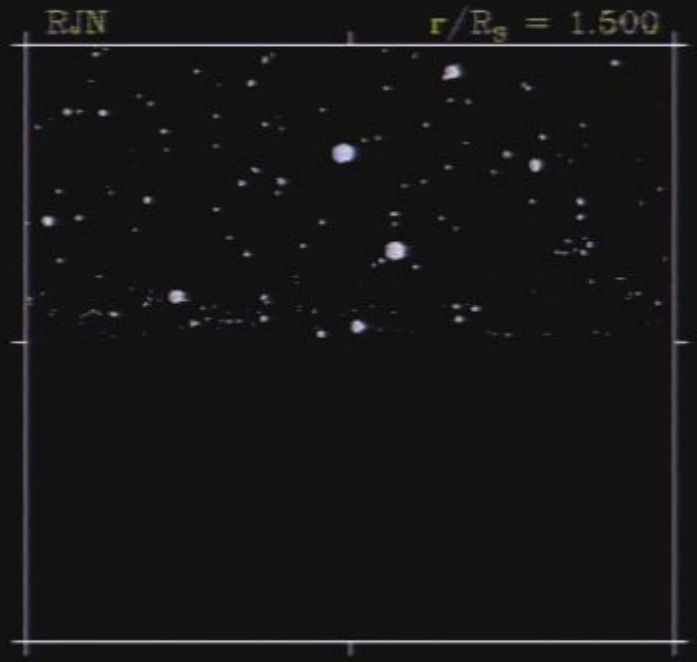

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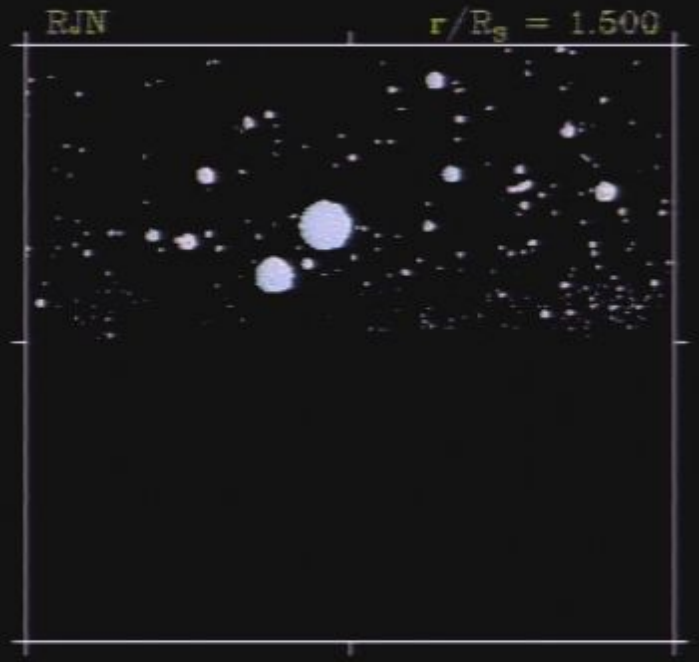

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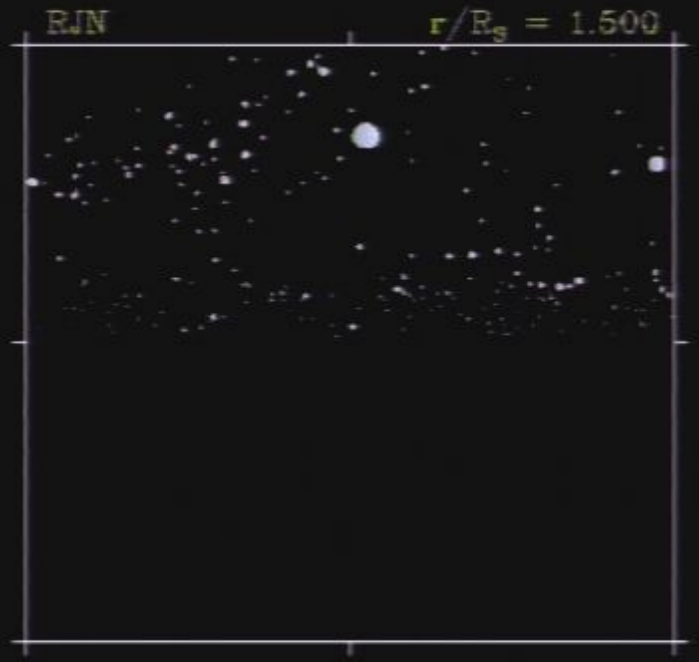

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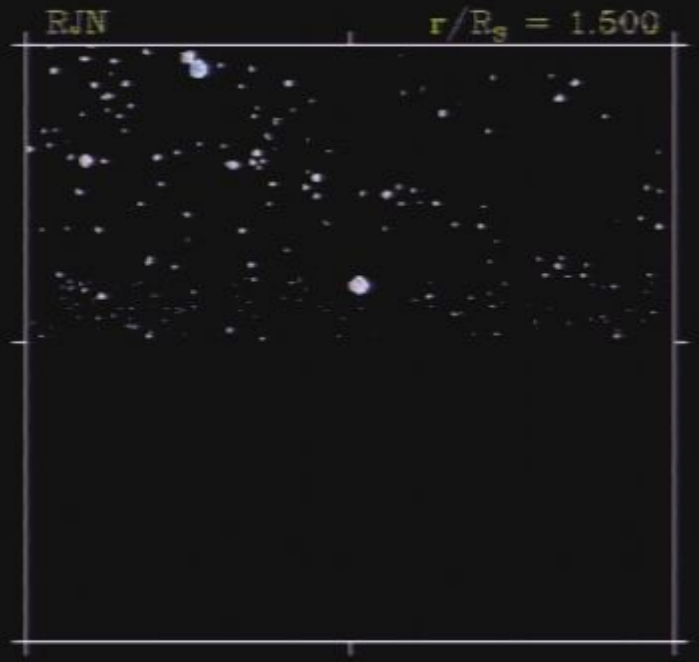

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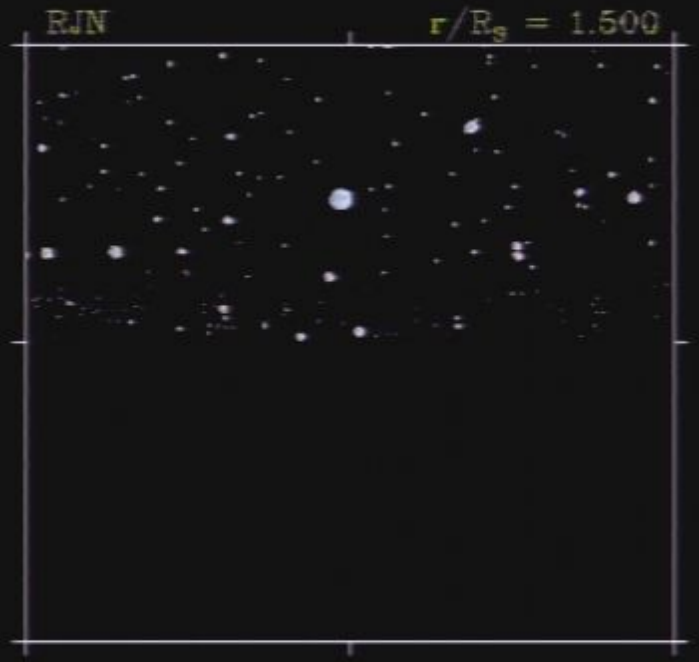

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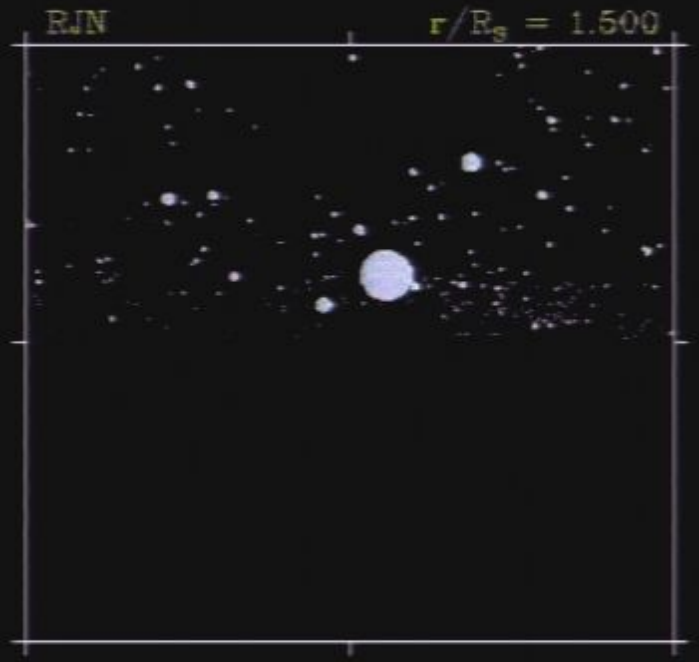

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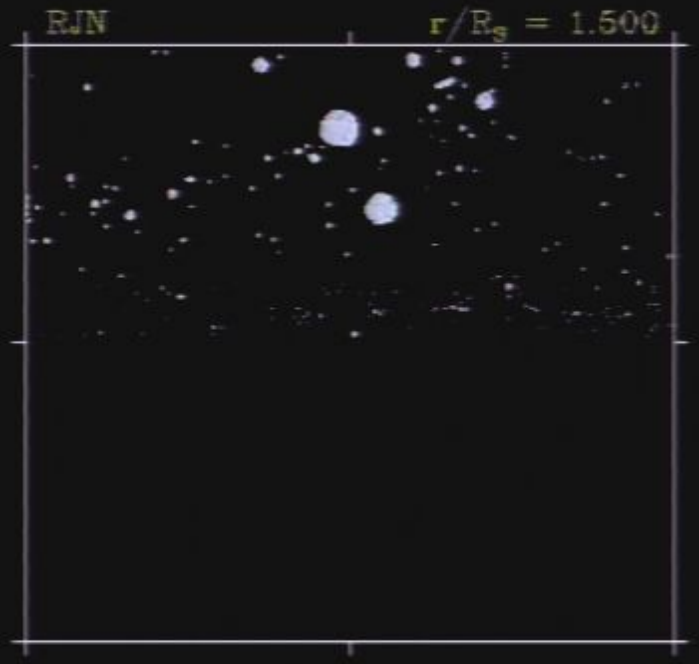

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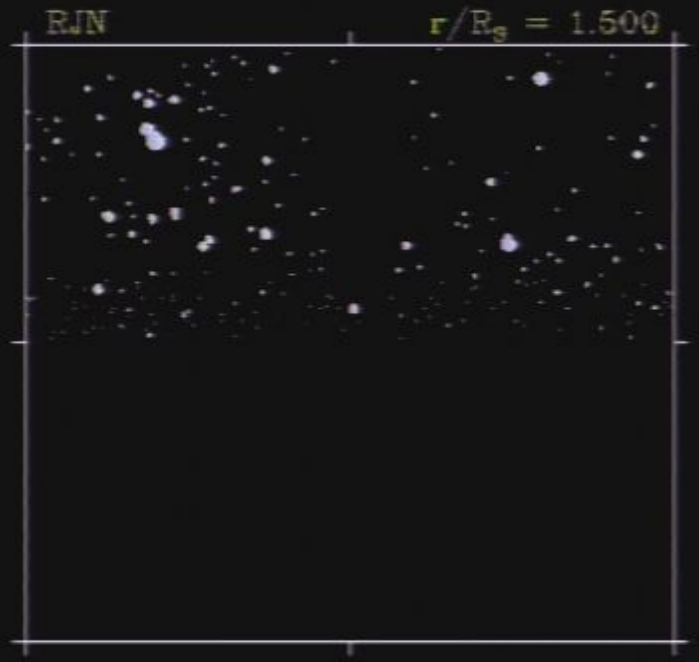

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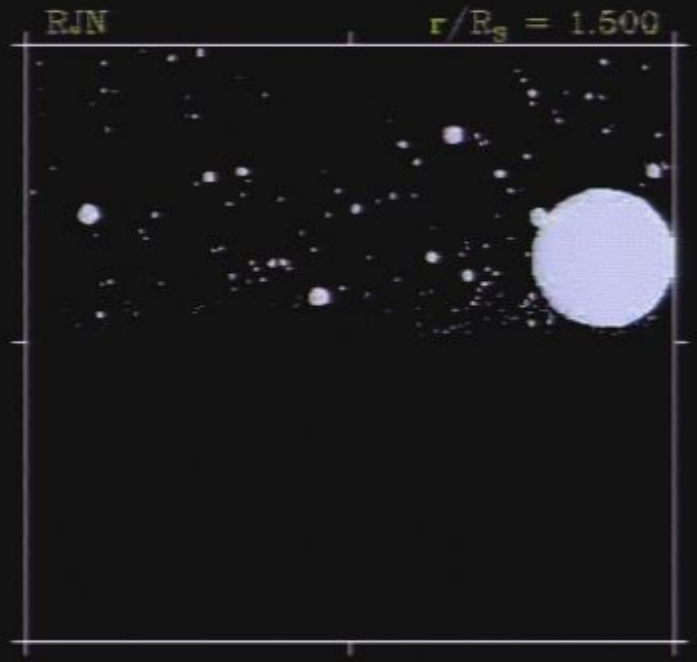

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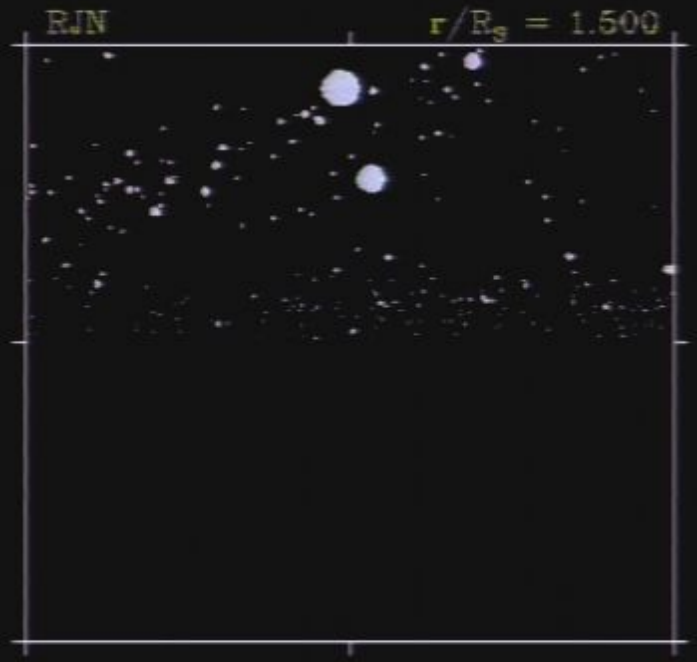

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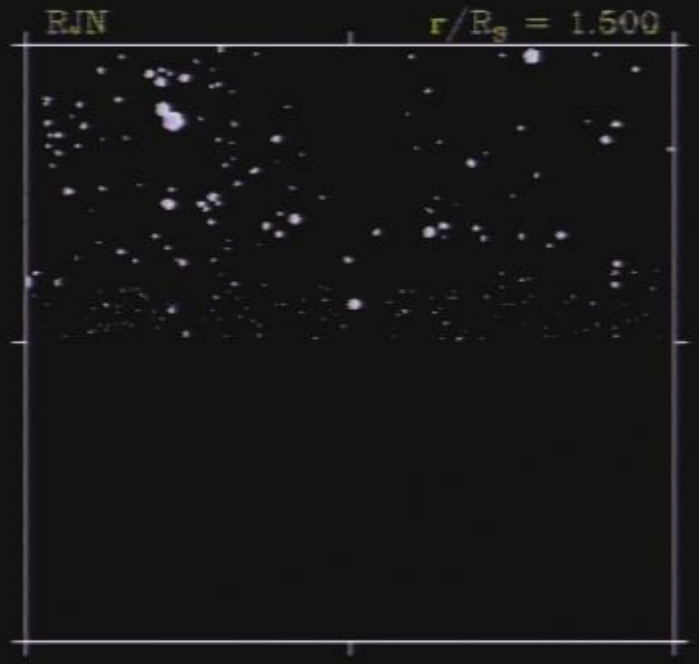

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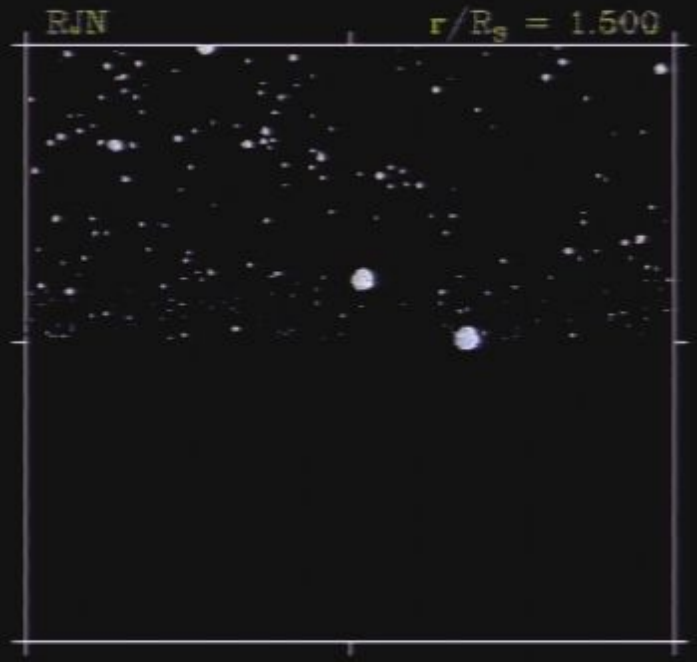

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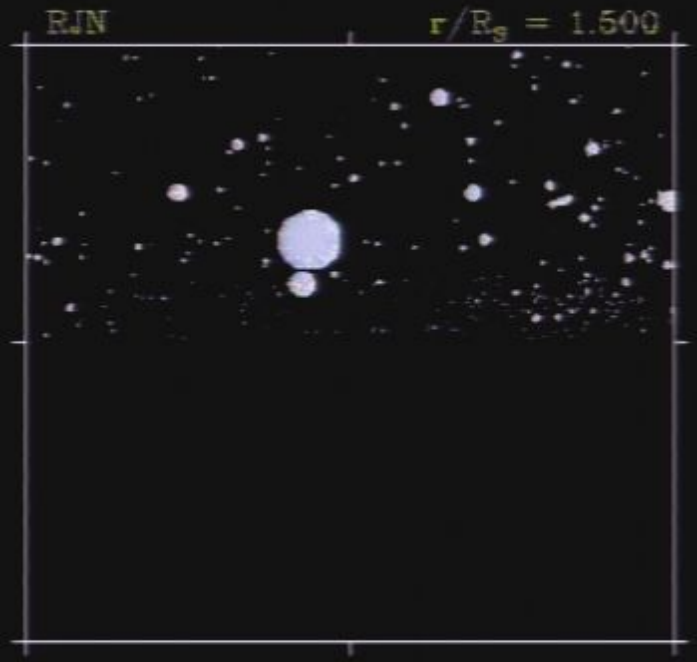

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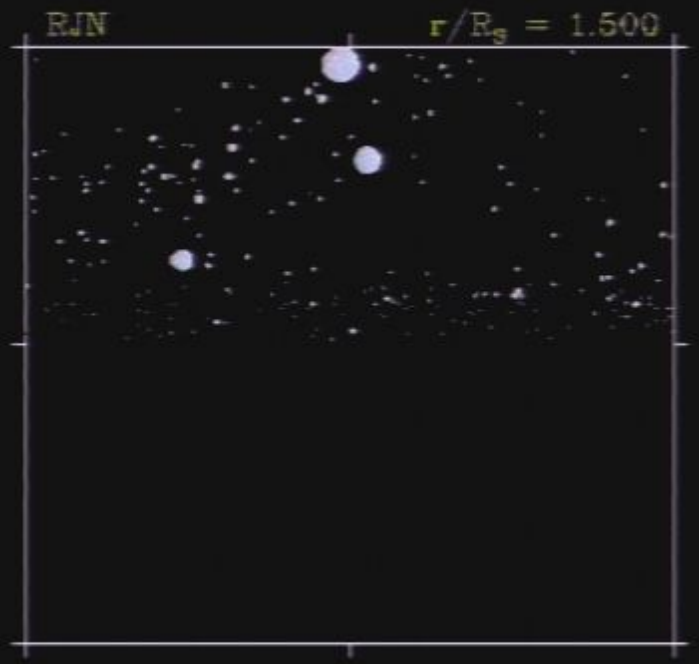

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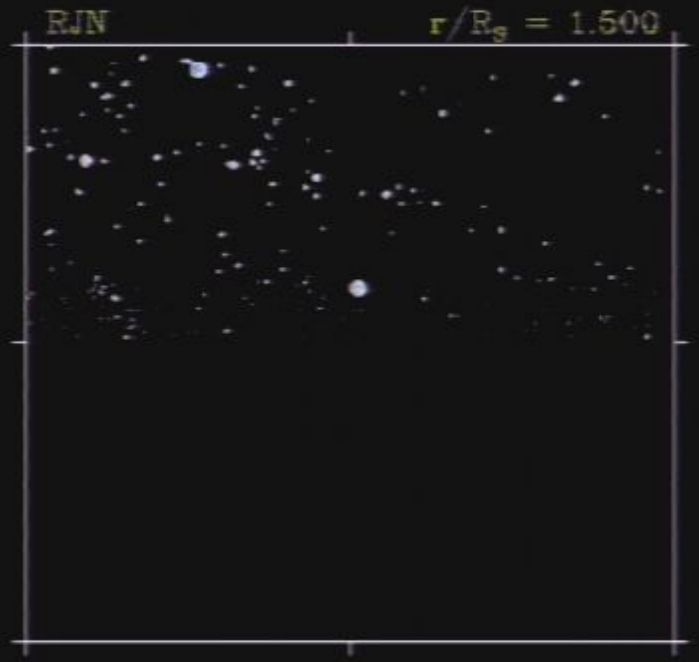
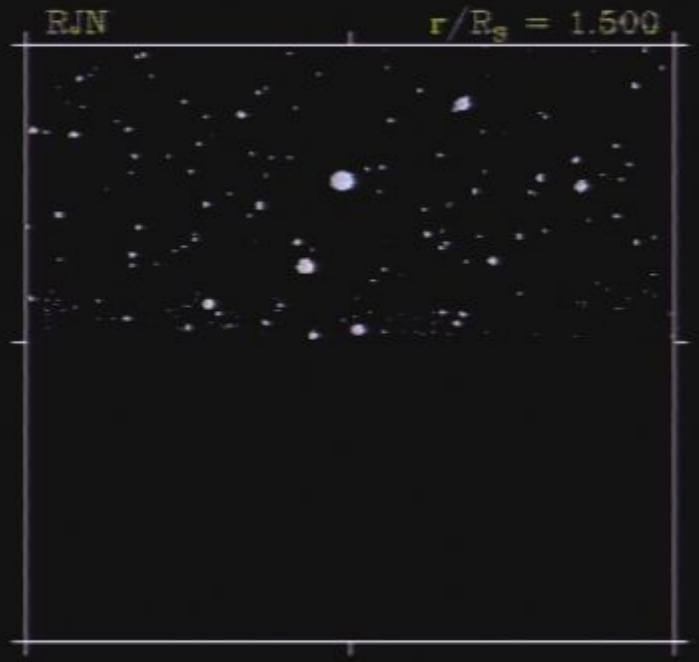


Orbiting Looking Horizontally at Photon Sphere



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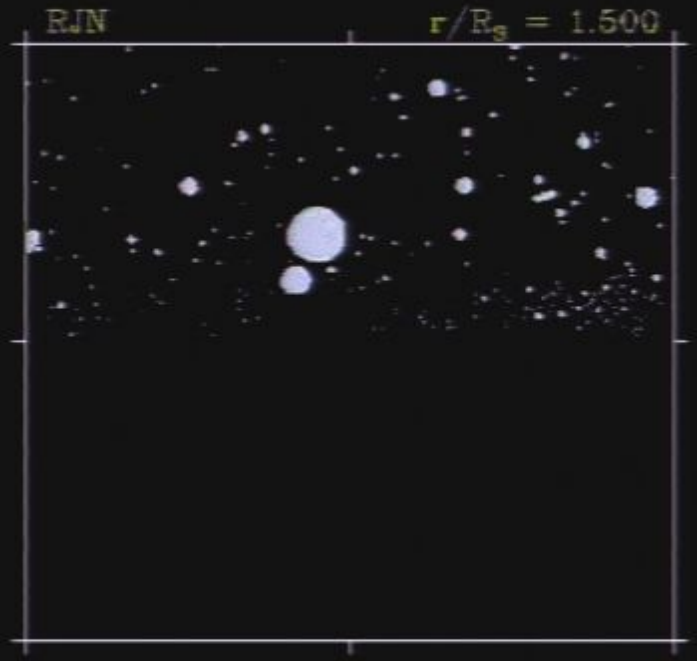

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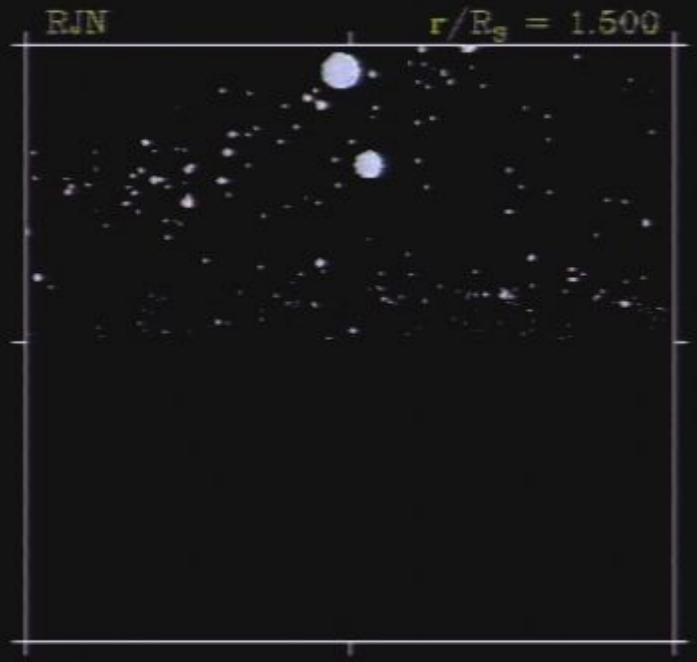

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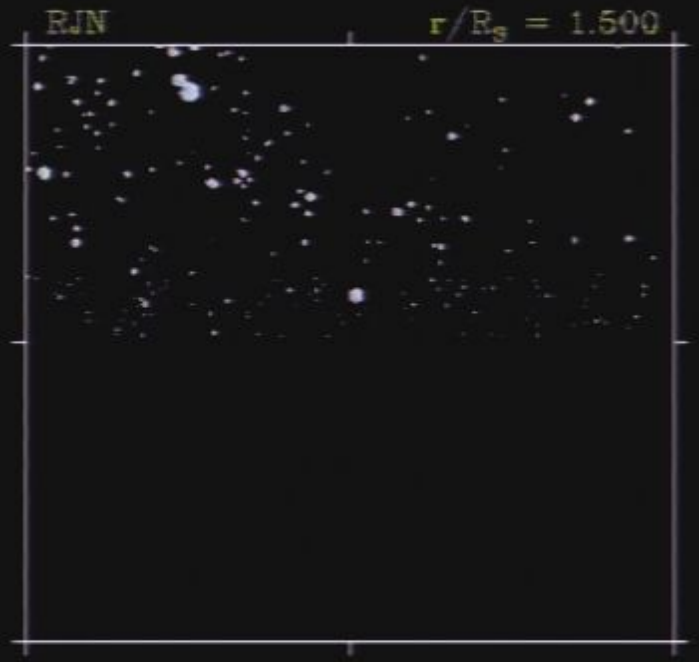

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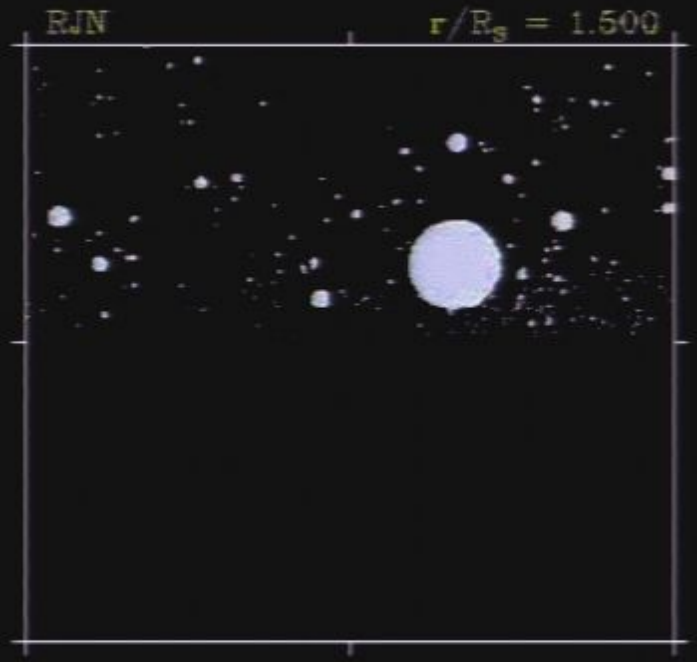

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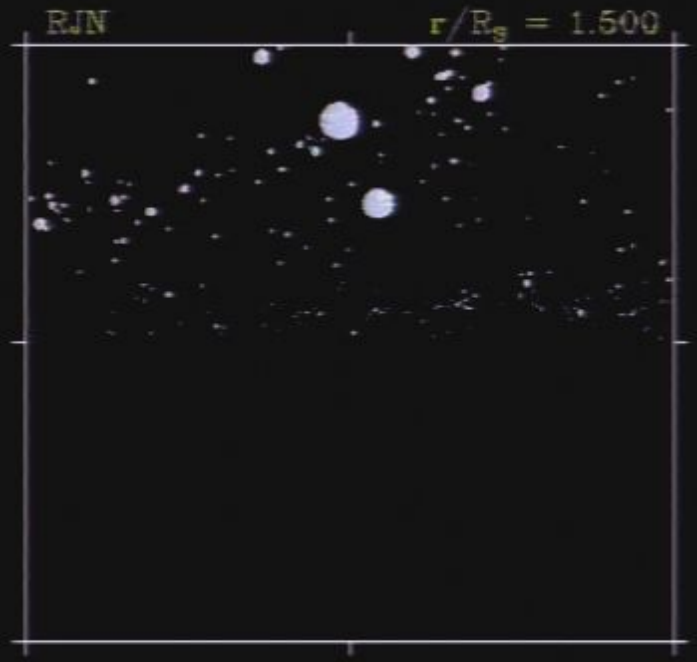

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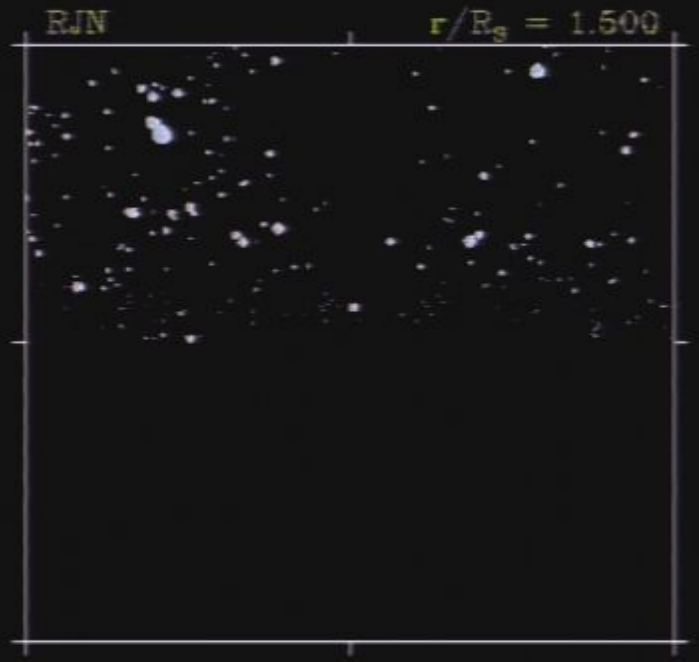

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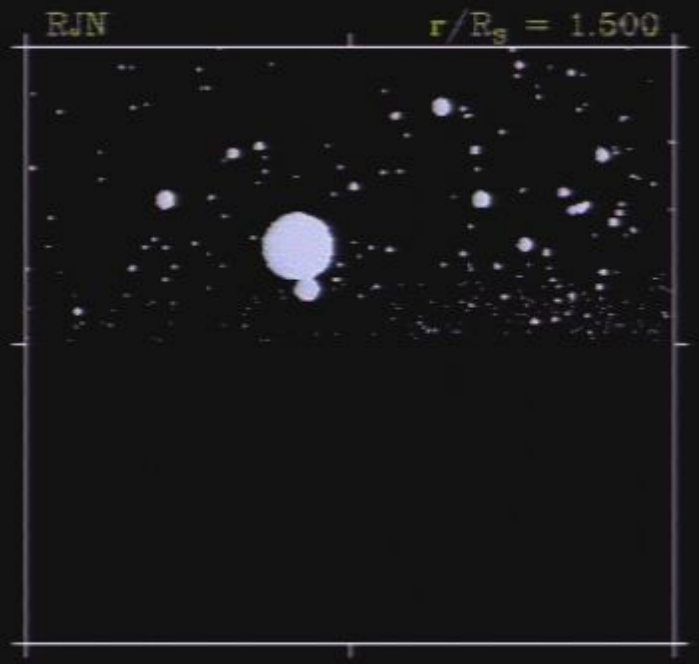

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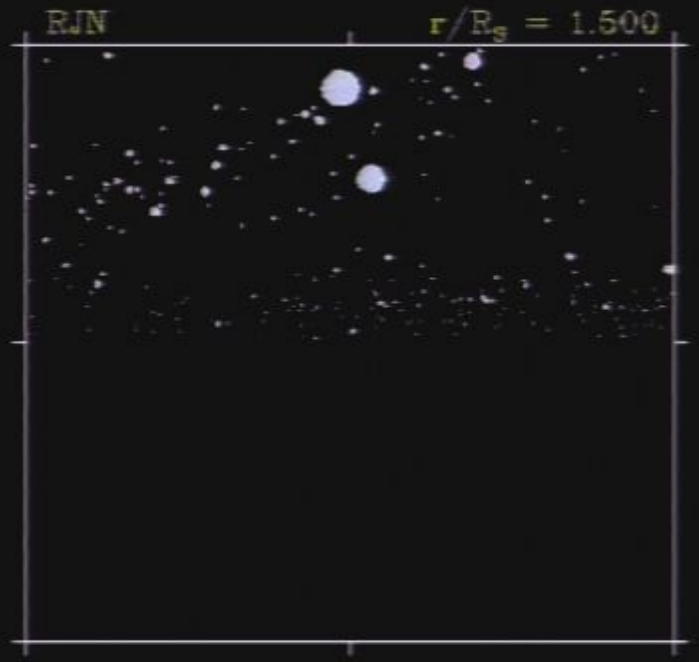

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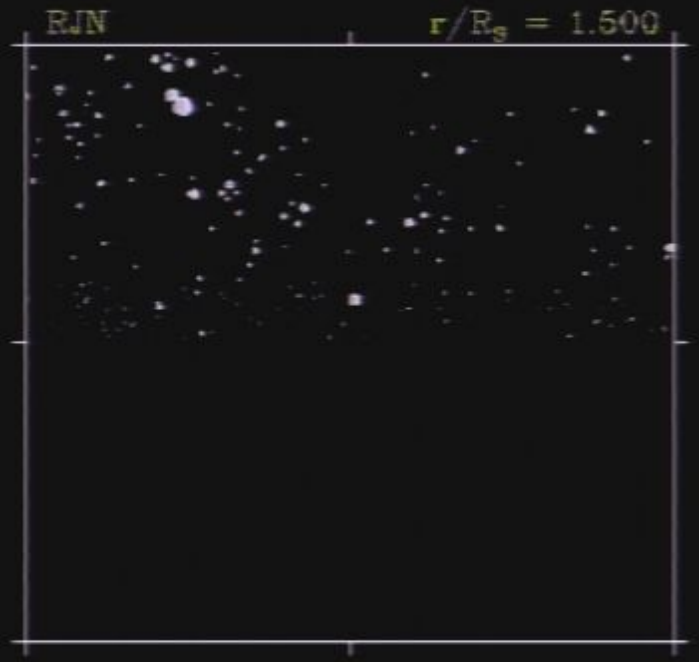

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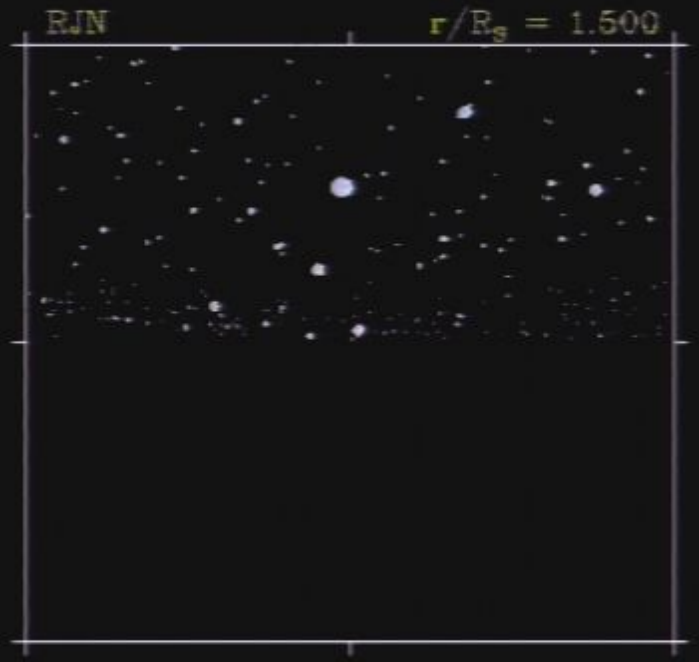

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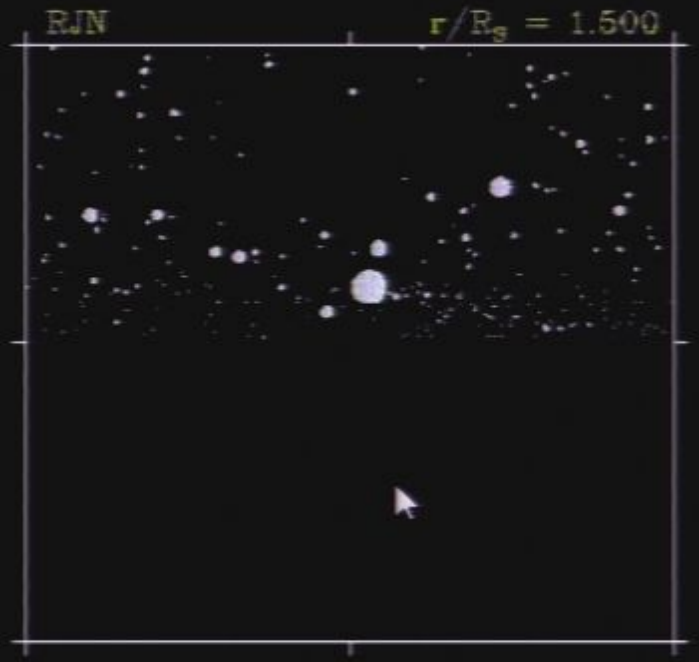

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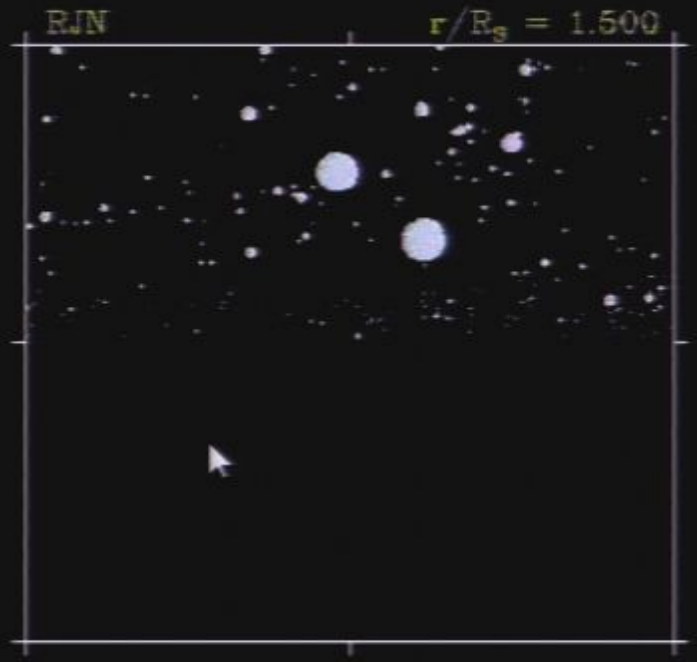

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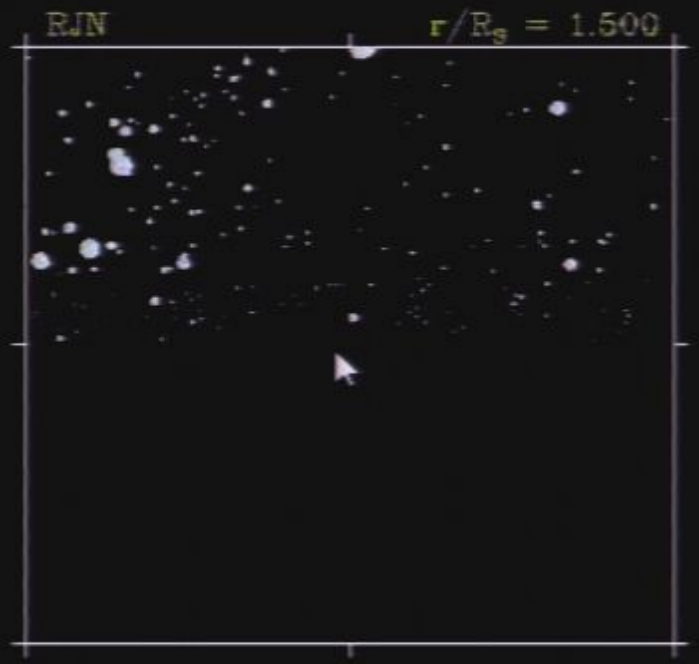

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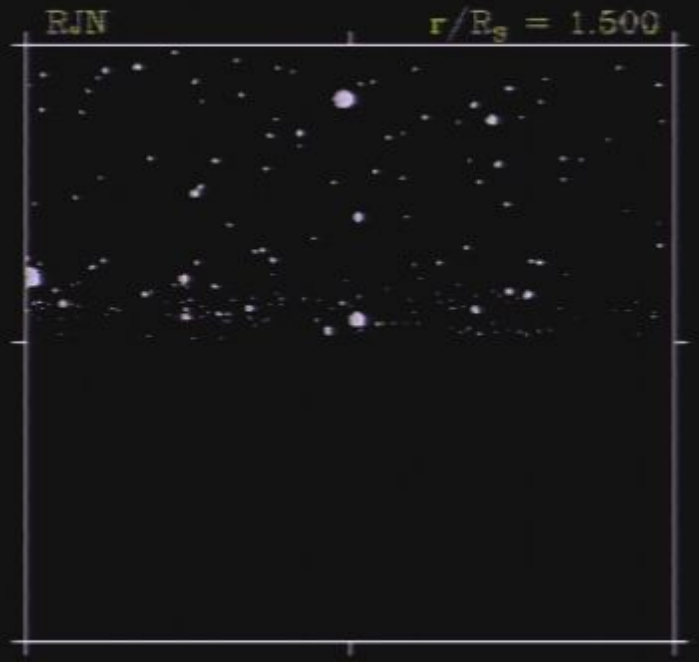

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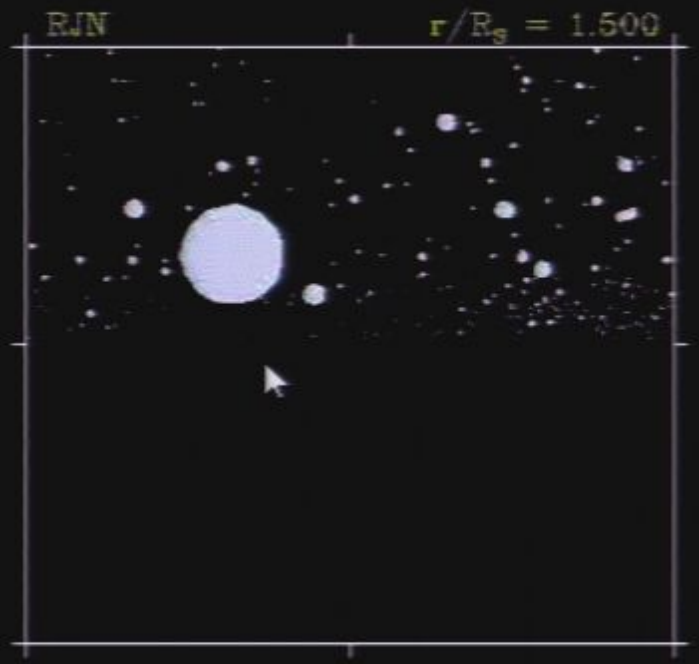

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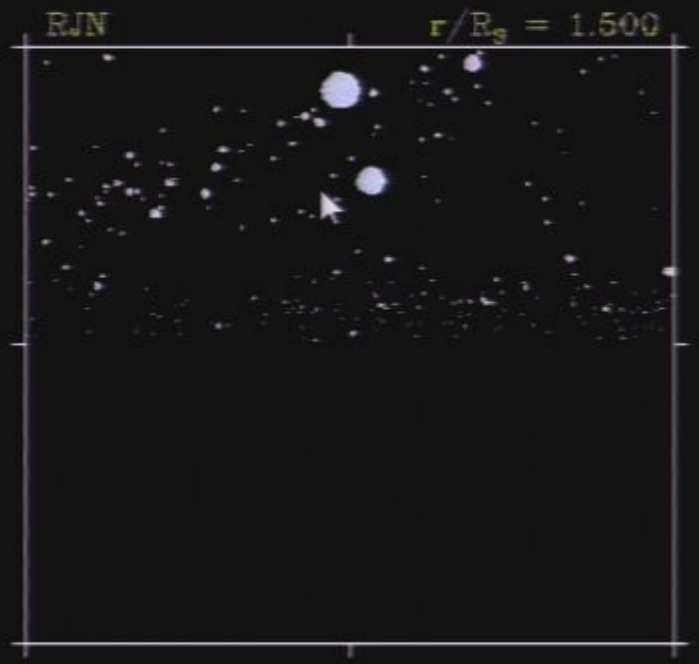

Looking Up

$$r = 12 \tan\left(\frac{5\pi}{6}\sqrt{1-\frac{C_b}{C}}\right)$$

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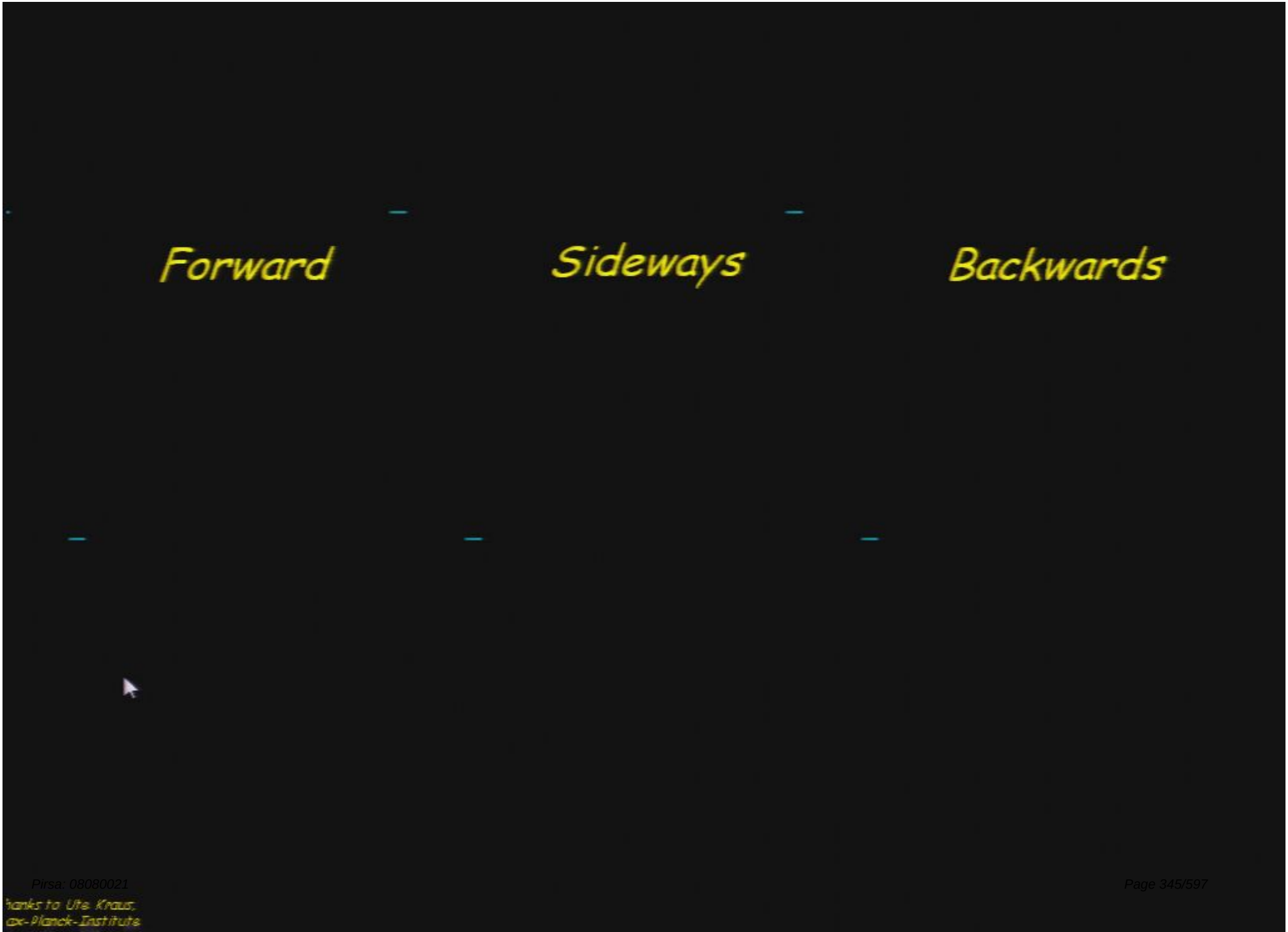
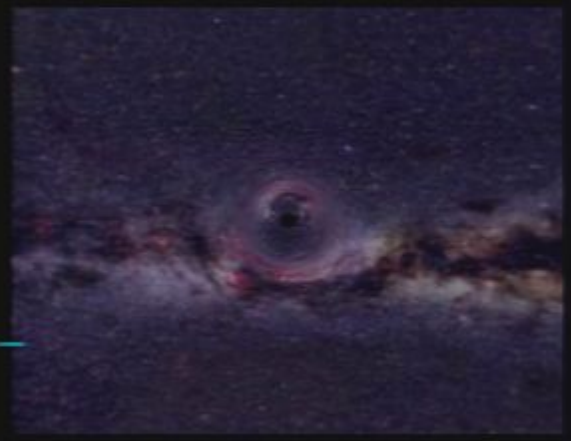


hanks to Ute Kraus,
ax-Planck-Institute

Forward



Sideways

Backwards

r = 100 rs

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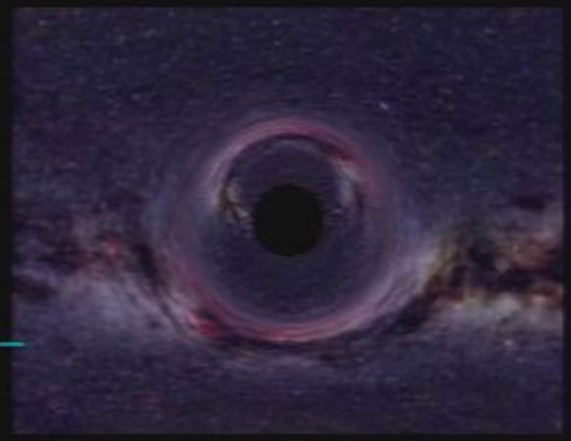
Forward

Sideways

Backwards



r = 20 rs

hanks to Ute Kraus,
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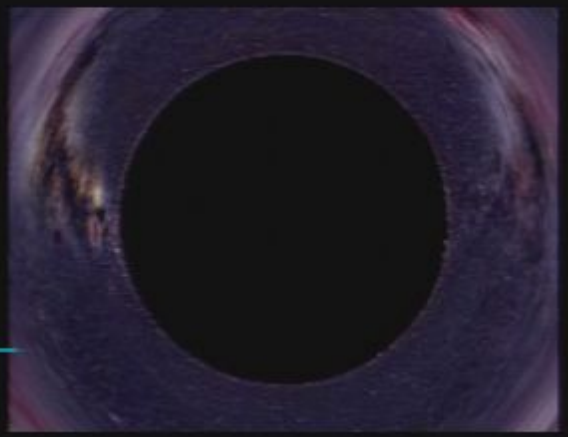
Forward



Sideways

Backwards

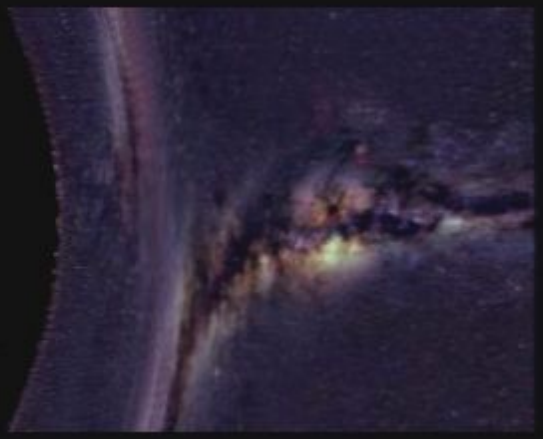
$r = 4.5\ r_s$

hanks to Ute Kraus,
ax-Planck-Institute

Forward

Sideways

Backwards



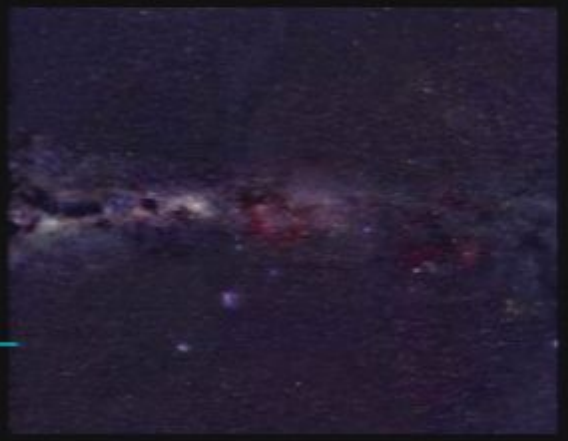
r = 2.5 rs

Thanks to Ute Kraus,
ax-Planck-Institute

Forward

Sideways

Backwards



r = 1.5 rs

hanks to Lita Kraus,
ax-Planck-Institute

Forward

Sideways

Backwards

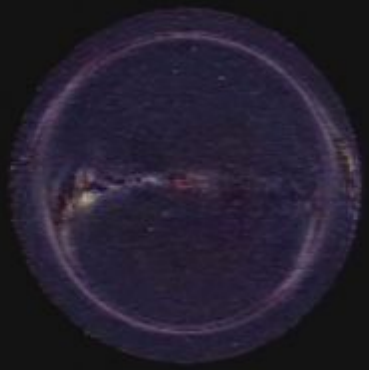
r = 1.2 rs

hanks to Uta Kraus,
ax-Planck-Institute

Forward

Sideways

Backwards



r = 1.05 rs

hanks to Ute Kraus.
ax-Planck-Institute

Forward

Sideways

Backwards

r = 1.005 rs

hanks to Ute Kraus,
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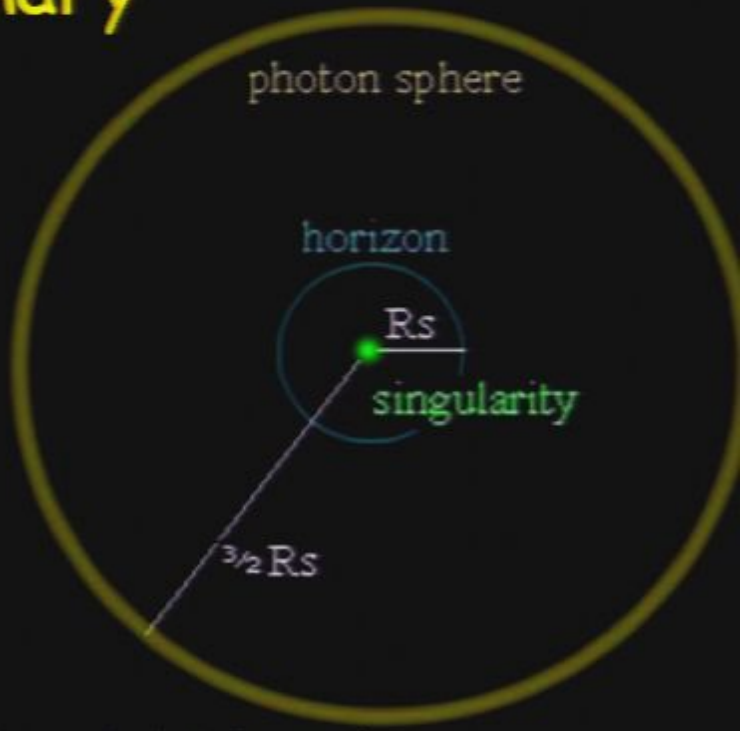
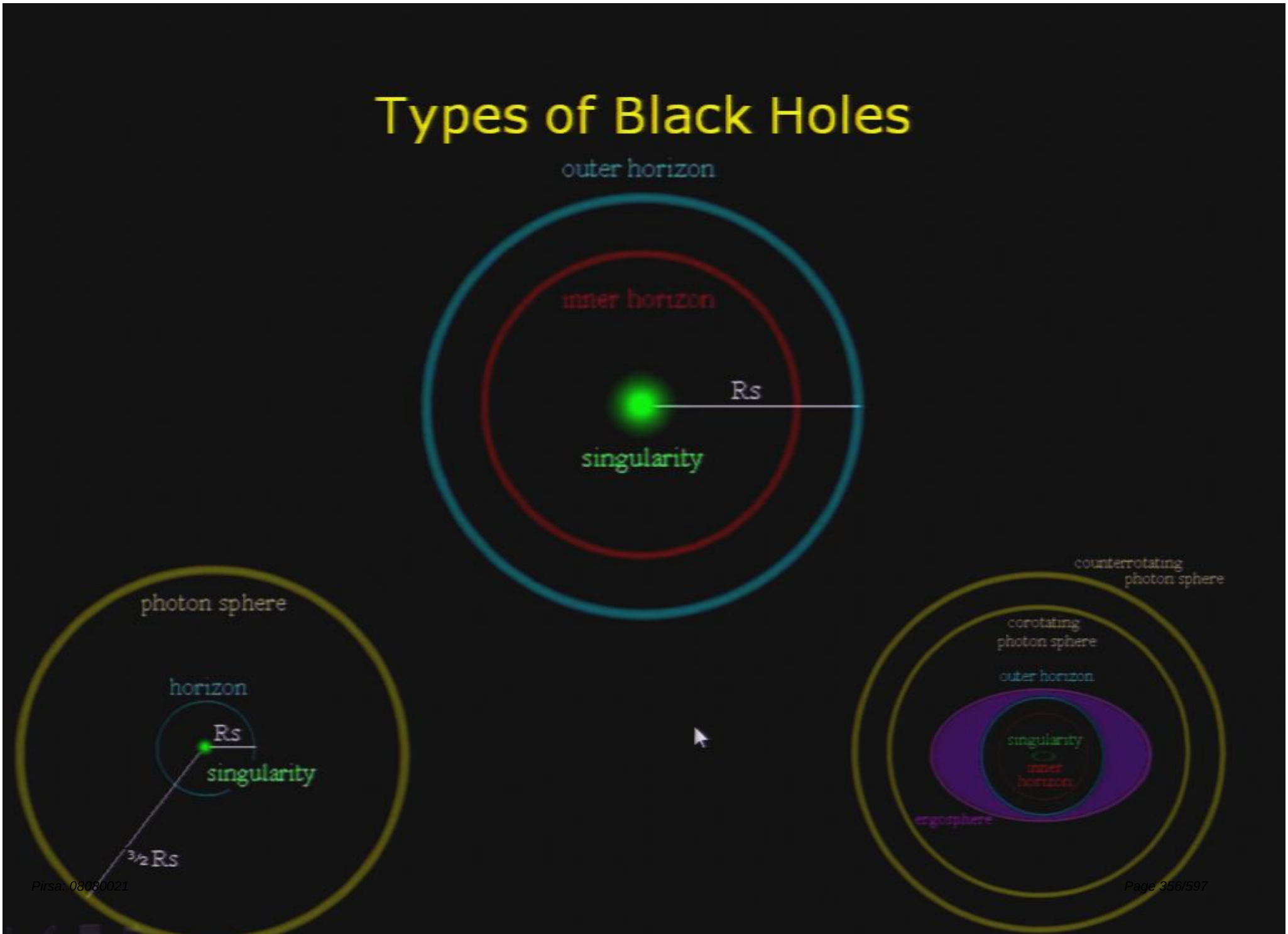
The Anatomy Summary

If you calculate the size of an object whose escape velocity is the speed of light, you get the "Schwarzschild radius", which defines the "event horizon". This is the formal size of a black hole (even though there is nothing at that location). It is given by $R_s=3km(M_*/M_{sun})$. It is the horizon over which you can see no more events. Outside that at 1.5 R_s photons would orbit the hole the photon sphere).



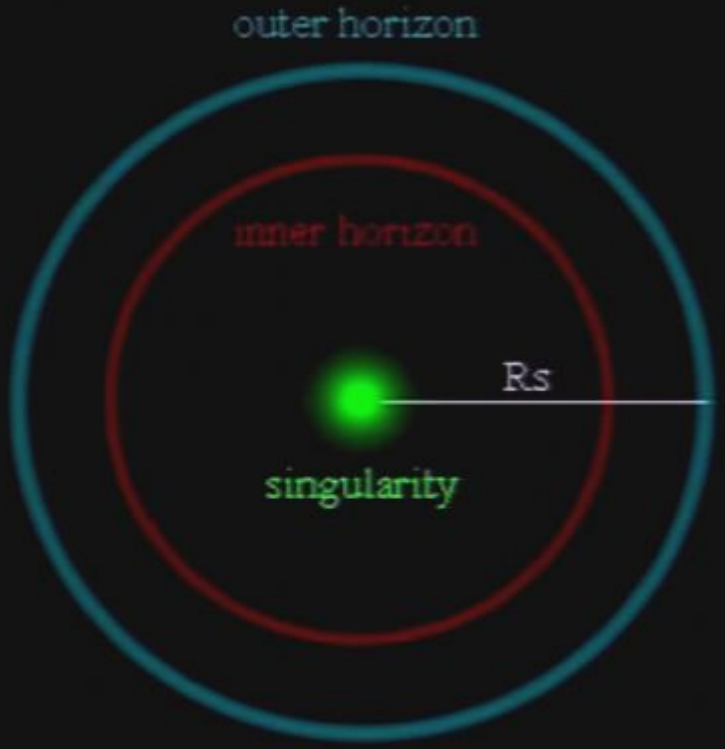
Far from the hole, the gravity is the same as it would be if the star were still there (so no "vacuum cleaner" effect). If the Sun collapsed to a BH, the Earth's orbit would be unaffected.

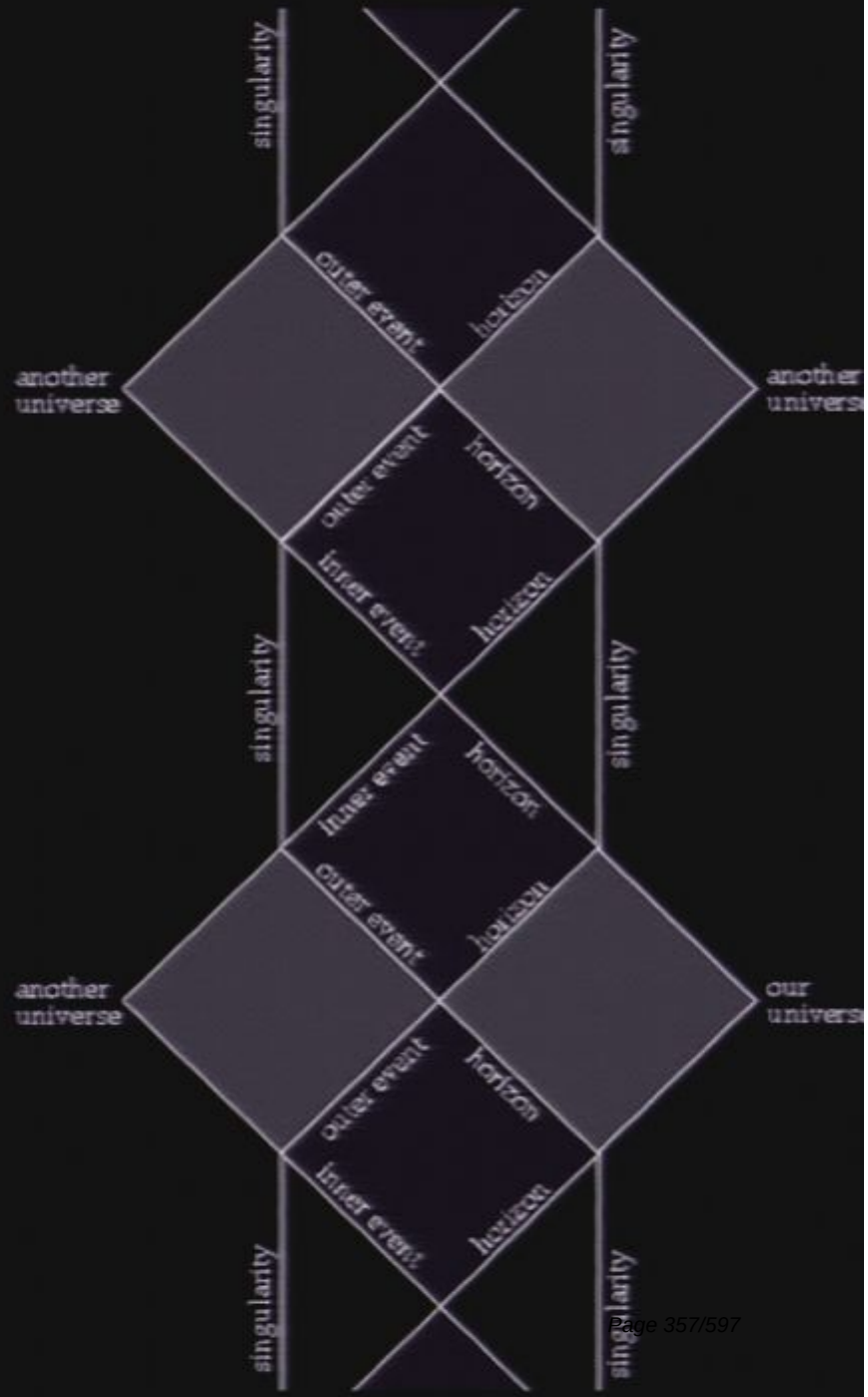
Types of Black Holes

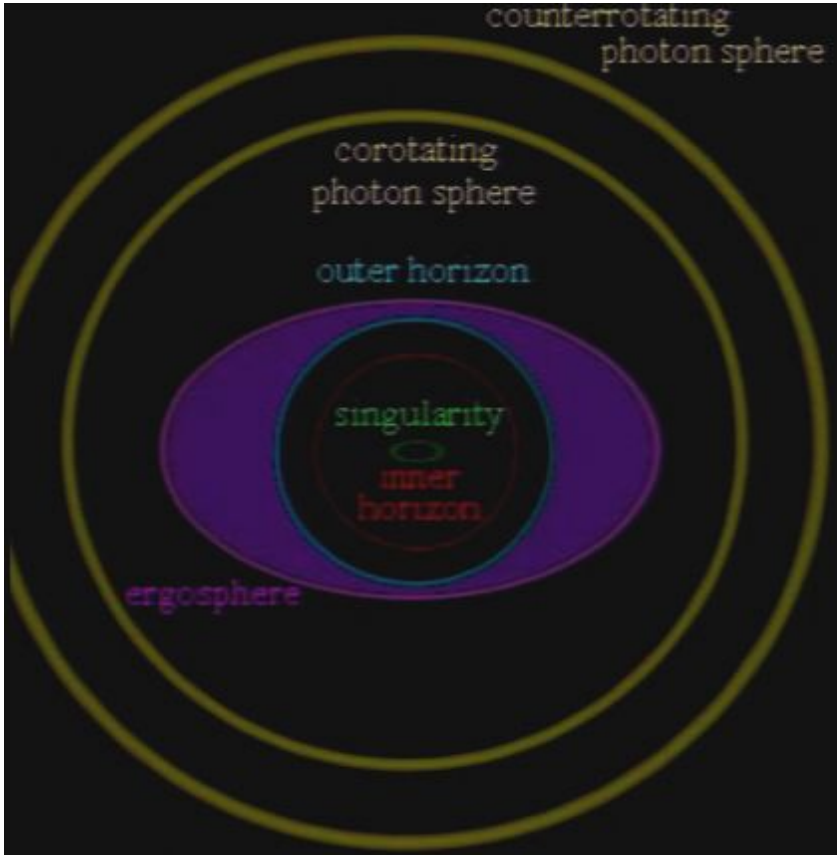


Reissner-Nordström Black Hole

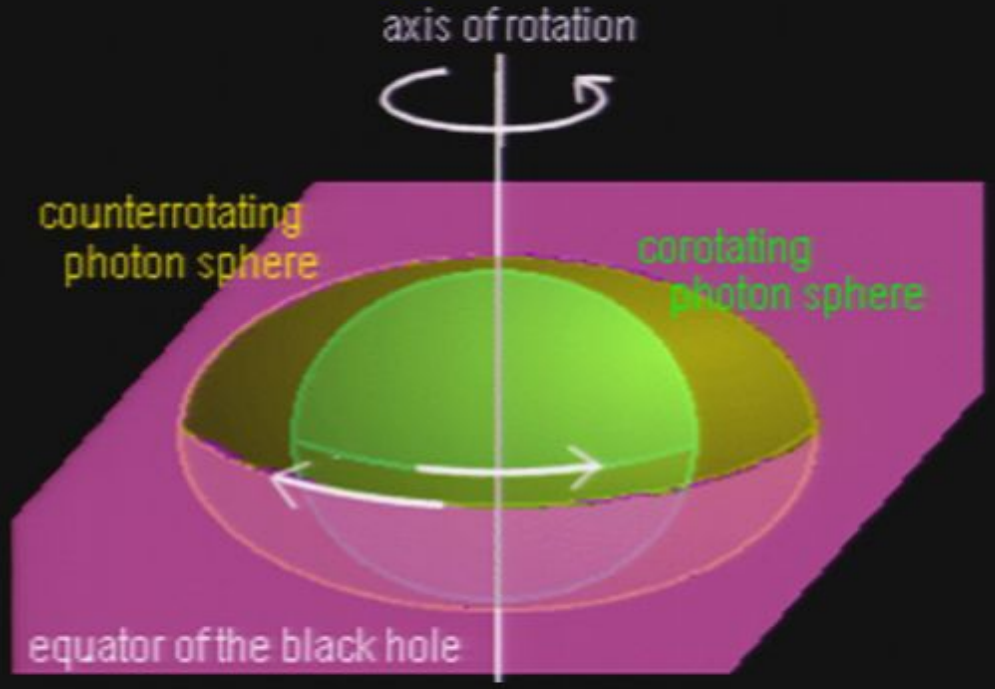
An electrically Charged Black Hole







Rotating Black Holes



$$r_{inner} = \frac{r_s + \sqrt{r_s^2 + 4\frac{J}{Mc}}}{2}$$

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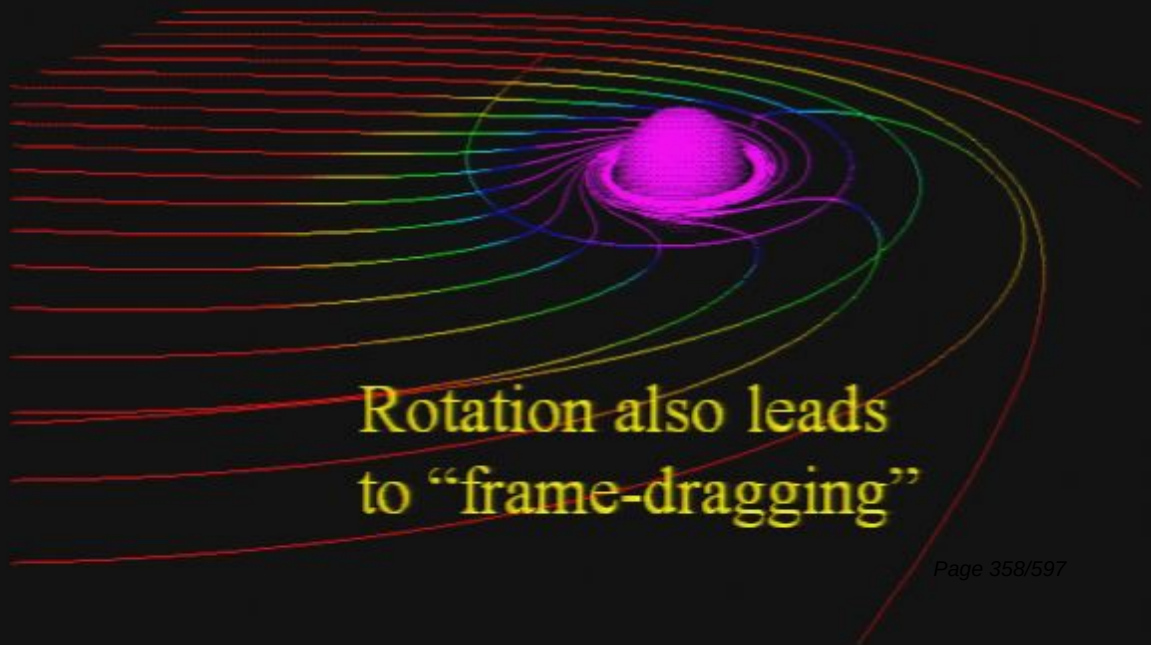

Rotation also leads
to "frame-dragging"

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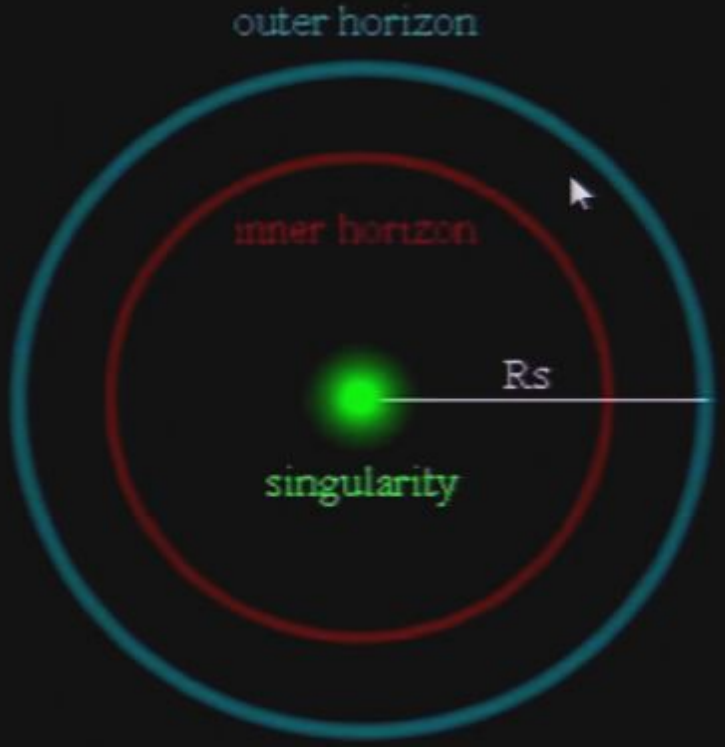

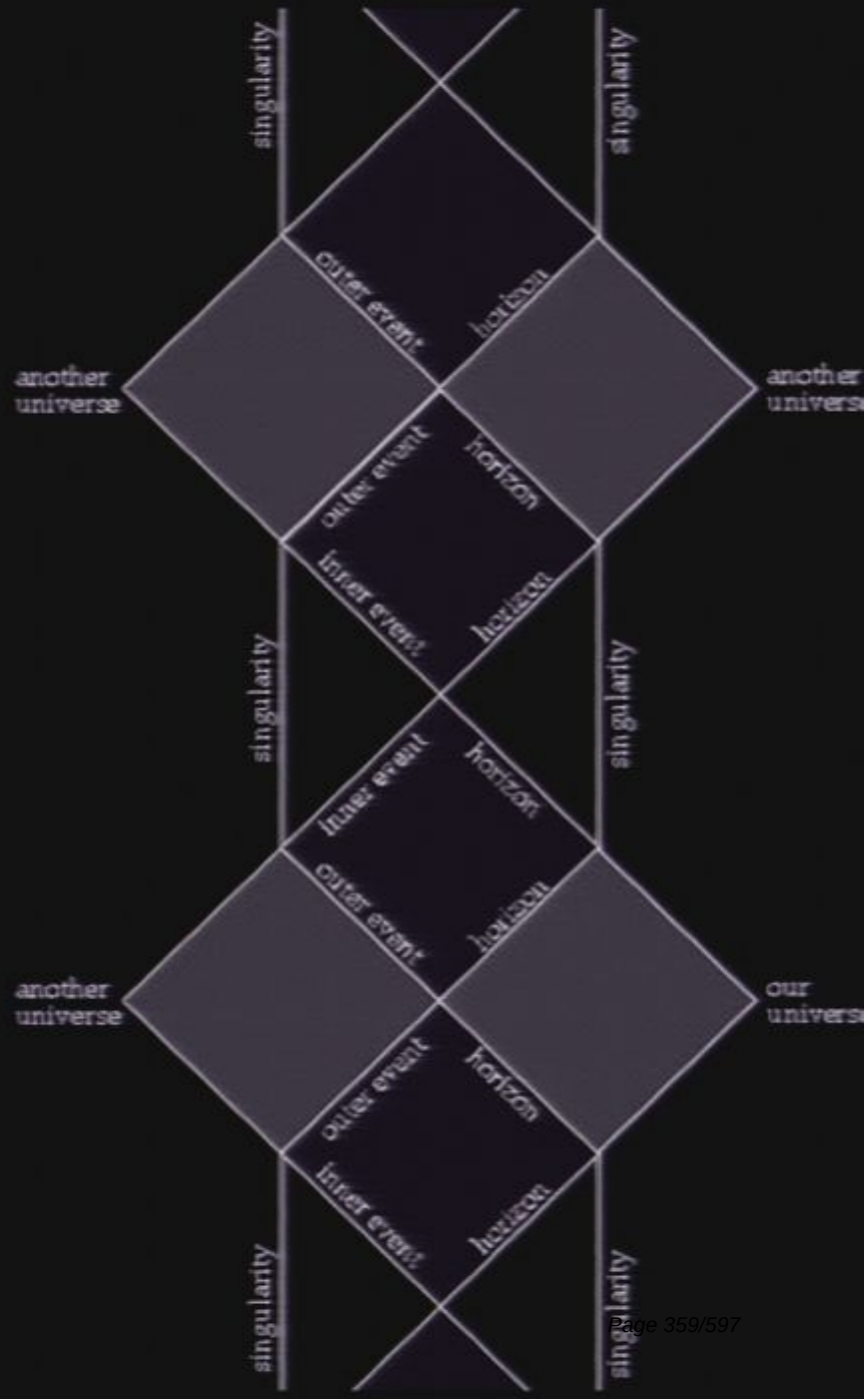

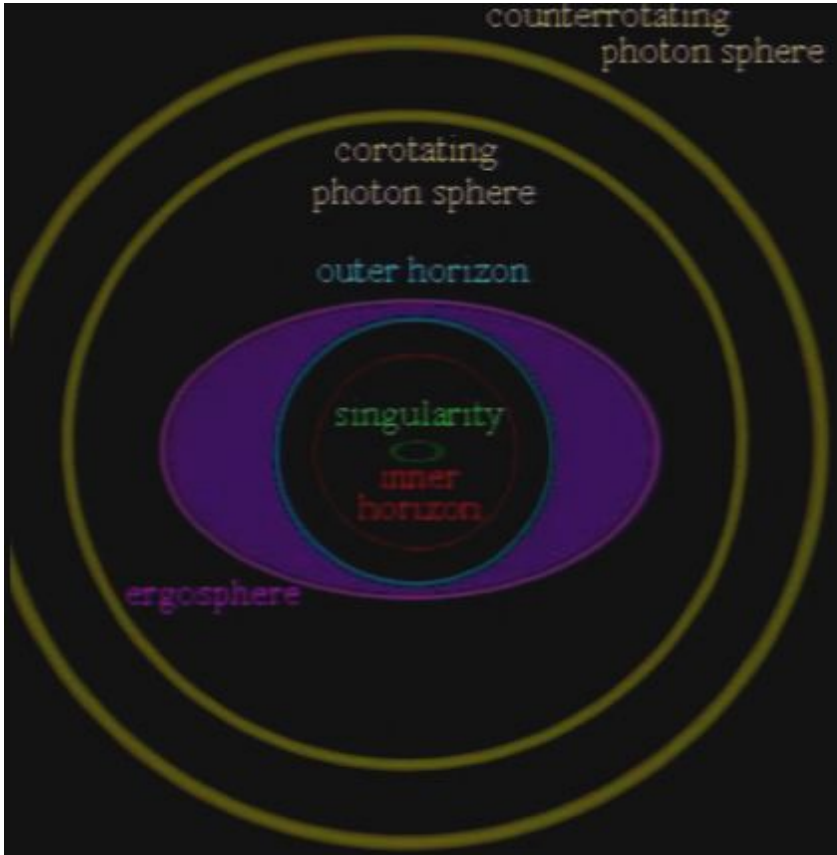

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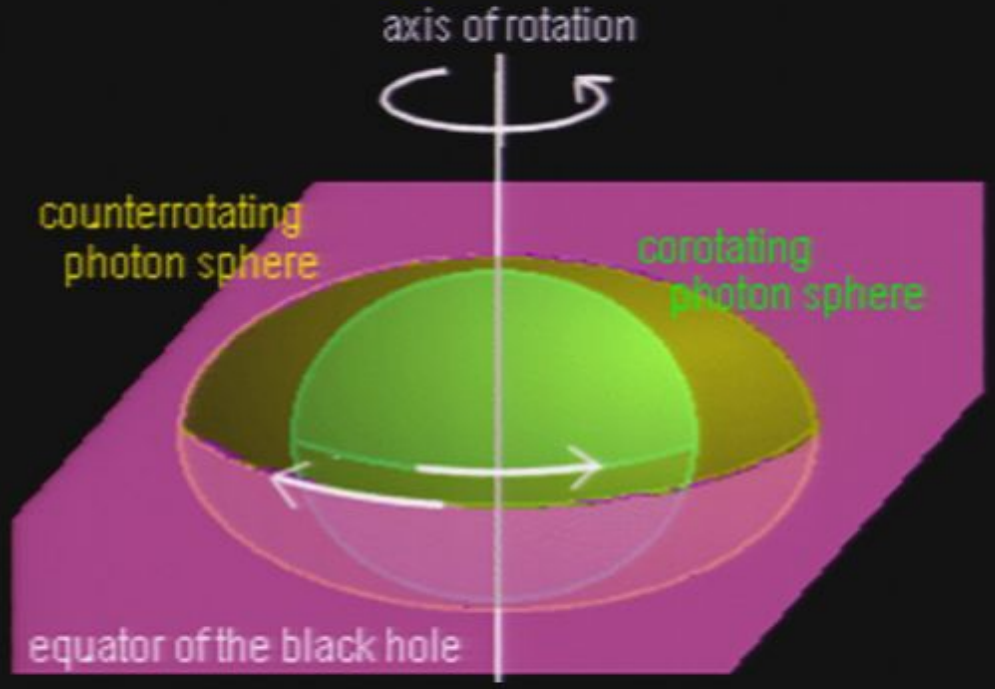

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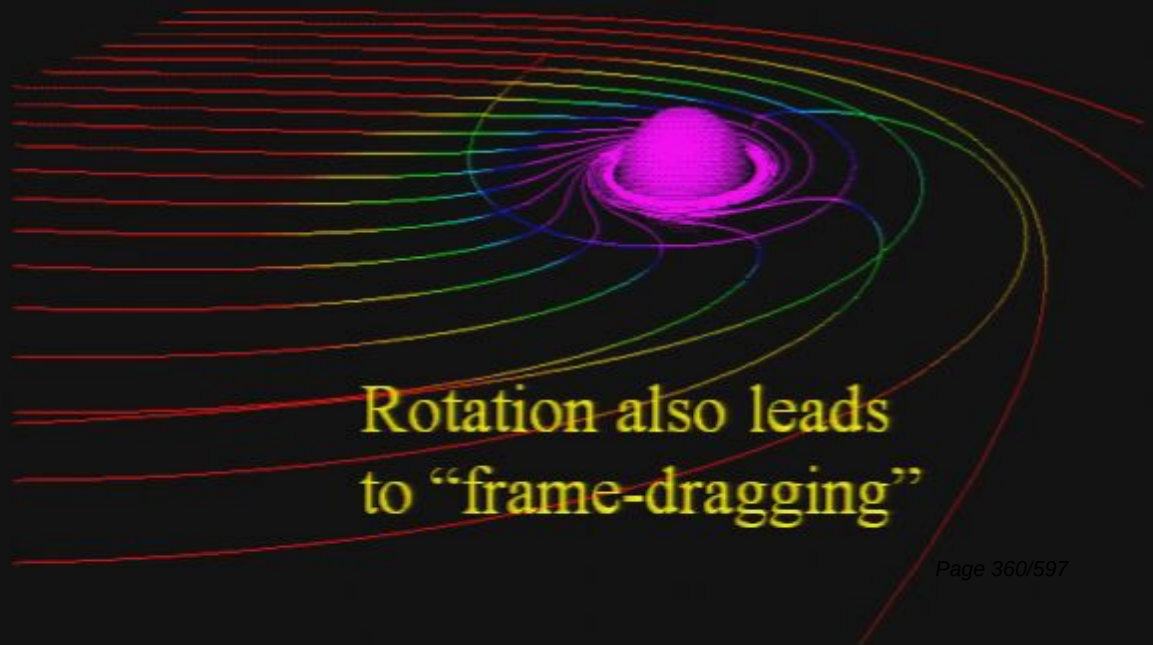

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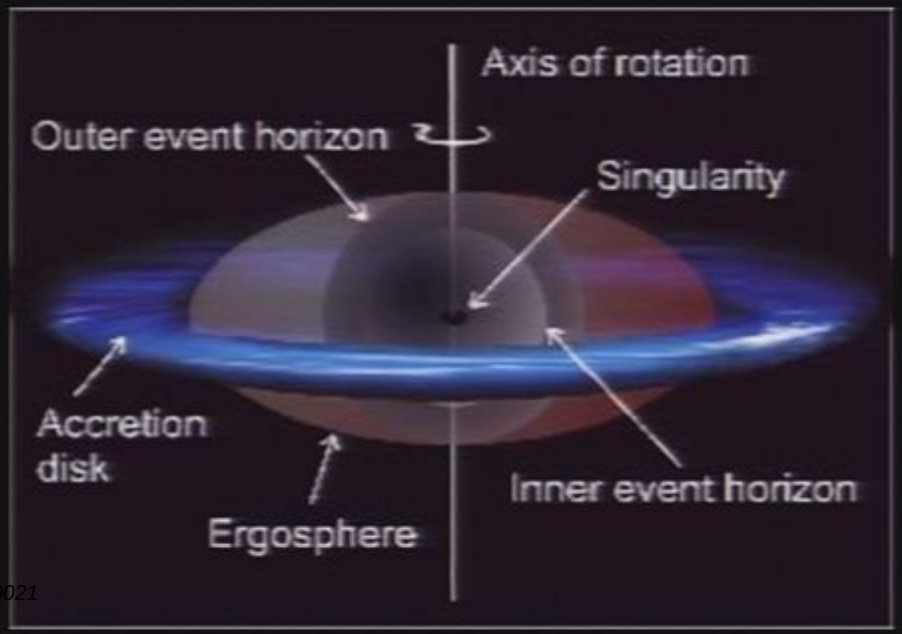
A Rotating Black Hole (The Kerr Black Holes)

Why is it called a rotating black hole? The event horizon doesn't rotate---it's just a boundary-line, Though anything inside the ergosphere must co-rotate, that nothing can remain stationary



The Penrose effect allows for the black hole to lose energy from ergosphere and thus will slow down and eventually stop

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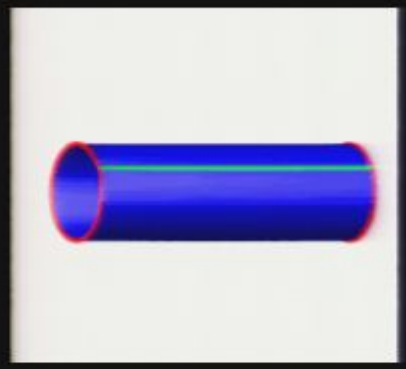

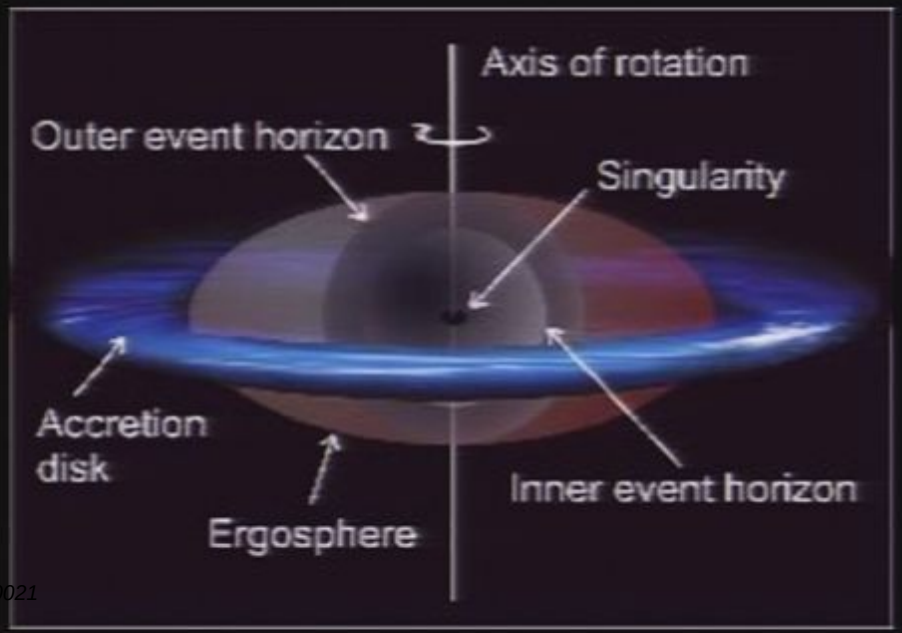

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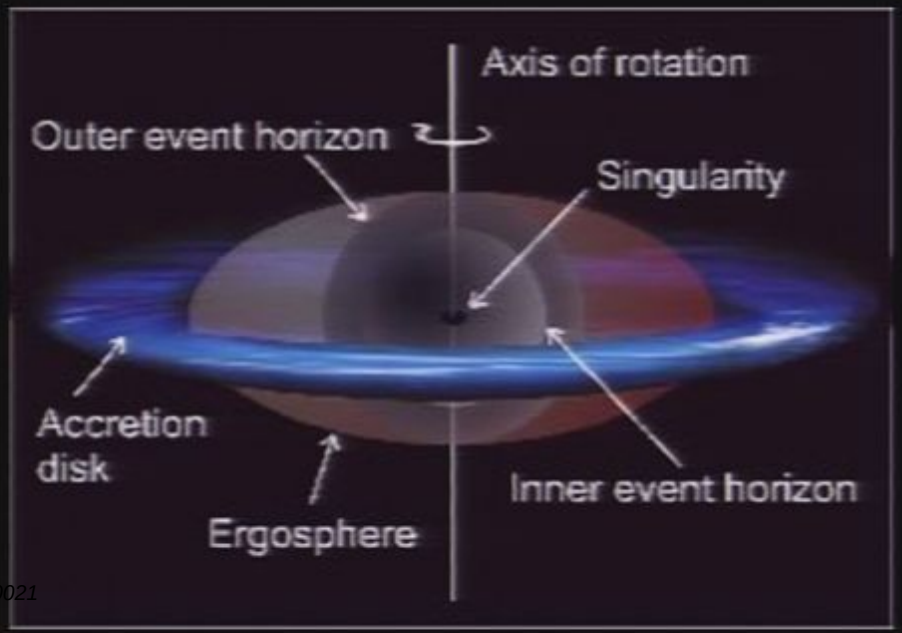

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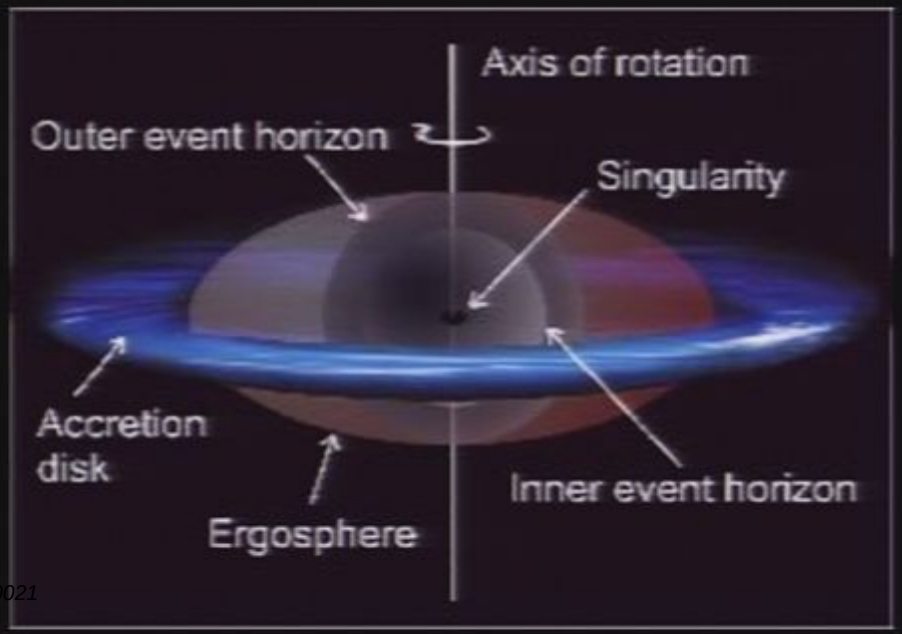

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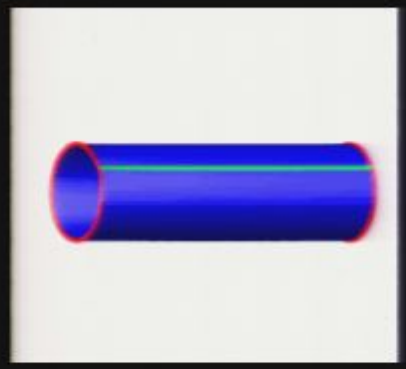

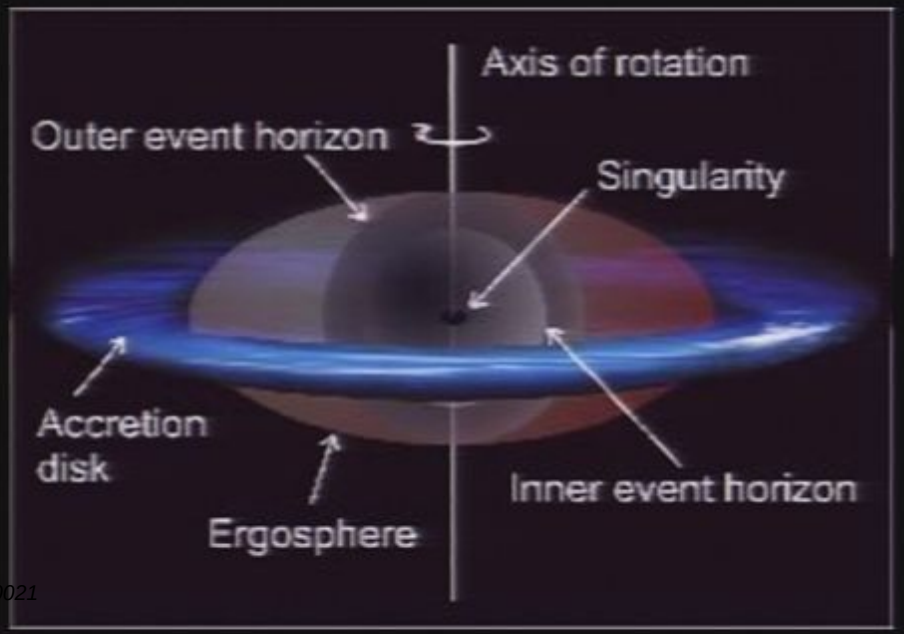

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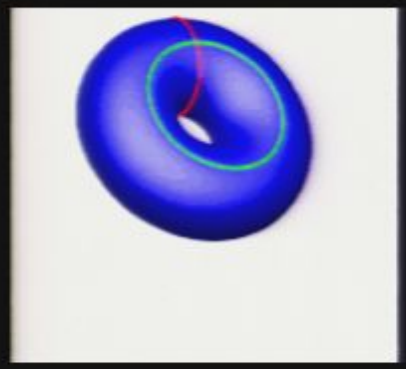

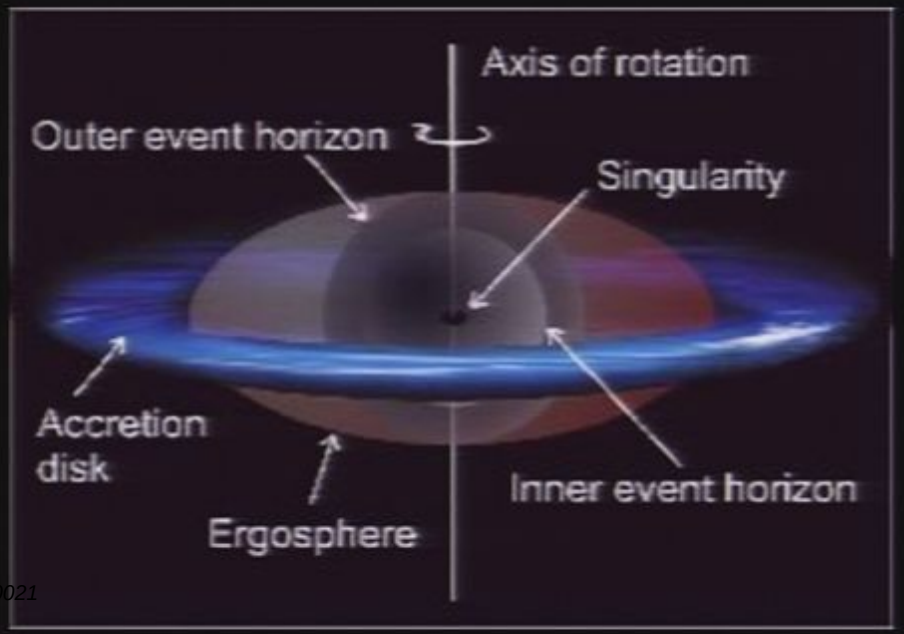

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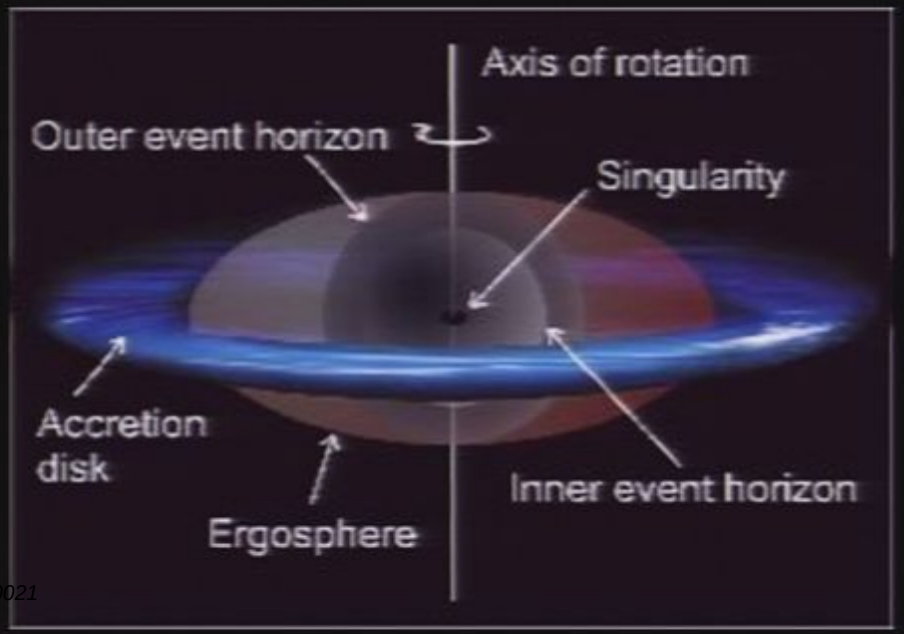

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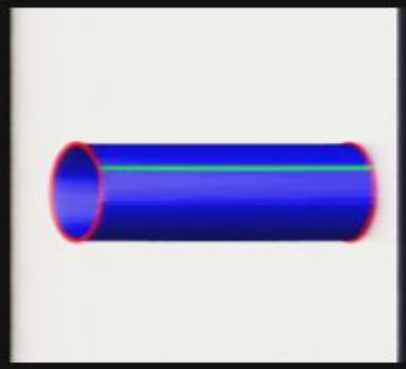

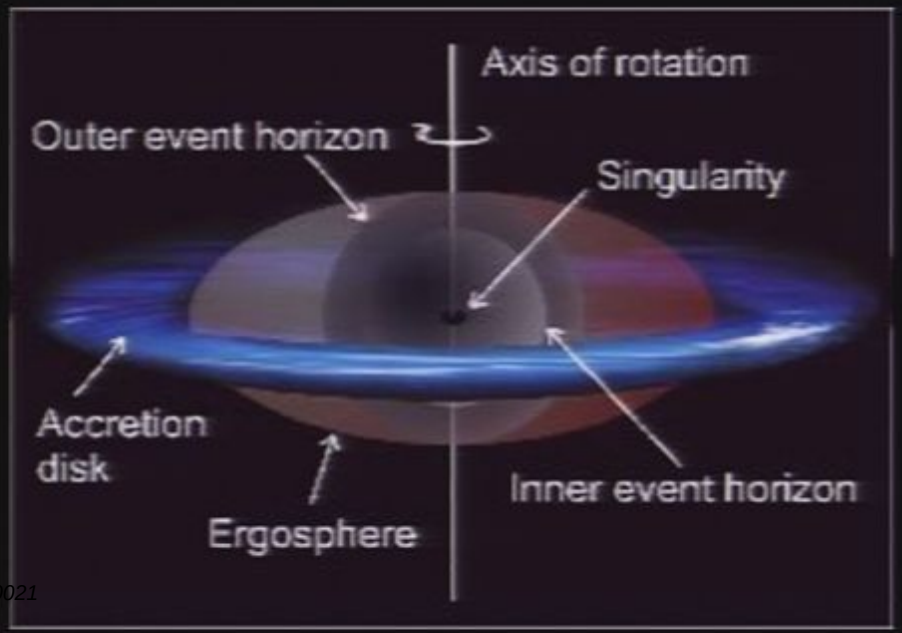

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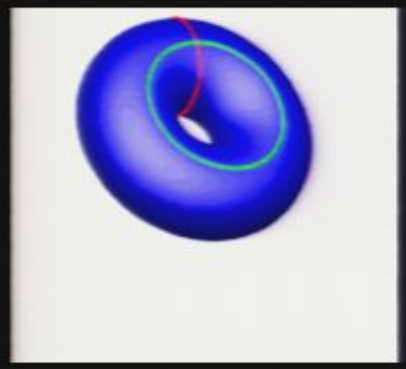

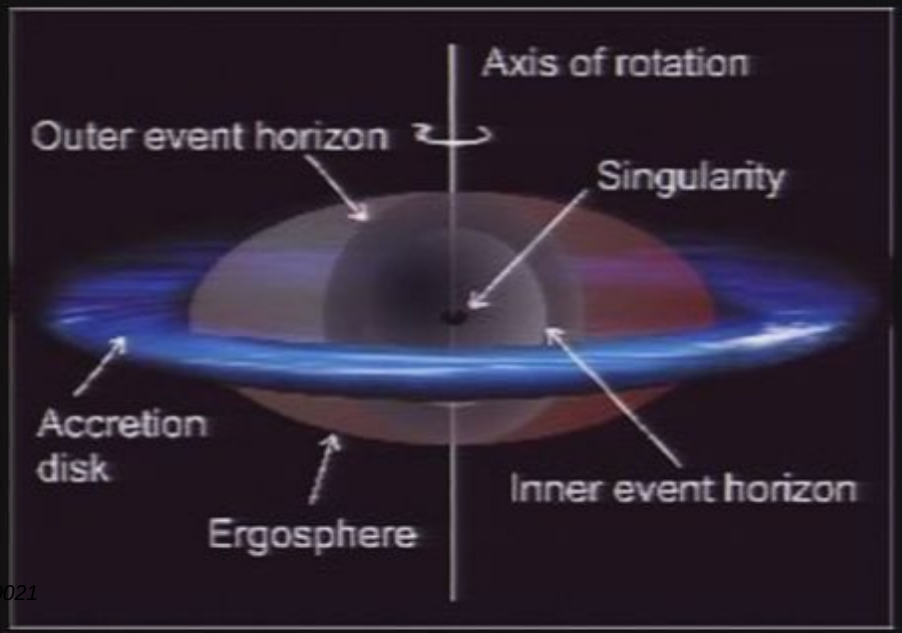

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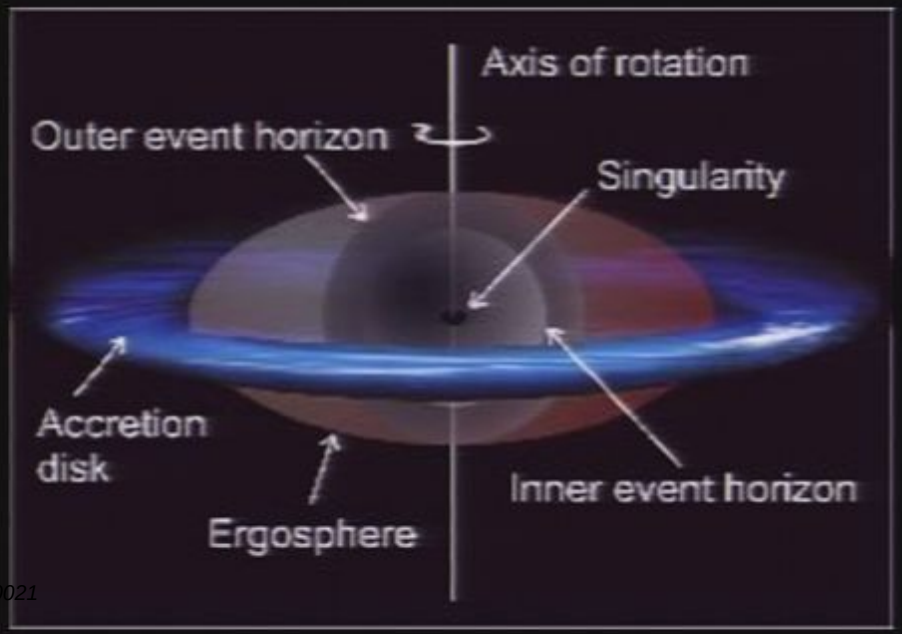

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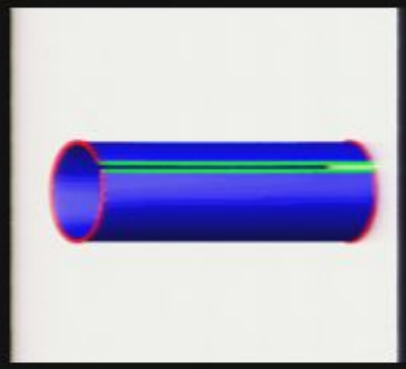

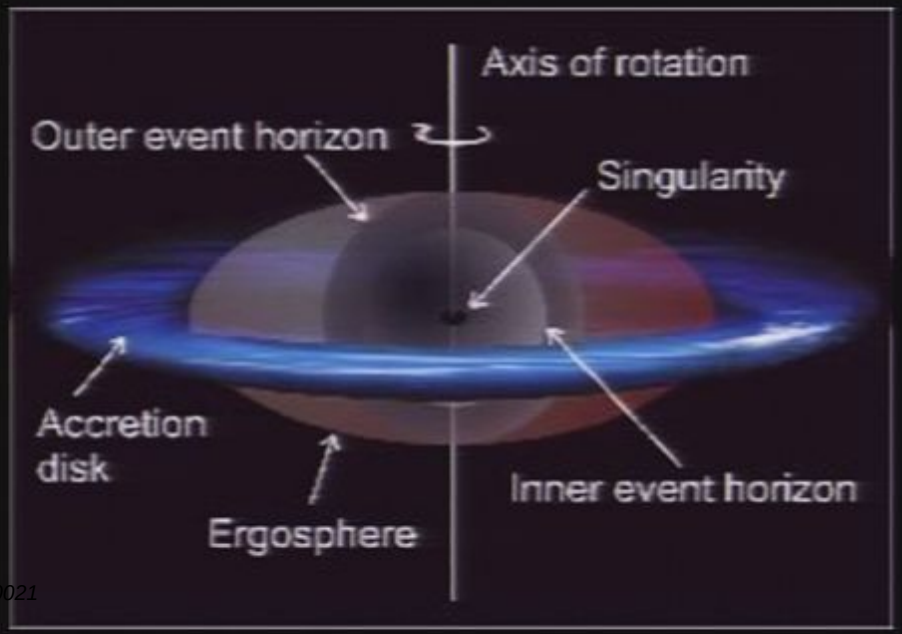

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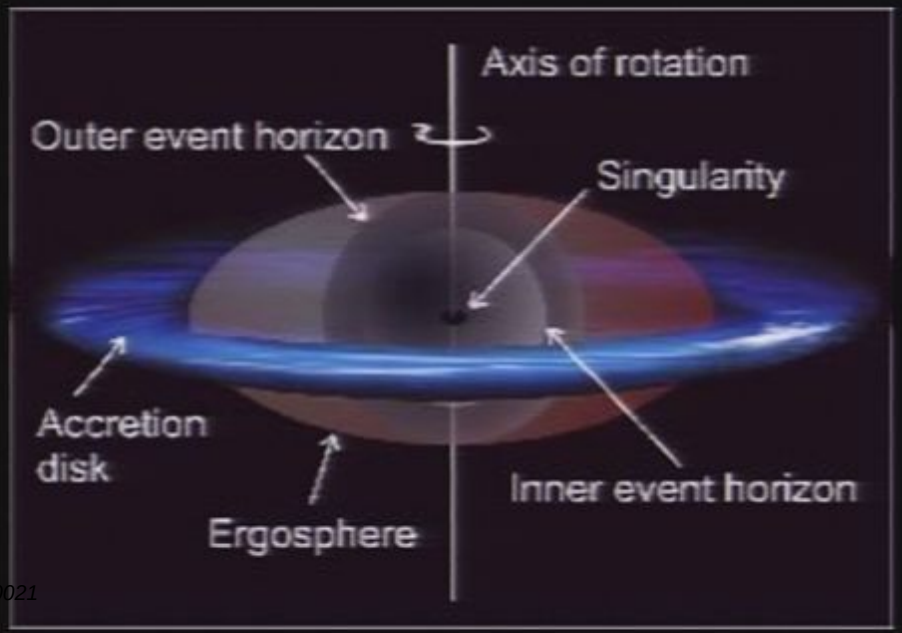

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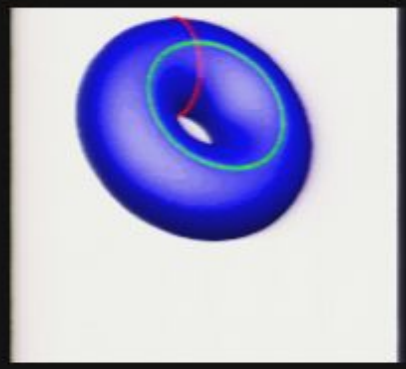

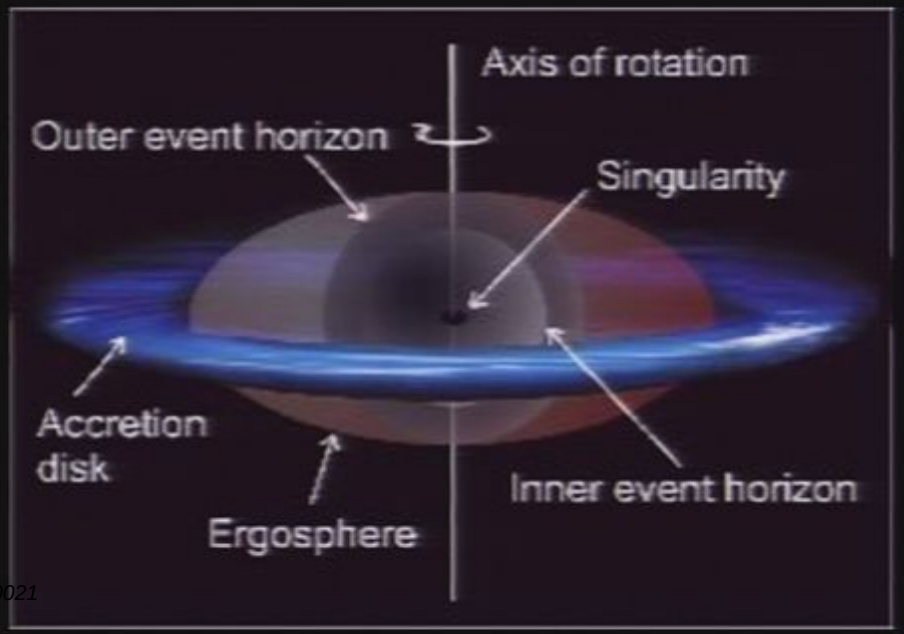

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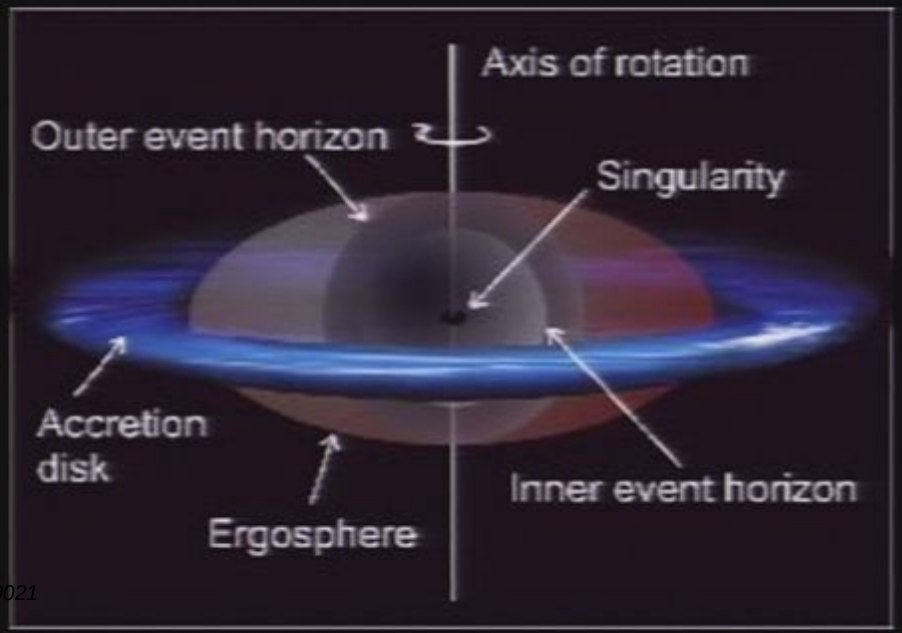

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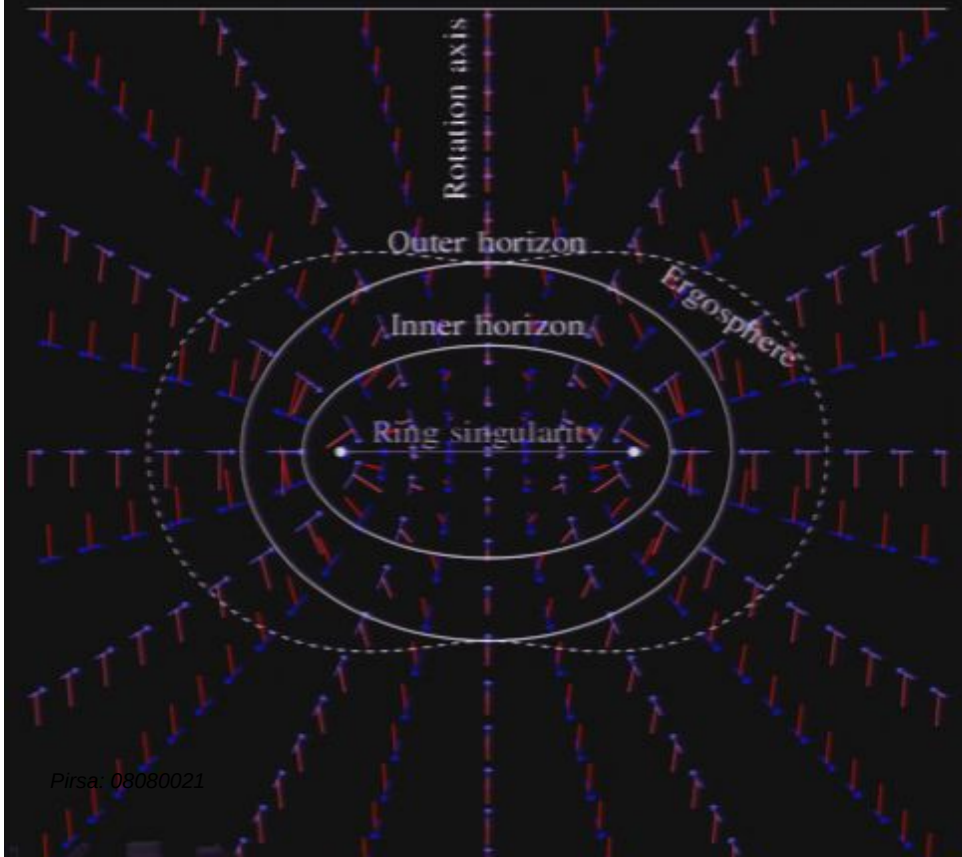

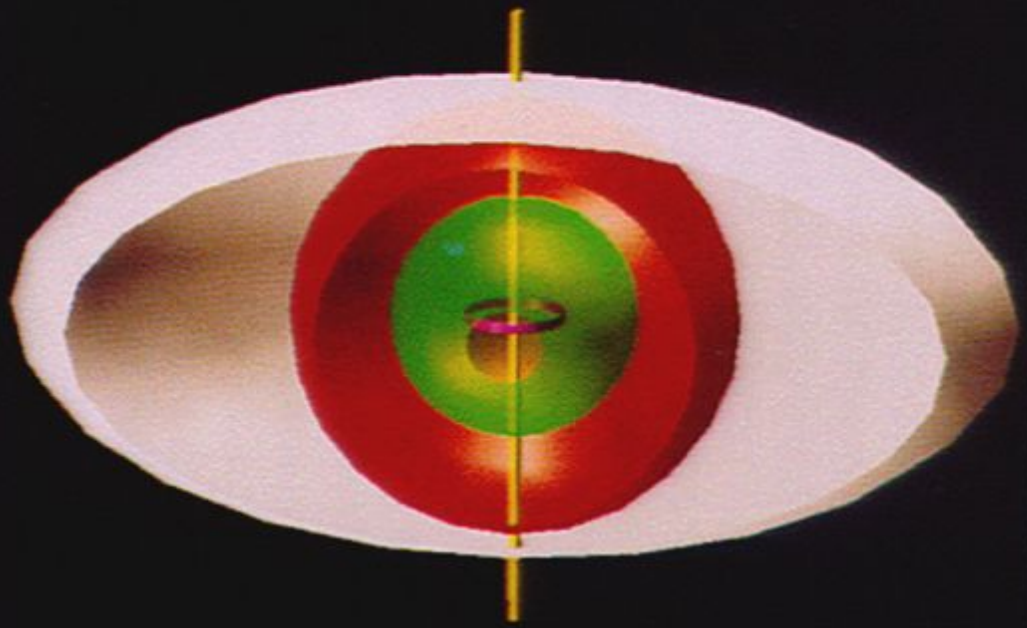

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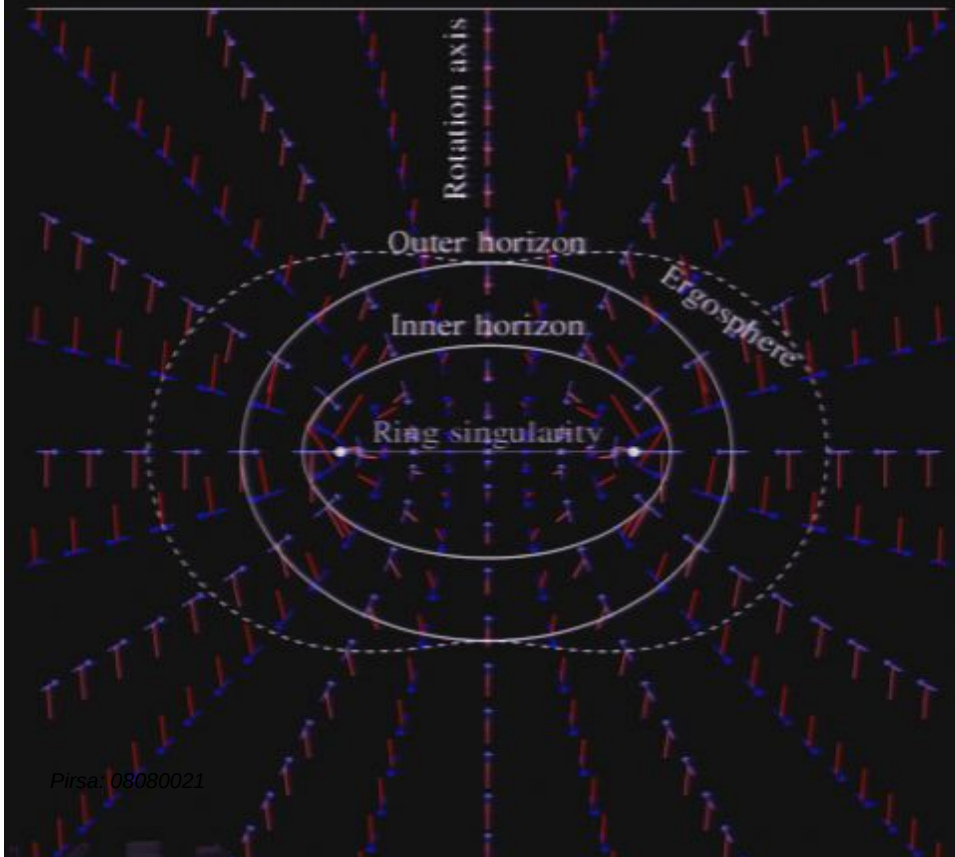

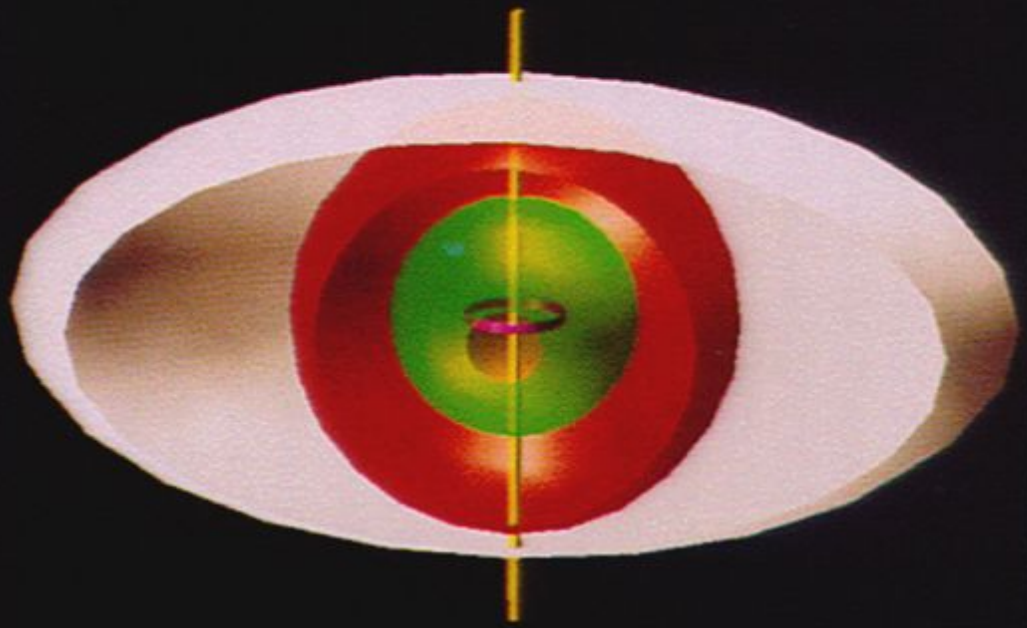

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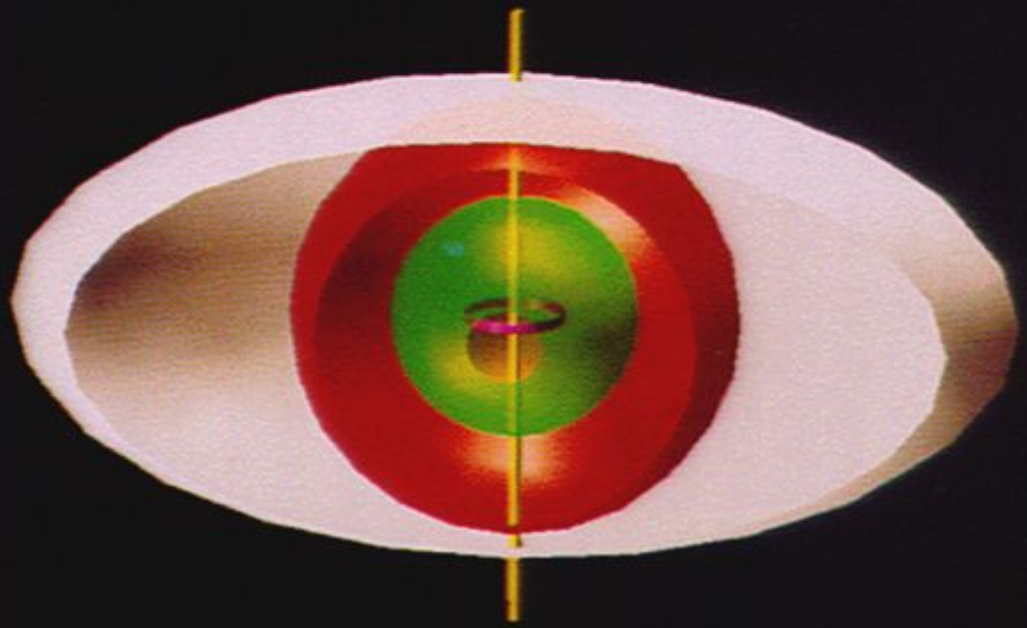

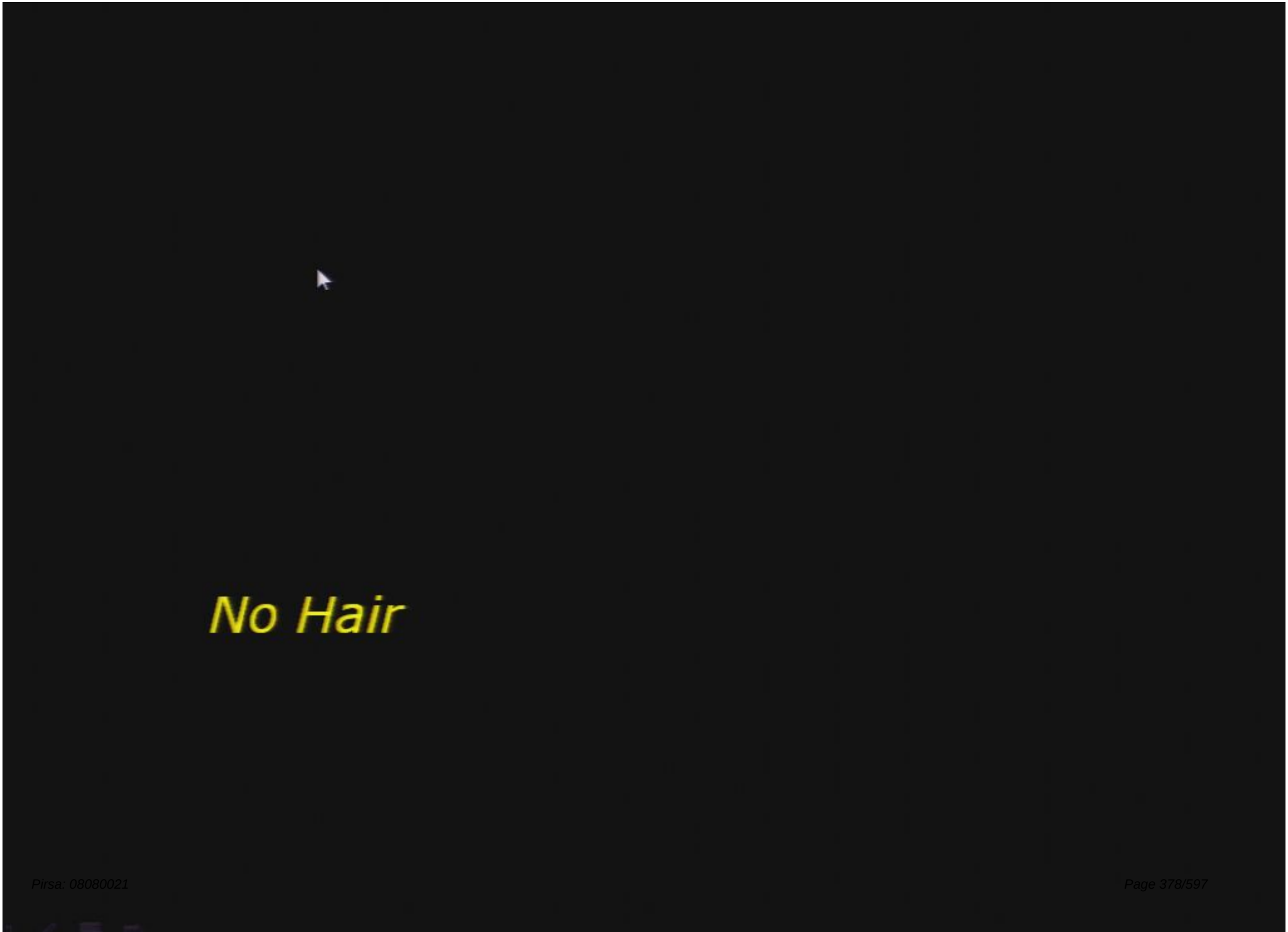
No Hair

particles as
yet undetected
gravitational and
electromagnetic
waves
known
particles
No Hair
mass
charge
angular momentum

No-hair theorem (well maybe 3 hairs)

- A black hole has no hair;
  its only 'hair' are its

1. Mass
2. Angular momentum
3. Electric charge

John A. Wheeler (b1911)

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Stars of all Shapes and Sizes

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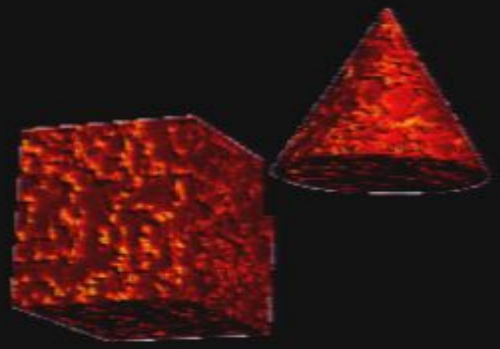

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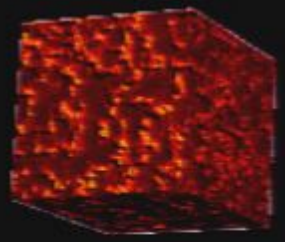

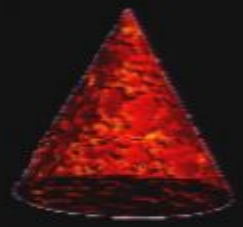

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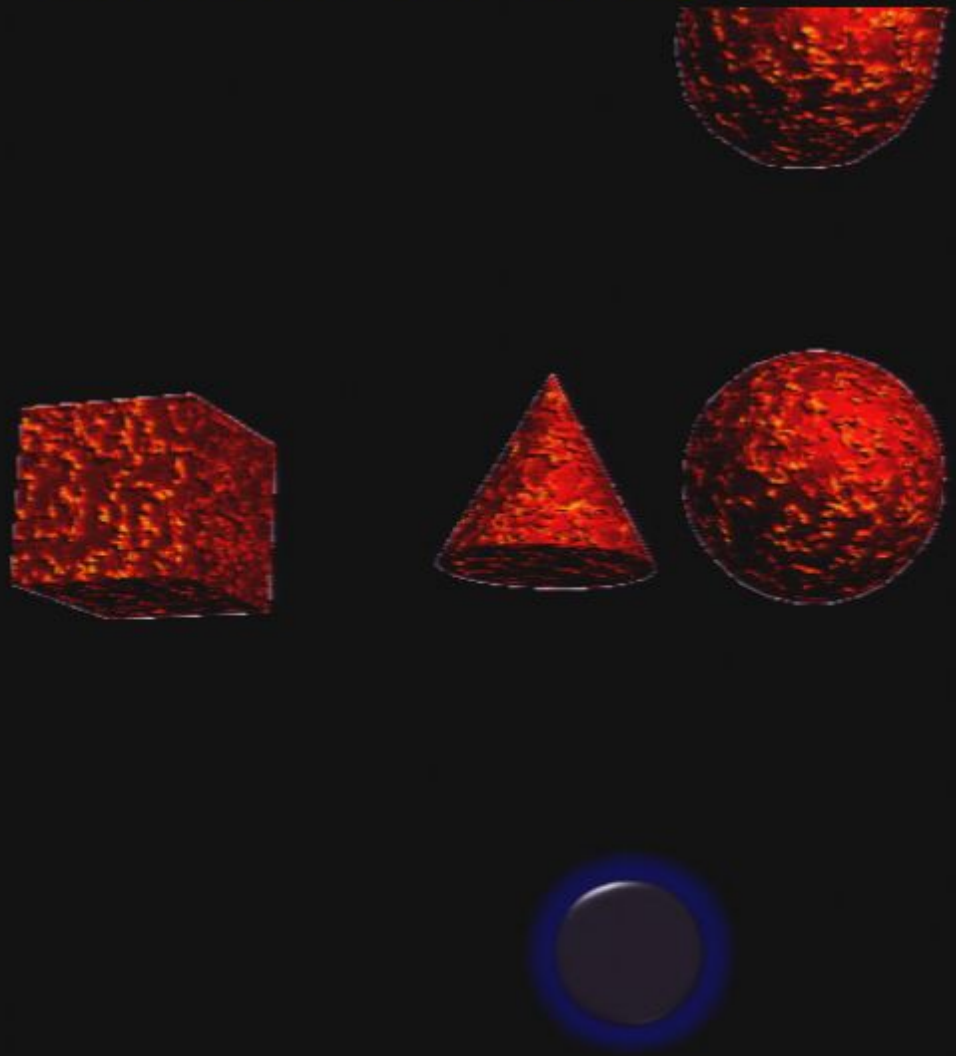

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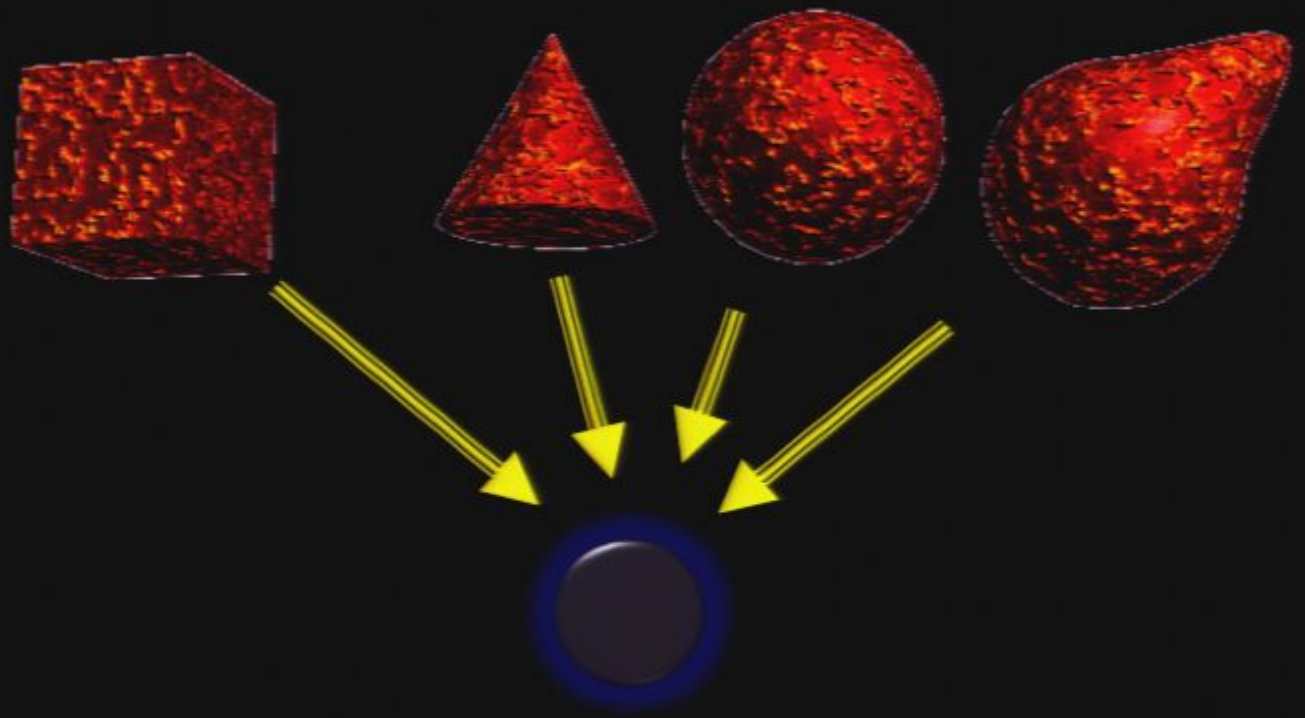

All end up looking the same

Types of black holes

- Schwarzschild (1916)
  - mass
- Reissner-Nordström (1916, 1918)
  - mass, electric charge
- Kerr (1963)
  - mass, angular momentum
- Kerr-Newman (1965)
  - mass, angular momentum, electric charge

Latest Mathematical Model of falling into a Black Hole

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Entropy of Black Hole

- Black hole presents us with a problem: What happens to the information when a particle falls inside a Black Hole?
- Remember only 3 parameters are required to describe a Black Hole (charge, mass, and angular momentum).
- In order to describe a physical system, we need entropy (a measure of disorder).
- Hawking had no problem with this "entropy eater"
- Hawking (after changing mind) and Bekenstein produced laws of Black Hole mechanics that bore an amazing resemblance to laws of thermodynamics.
- The 2nd law of thermodynamics "Entropy (randomness) increases
- You replace "Horizon Area" with "Entropy"

$$S(entropy) = \frac{kAc^3}{4hG}$$

Entropy of Black Hole

New problem: if the Black Hole has an entropy, it must have a temperature too.

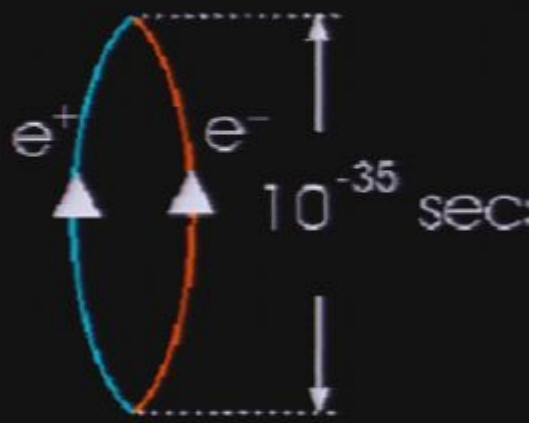
Worse Problem: If is has a temperature it must radiate, but in classical definition, nothing can escape a Black Hole.

Crisis:

- *Several ways to picture how a black Hole evaporates*
  - *Some ways correspond to different ways of formulating laws of quantum fields.*
  - *Some ways correspond to String Theory*
  - *Some ways correspond to Quantum Gravity*
  - *Some ways make no sense at all.*
  - *Next Talk will discuss this.*

Vacuum Fluctuations

- *A vacuum is a place which is anything but empty.*
- *It is a place of continuous creation and destruction. Pairs of virtual particles are born – live a short but happy life – then die.*
- *Possible by Heisenberg's uncertainty principle: The energy of a vacuum, that we suppose to be zero, can be defined with an uncertainty of ΔE during at ΔT.*
- *$\Delta T \times \Delta E \approx h$*
- *Therefore particles/antiparticles, with $\pm \Delta E$ are constantly being created (must be in lowest energy state).*
- *One particle has positive energy, one particle has negative energy.*
- *The particles live momentarily on fluctuational energy "borrowed" from neighbouring regions of space.*



Stephen W. Hawking (b1942)

Hawking radiation

Virtual photon is its own antiparticle

virtual particles

Black Holes Ain't So Black

Hawking Radiation

- The Hawking Radiation theory states that virtual particle-antiparticle pairs are sometimes created outside the event horizon of a black hole. Three things can happen to a pair of particles just outside the event horizon:
  - Both particles are pulled into the black hole.
  - Both particles escape from the black hole.
  - One particle escapes while the other is pulled into the black hole.
- For the third possibility, the particle that has escaped becomes real and can therefore be observed from Earth. The energy to separate the two virtual particles (thus making them real particles) is taken from the horizon, thus reducing the energy of the Black Hole.
- The wavelength of the particle/wave that enters the a hole will be of 25% of the hole's circumference.
- For Example: A black hole of 2 Solar Masses with a circumference of about 35Km will emit a wavelength of:

$$\frac{35}{4} \approx 9 \ km$$

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- For Example: A black hole of 2 Solar Masses with a circumference of about 35Km will emit a wavelength of:

$$\frac{35}{4} \approx 9 \ km$$

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Hawking Radiation

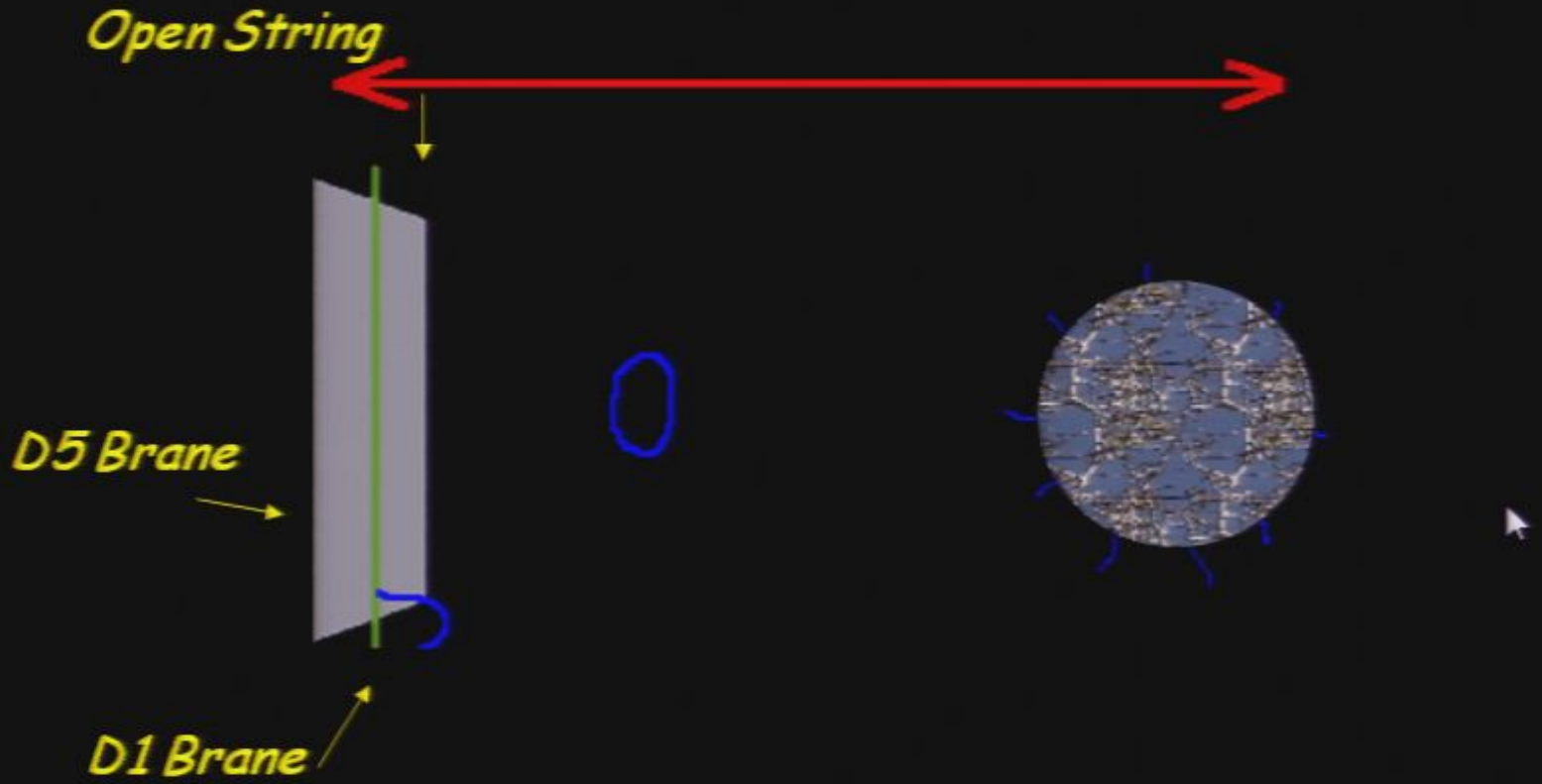
- The larger (more massive) the Black Hole the lower the temperature and the longer it takes to evaporate.

$$Temp_K \approx \frac{6\times10^{-8}}{M_\oplus}$$

$$\tau ime \approx 10^{66}\cdot\left[M_\oplus\right]^3$$

- Remember the age of the Universe is 10^{10} years give or take 3 days.

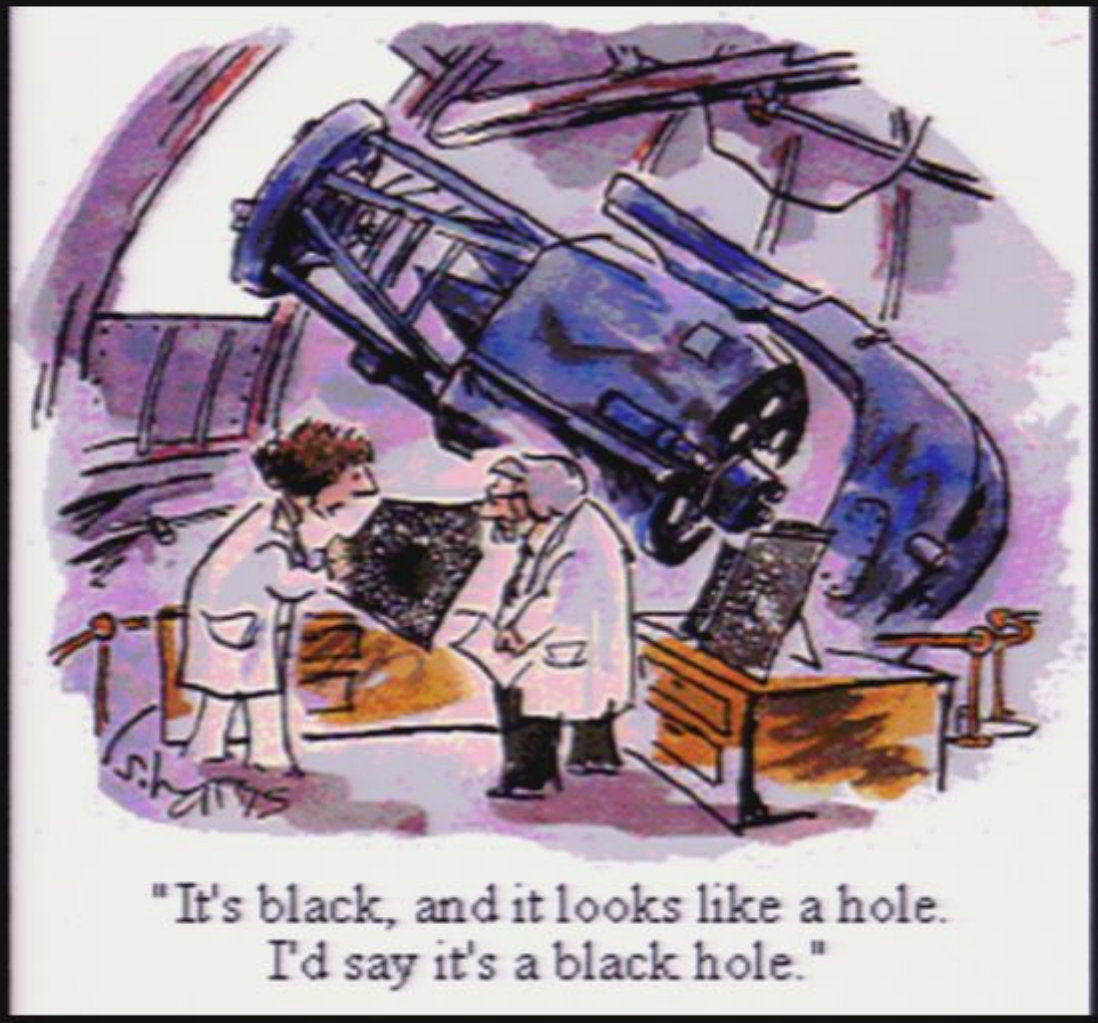
Superstring Method



One of the most dramatic recent results in string theory is the derivation of the Bekenstein-Hawking entropy

Are Black Holes Real

What are we going to look for if Black Holes are Real

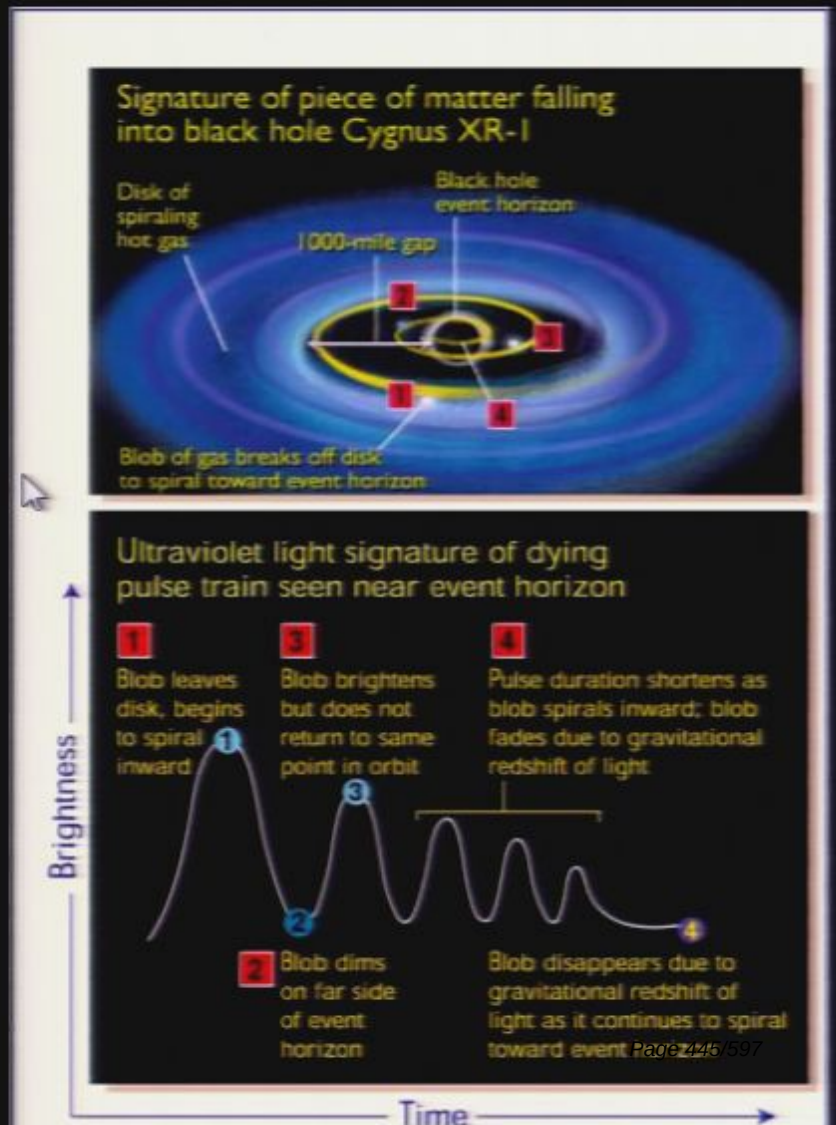


Finding Black Holes
Ultraviolet and X-rays
Seeing Matter Disappear

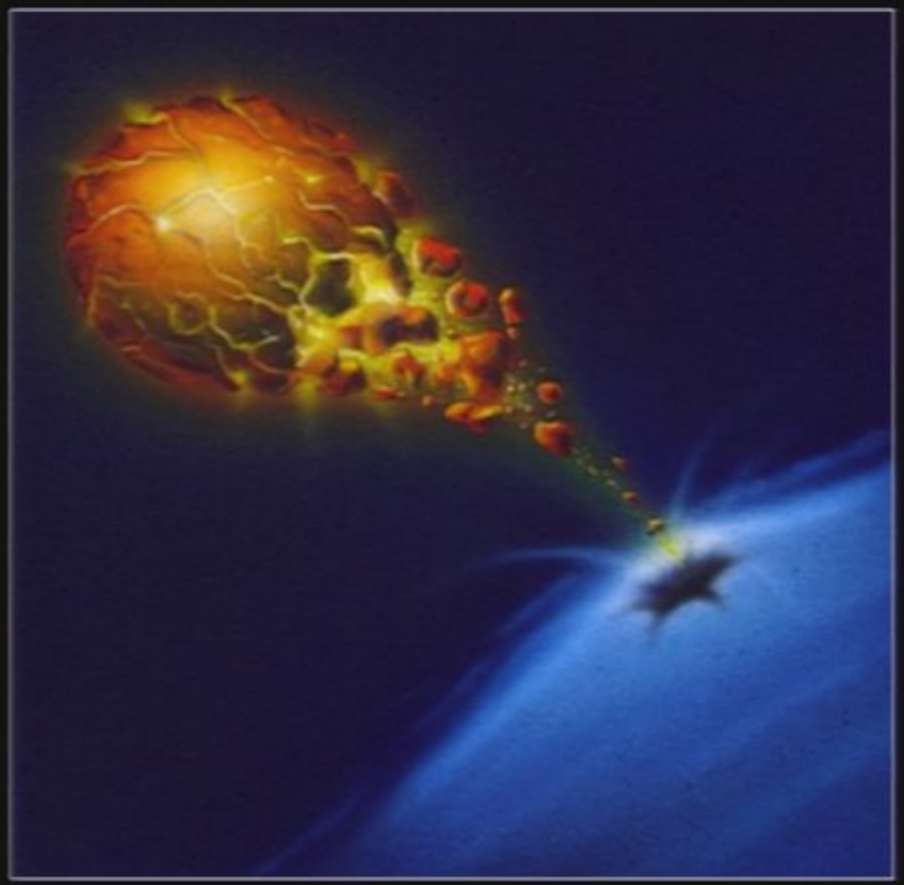
Hubble observed pulses of UV light emitted by material as it fell into a black hole.

- Pulses arise from material orbiting around intense gravity of the black hole.

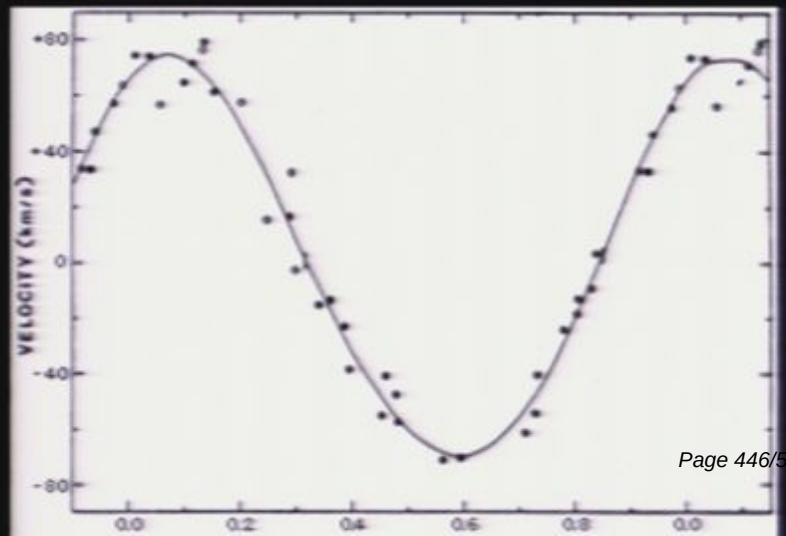
- Light pulses, lasting 0.2 s, are red-shifted from X-ray to UV, as they fall into gravity of the black hole.



Seeing Holes

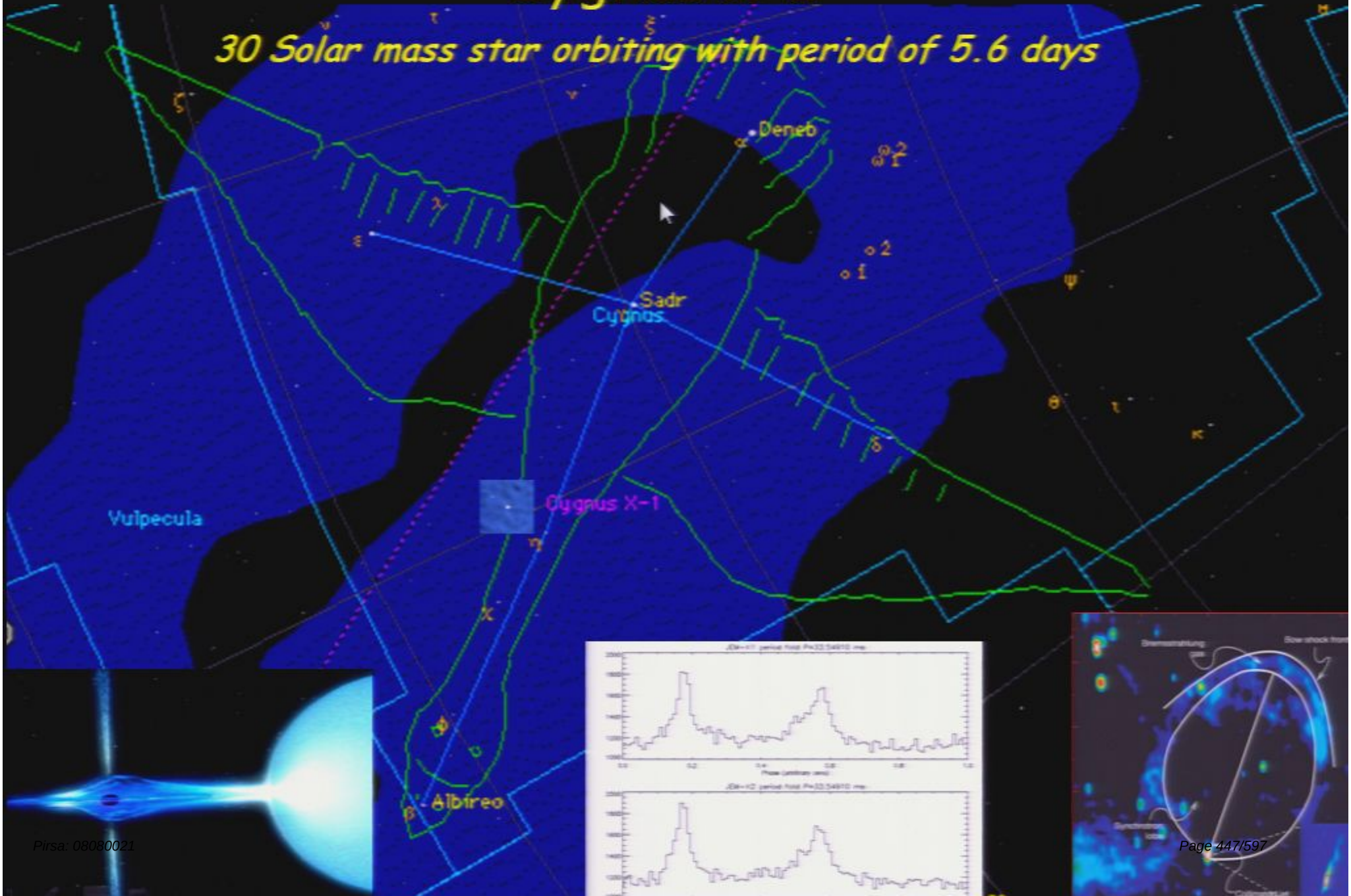


- Can't see black hole itself, but can see matter falling into a hole.
- Gravitational forces stretch and rip matter: heats up.
- Very hot objects emit in X-rays (interior of Sun)



Cygnus X-1

30 Solar mass star orbiting with period of 5.6 days

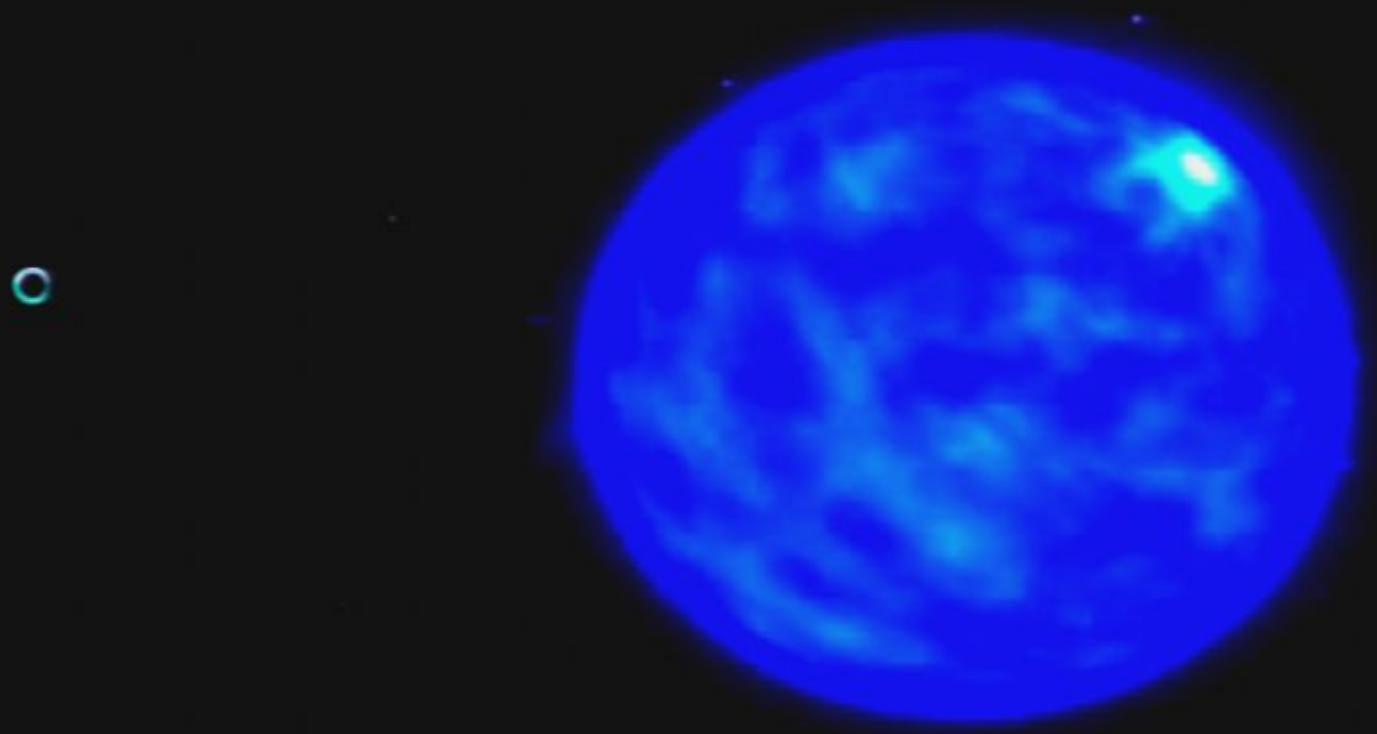


Even More Binary Black Holes

Even More Binary Black Holes

Name of Binary System	Companion Star Spectral Type	Orbital Period (days)	Black Hole Mass (Solar Units)
Cygnus X-1	B supergiant	5.6	6-15
LMC X-3	B main sequence	1.7	4-11
A0620-00 (V616 Mon)	K main sequence	7.8	4-9
GS2023+338 (V404 Cyg)	K main sequence	6.5	> 6
GS2000+25 (QZ Vul)	K main sequence	0.35	5-14
GS1124-683 (Nova Mus 1991)	K main sequence	0.43	4-6
GRO J1655-40 (Nova Sco 1994)	F main sequence	2.4	4-5
H1705-250 (Nova Oph 1977)	K main sequence	0.52	> 4

Looking for Evidence



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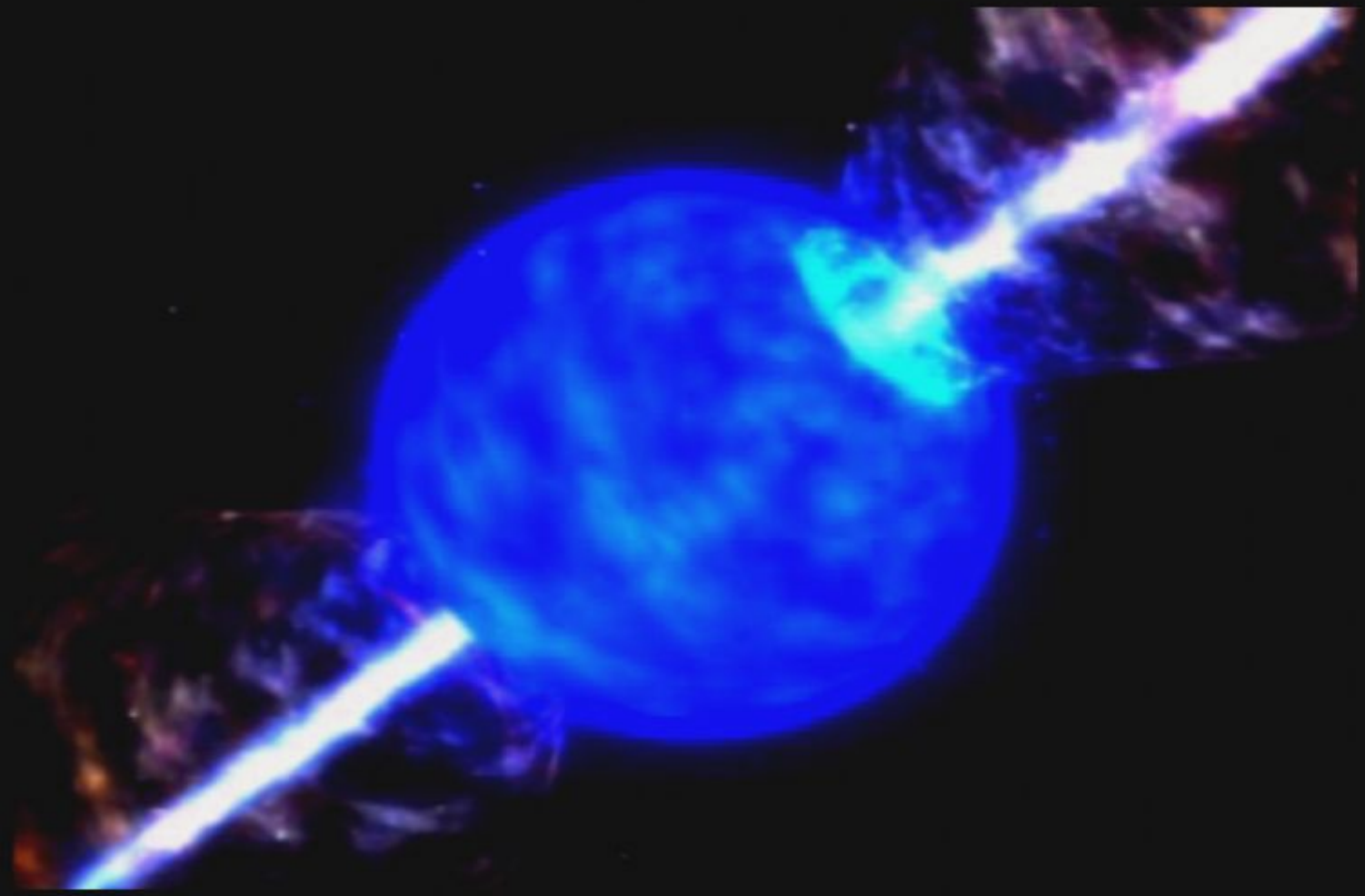

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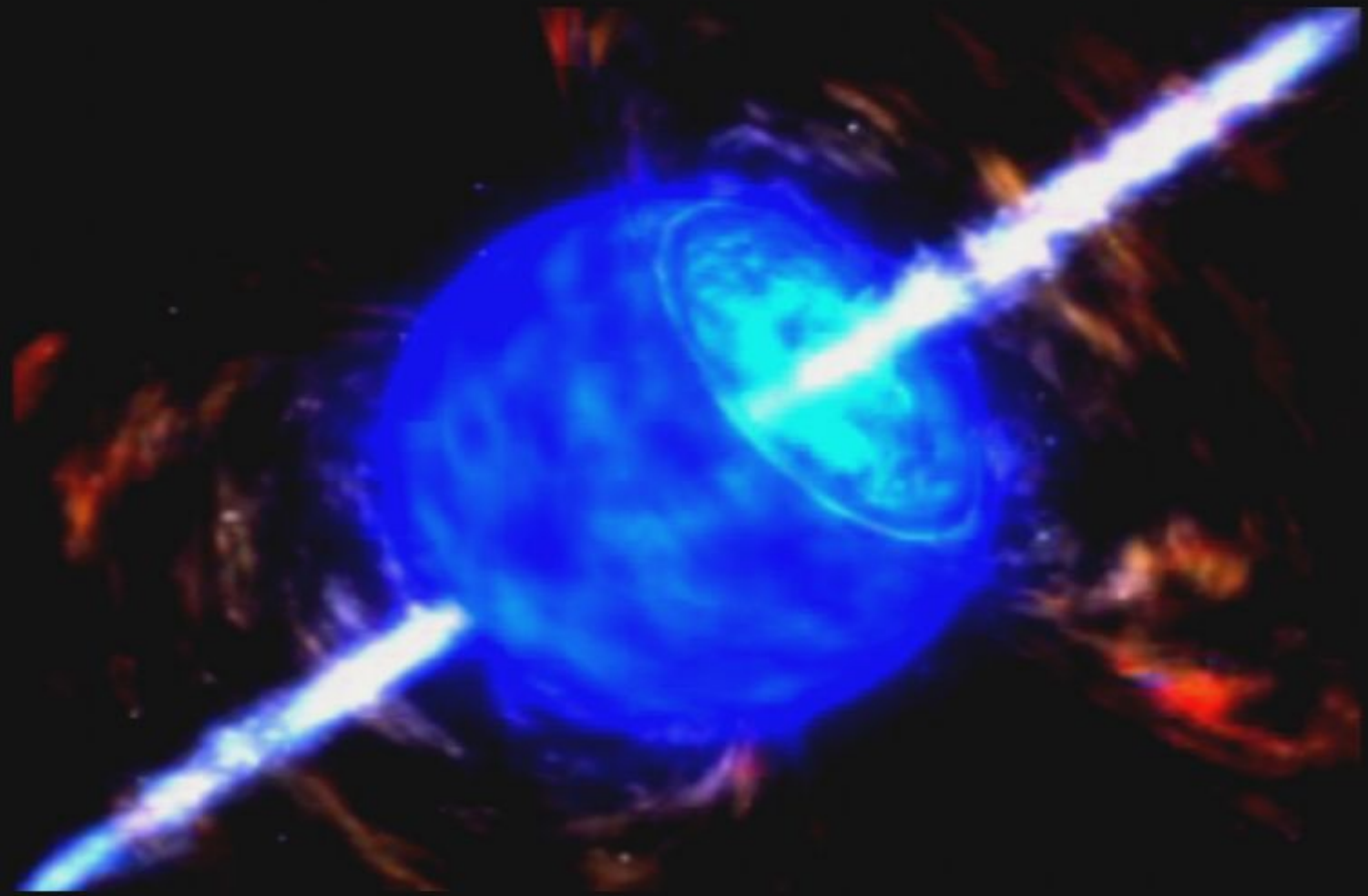

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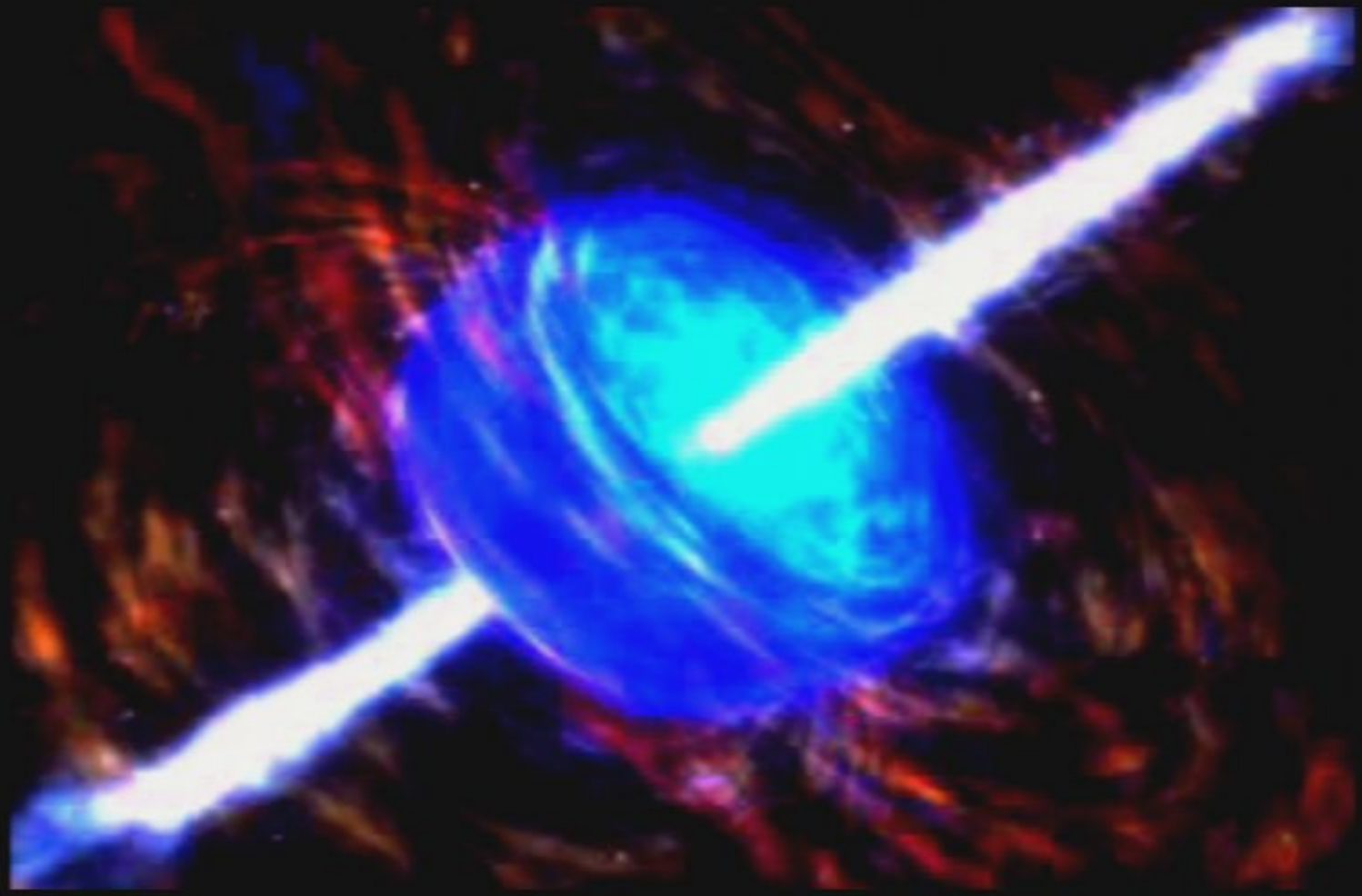

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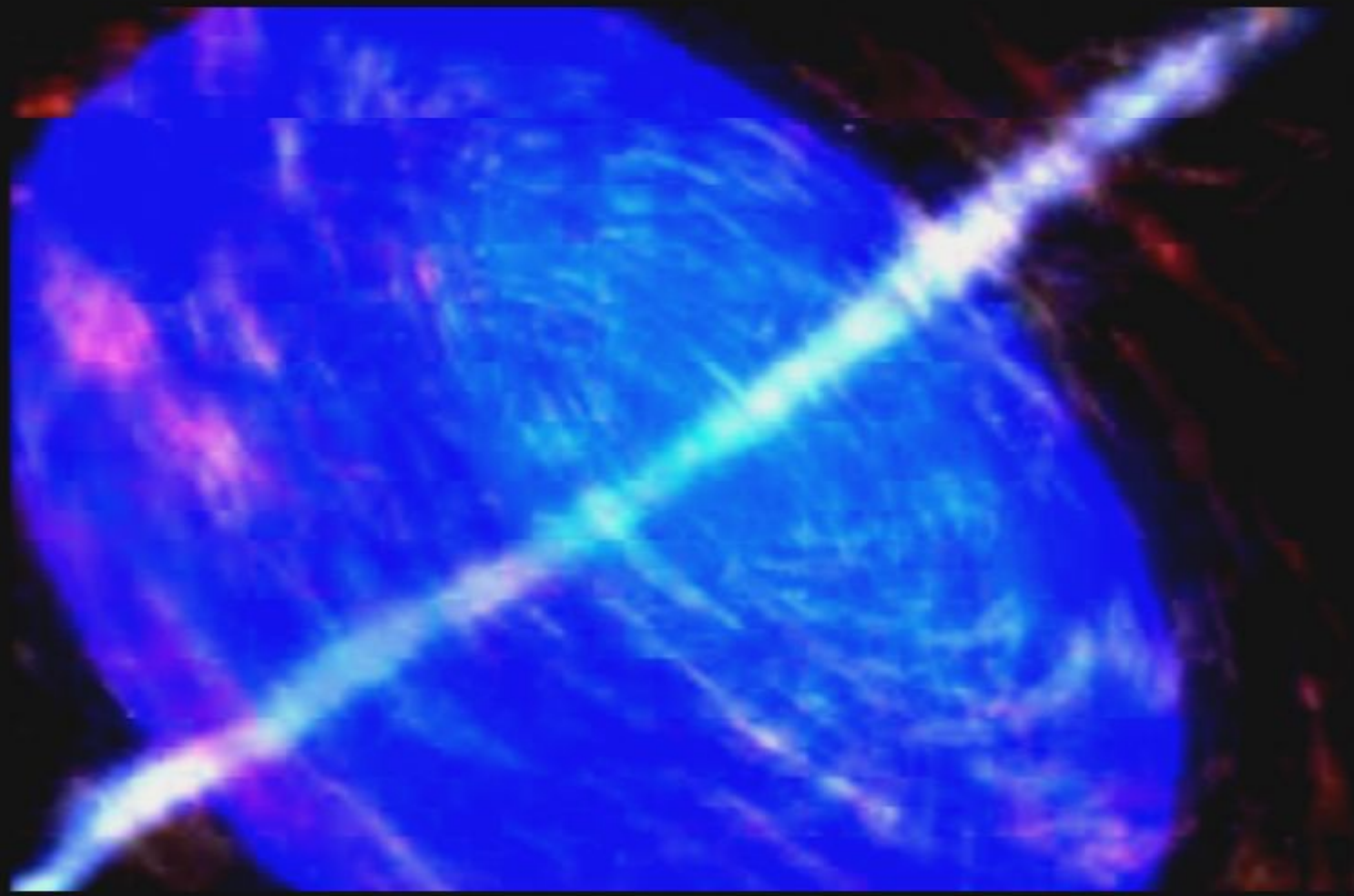

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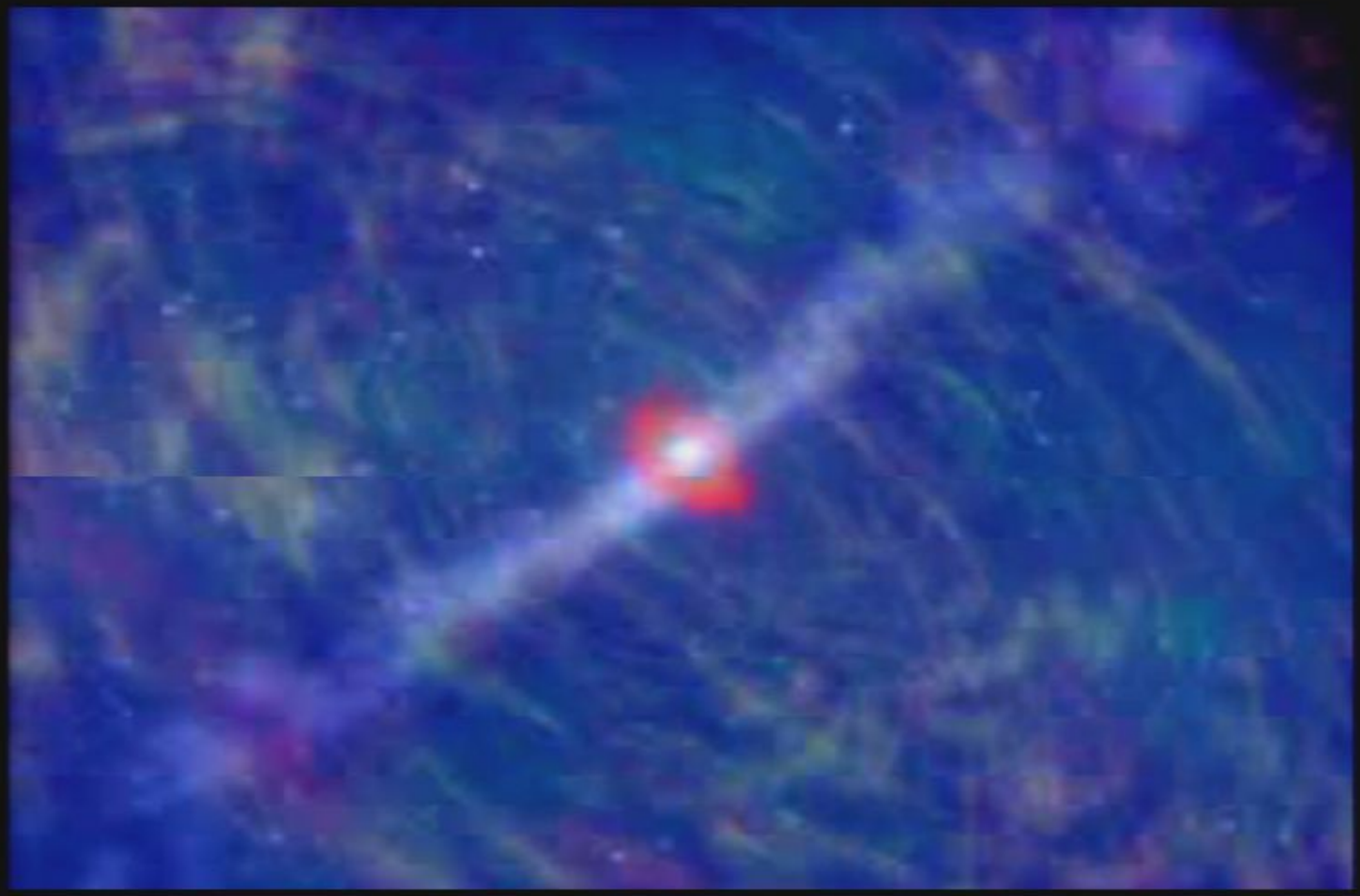

Looking for Evidence

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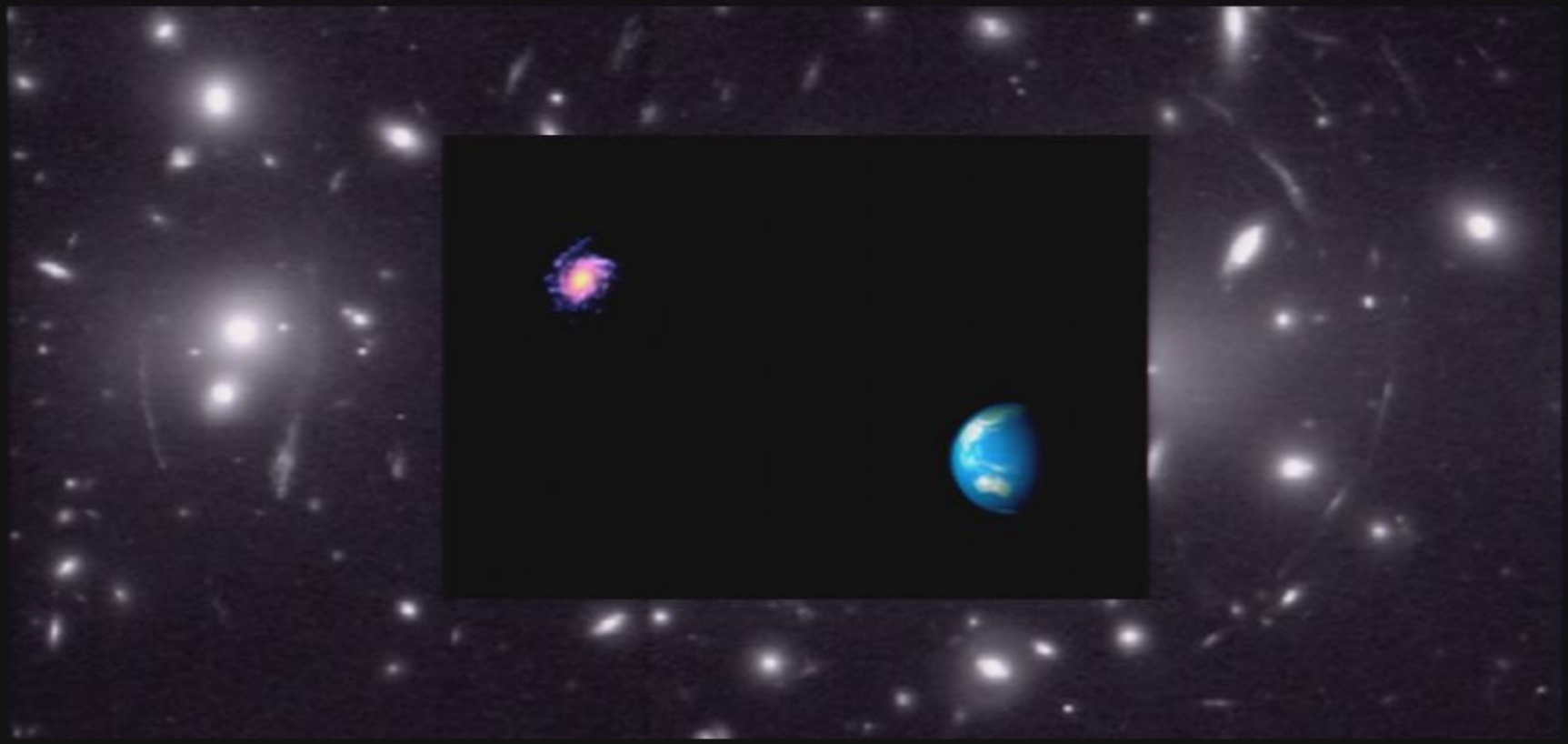
Lens



Black Holes can act like a lens. Almost all of the bright objects in this image are galaxies in the cluster known as Abell 2218..

What else should we look for?

Jets

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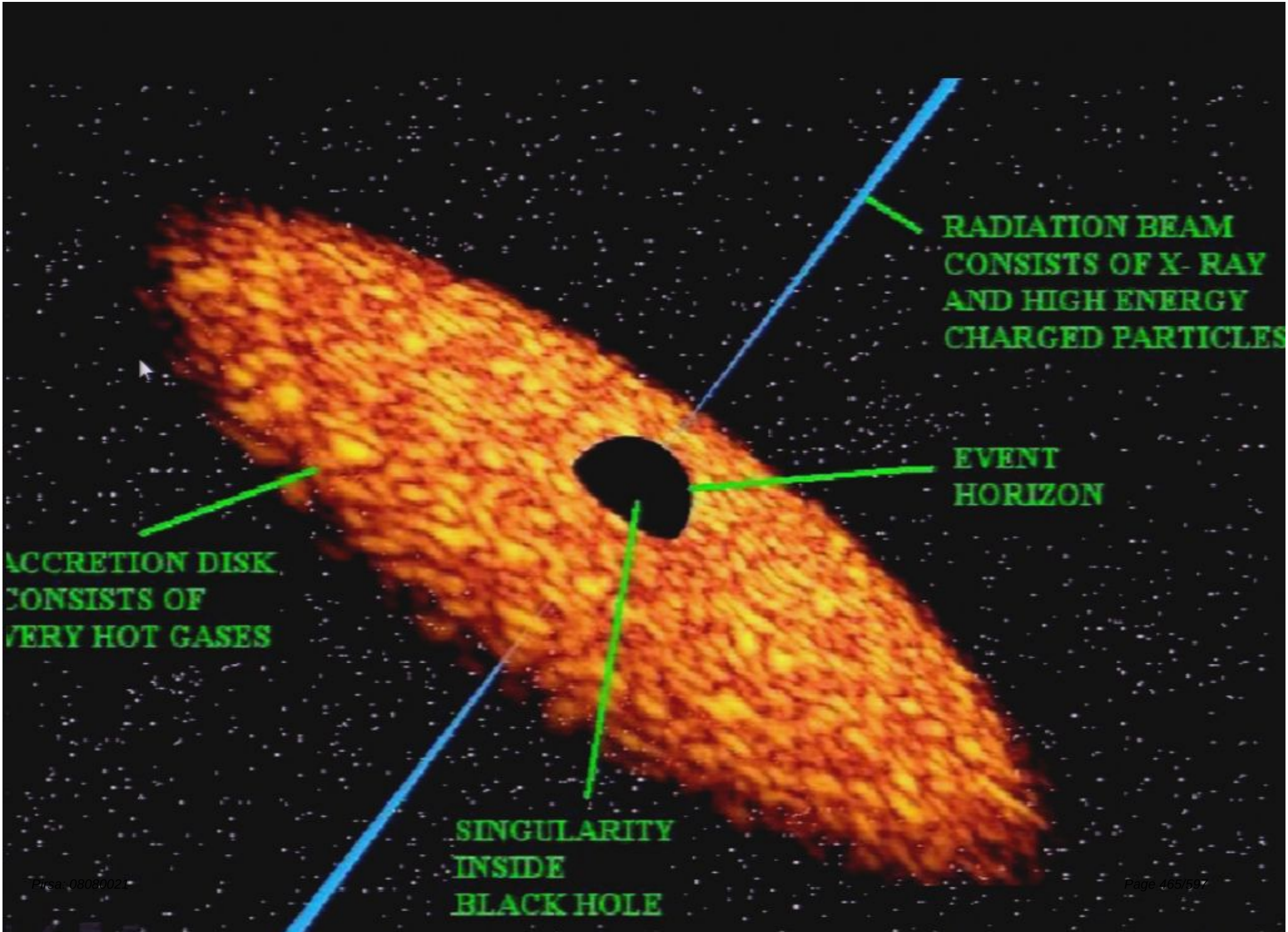
Jets


RADIATION BEAM
CONSISTS OF X- RAY
AND HIGH ENERGY
CHARGED PARTICLES
EVENT
HORIZON
ACCRETION DISK
CONSISTS OF
VERY HOT GASES
SINGULARITY
INSIDE
BLACK HOLE

Radio Jets from Black Holes

- Many black holes emit jets.
  - Material in jet moving at 0.9c.
  - Jet likely composed of electrons and positrons.
- Magnetic fields surrounding black hole expel material and form the jet.
  - Interaction of jet material with magnetic field gives rise to Radio emission.

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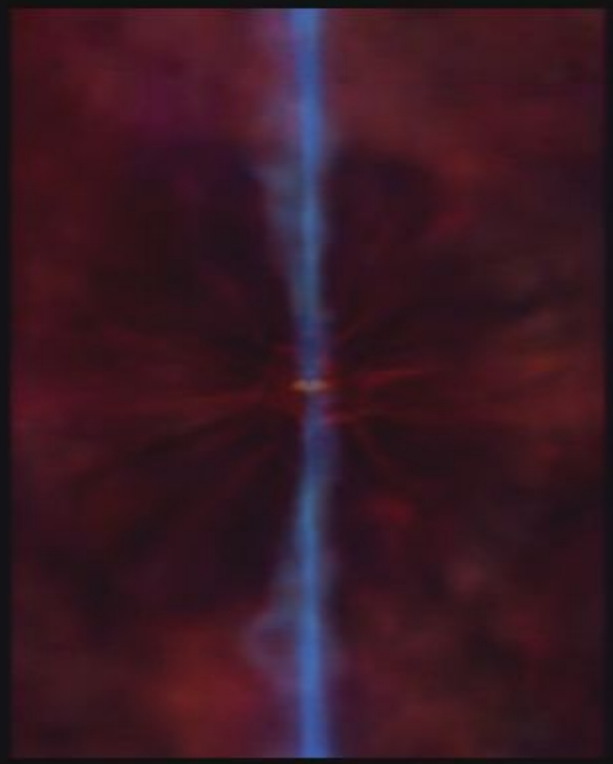

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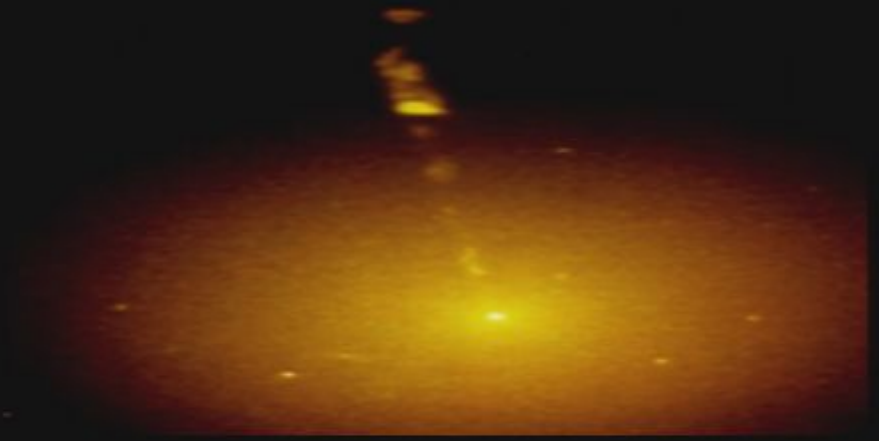
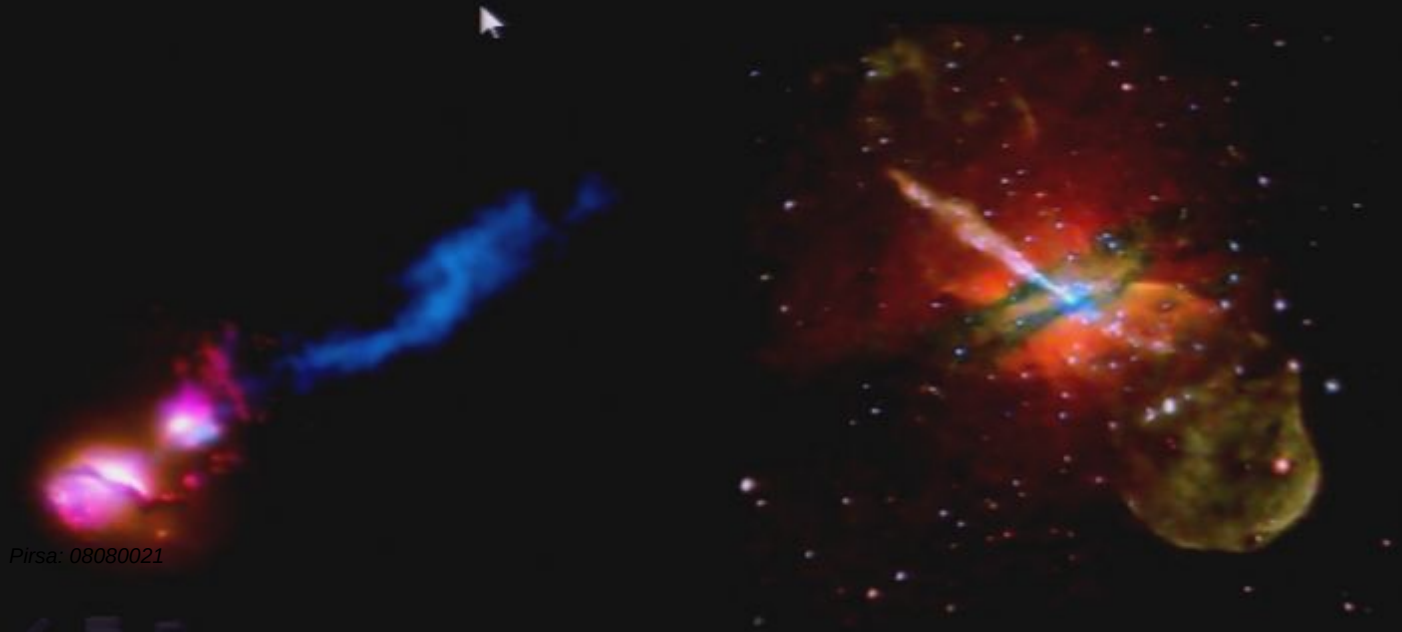
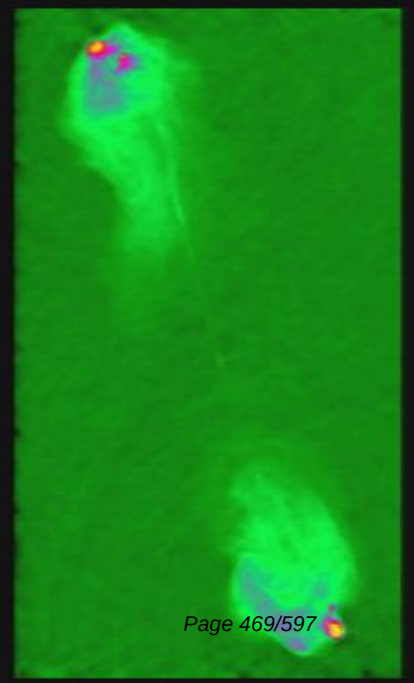


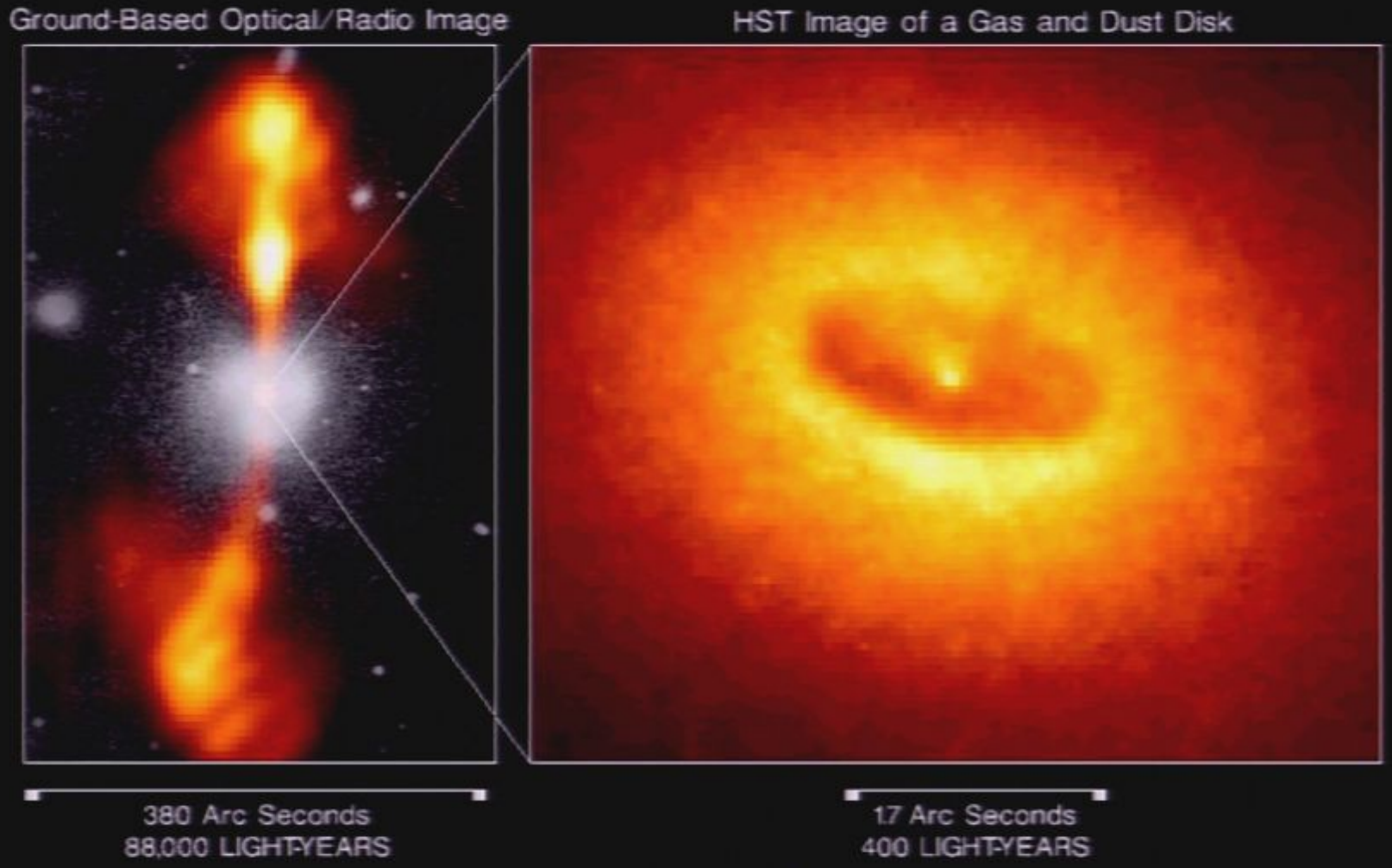




Core of Galaxy NGC 4261

Hubble Space Telescope

Wide Field / Planetary Camera

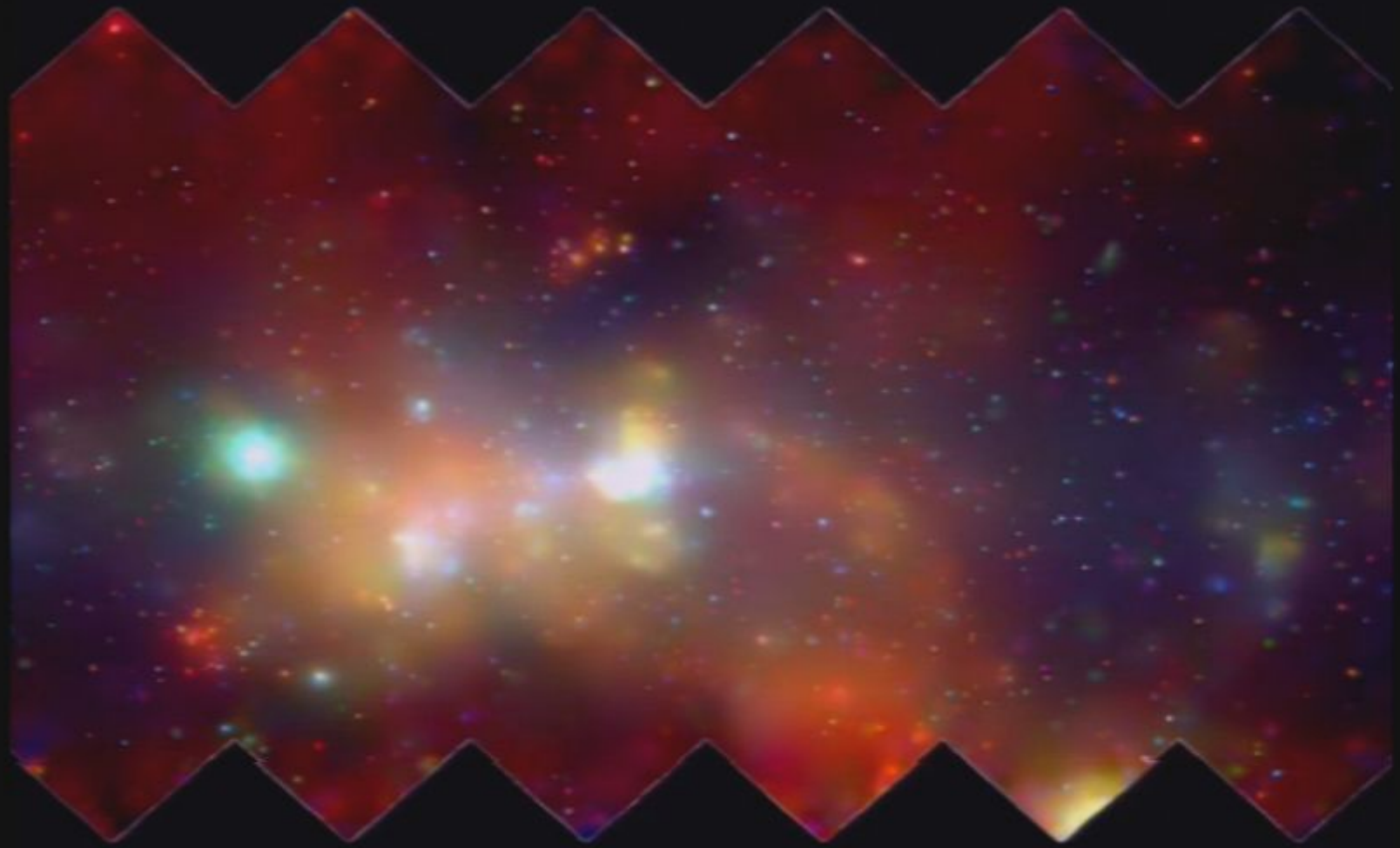


More Evidence

More Evidence

What about inside our own Galaxy?

More Evidence



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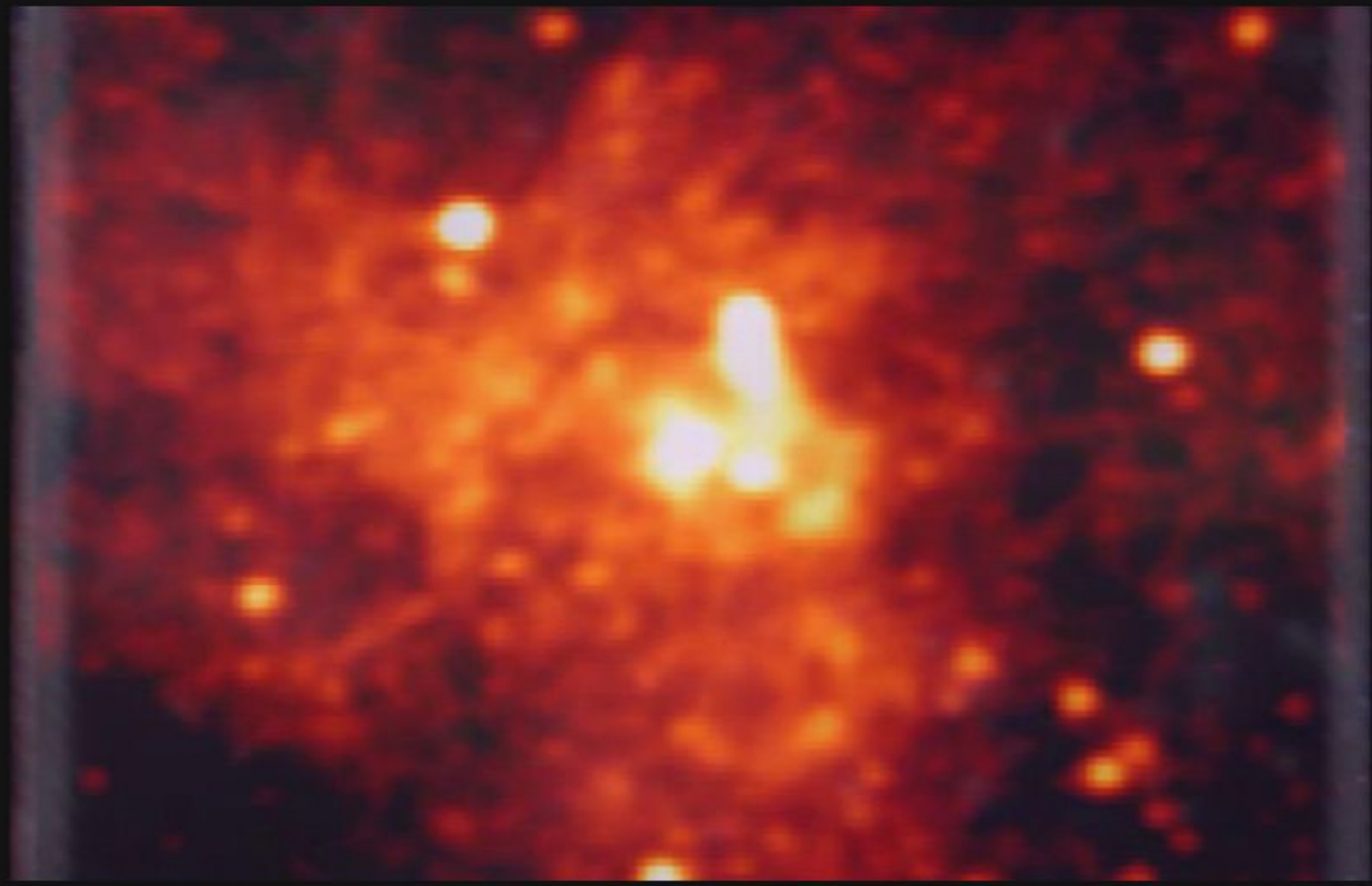

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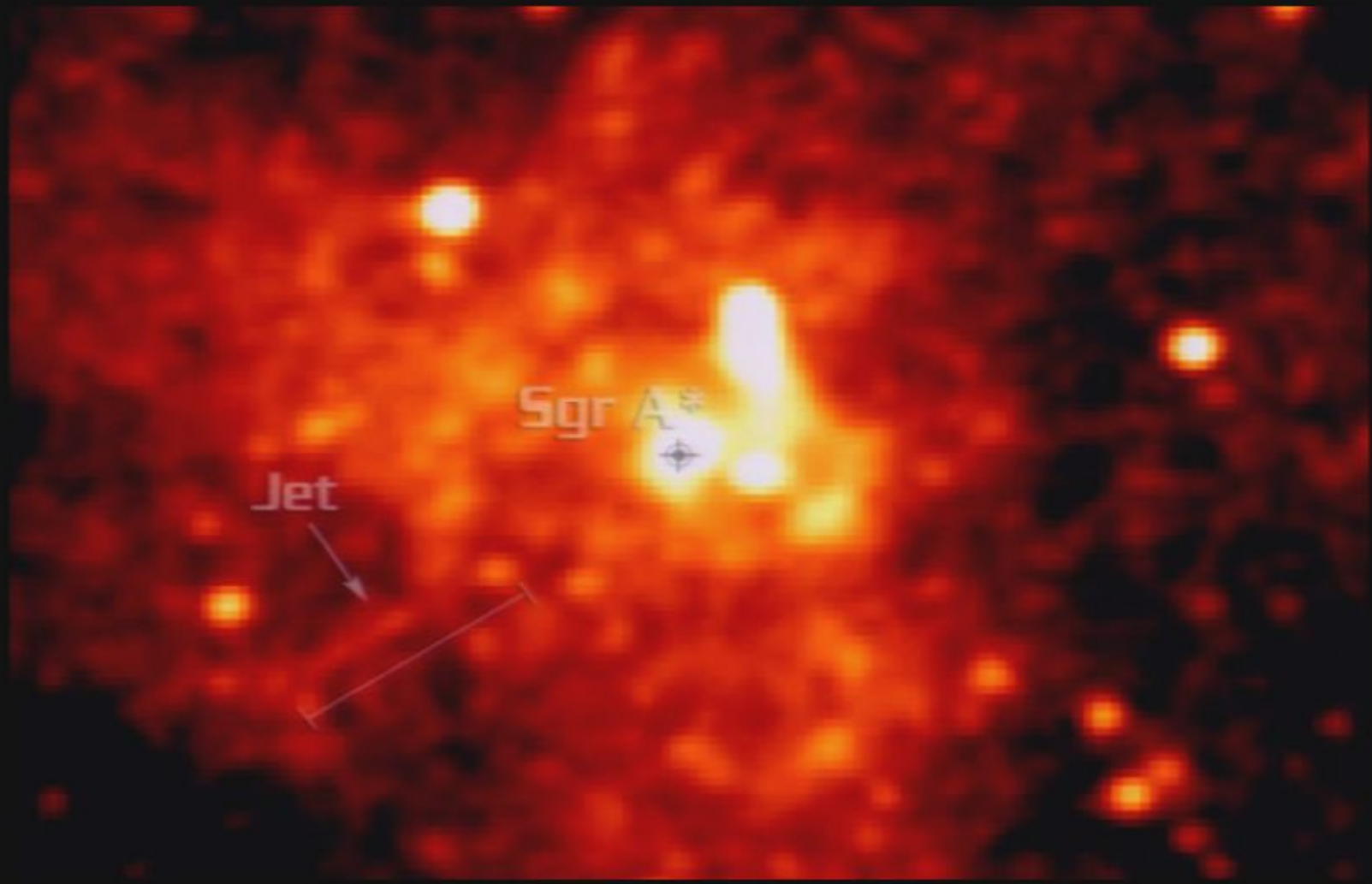
More Evidence



What about inside our own Galaxy?

More Evidence

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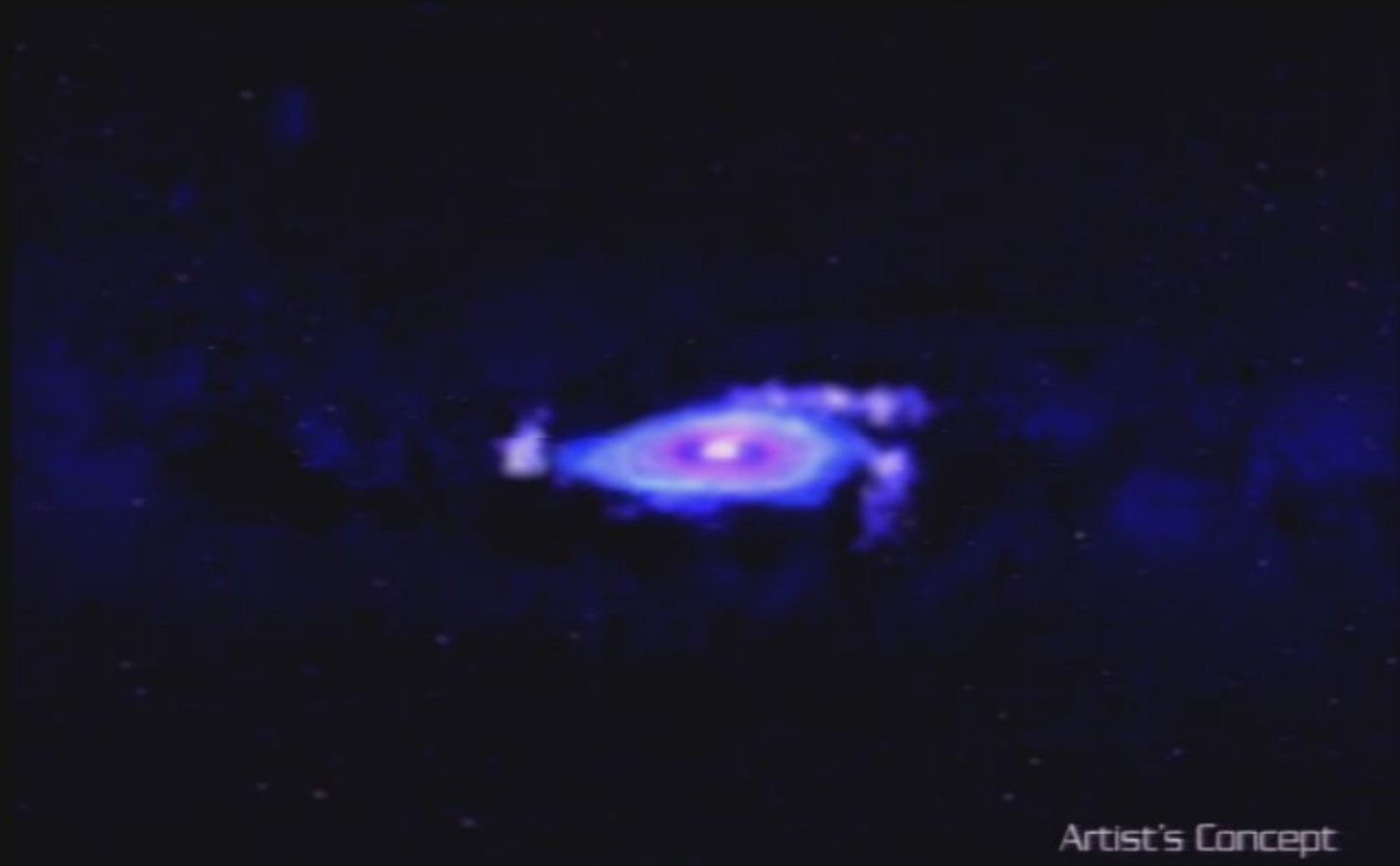
More Evidence



What about inside our own Galaxy?

More Evidence

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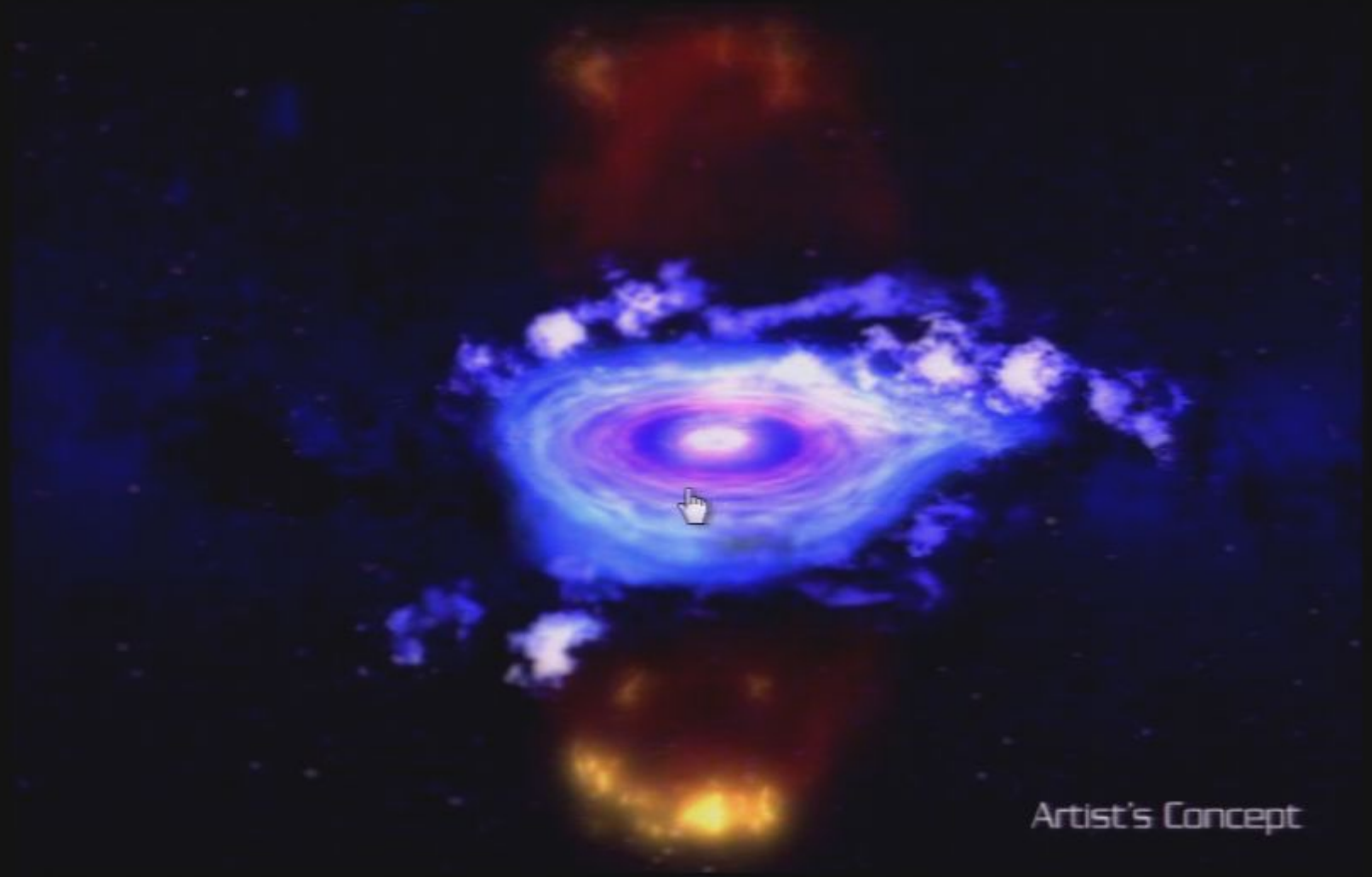
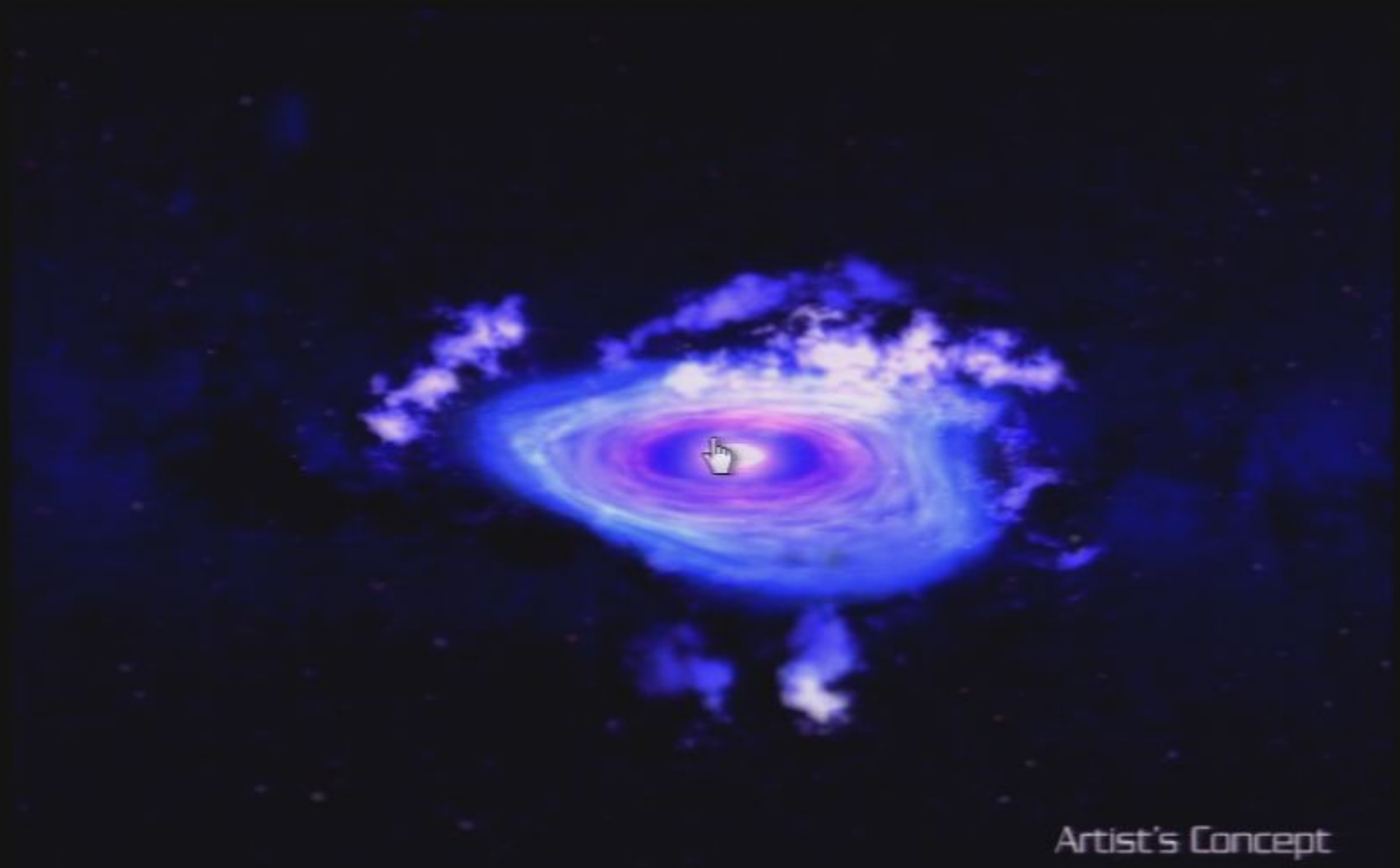


What about inside our own Galaxy?

More Evidence



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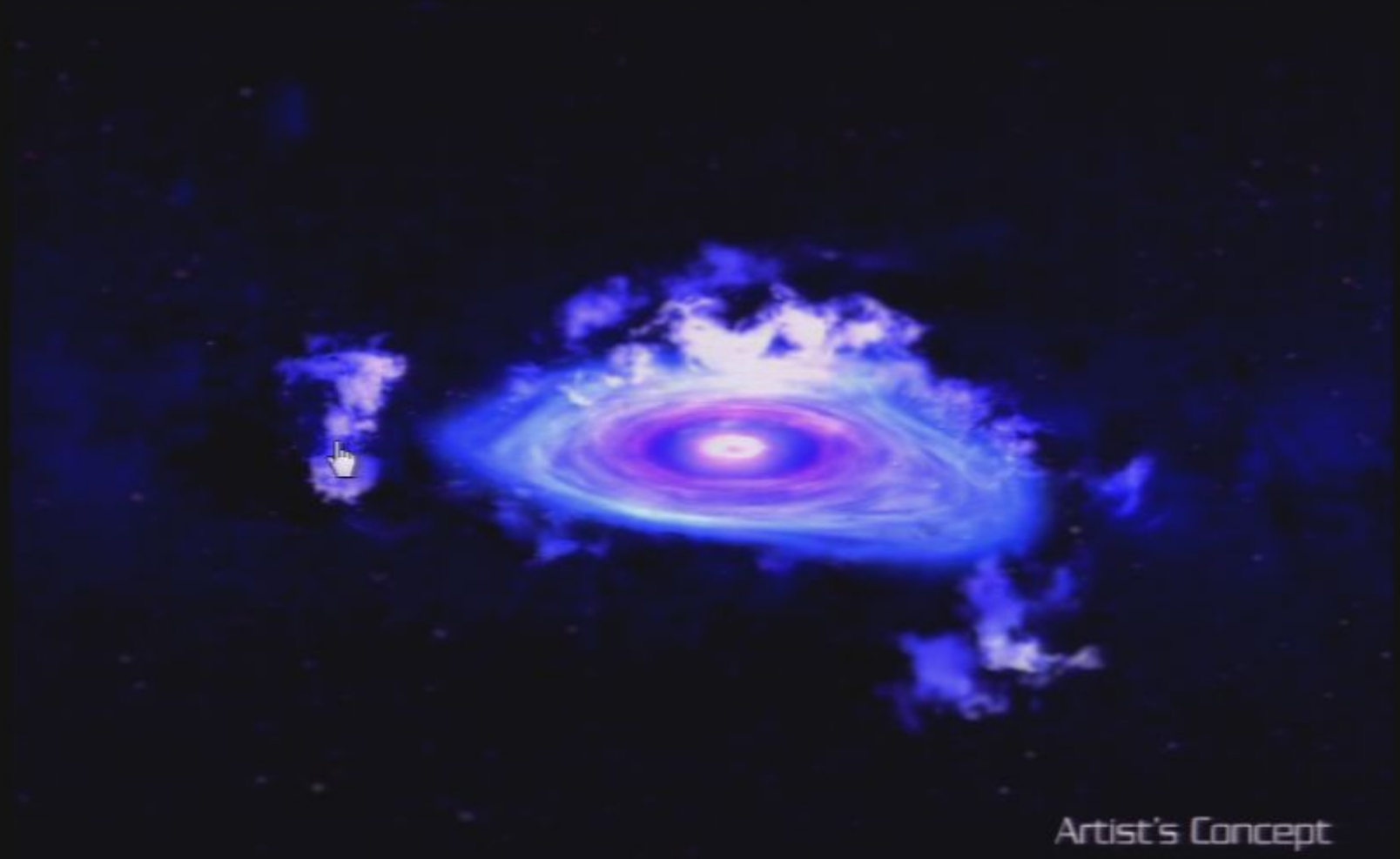
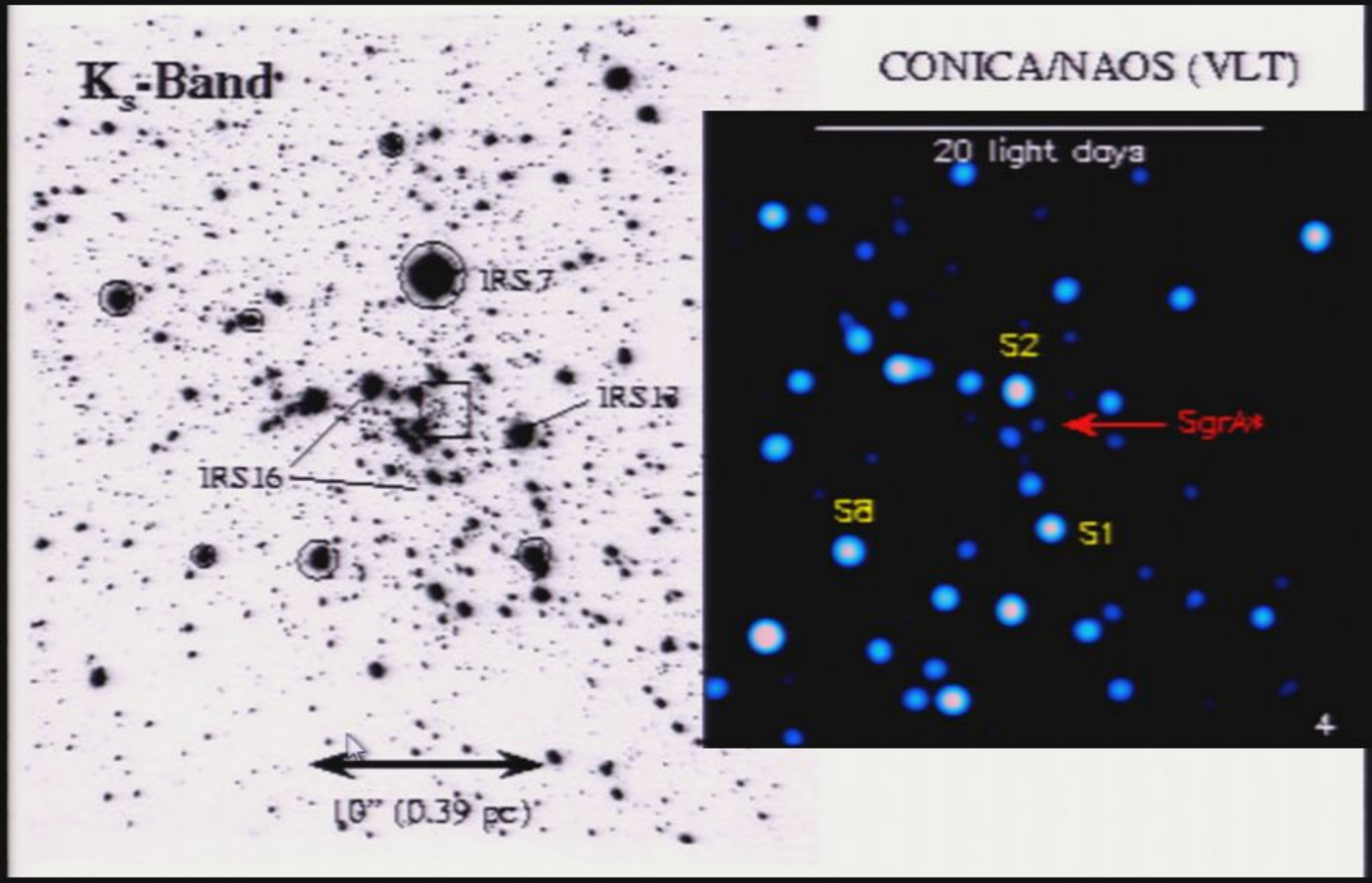
More Evidence



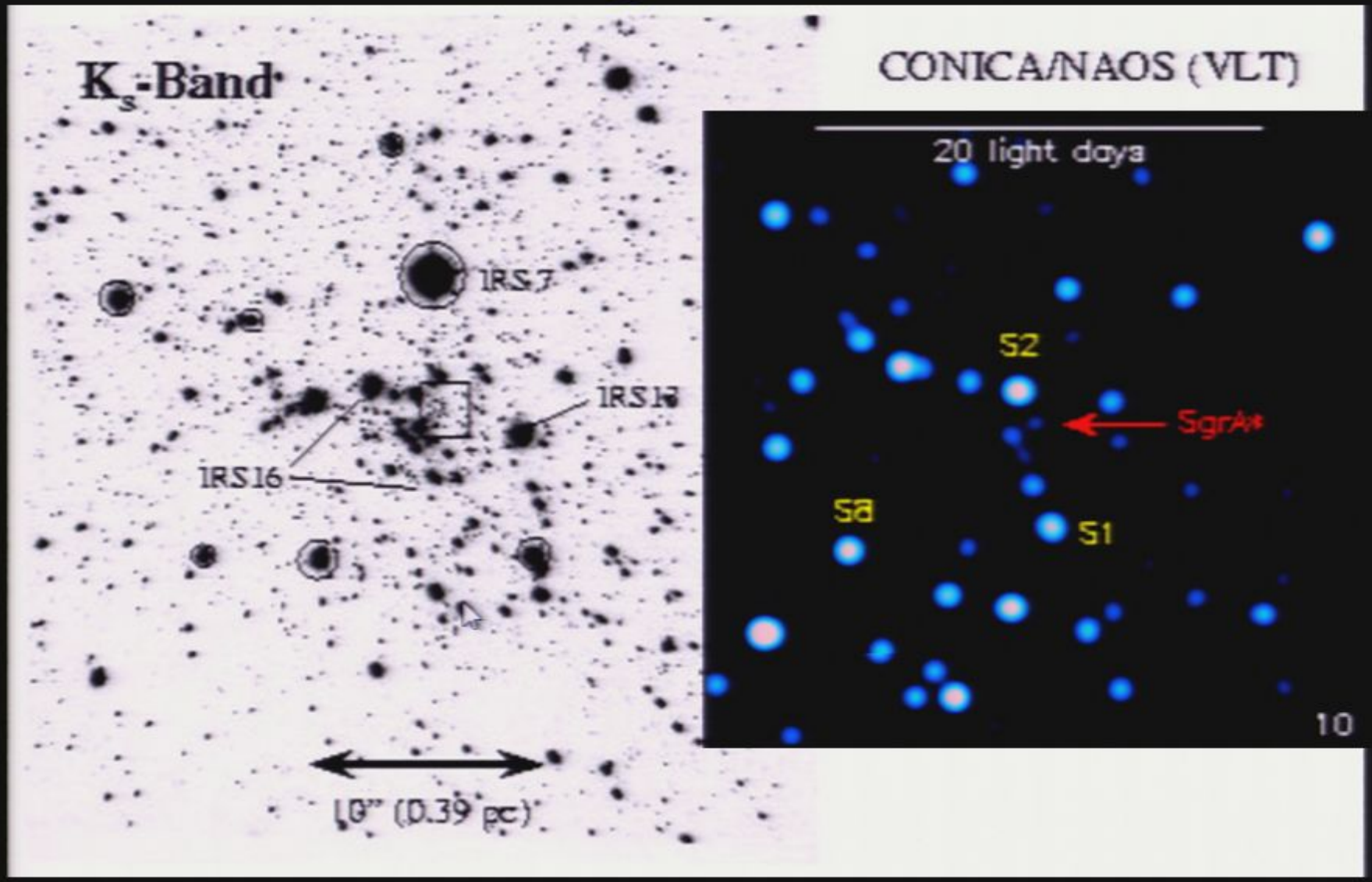
What about inside our own Galaxy?

SgrA*



3,700,000 solar masses

SgrA*



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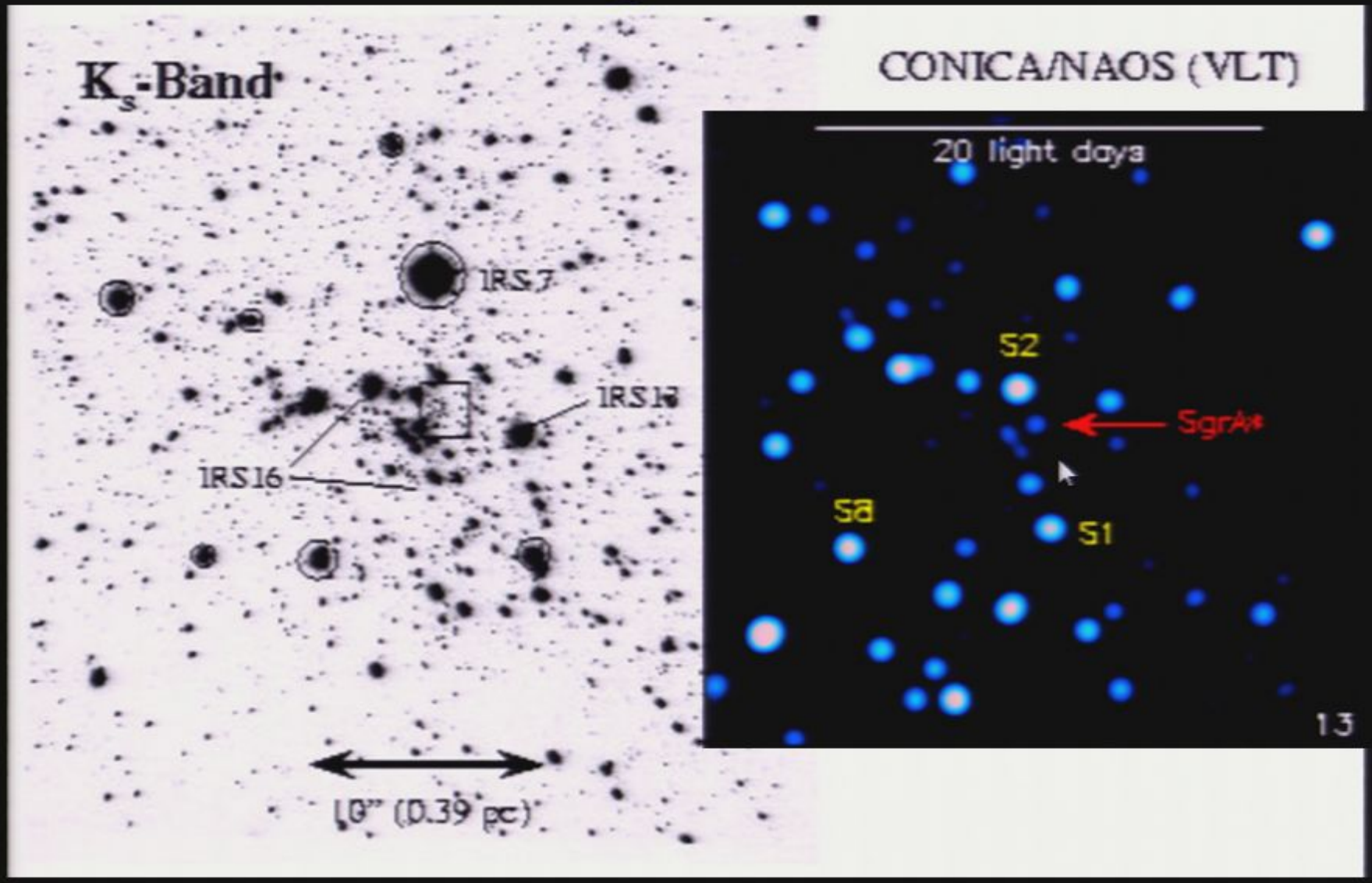
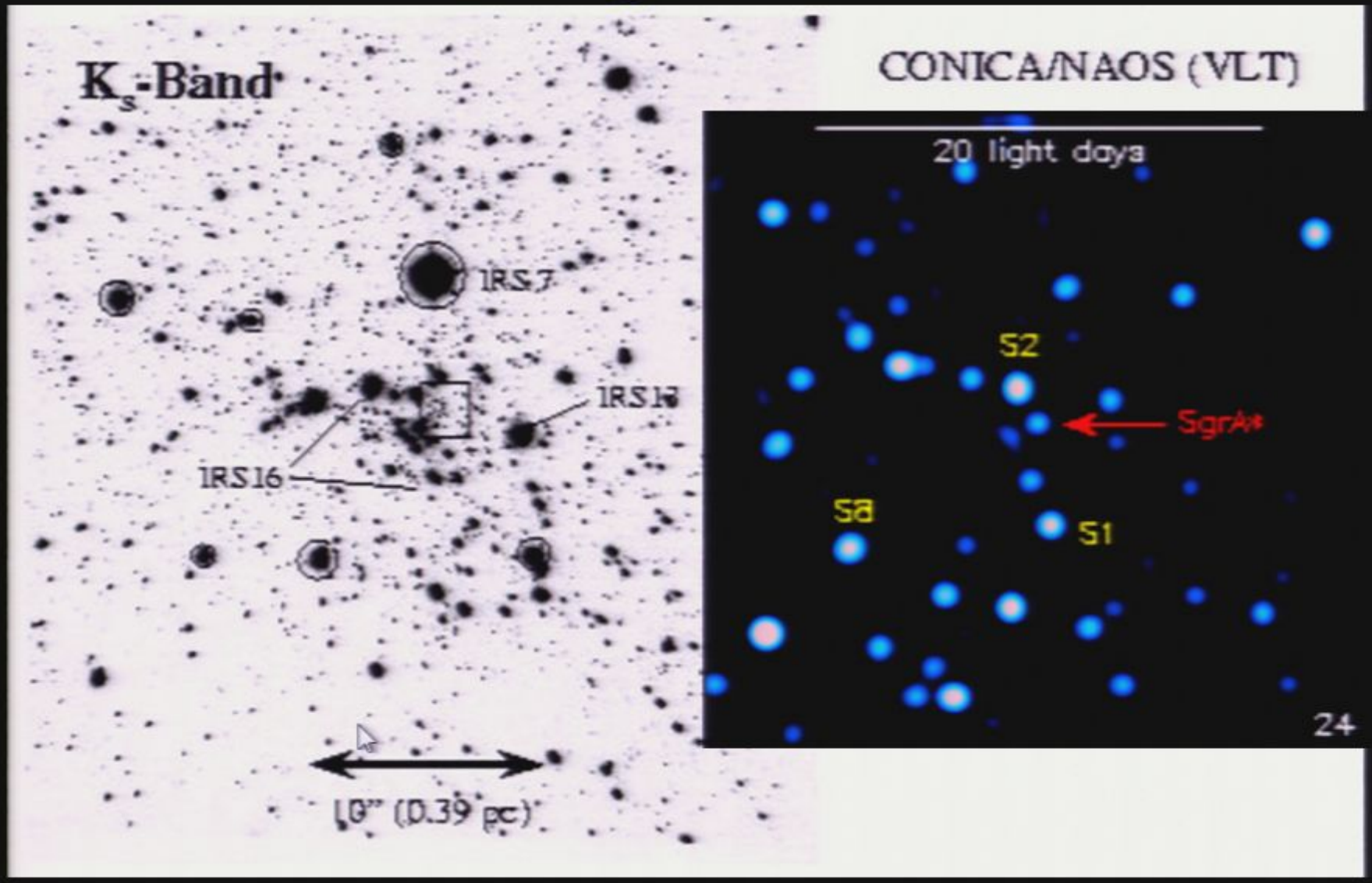
SgrA*



3,700,000 solar masses

SgrA*



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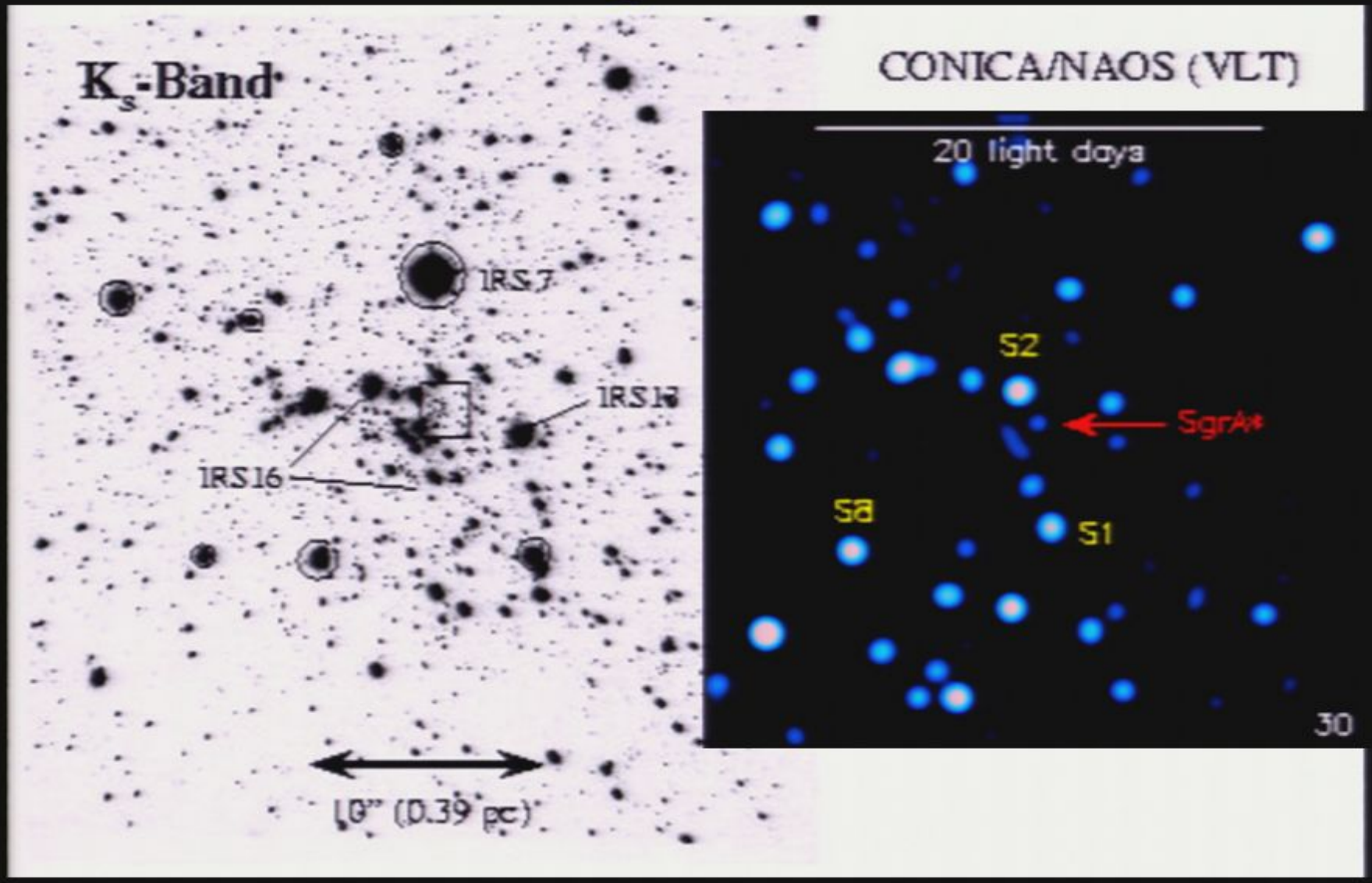

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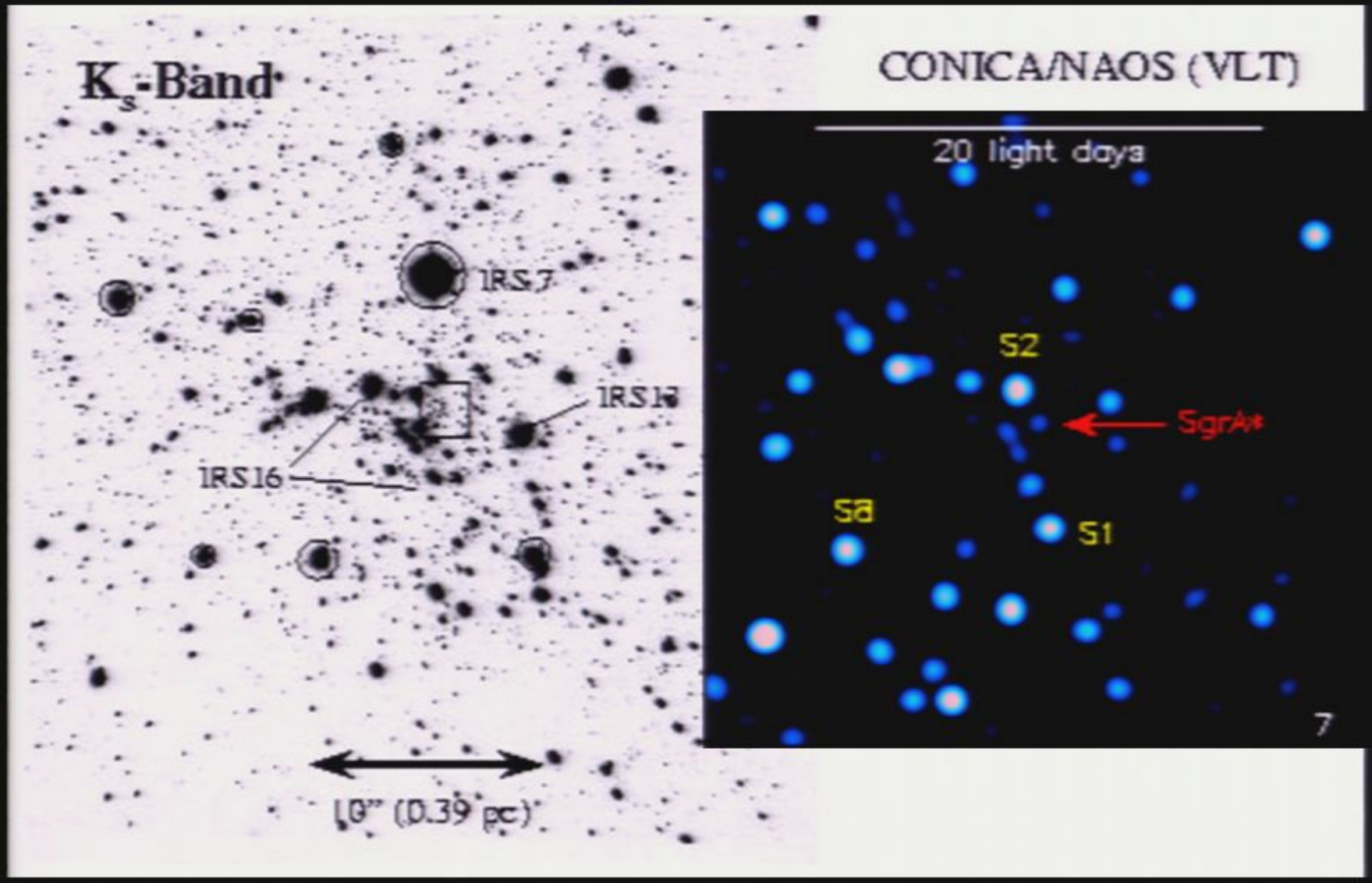

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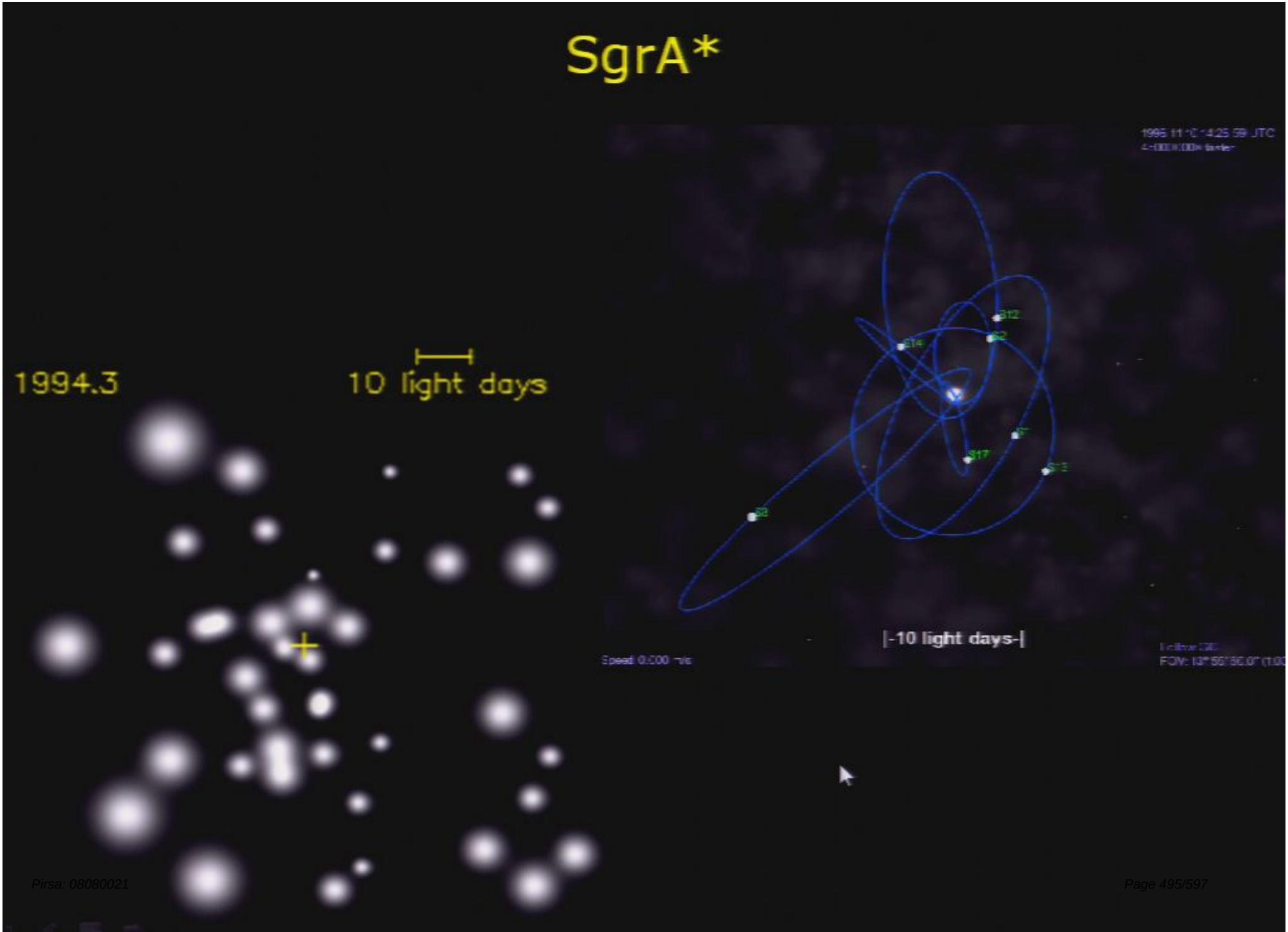
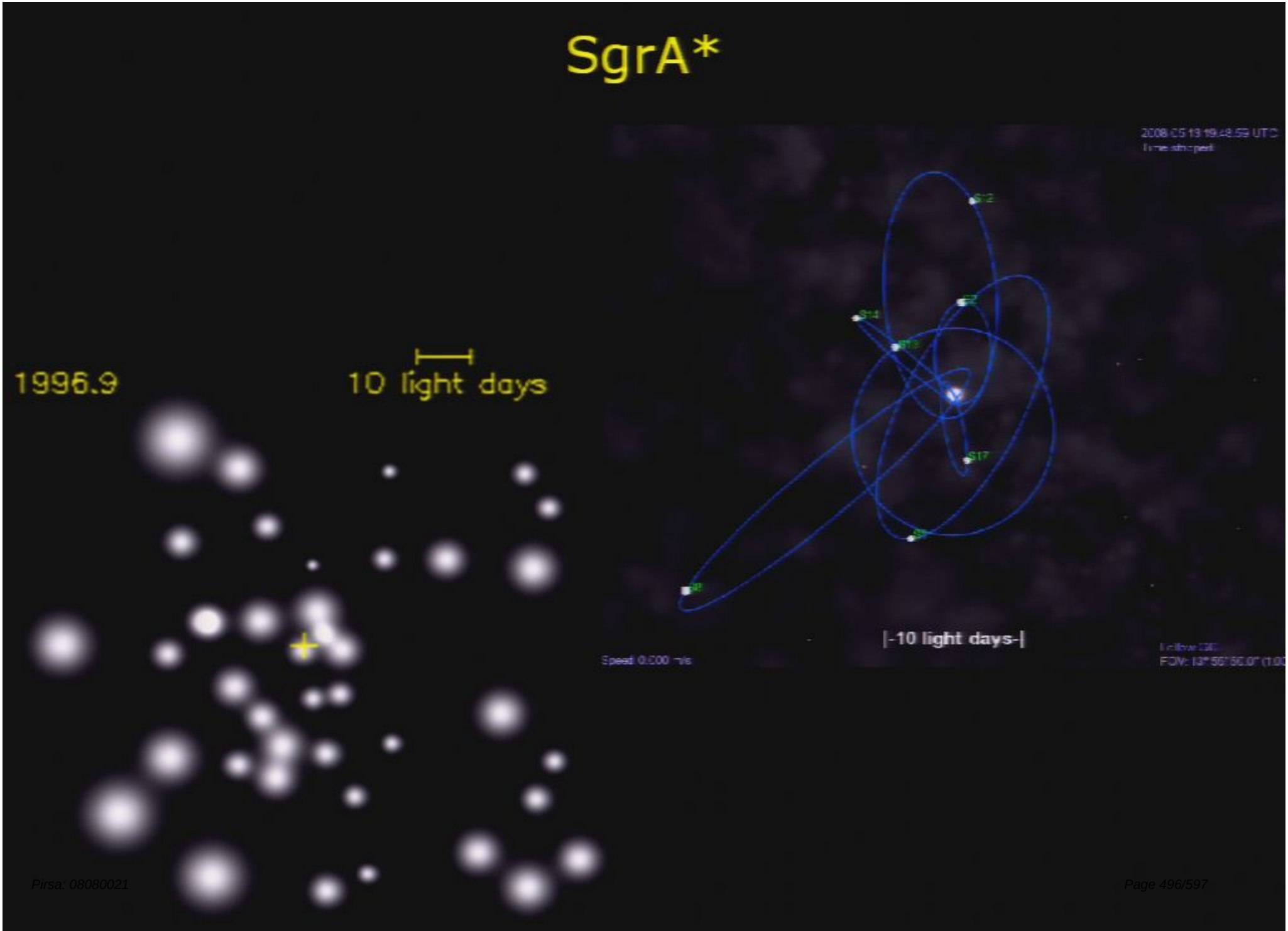
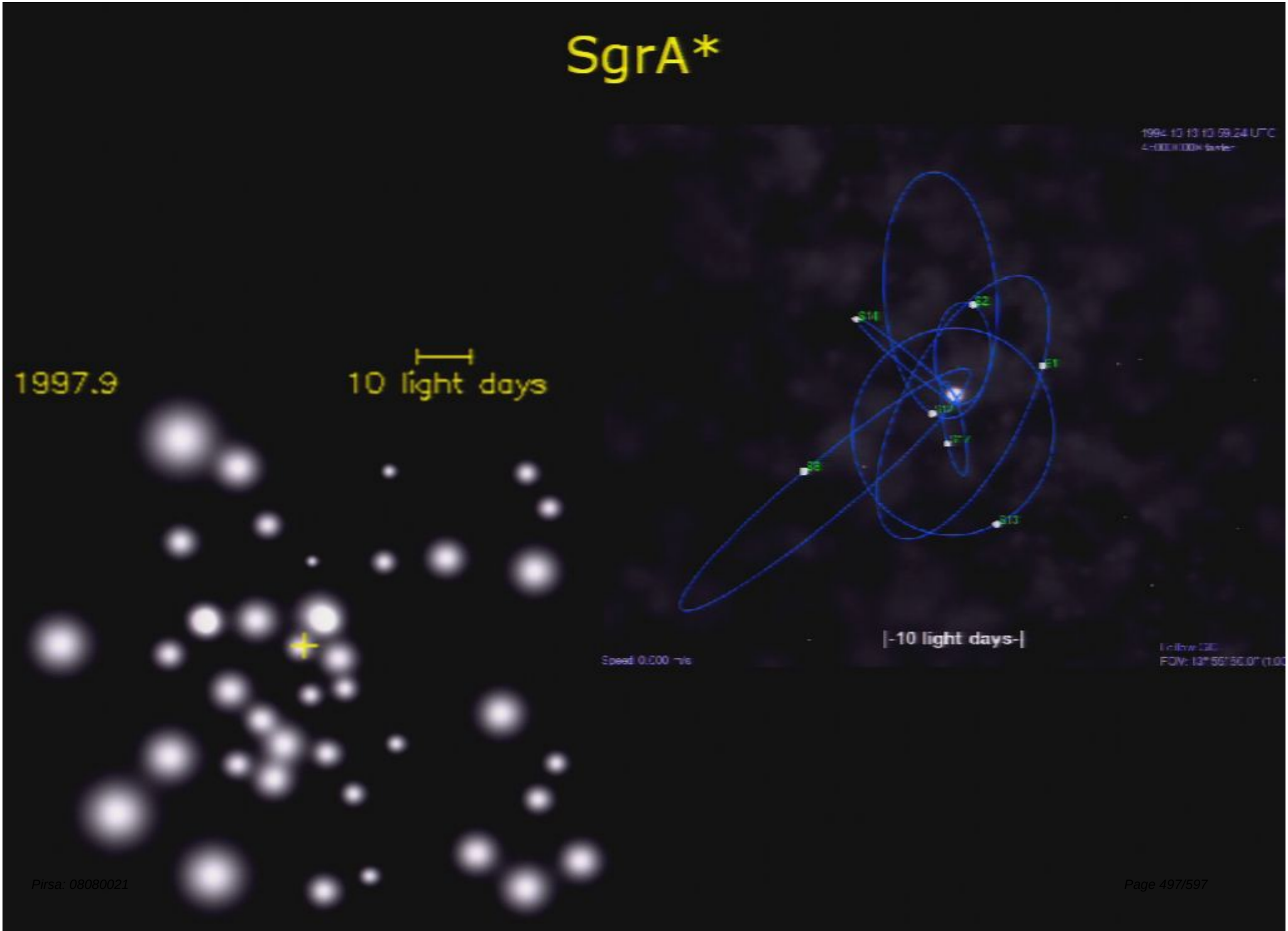
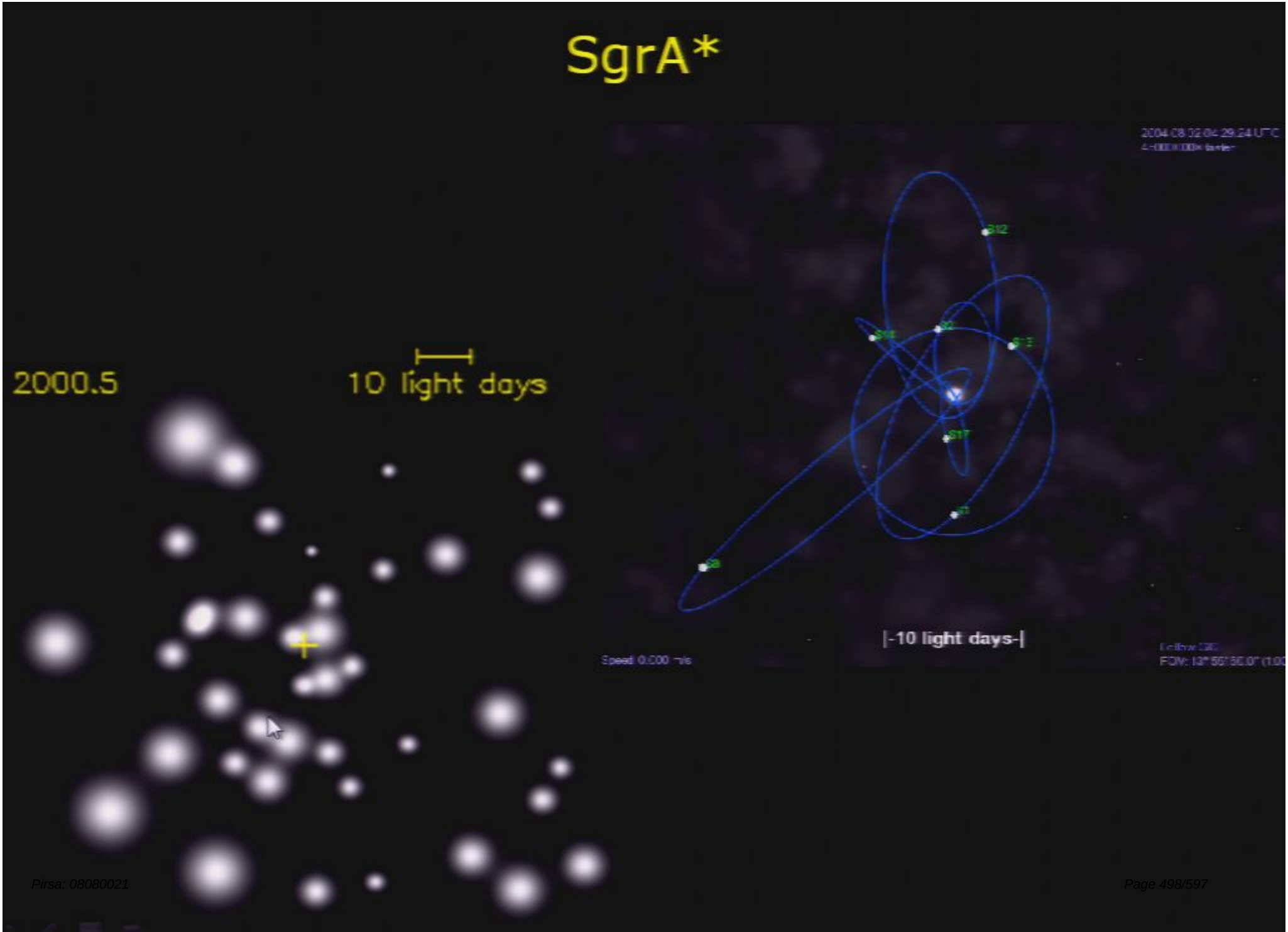
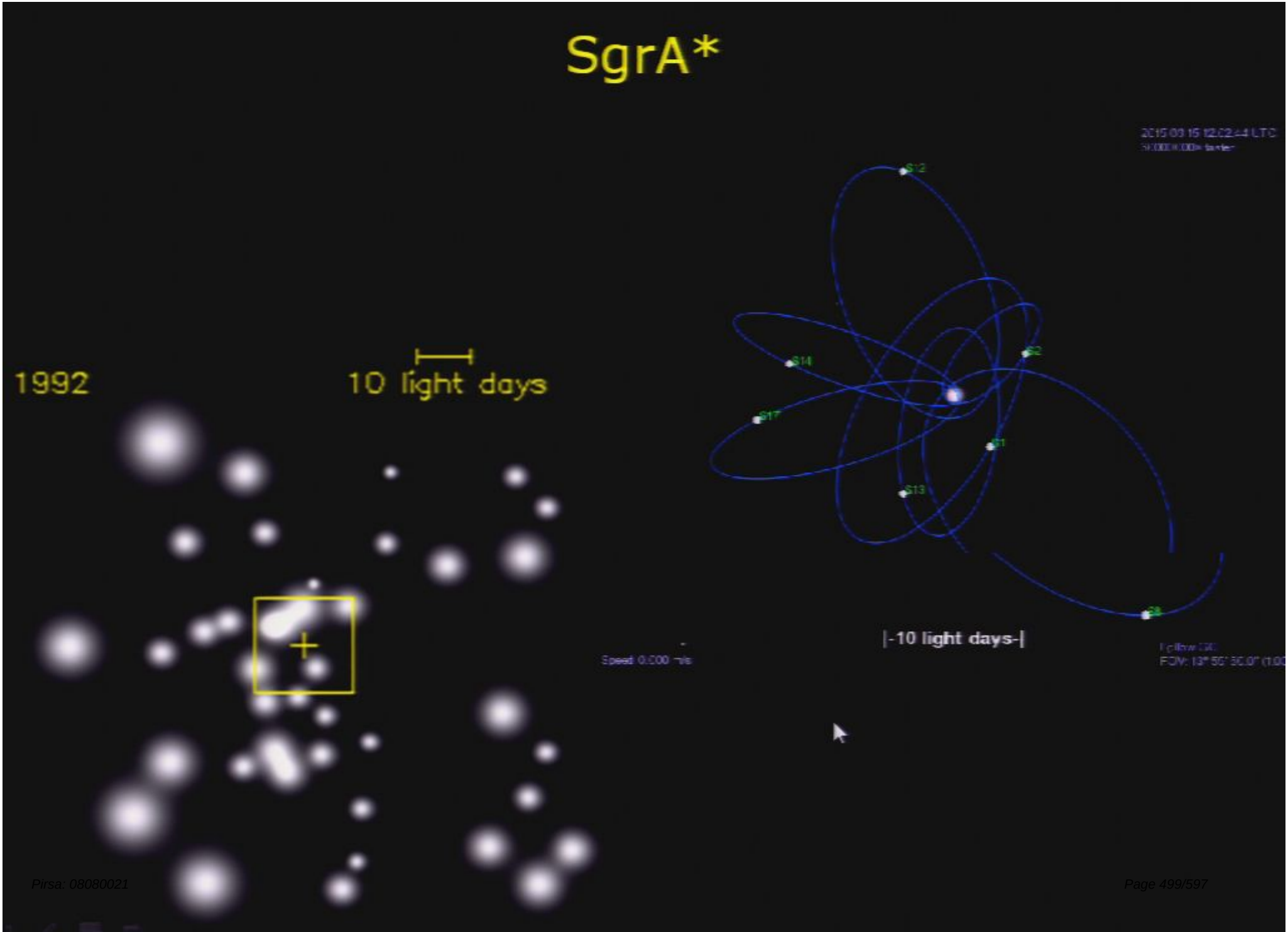
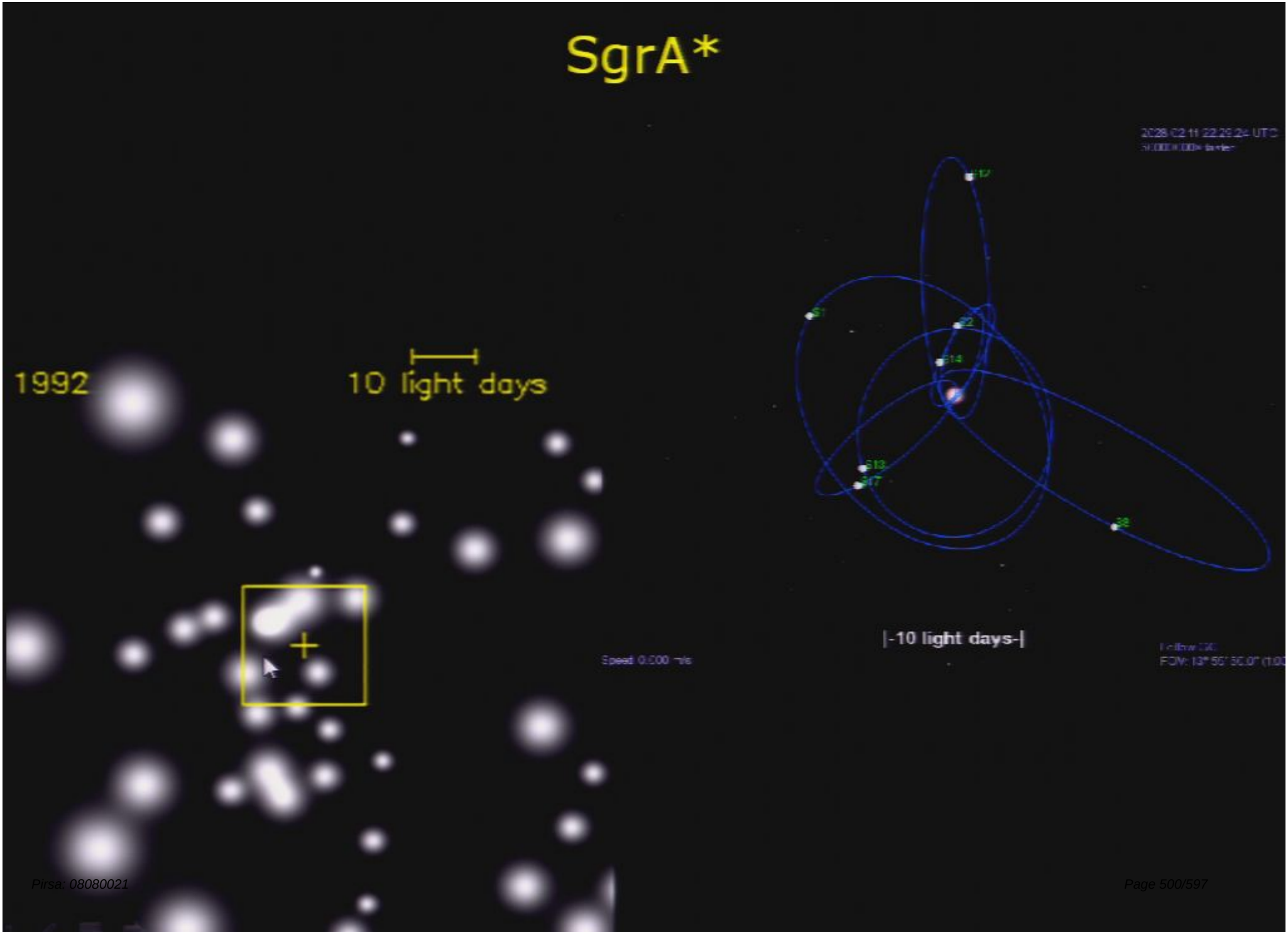

SgrA*
1994.3
10 light days
S12
S2
S14
S17
S13
S9
|-10 light days-|

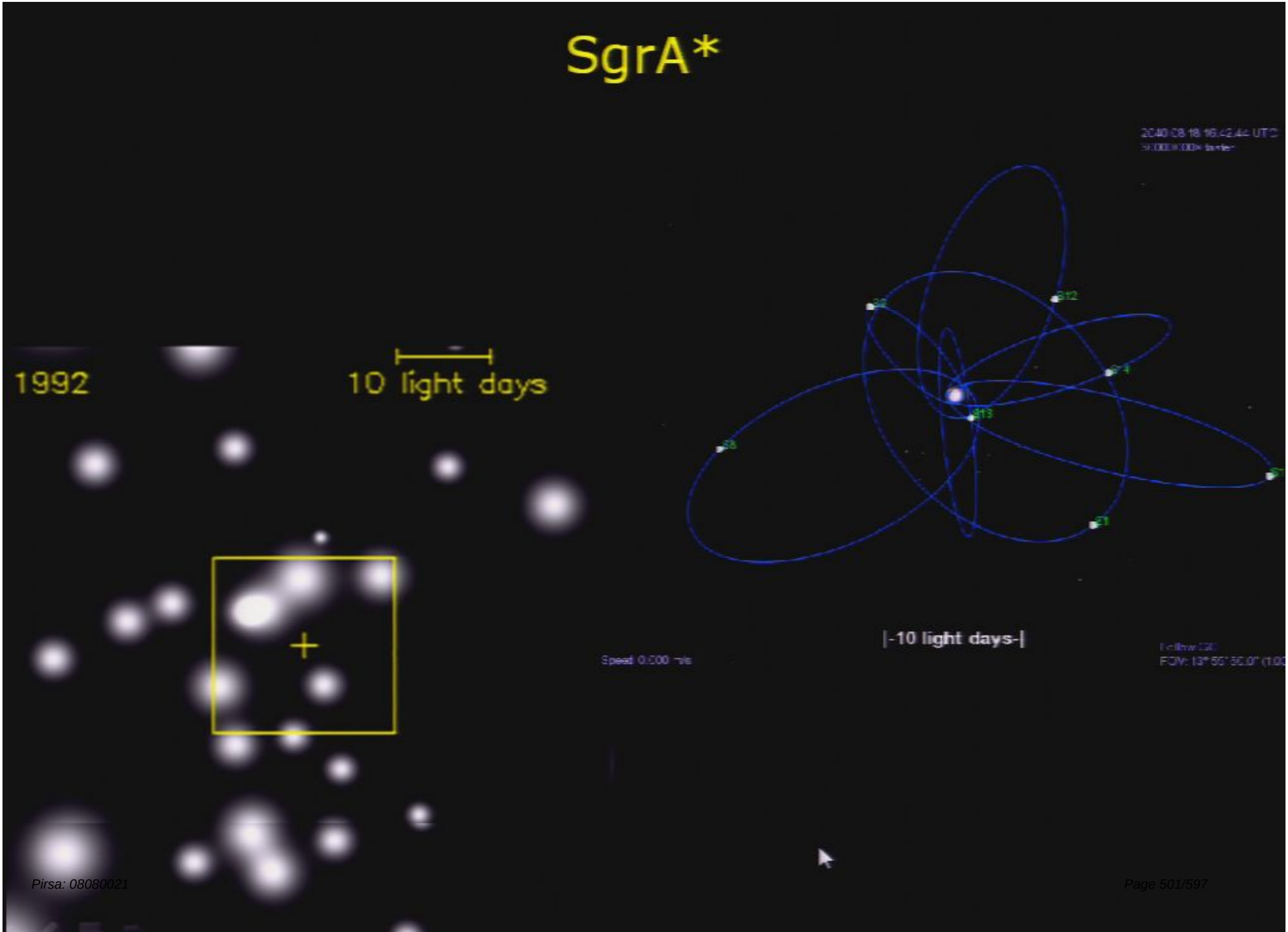

SgrA*
1996.9
10 light days
|-10 light days-|

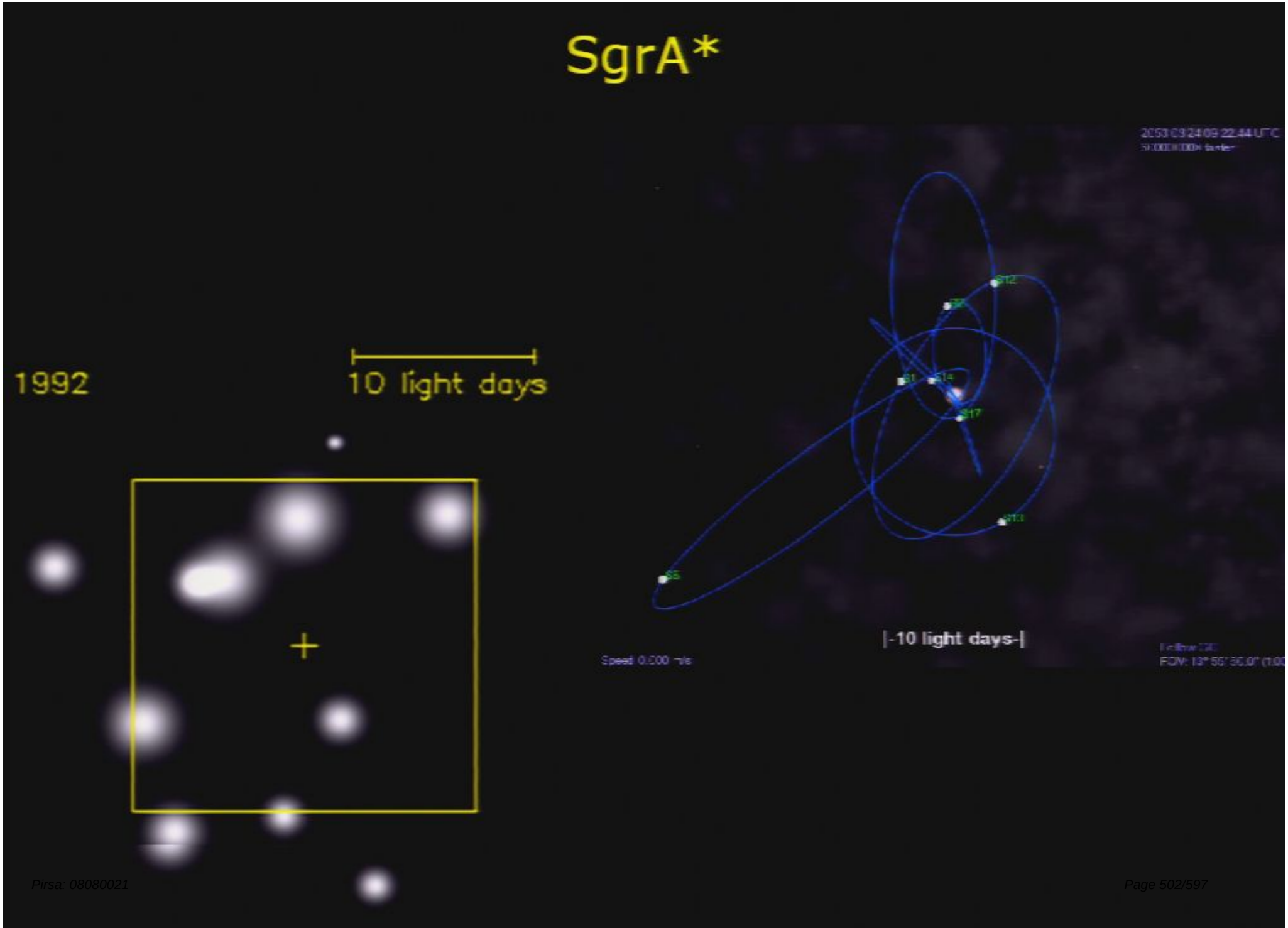

SgrA*
1997.9
10 light days
|-10 light days-|

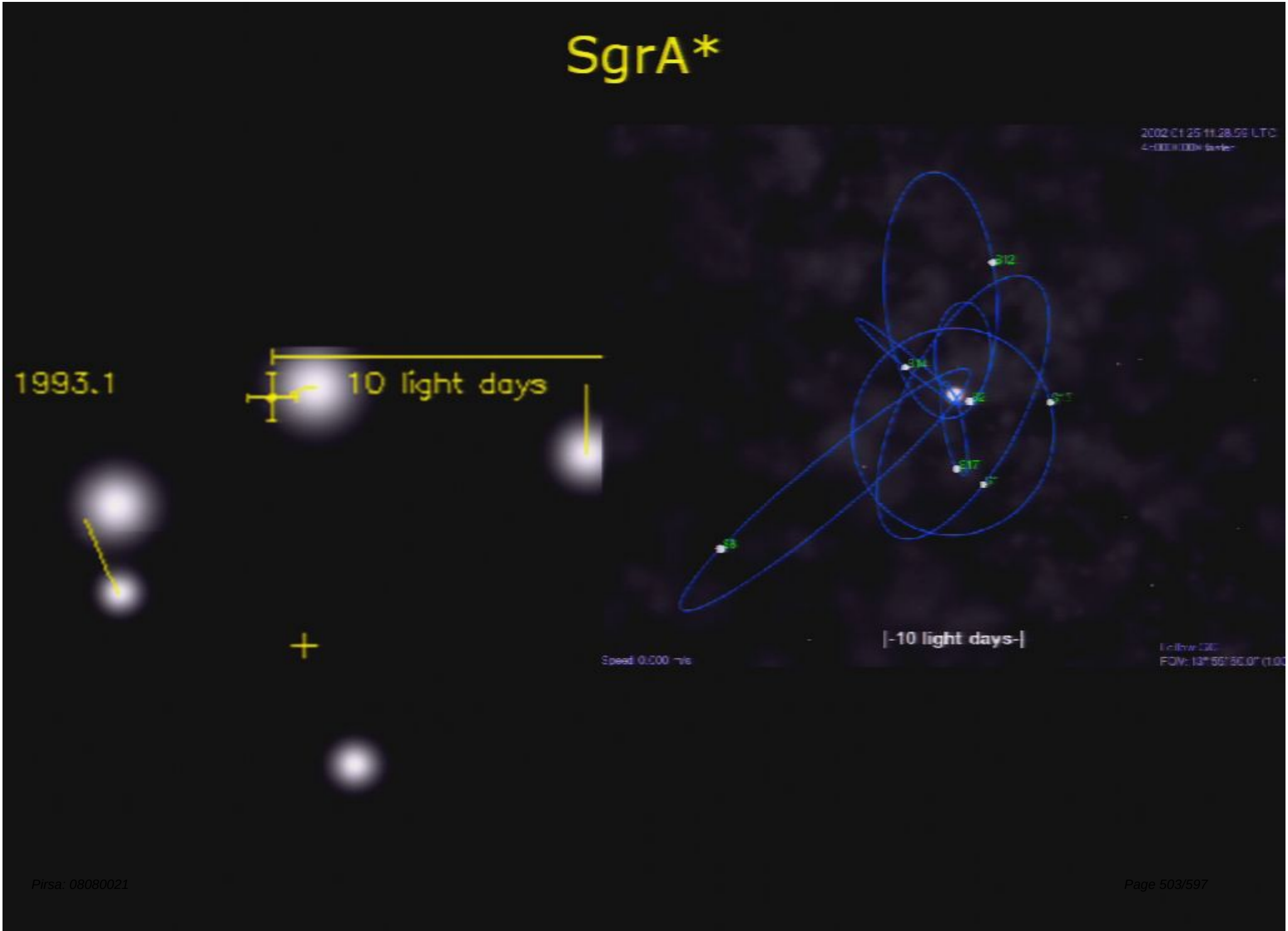

SgrA*
2000.5
10 light days
|-10 light days-|


SgrA*
1992
10 light days
S12
S14
S2
S17
S1
S13
S9
|-10 light days-|


SgrA*
1992
10 light days
S2
S14
S13
S17
S38
|-10 light days-|
Speed 0.000 c/s

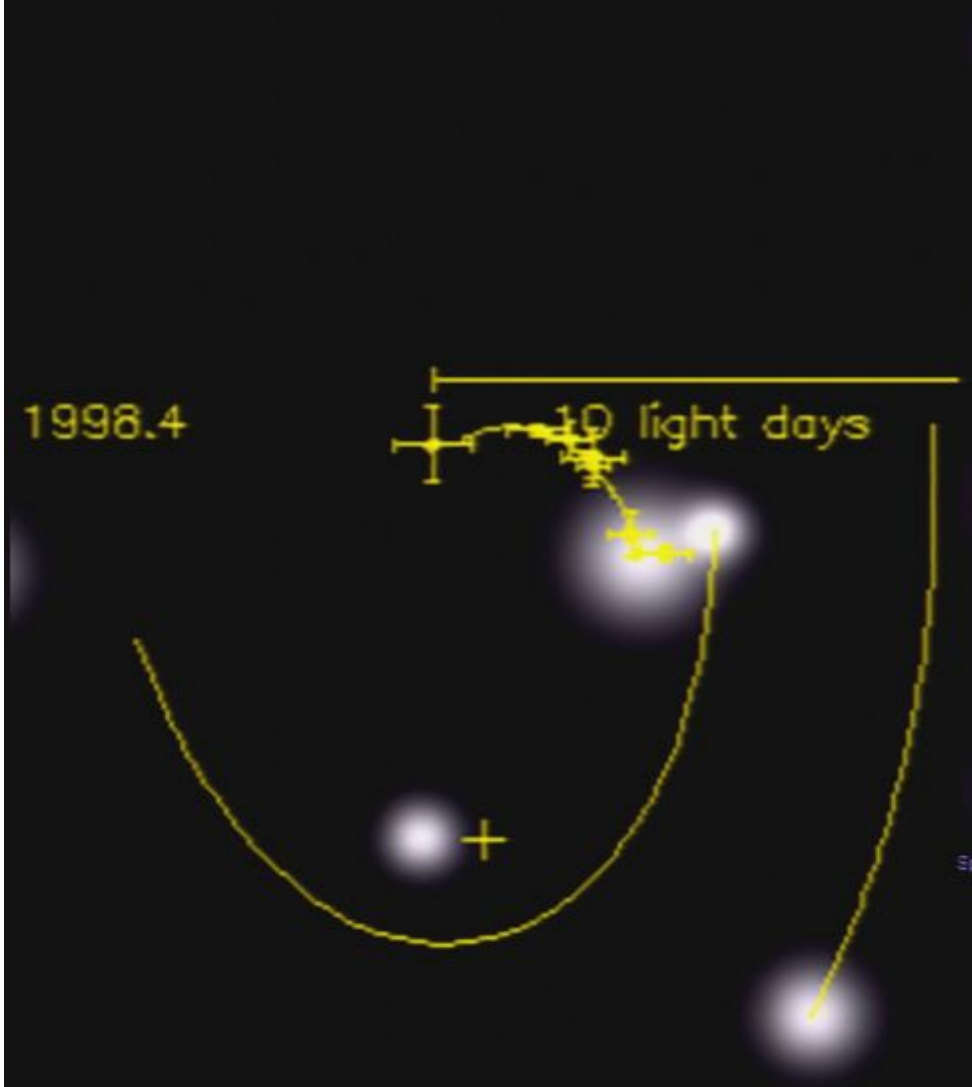

SgrA*
1992
10 light days
|-10 light days-|

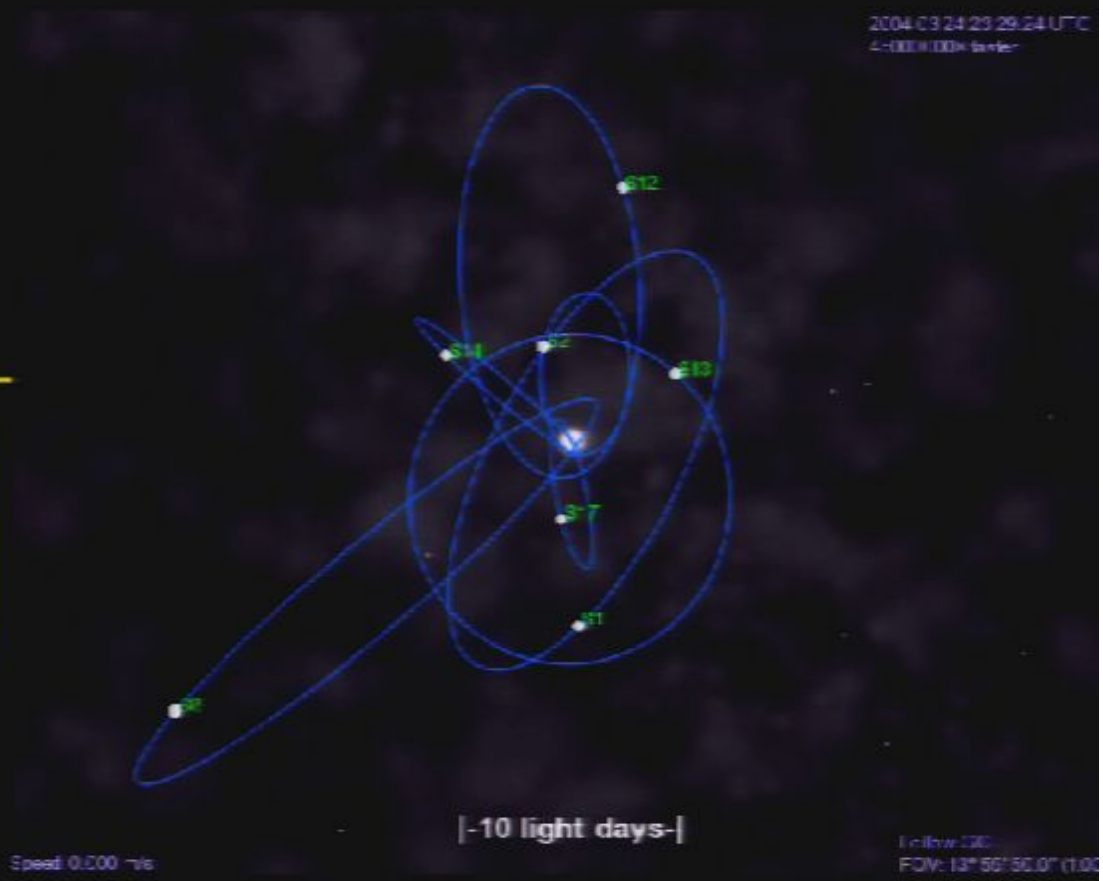

SgrA*
1992
10 light days
|-10 light days-|

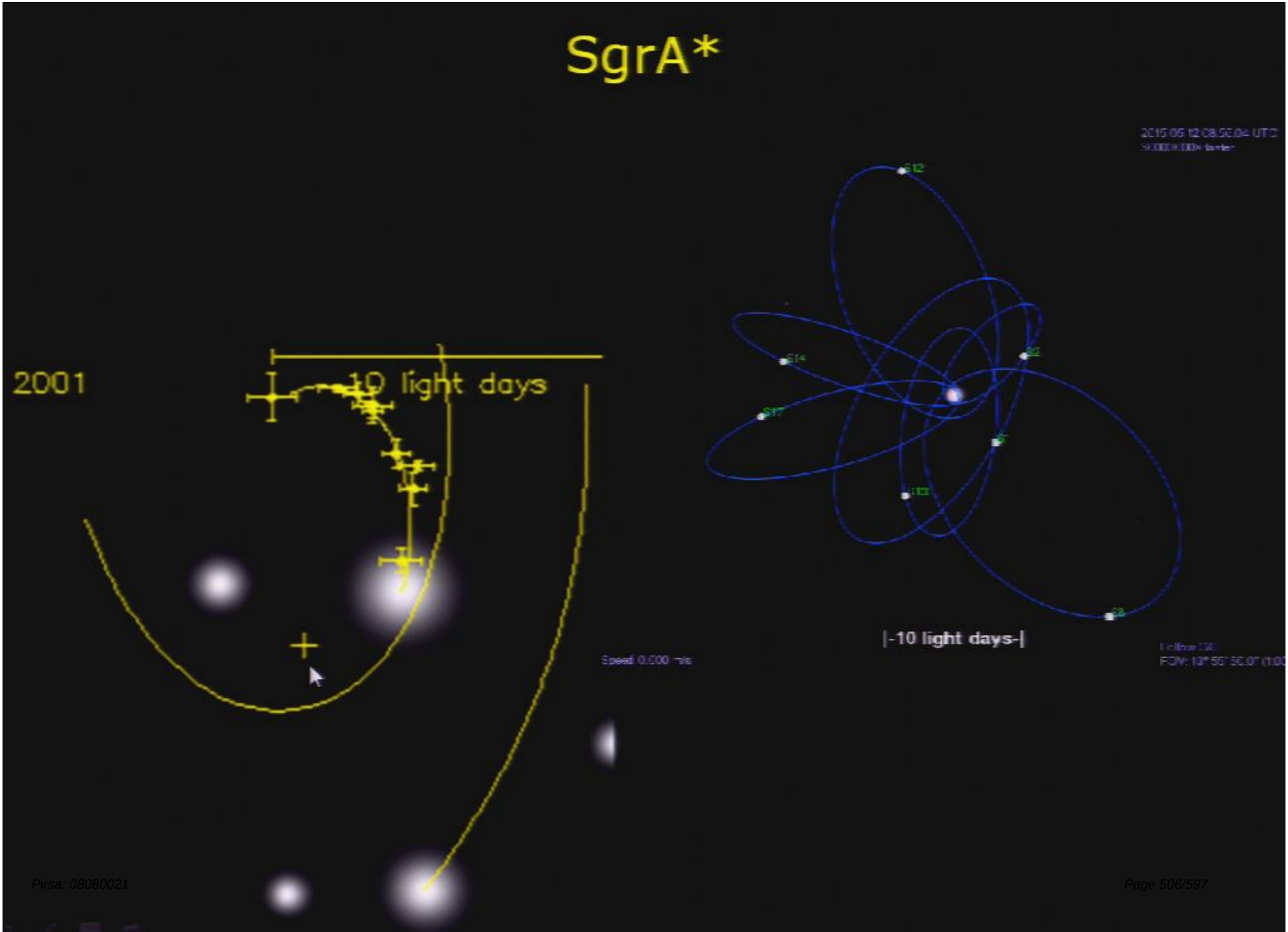

SgrA*
1993.1
10 light days
S12
S14
S2
S17
S8
|-10 light days-|

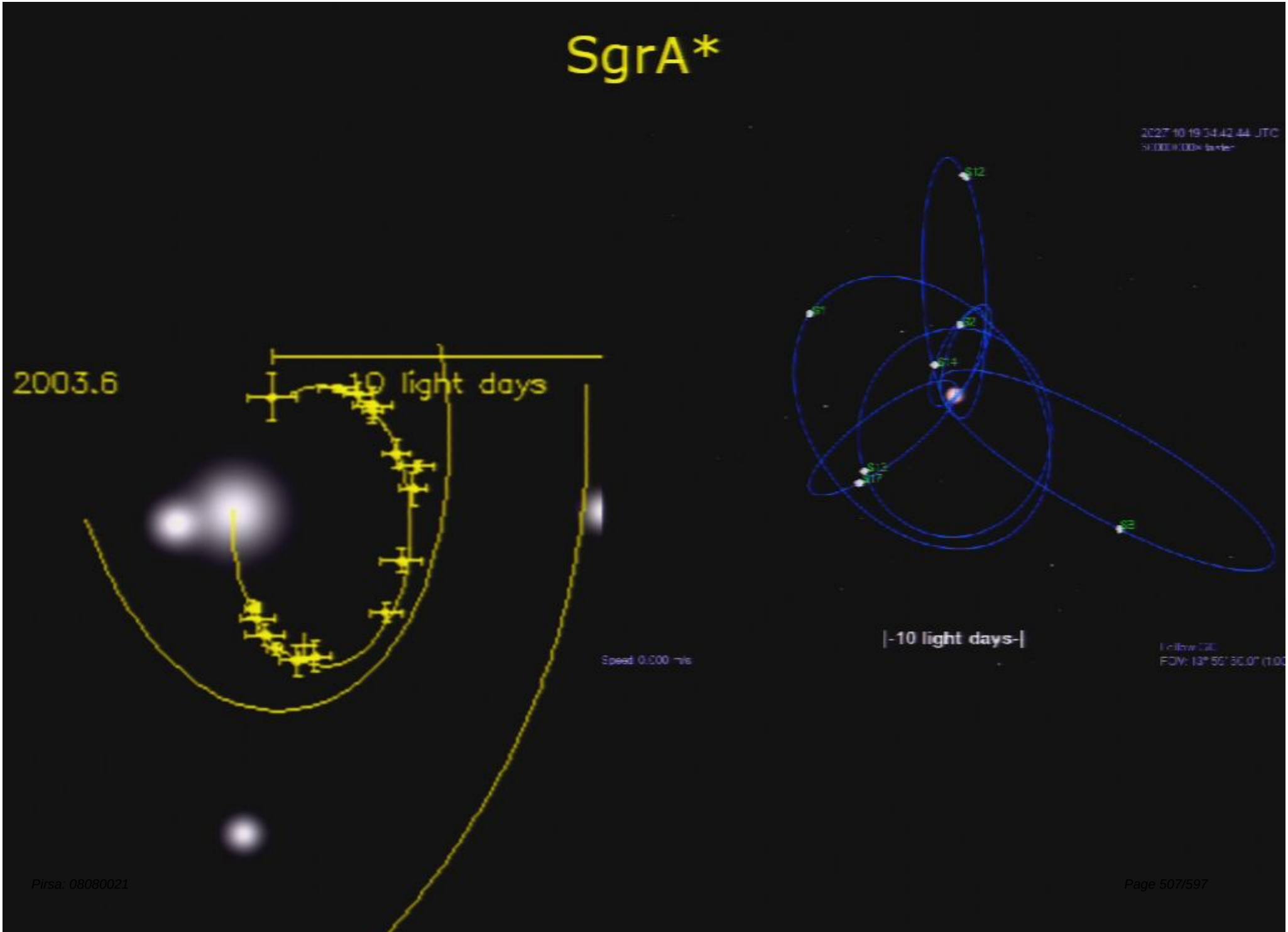
SgrA*

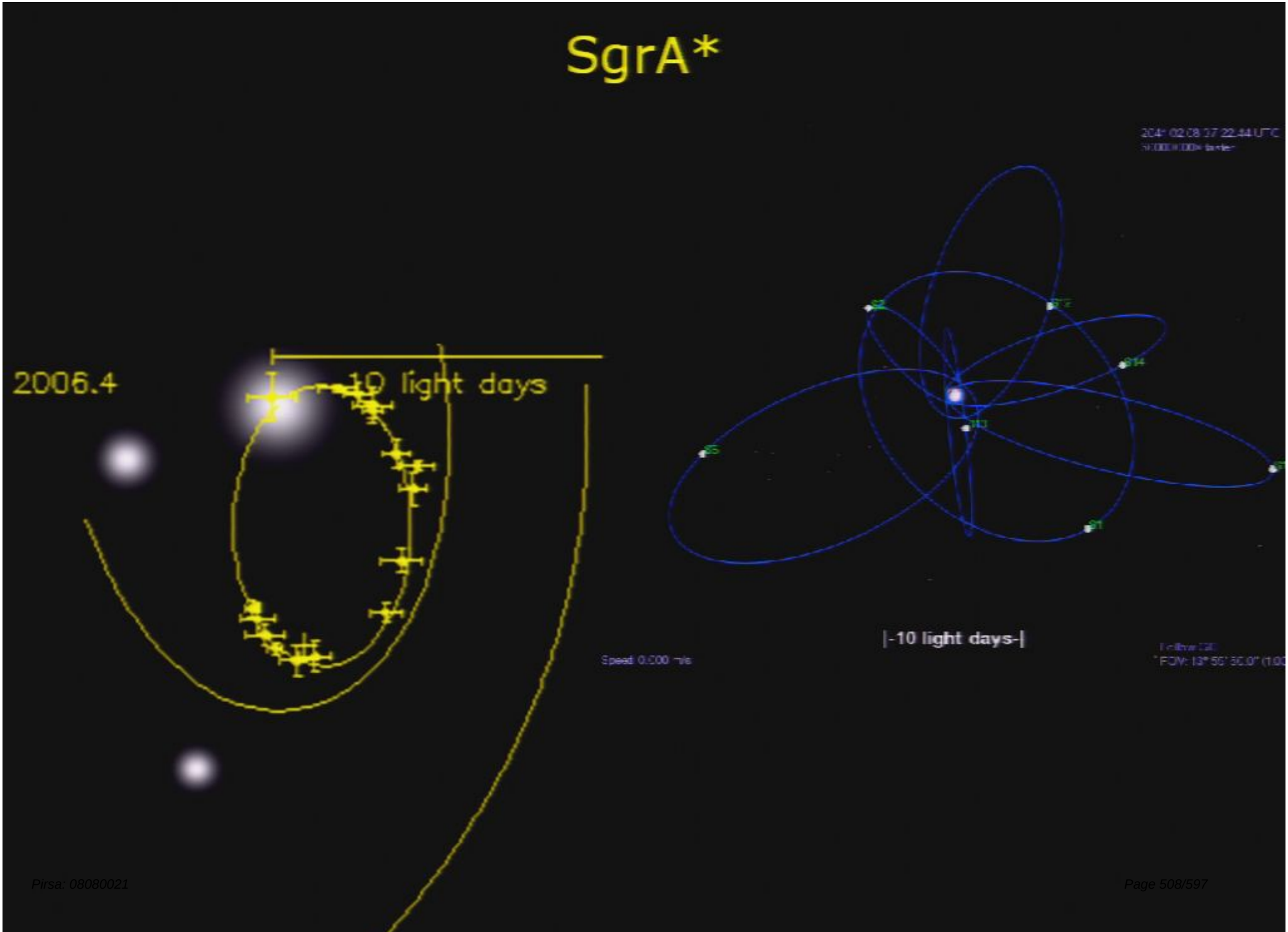
SgrA*



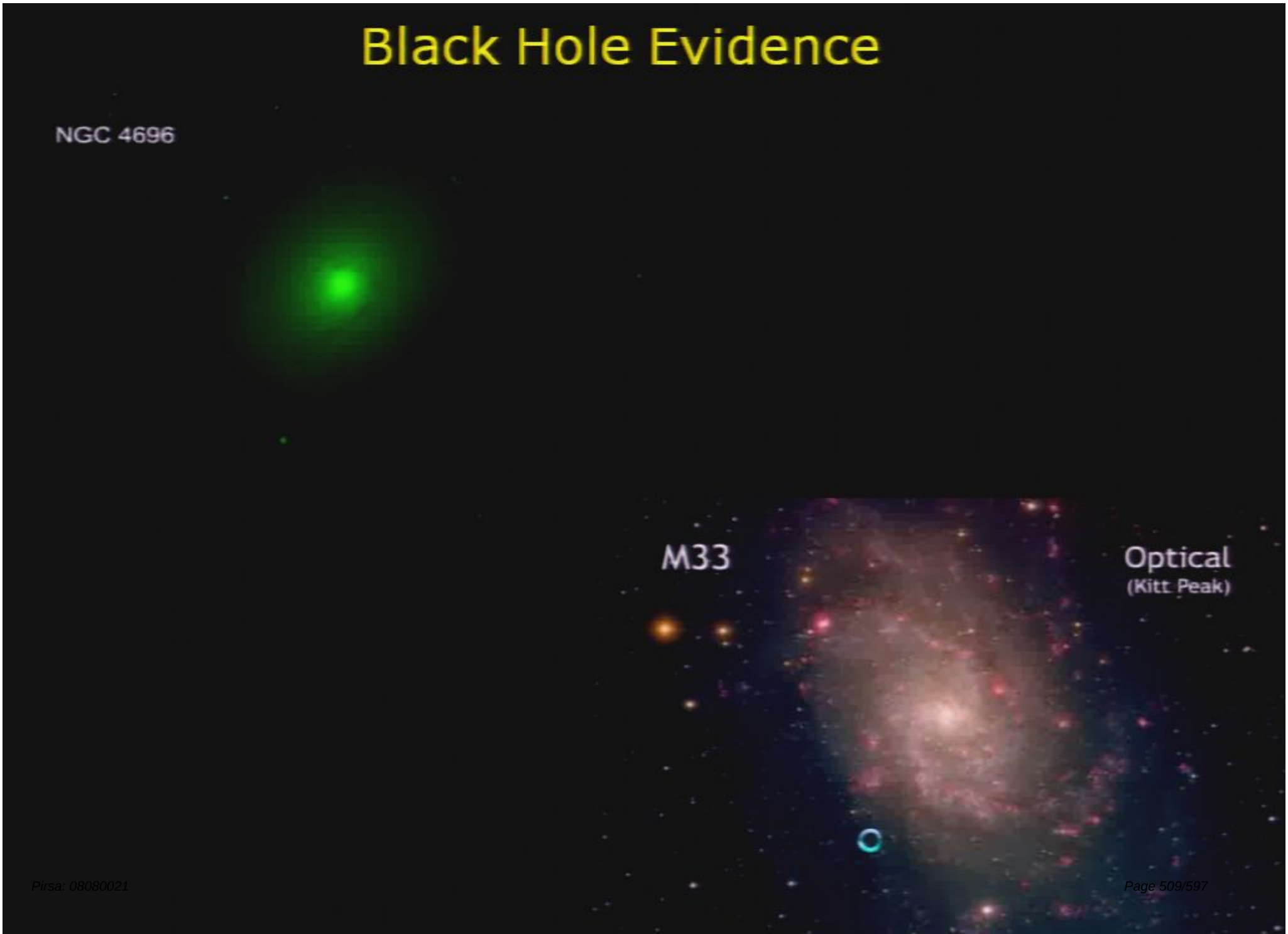



SgrA*
2001
10 light days
|-10 light days-|


SgrA*
2003.6
10 light days
|-10 light days-|

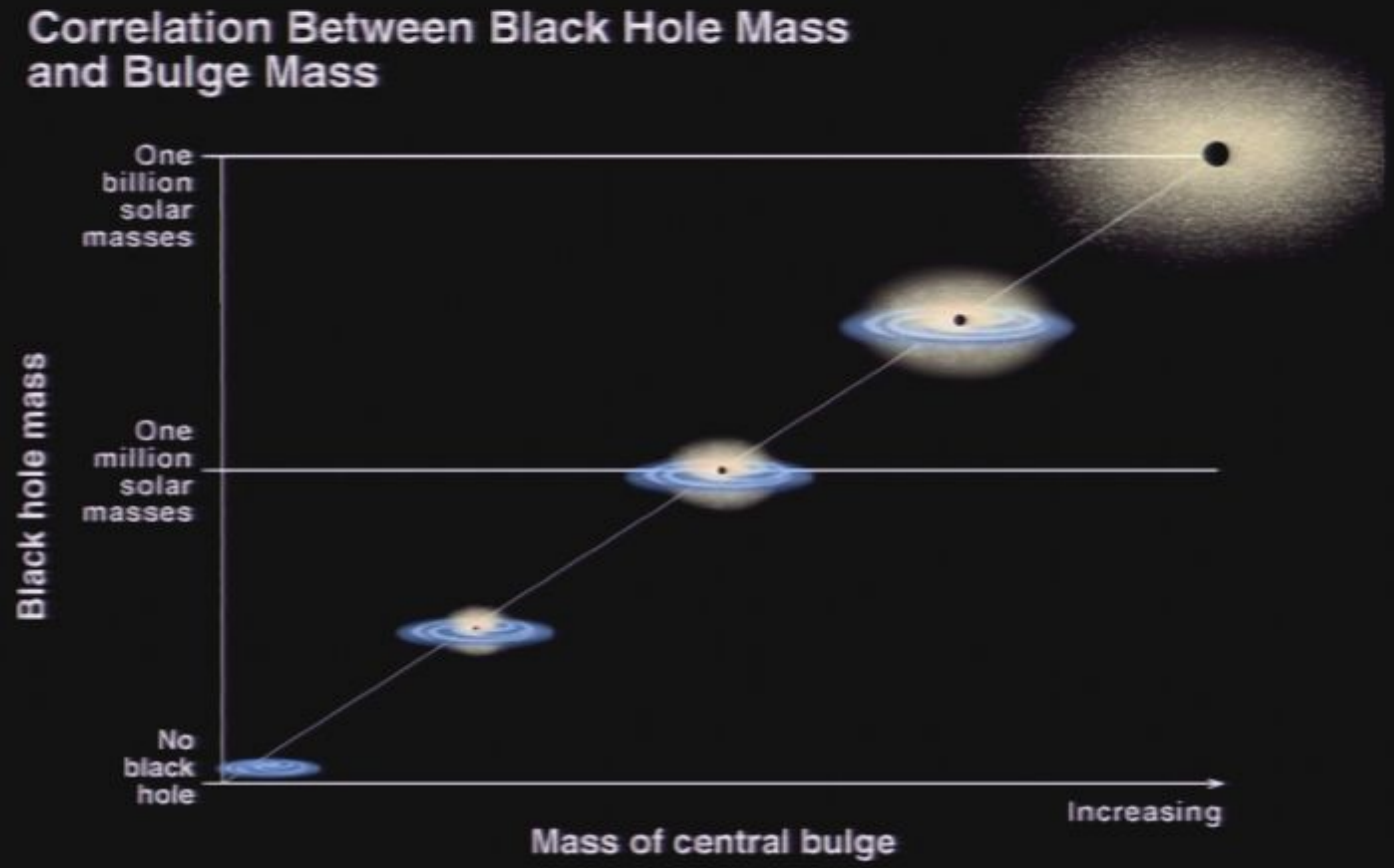

SgrA*
2006.4
10 light days
|-10 light days-|

Black Hole Evidence



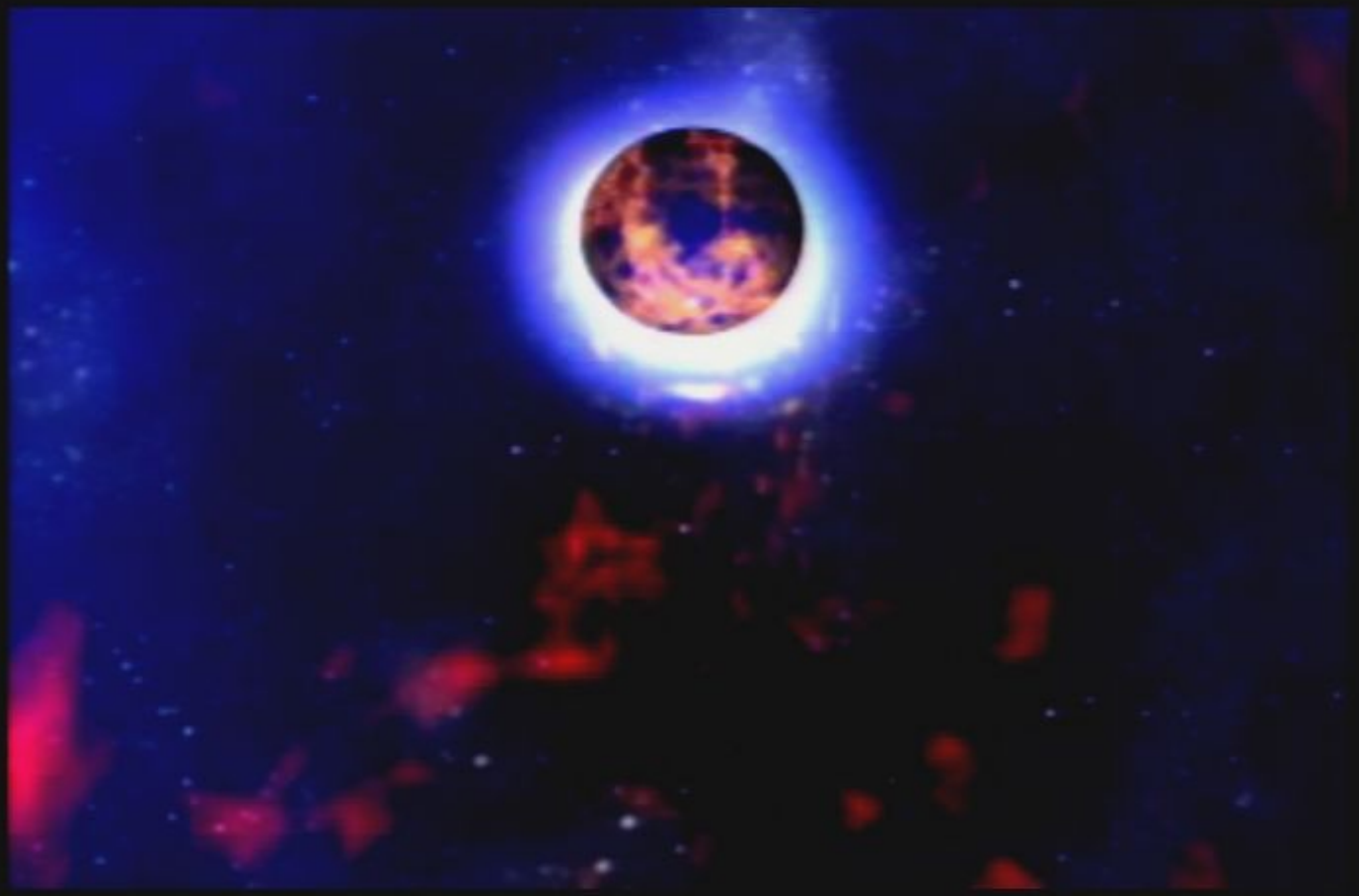
Black Hole Evidence

Speed of Gas and Black Holes



- It discovered a correlation between a Black Hole's mass and the average speed of the stars in the galaxy's central bulge.
- The faster the stars are moving, the larger the black hole.
- The central Black Hole comprises 0.5% of mass of stars in the spheroid of the galaxy. (Magorrian Relation)
- Previously, black holes were seen as the endpoints of evolution, the final resting state of most or all of the matter in the universe. Now we believe black holes also play a critical role in the birth of galaxies."

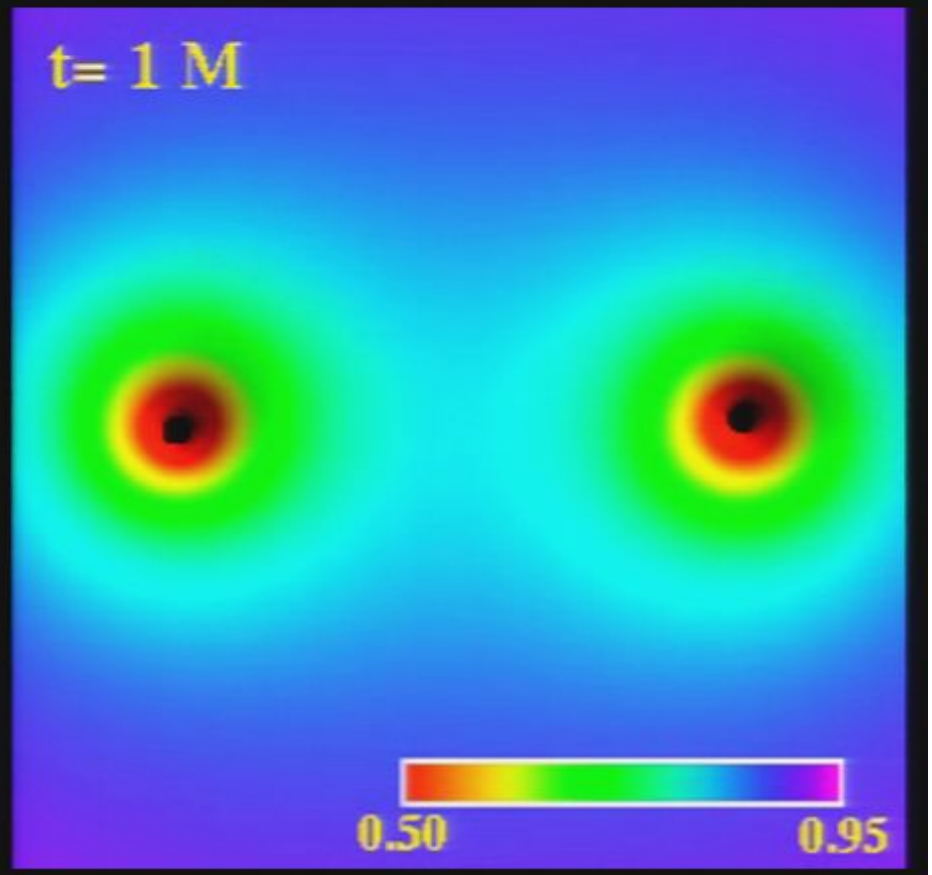
When Black Holes Collide



The Best Simulation

For over 20 years cosmologist have being trying to simulate colliding black holes.

In 2005 at Banff, Frans Pretorius was able to provide an accurate simulation of only 5 orbits of two colliding black holes



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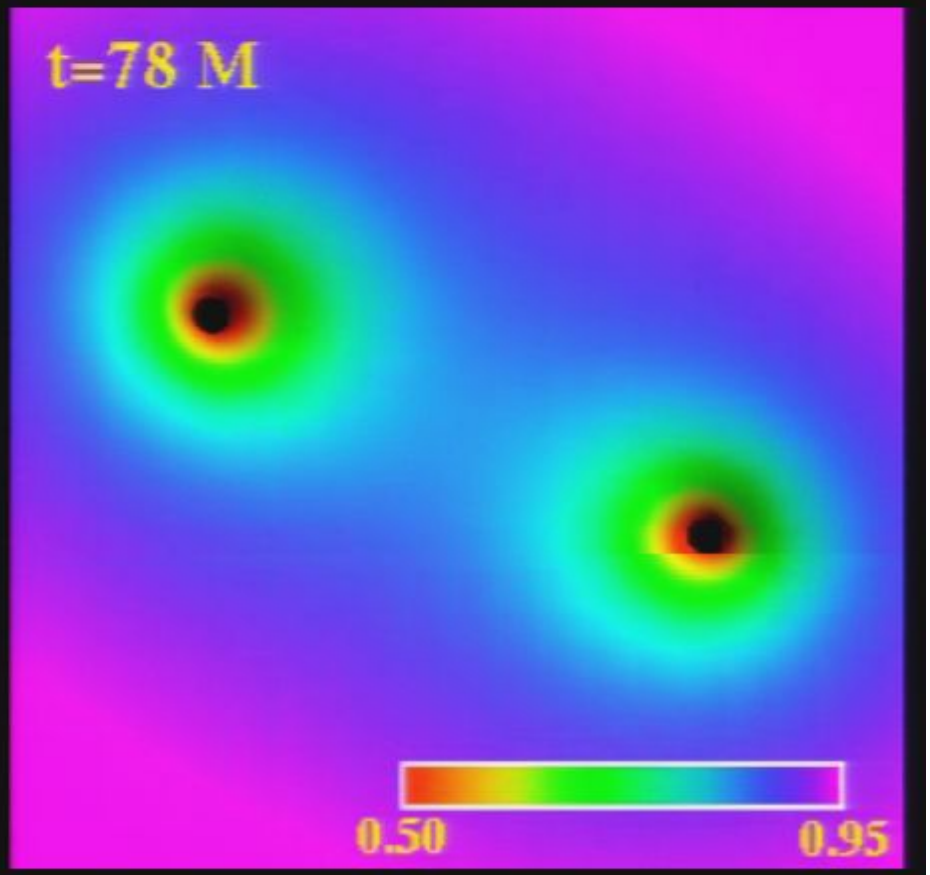

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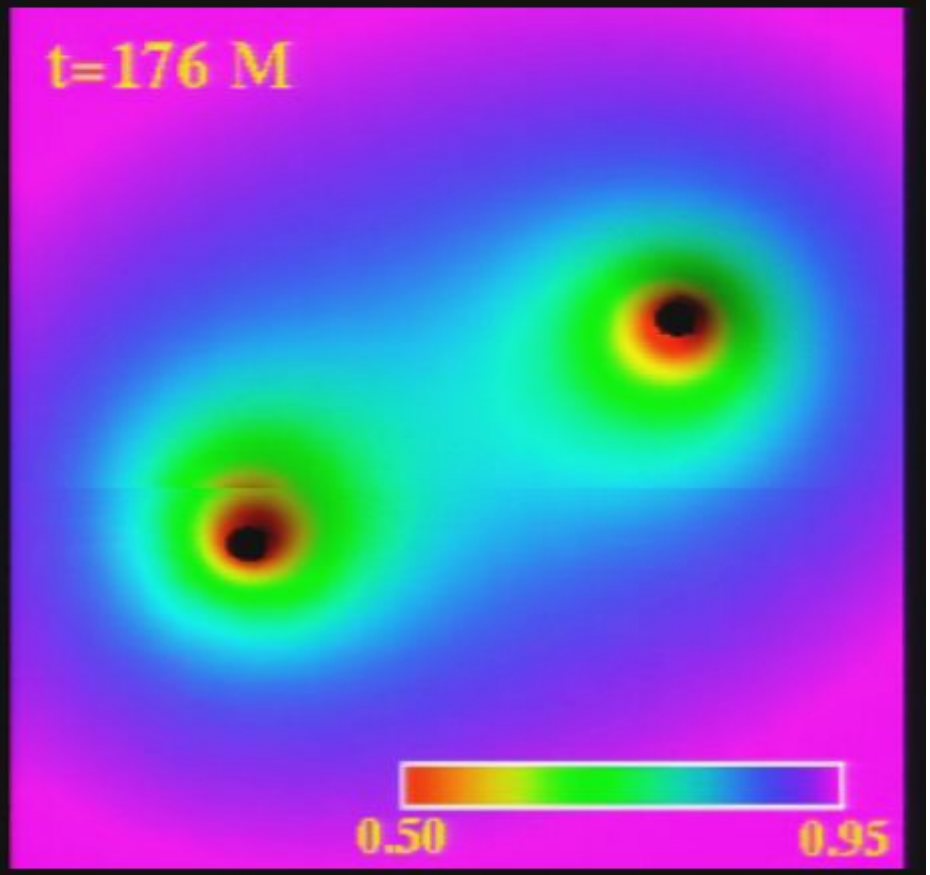

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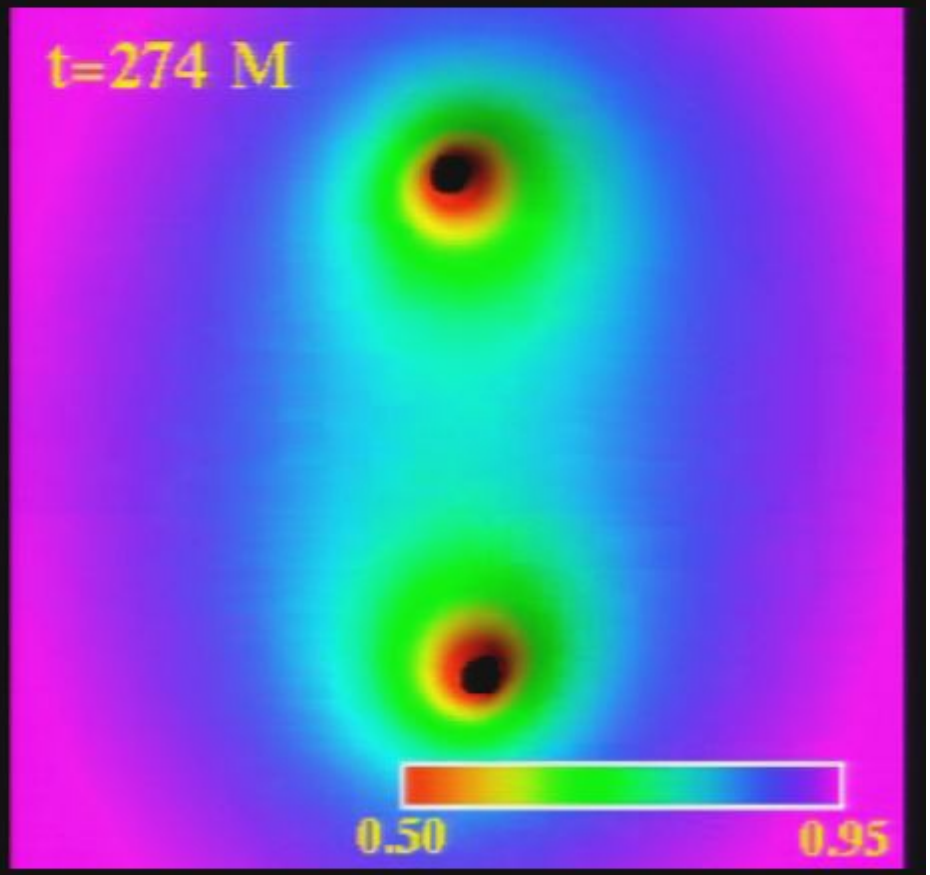

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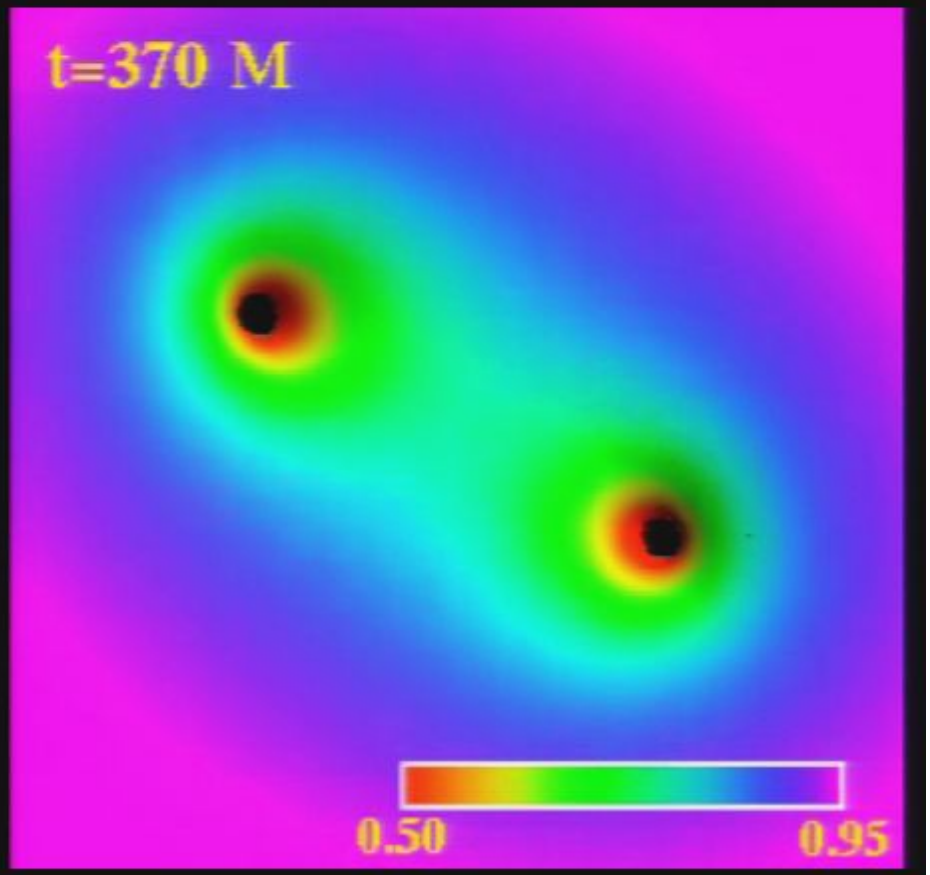

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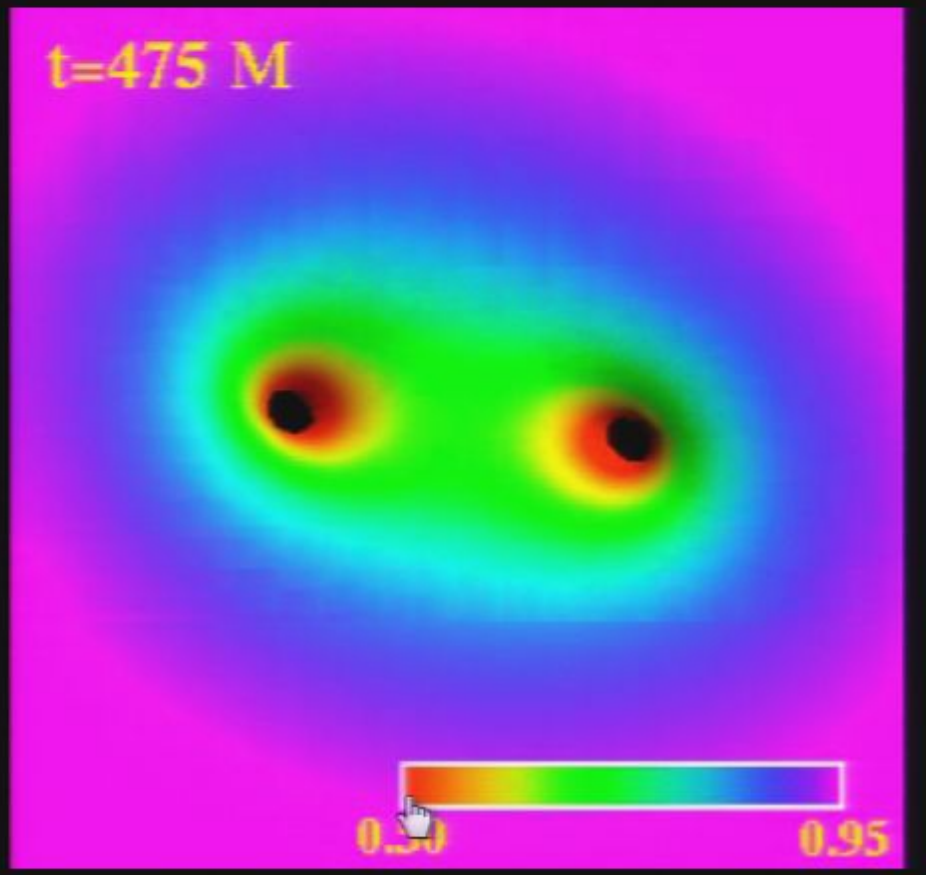

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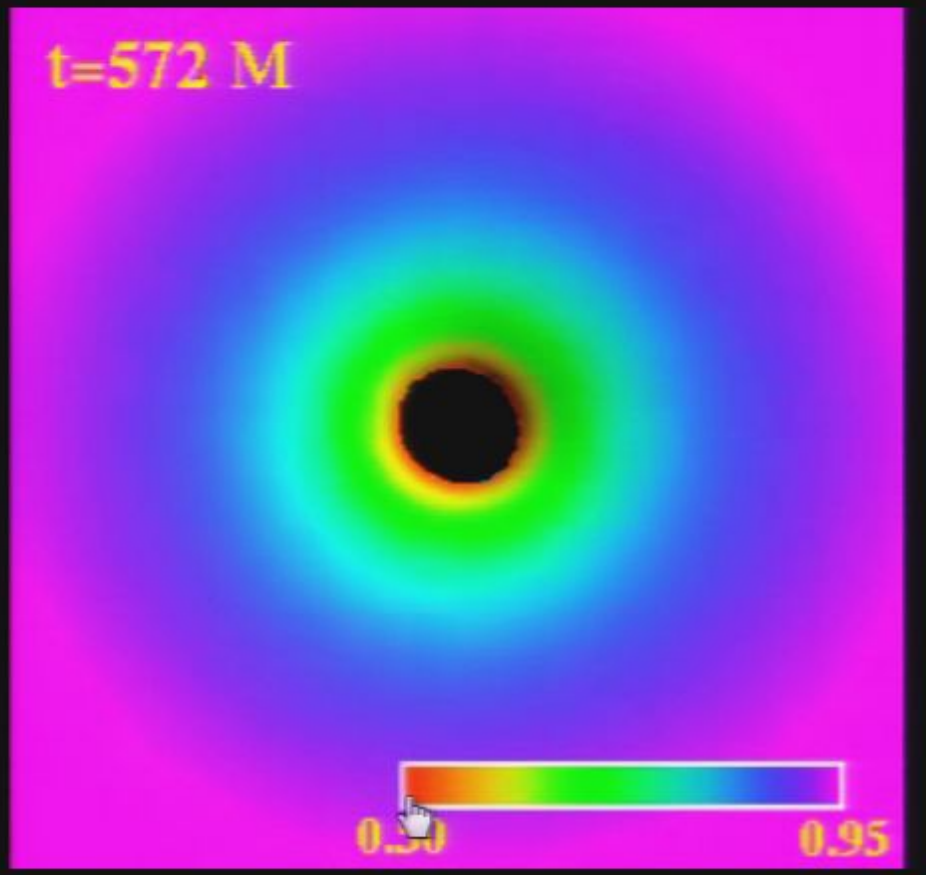
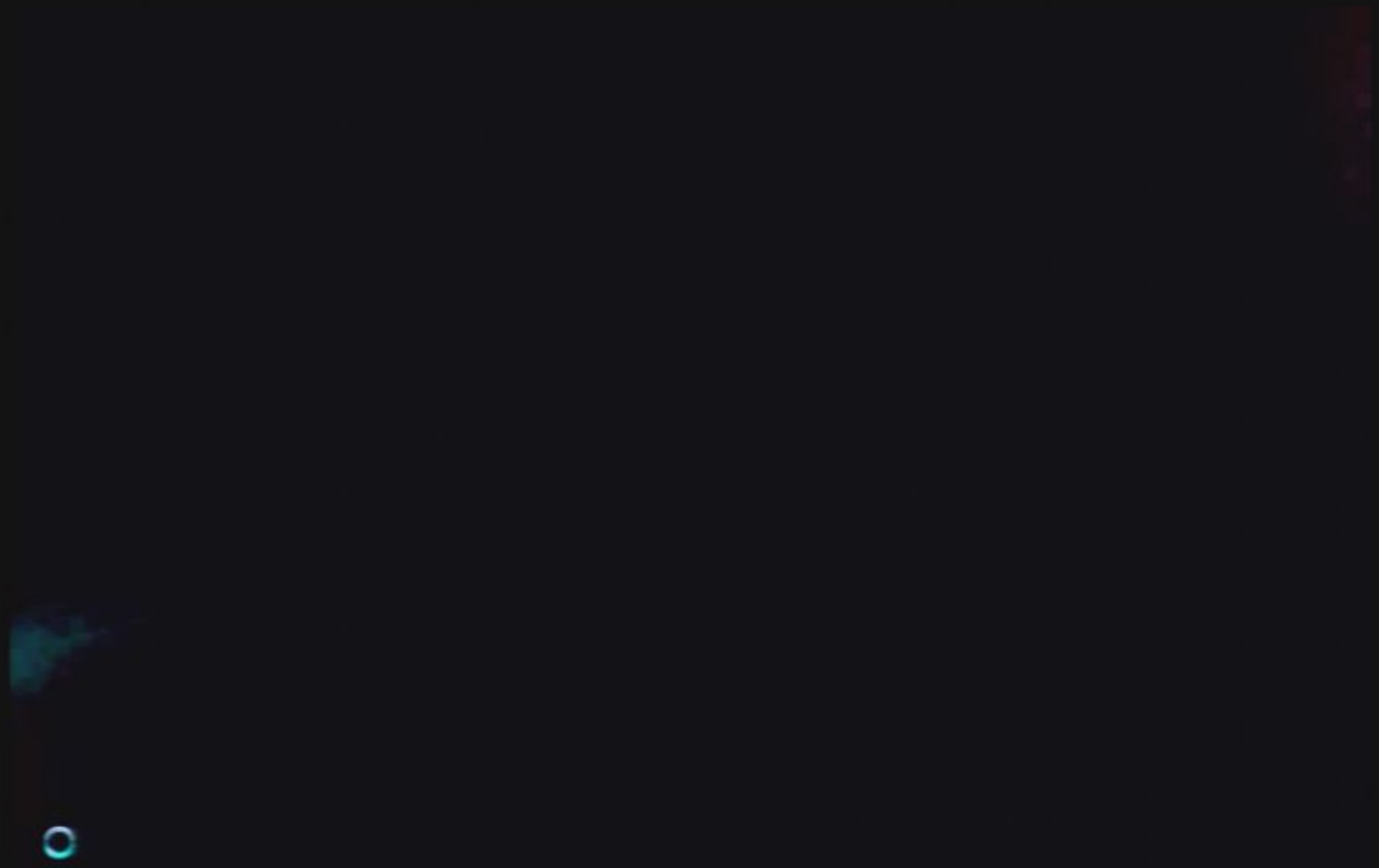
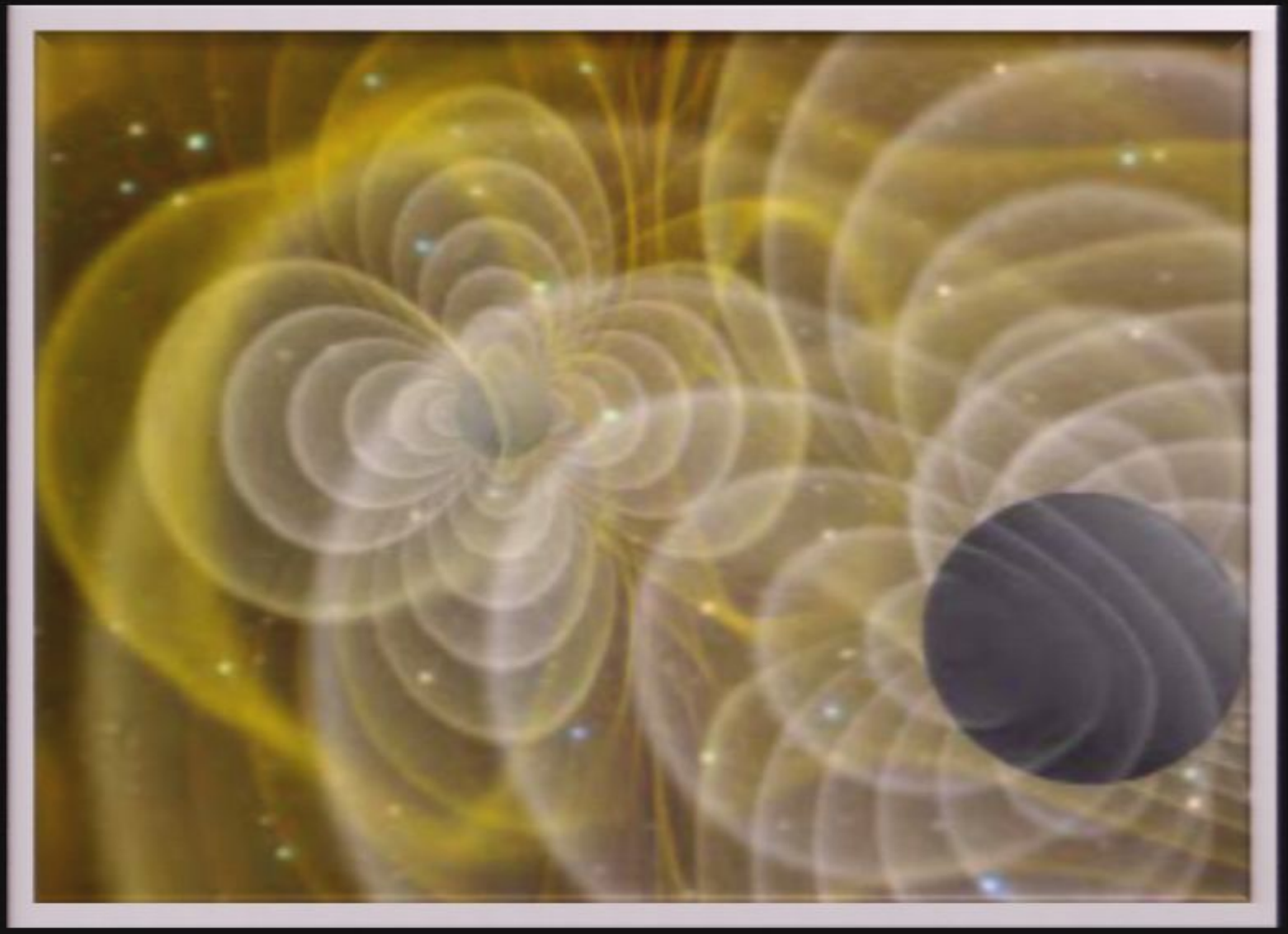


Frame Dragging and Gravitational Waves



Frame Dragging and Gravitational Waves

Nasa's Latest Animation



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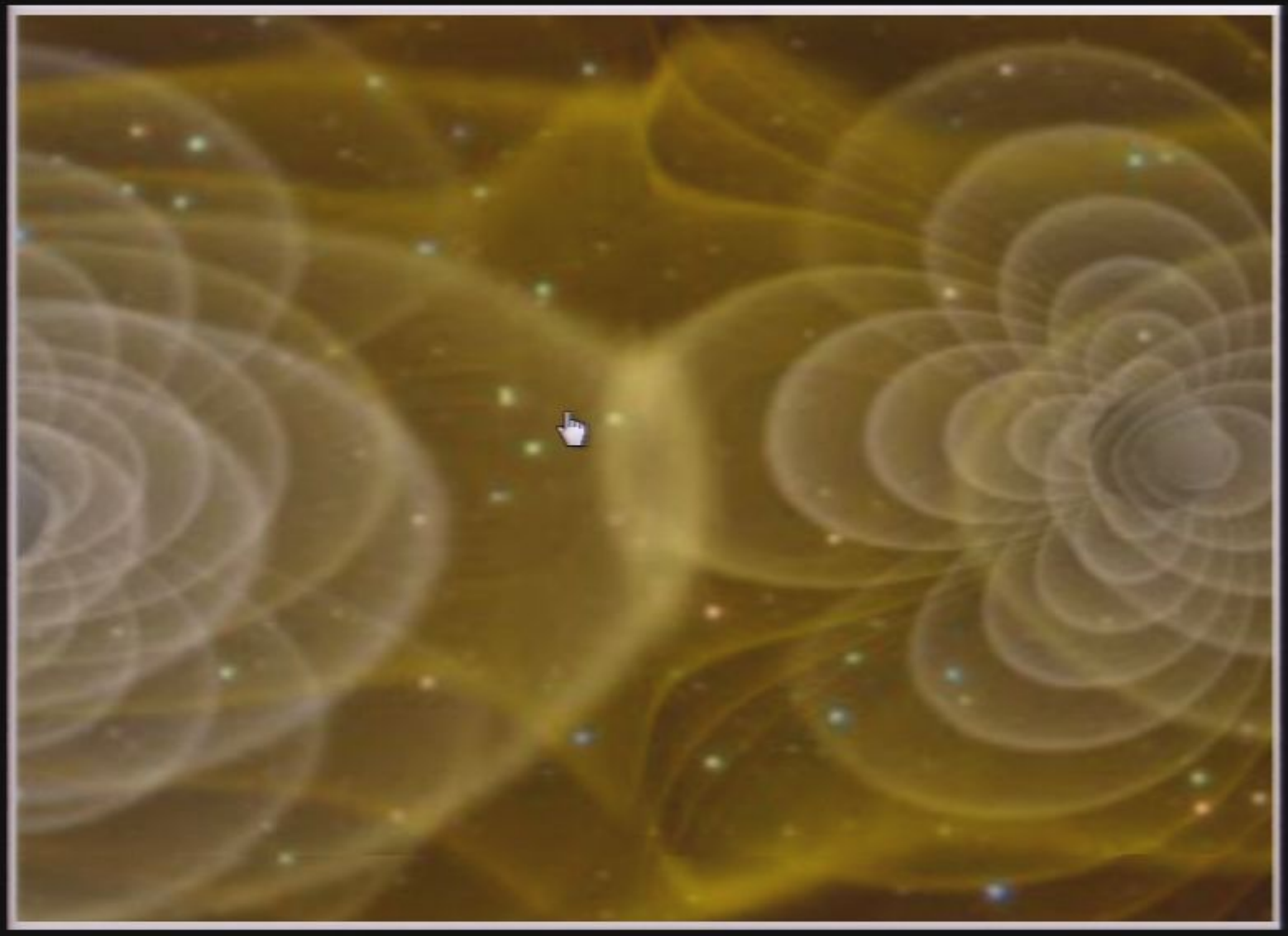

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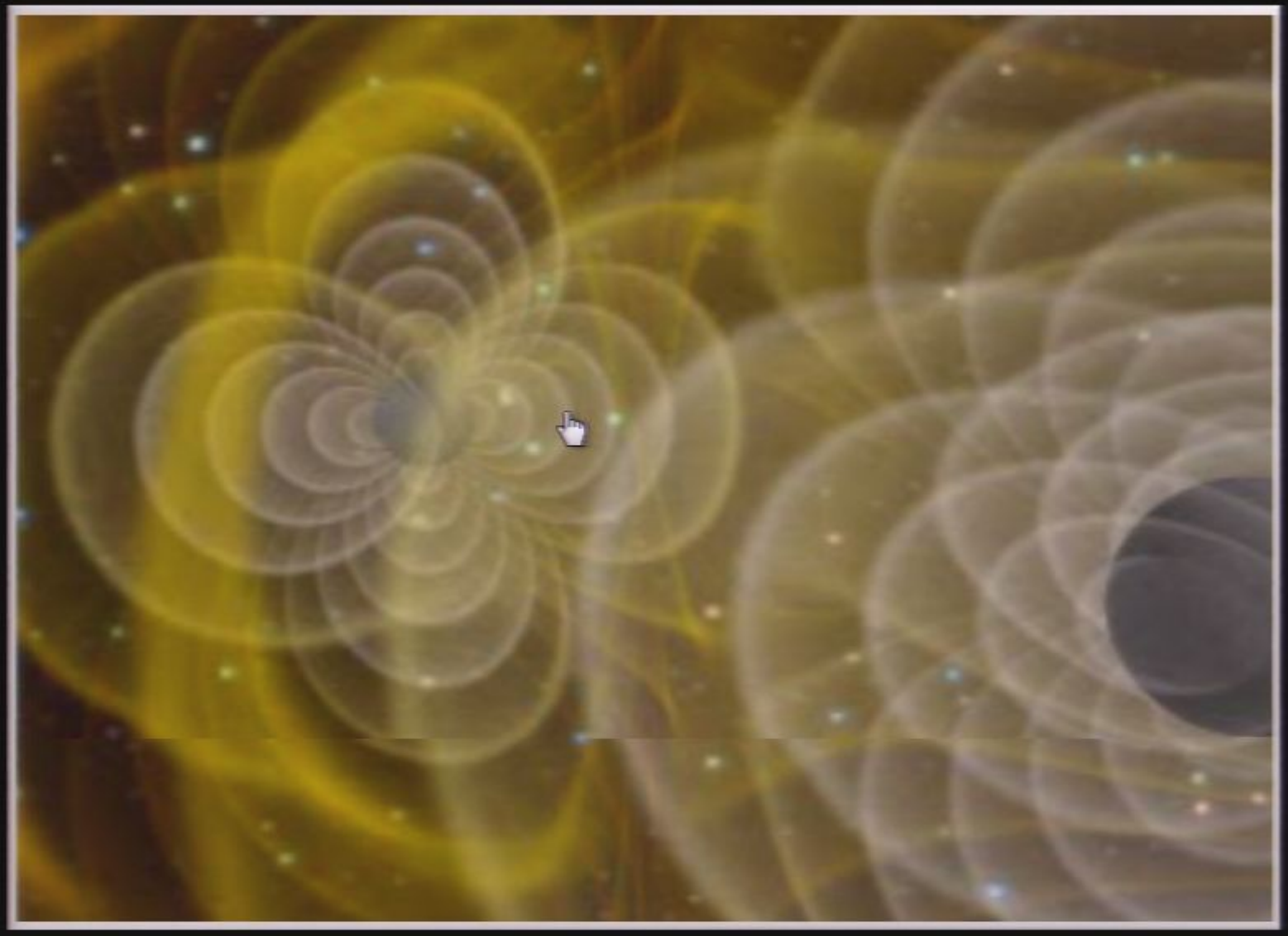

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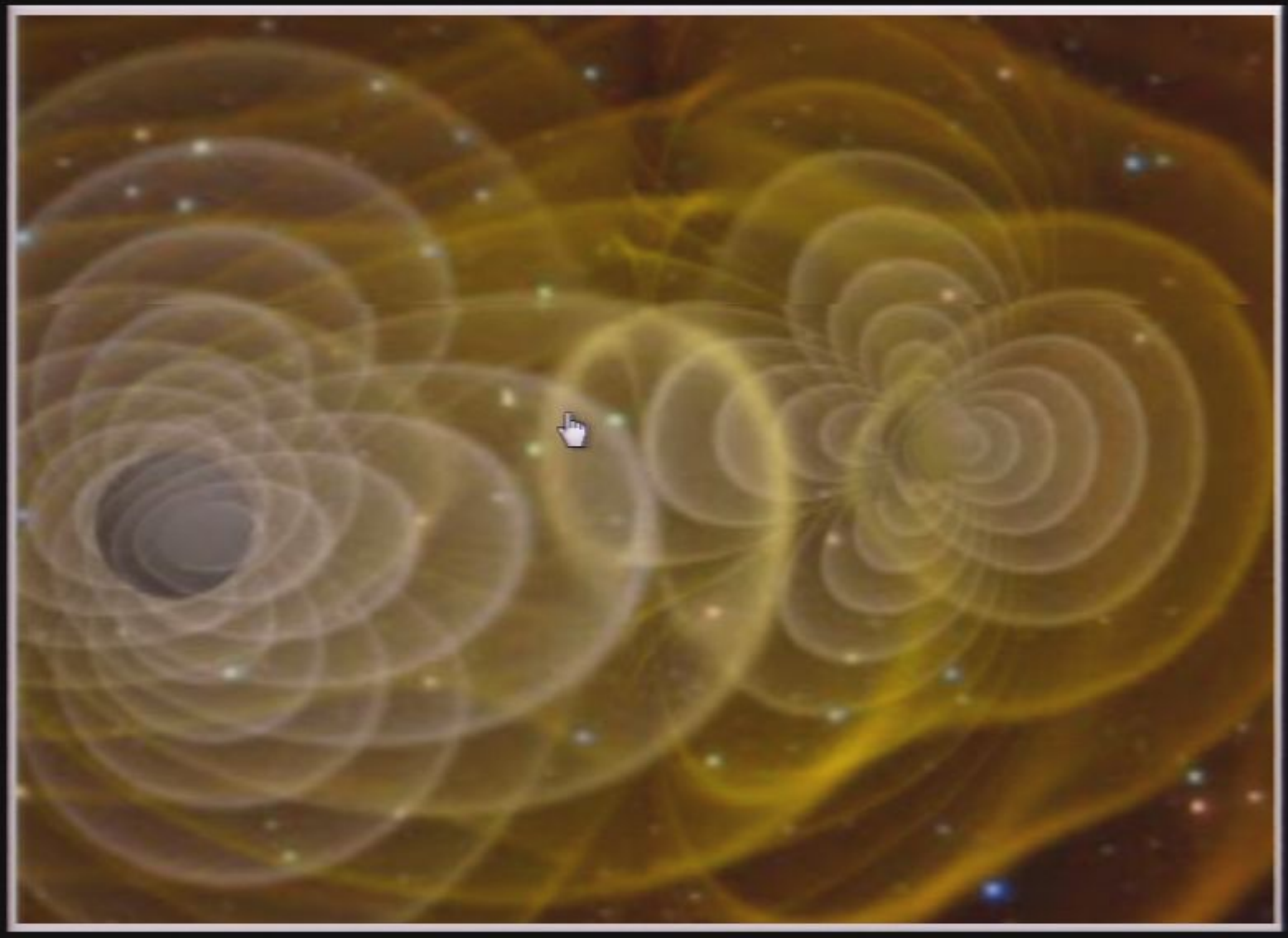

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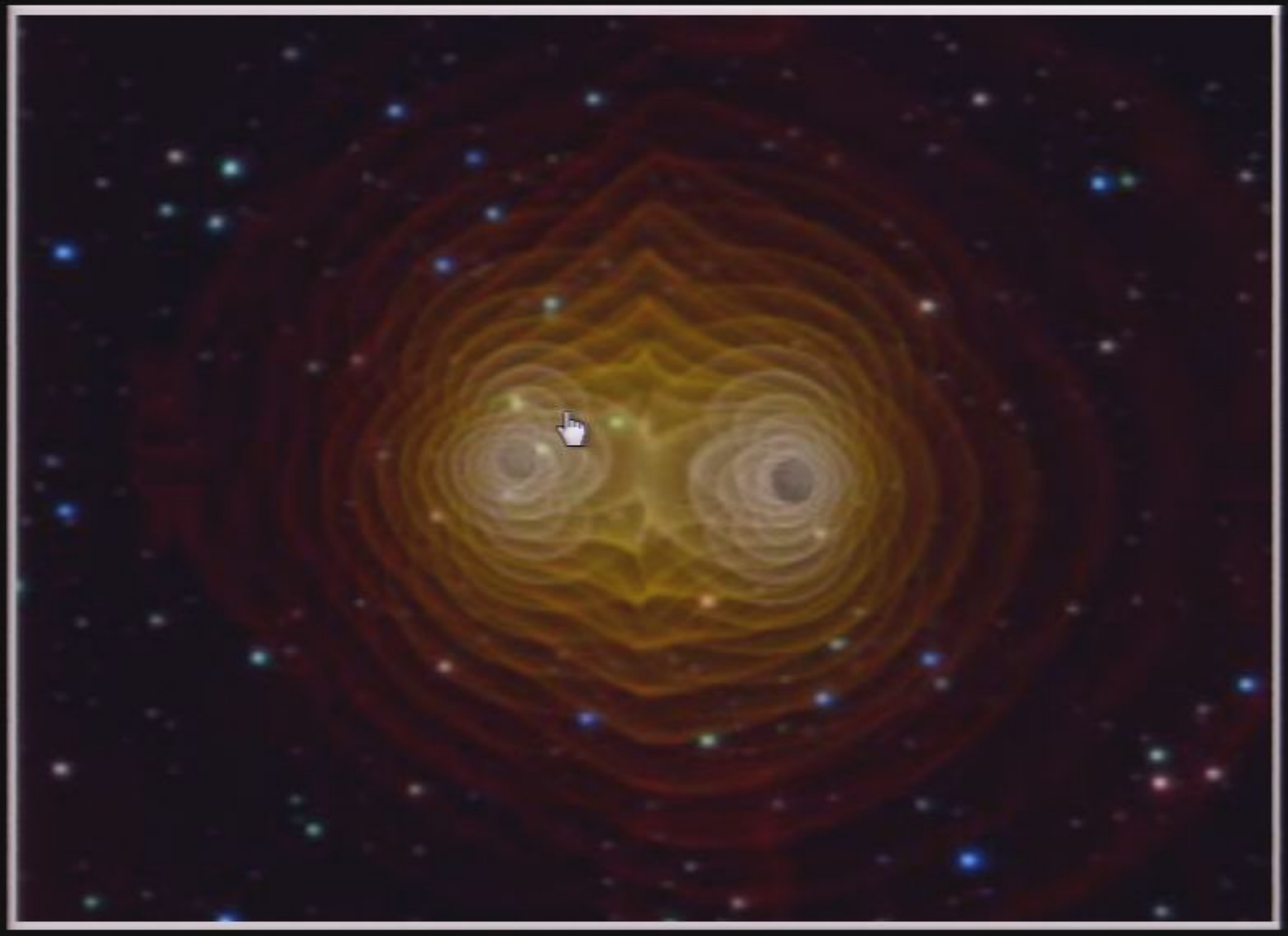

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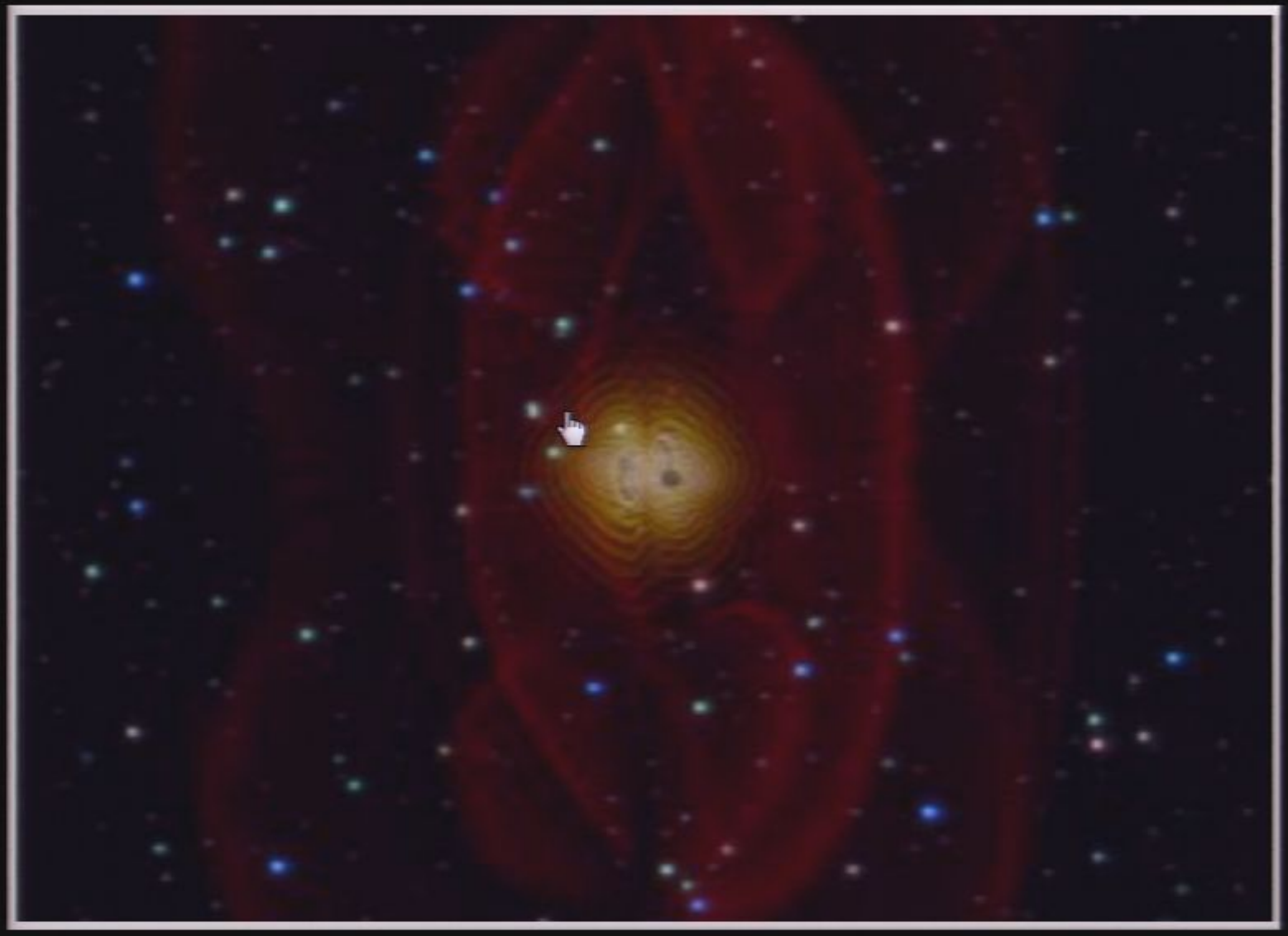

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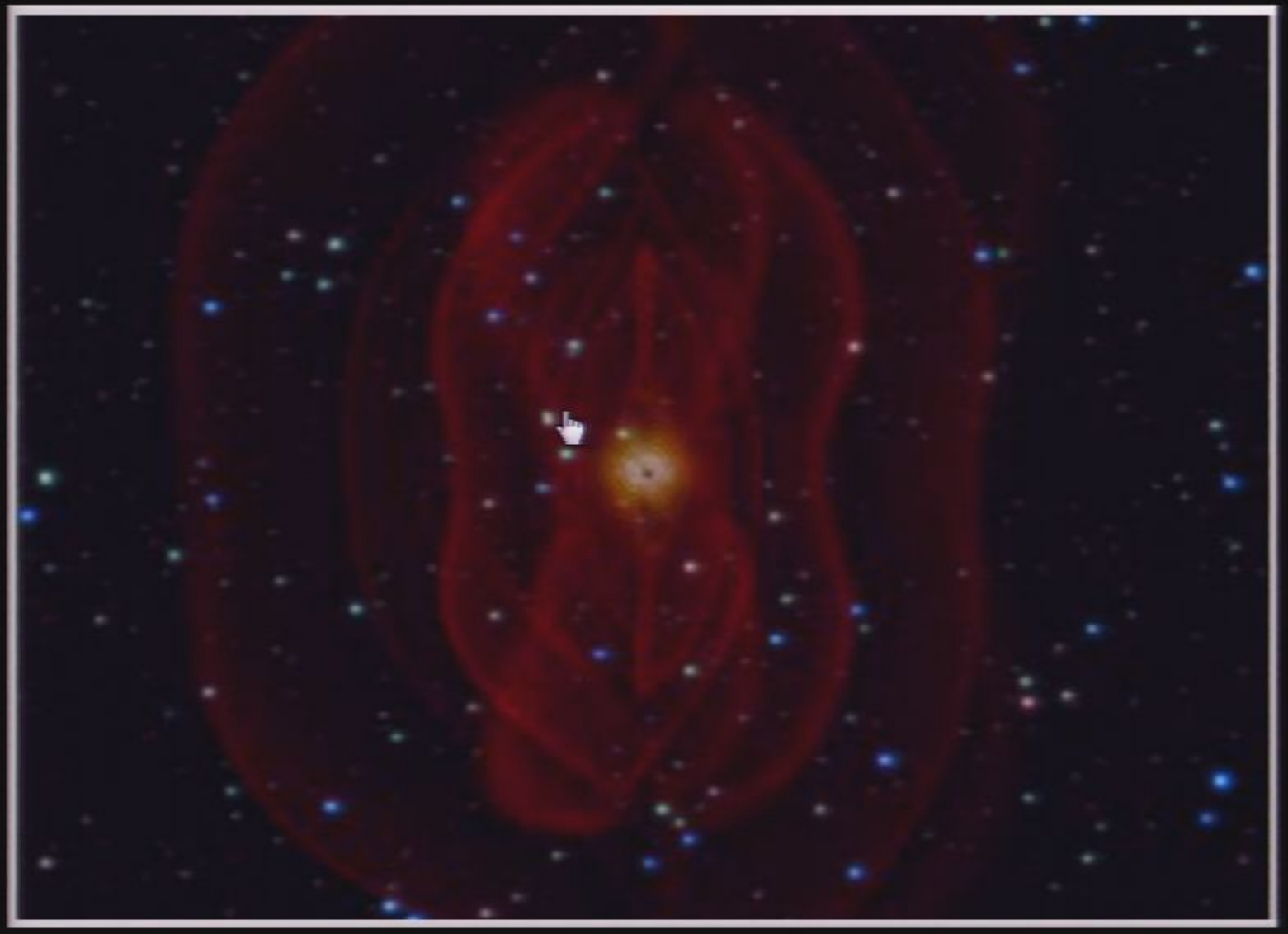

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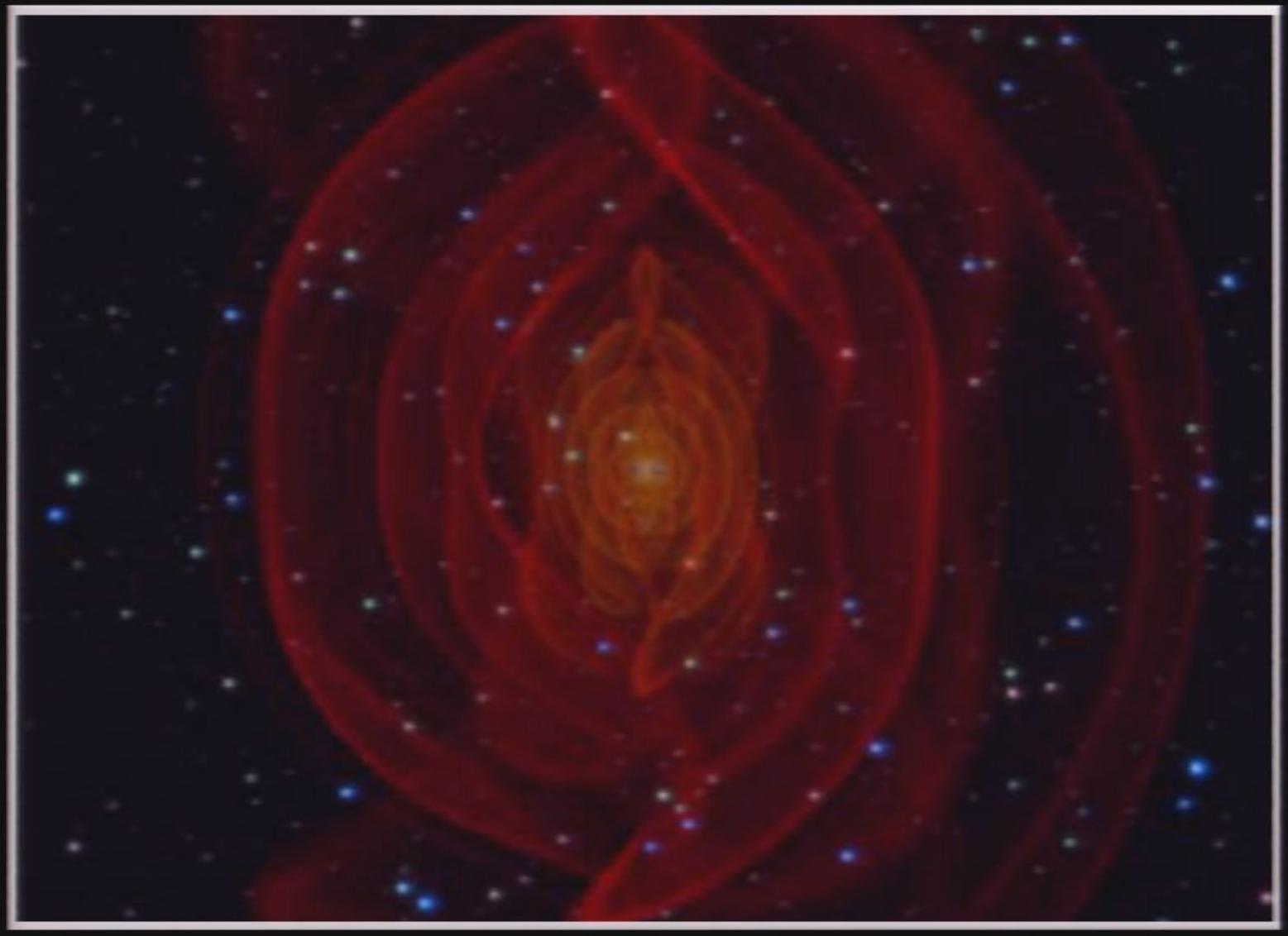

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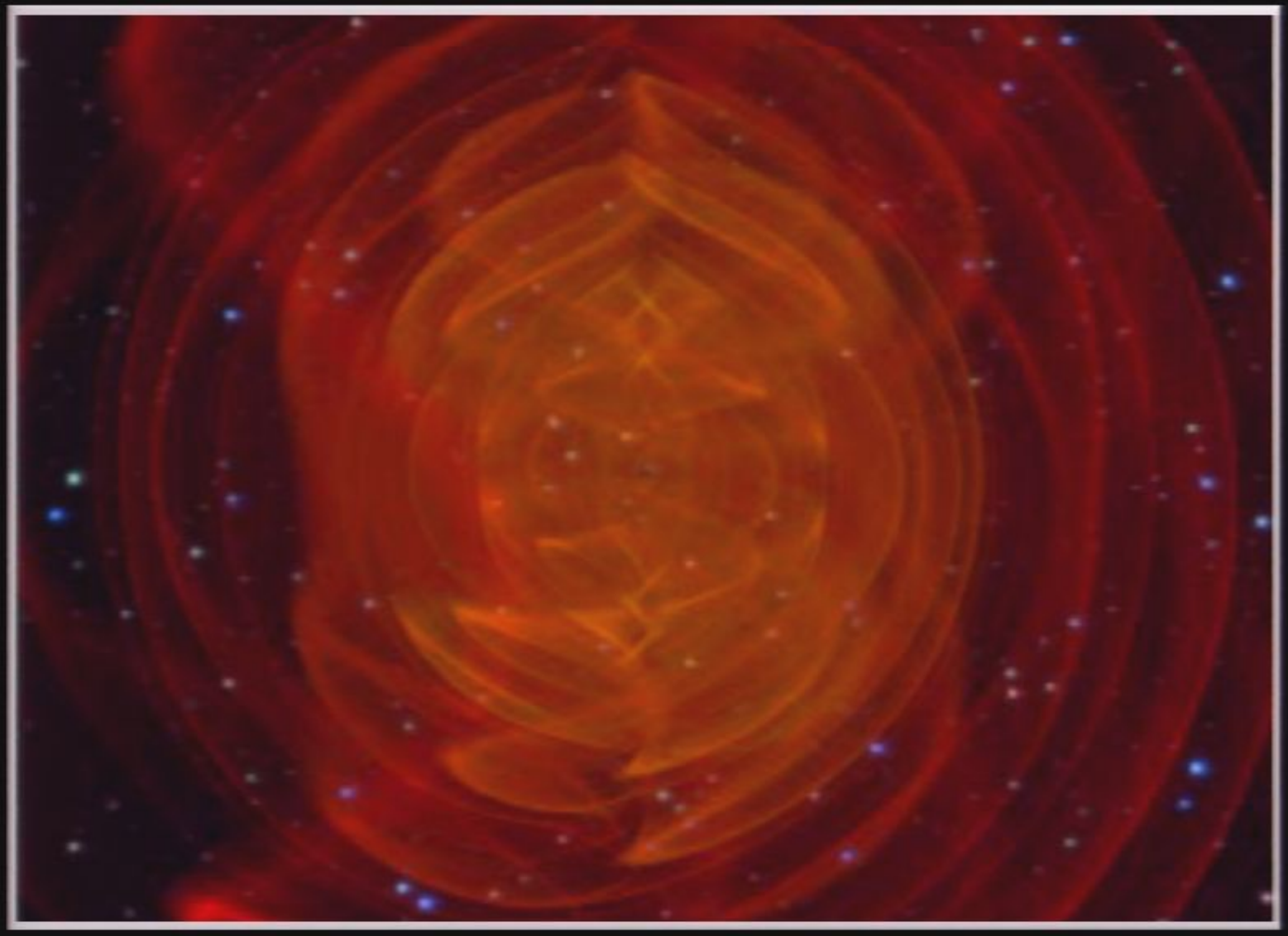

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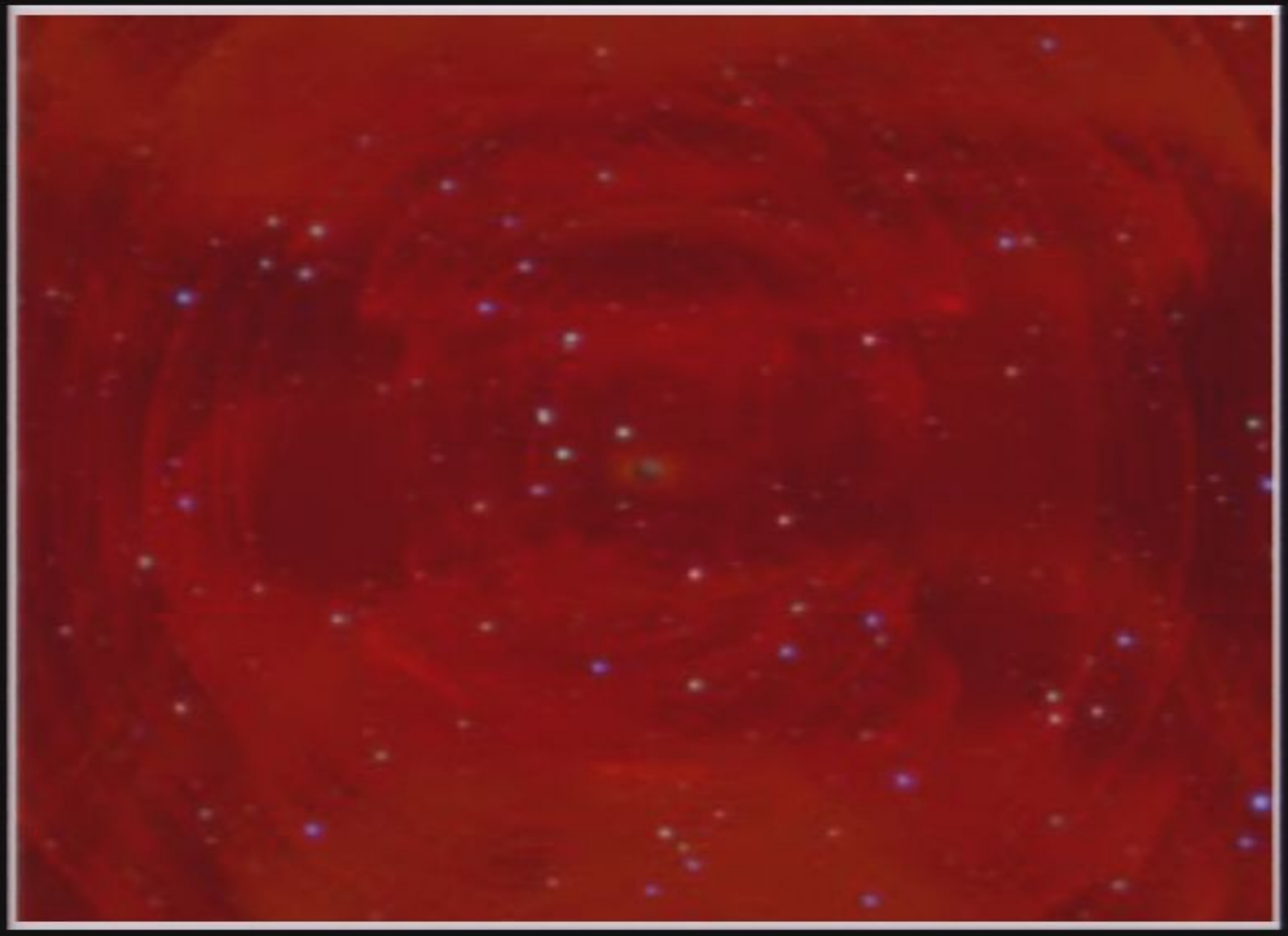

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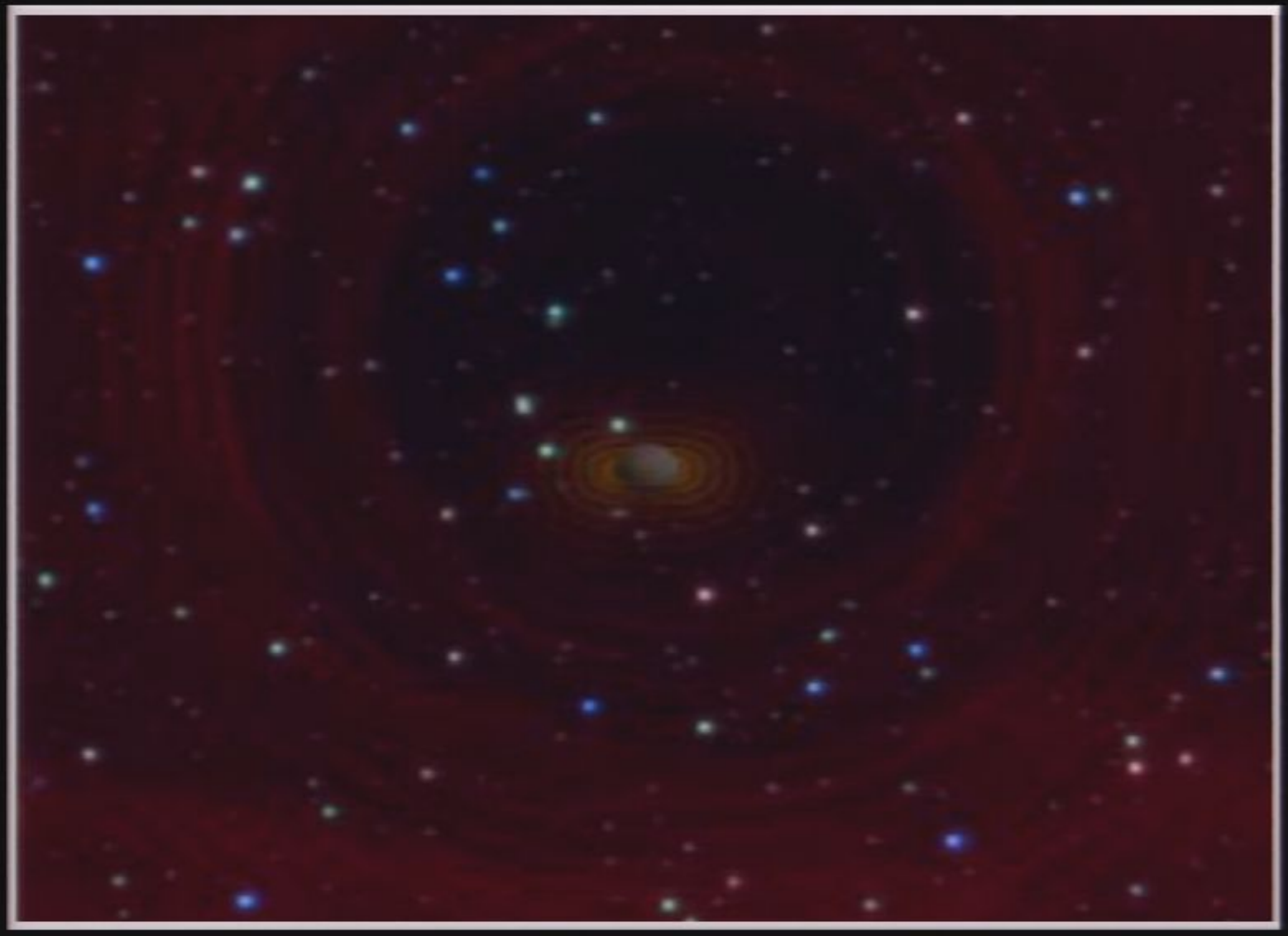

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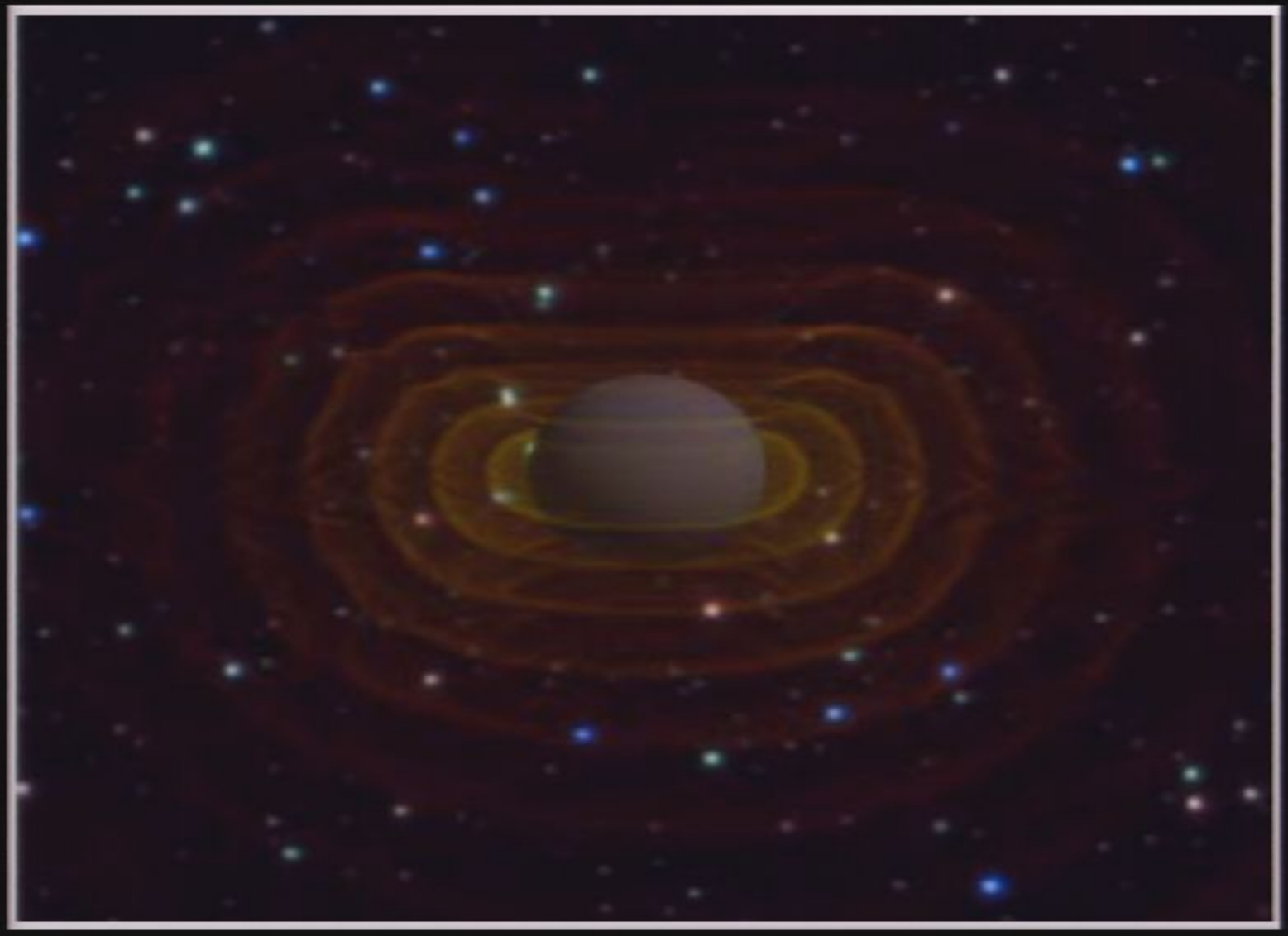
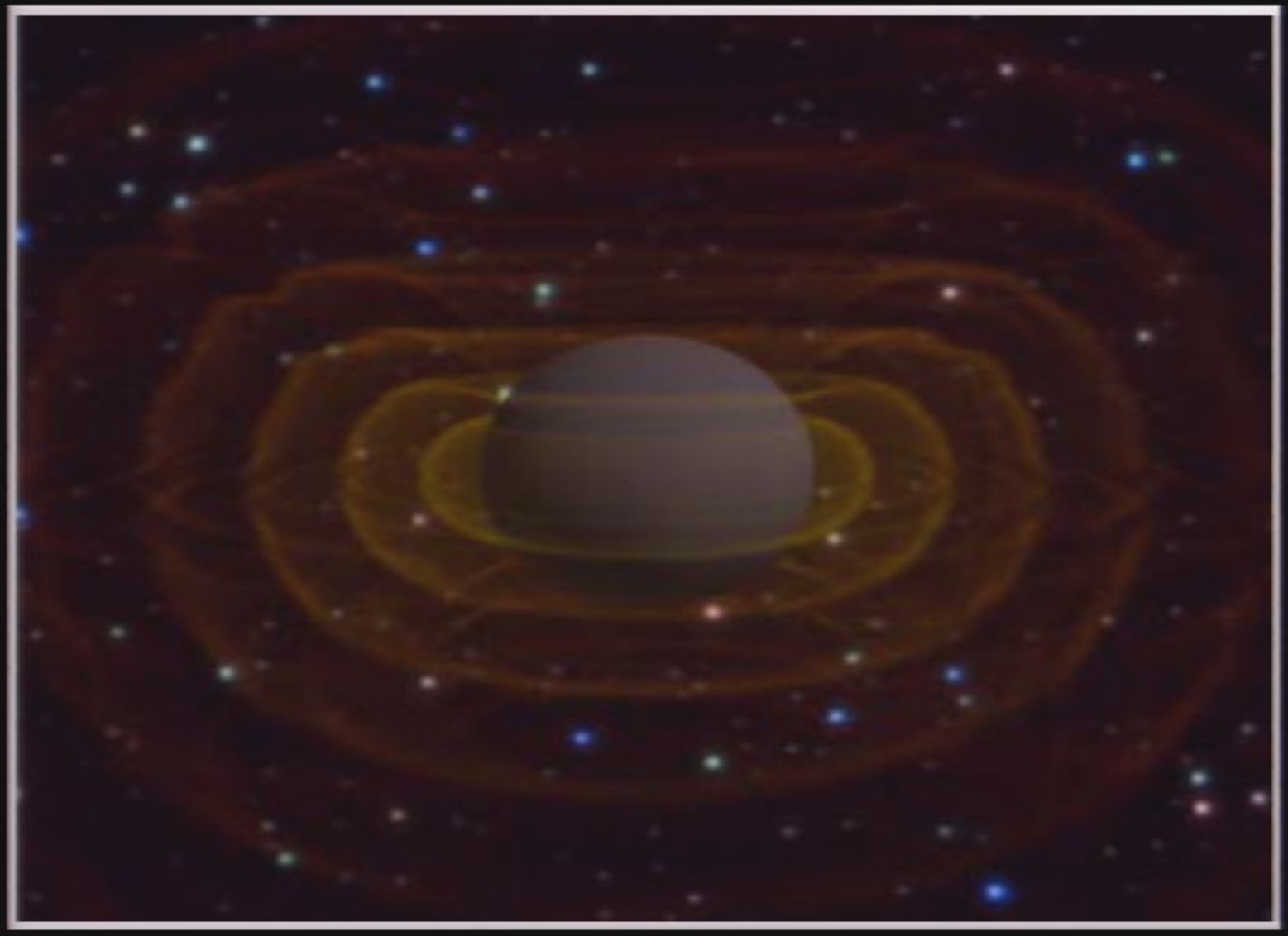
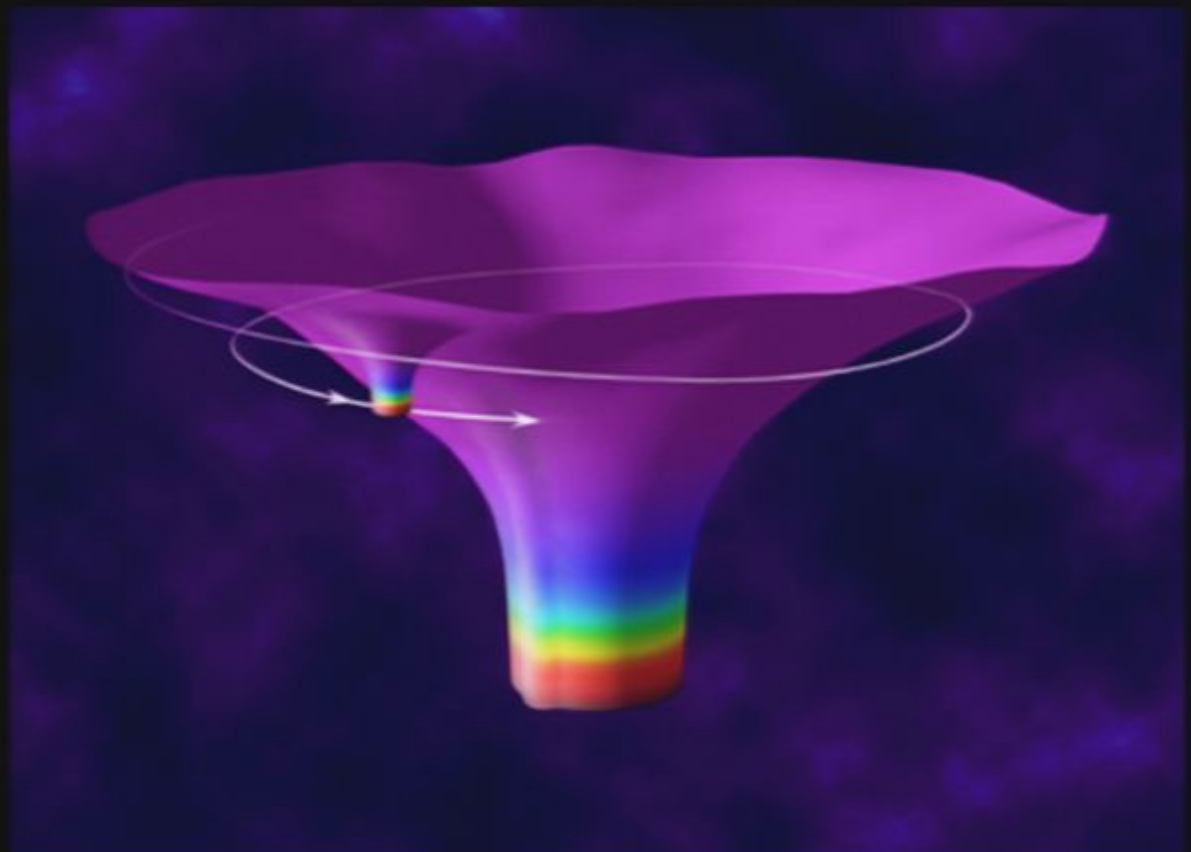


Nasa's Latest Animation



This is the final piece of the puzzle that needs to be verified



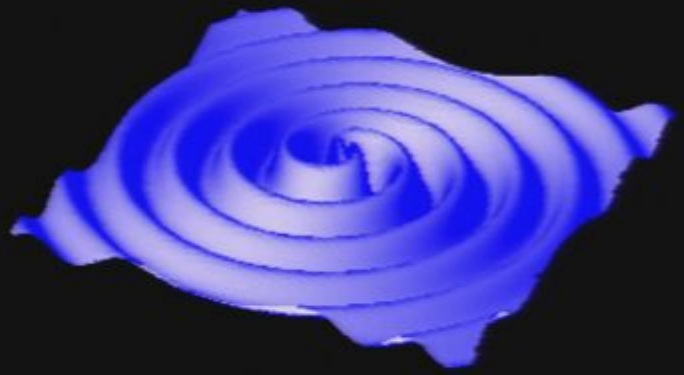
Wave Detection

The race is on and the detectors are in place or being readied for orbit:

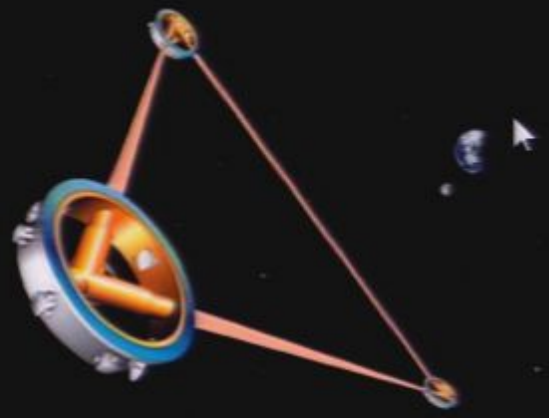
LIGO
VIRGO
GEO600
TAMA
AURIGA

Wave Detection

The GEO600 detector, located in a field outside Hannover in Germany



Auriga



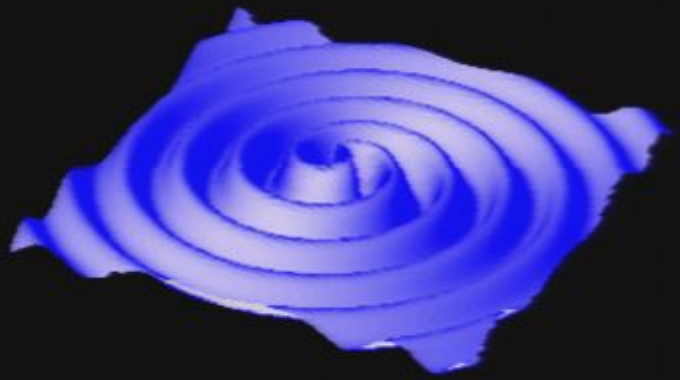
Laser Interferometer Space Antenna

Laser Interferometer Gravitational Wave Observatory (LIGO), Richland

Pirsa: 08080021

Wave Detection

The GEO600 detector, located in a field outside Hannover in Germany



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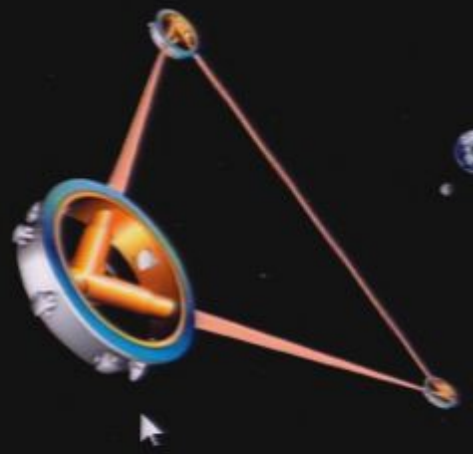

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Pirsa: 08080021

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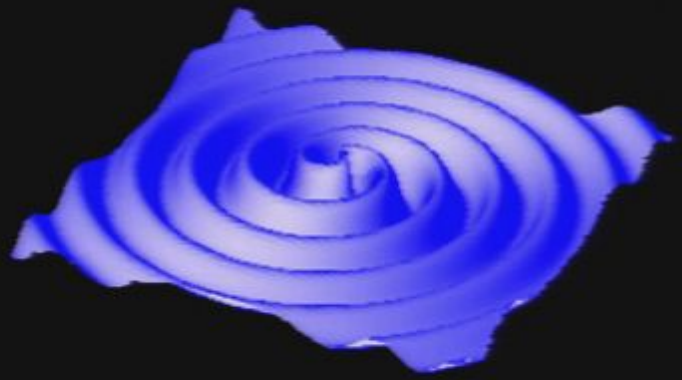

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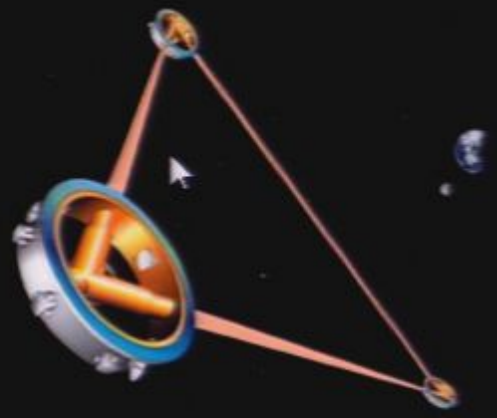

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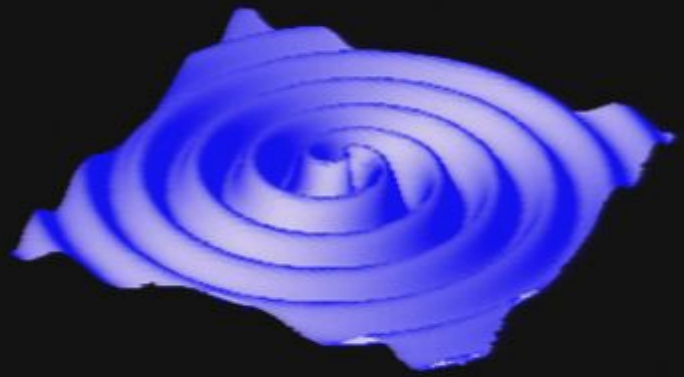

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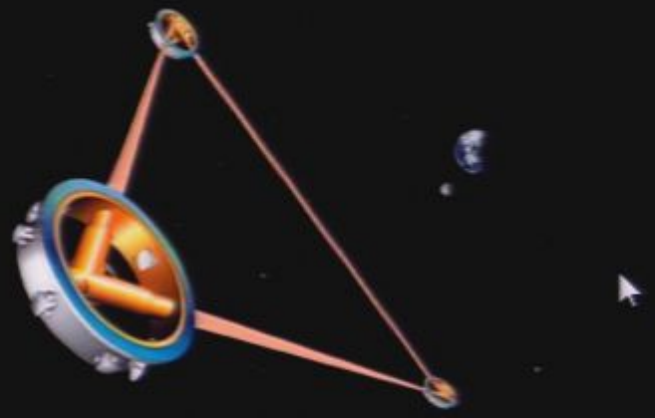

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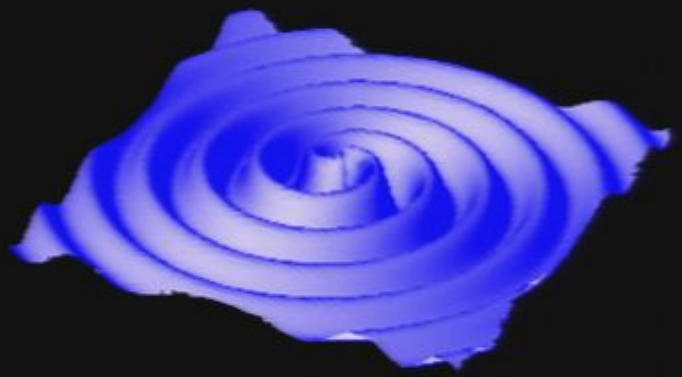

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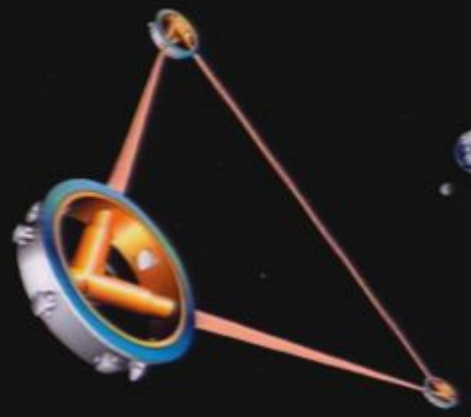

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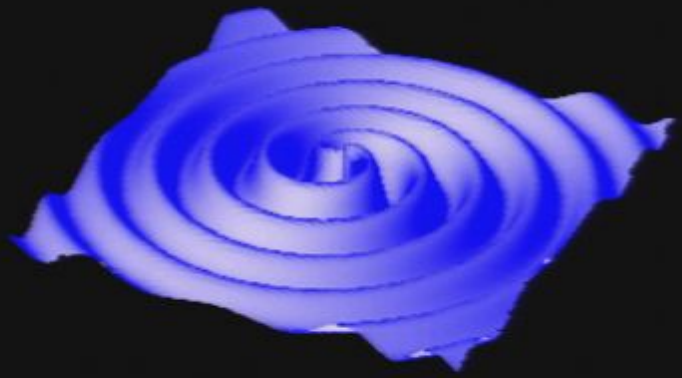

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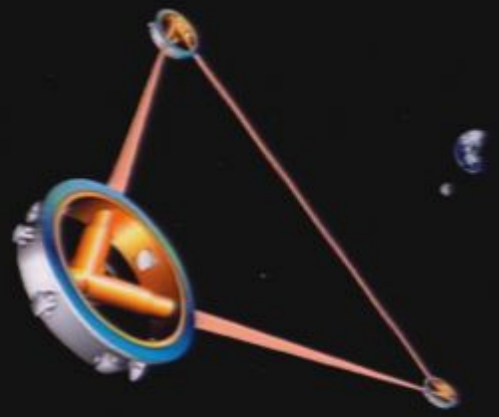
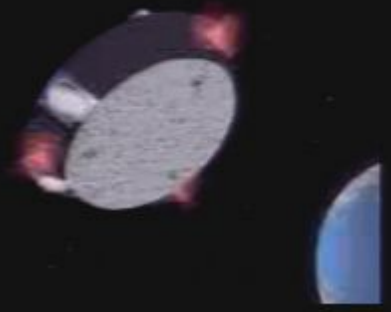


Laser Interferometer Space Antenna

Laser Interferometer Gravitational Wave Observatory (LIGO), Richland

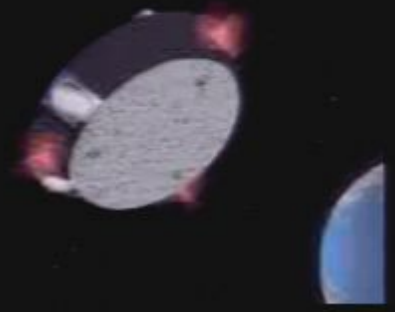
Pirsa: 08080021

Lisa



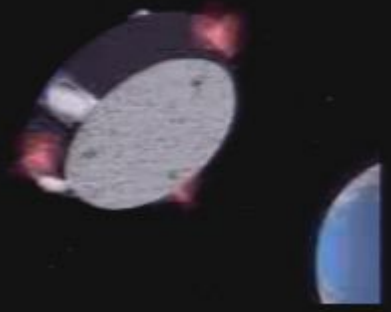
Lisa

- Distance between each craft is 5,000,000 km



Lisa

- Distance between each craft is 5,000,000 km
- Will follow Earth's orbit by 20 degrees



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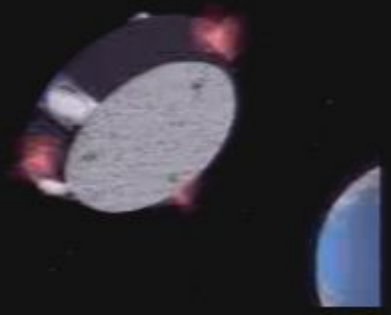
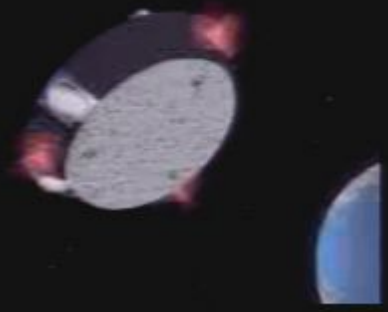


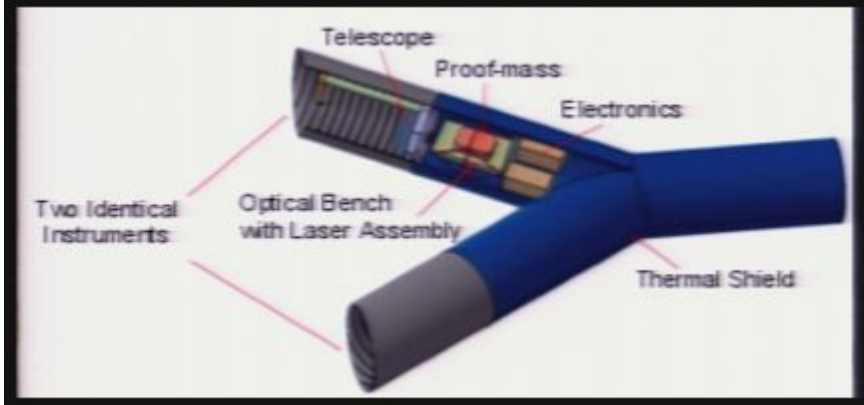
Lisa

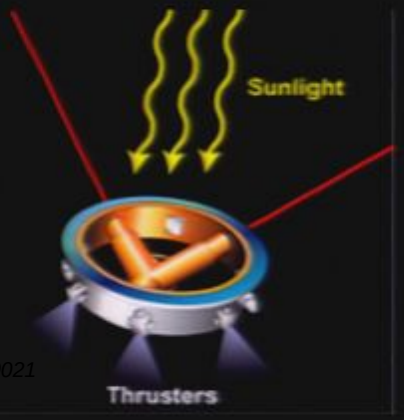
- Distance between each craft is 5,000,000 km
- Will follow Earth's orbit by 20 degrees
- Will be able to detect $\Delta L/L$ less then 10^{-21} (that ΔL of 10^{-10} cm)

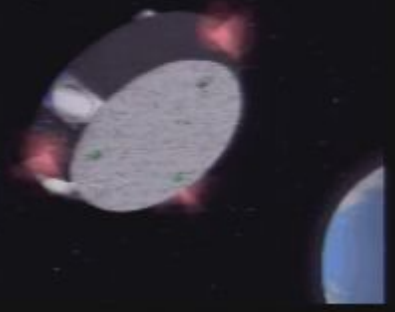


Lisa

- Distance between each craft is 5,000,000 km
- Will follow Earth's orbit by 20 degrees
- Will be able to detect $\Delta L/L$ less then 10^{-21} (that ΔL of 10^{-10} cm)
- Launch date set for 2015 (5 year duration)







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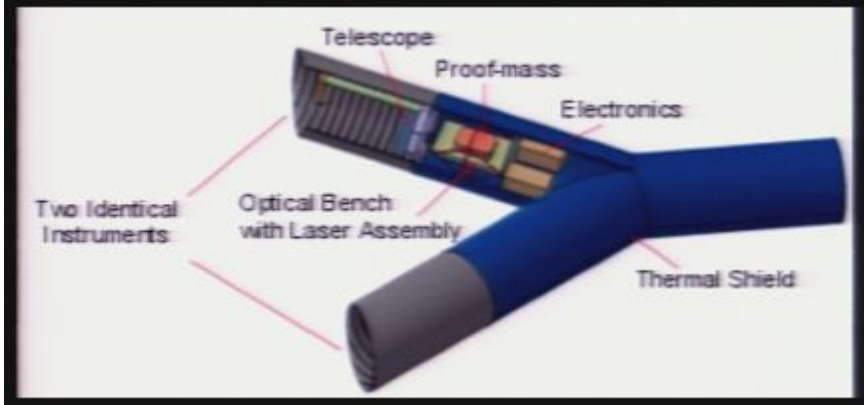

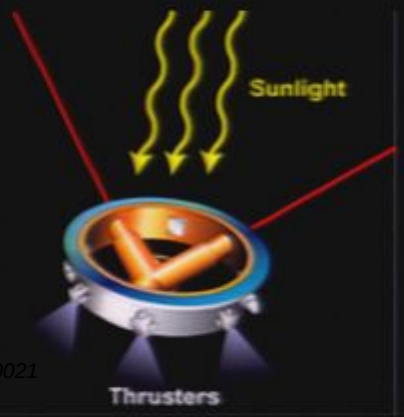

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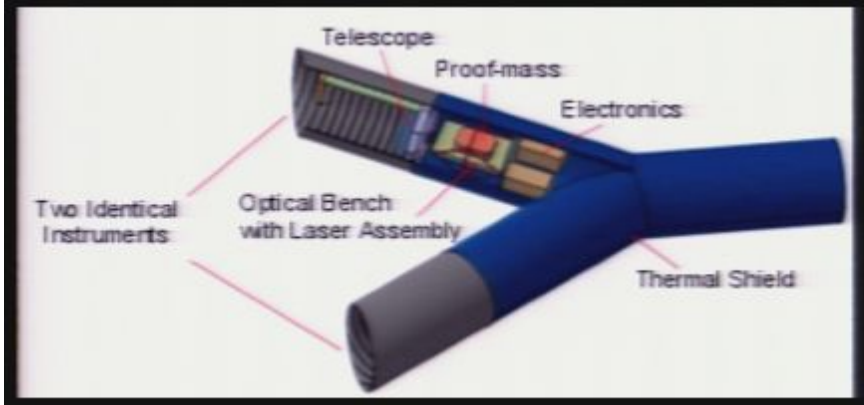

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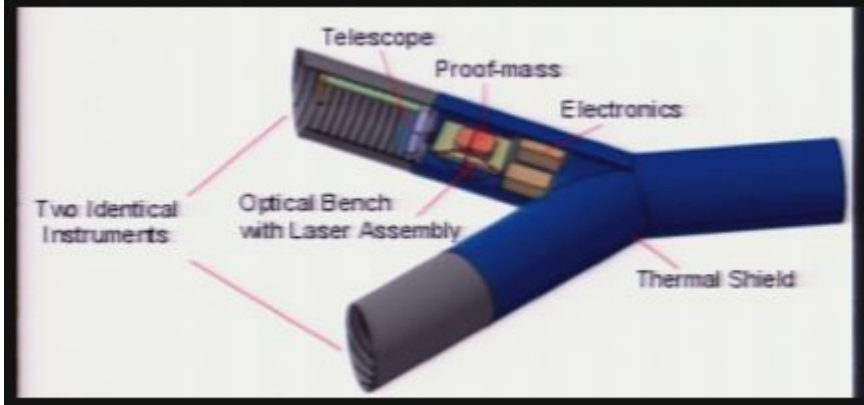
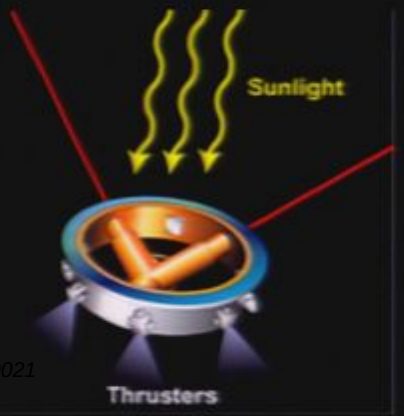
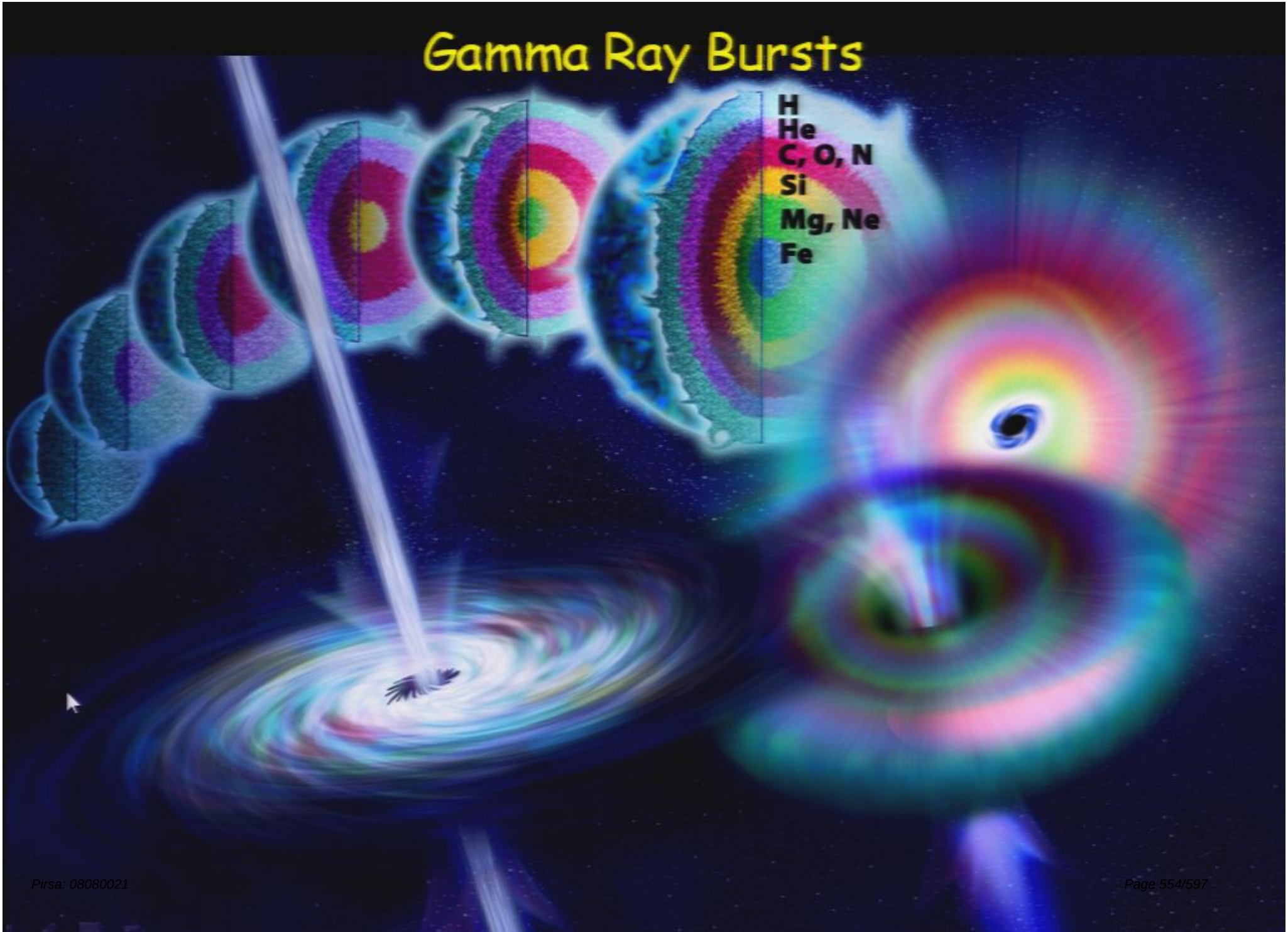




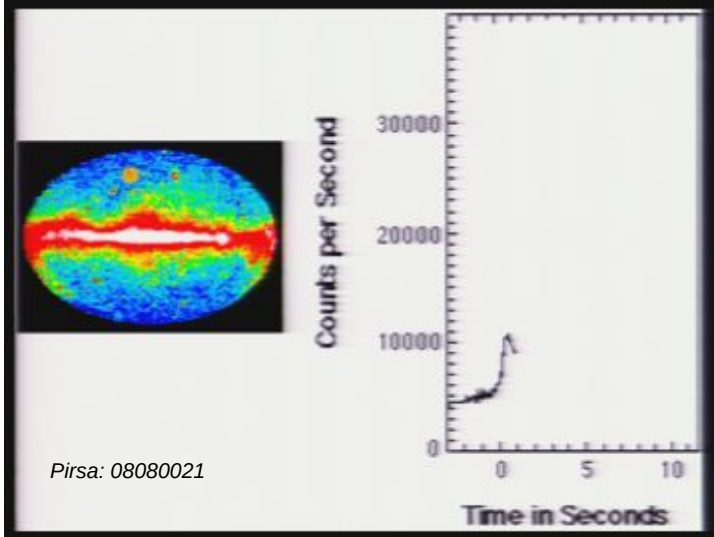
The Sound of collapse

Strange Predictions


Gamma Ray Bursts
H
He
C, O, N
Si
Mg, Ne
Fe

GRB

Record-breaking Gamma Ray Burst (GRB) in the act on Wednesday (March 19th, 2008), the worlds telescopes swung toward the constellation of Boötes to watch the afterglow of this massive explosion. One instrument in a Chile observatory was observing in Swift's field of view at the time of the blast and has put together a short frame-by-frame video of the event. So if you missed this historic burst from 7.5 billion years ago (which you probably did!) you can watch it now...



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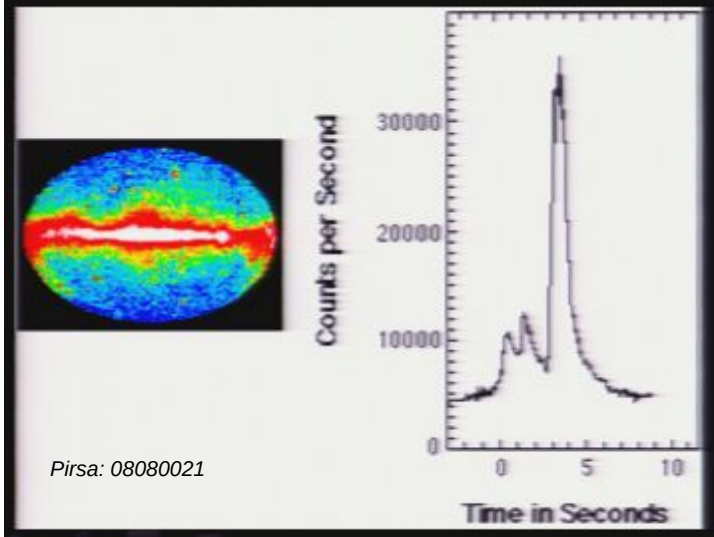

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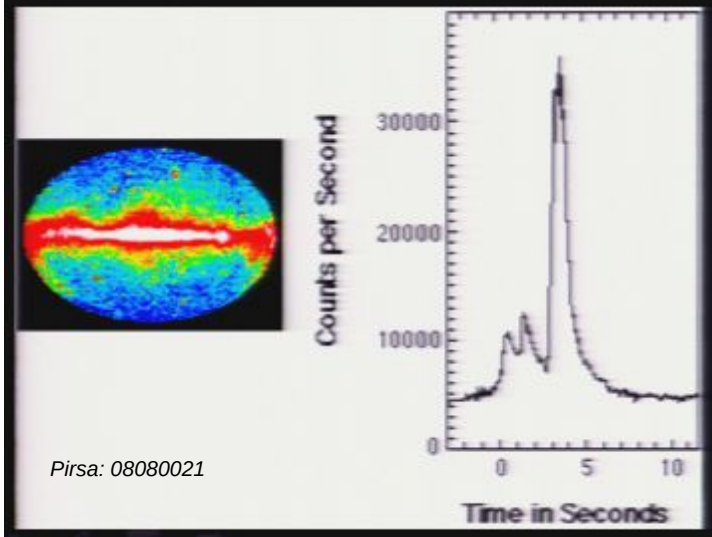

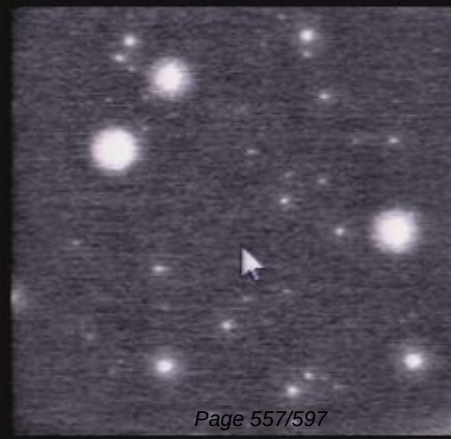

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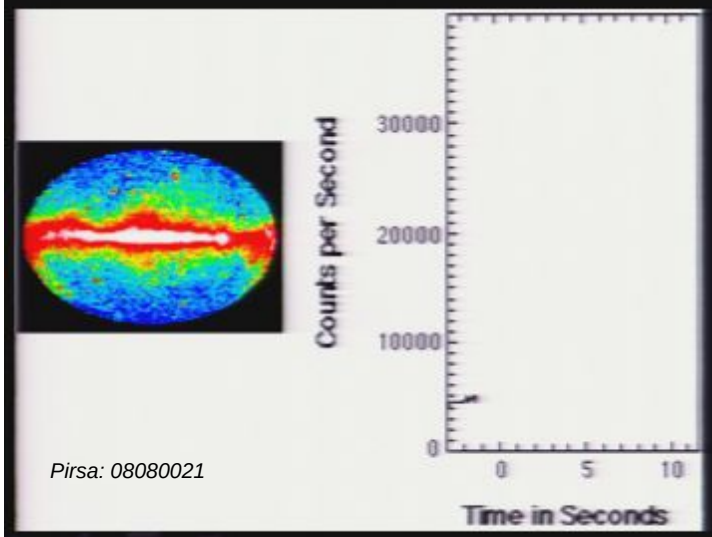

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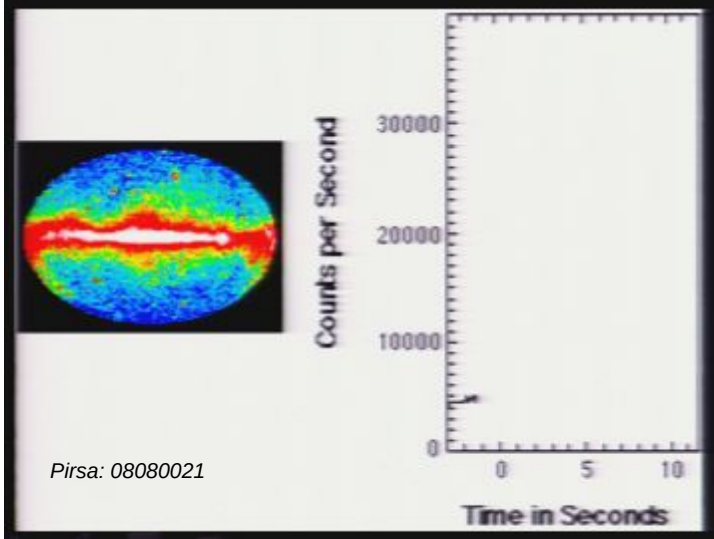

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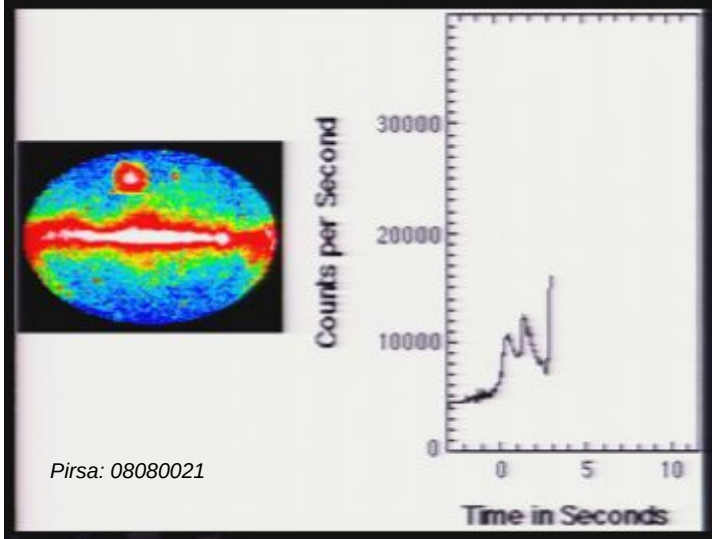

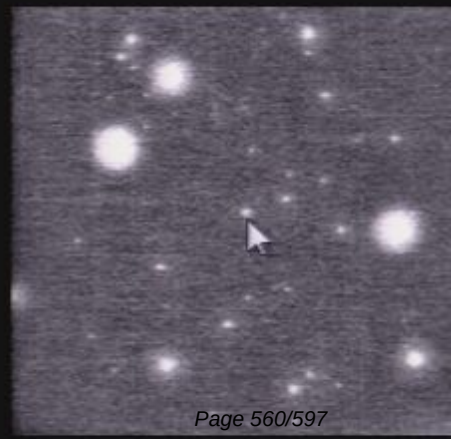

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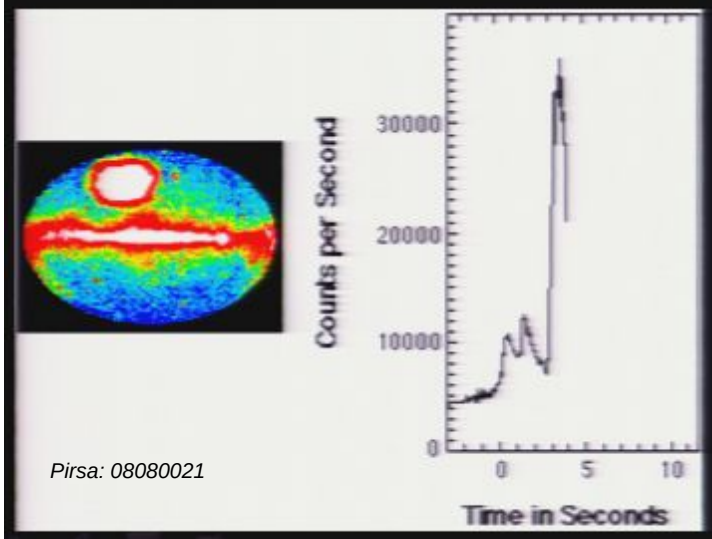

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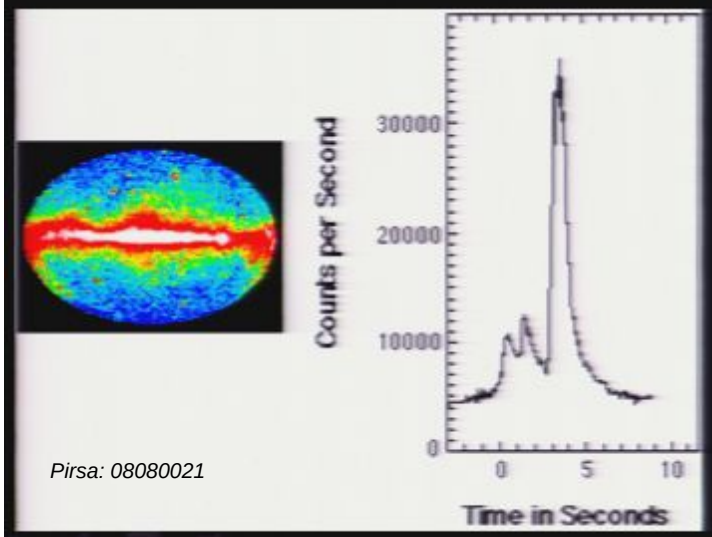

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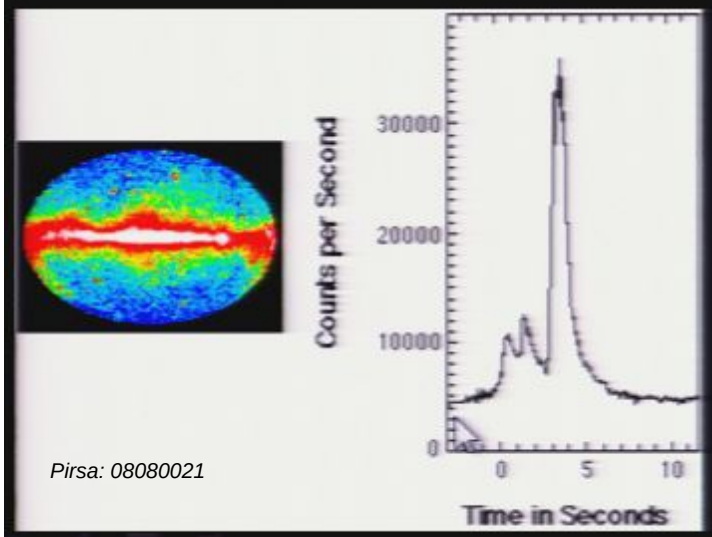

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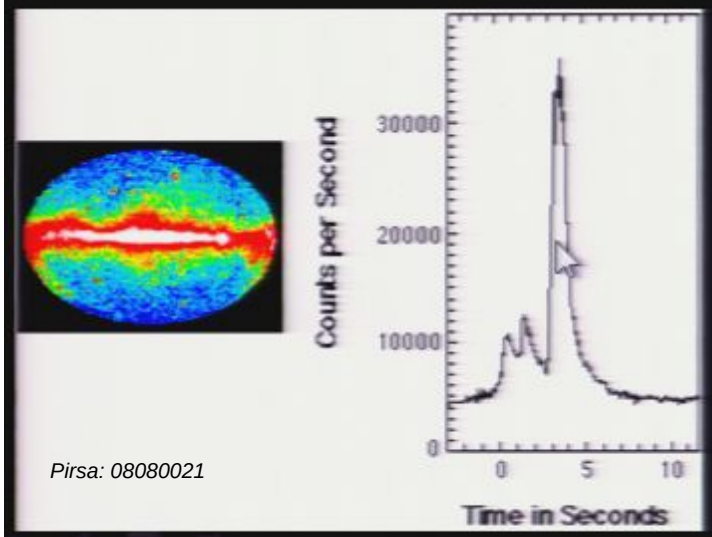

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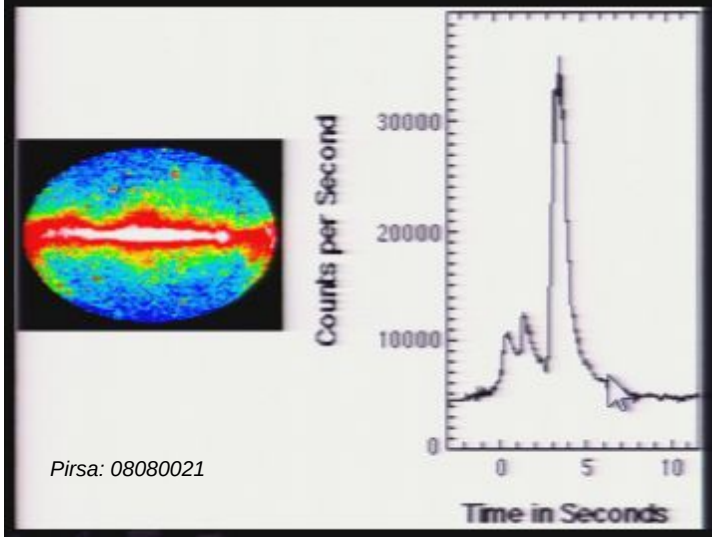
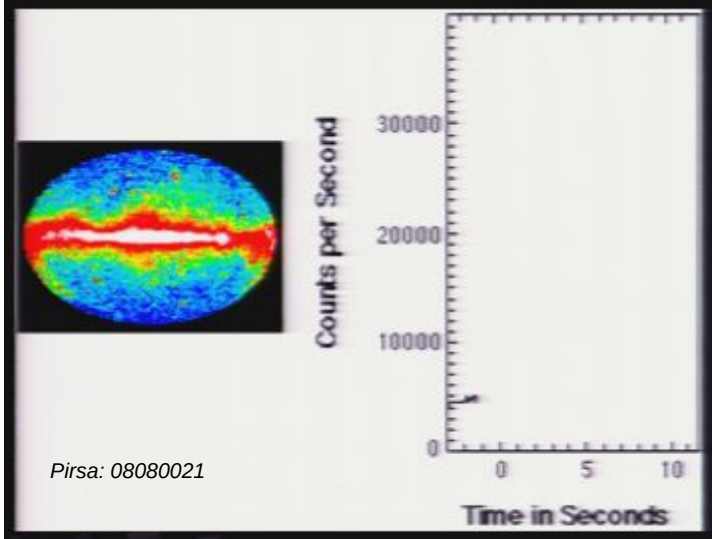
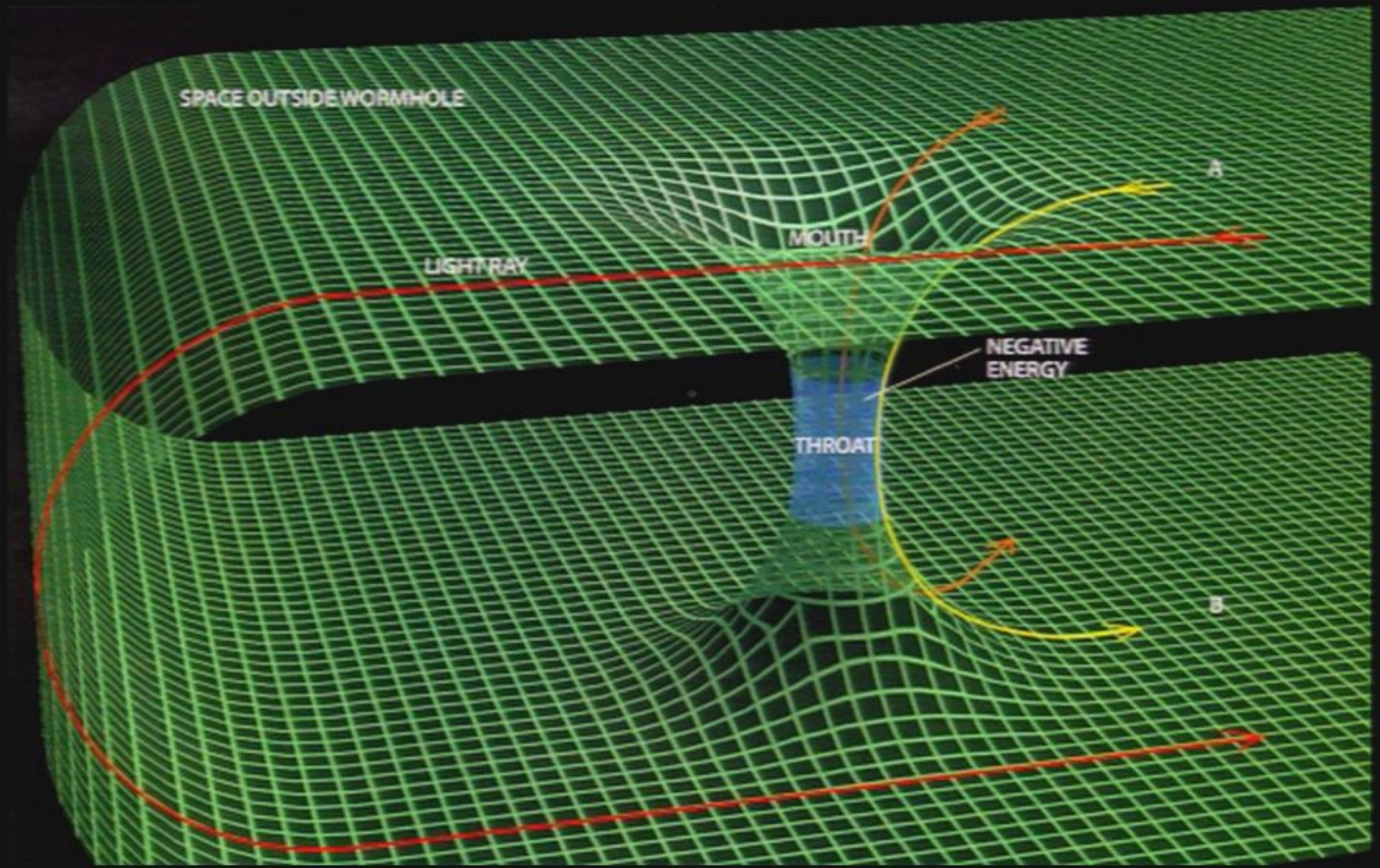


GRB

Record-breaking Gamma Ray Burst (GRB) in the act on Wednesday (March 19th, 2008), the worlds telescopes swung toward the constellation of Boötes to watch the afterglow of this massive explosion. One instrument in a Chile observatory was observing in Swift's field of view at the time of the blast and has put together a short frame-by-frame video of the event. So if you missed this historic burst from 7.5 billion years ago (which you probably did!) you can watch it now...



Wormholes


SPACE OUTSIDE WORMHOLE
A
MOUTH
LIGHT RAY
NEGATIVE ENERGY
THROAT
B

Wormholes (the traveler's view)

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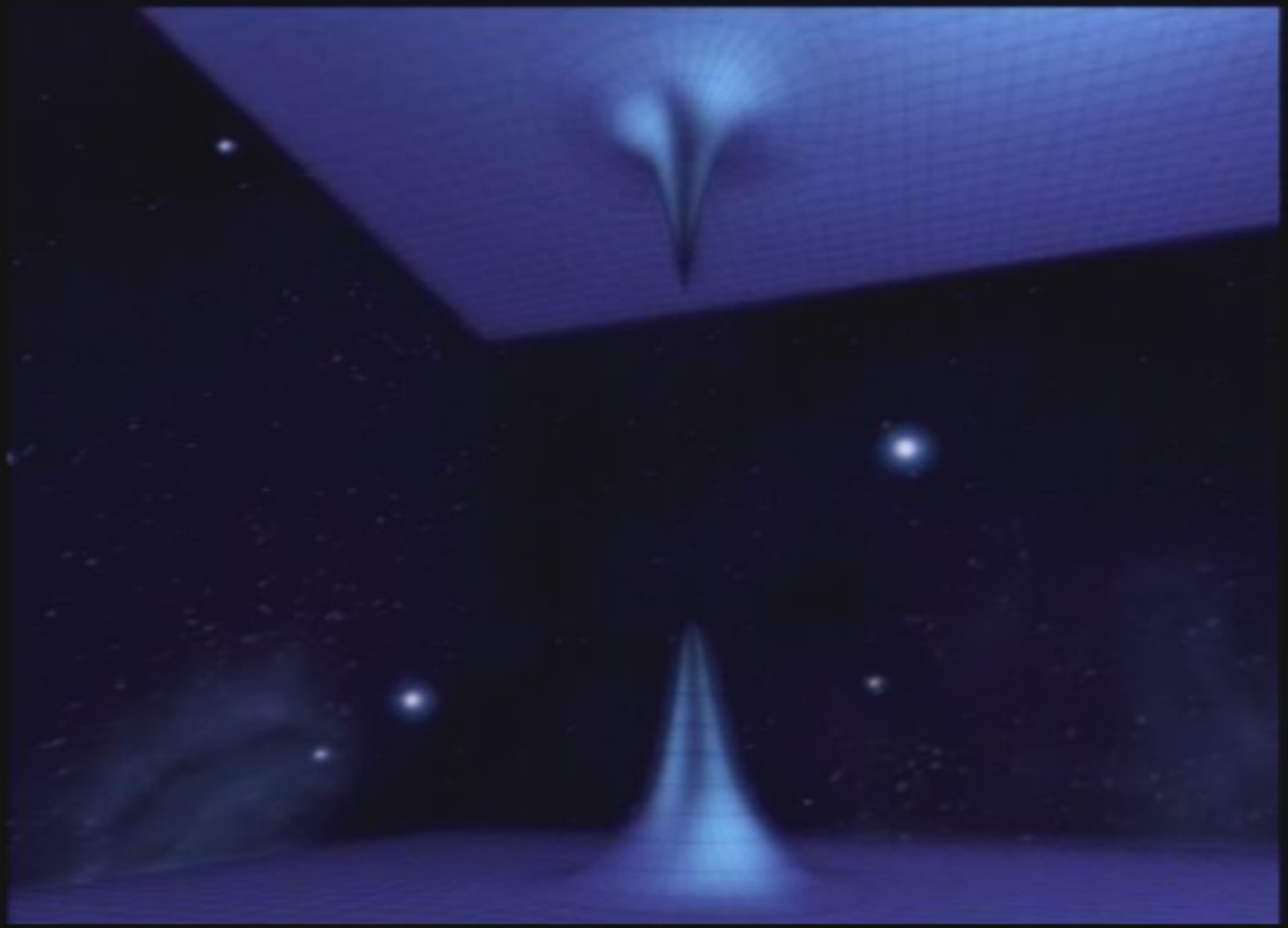

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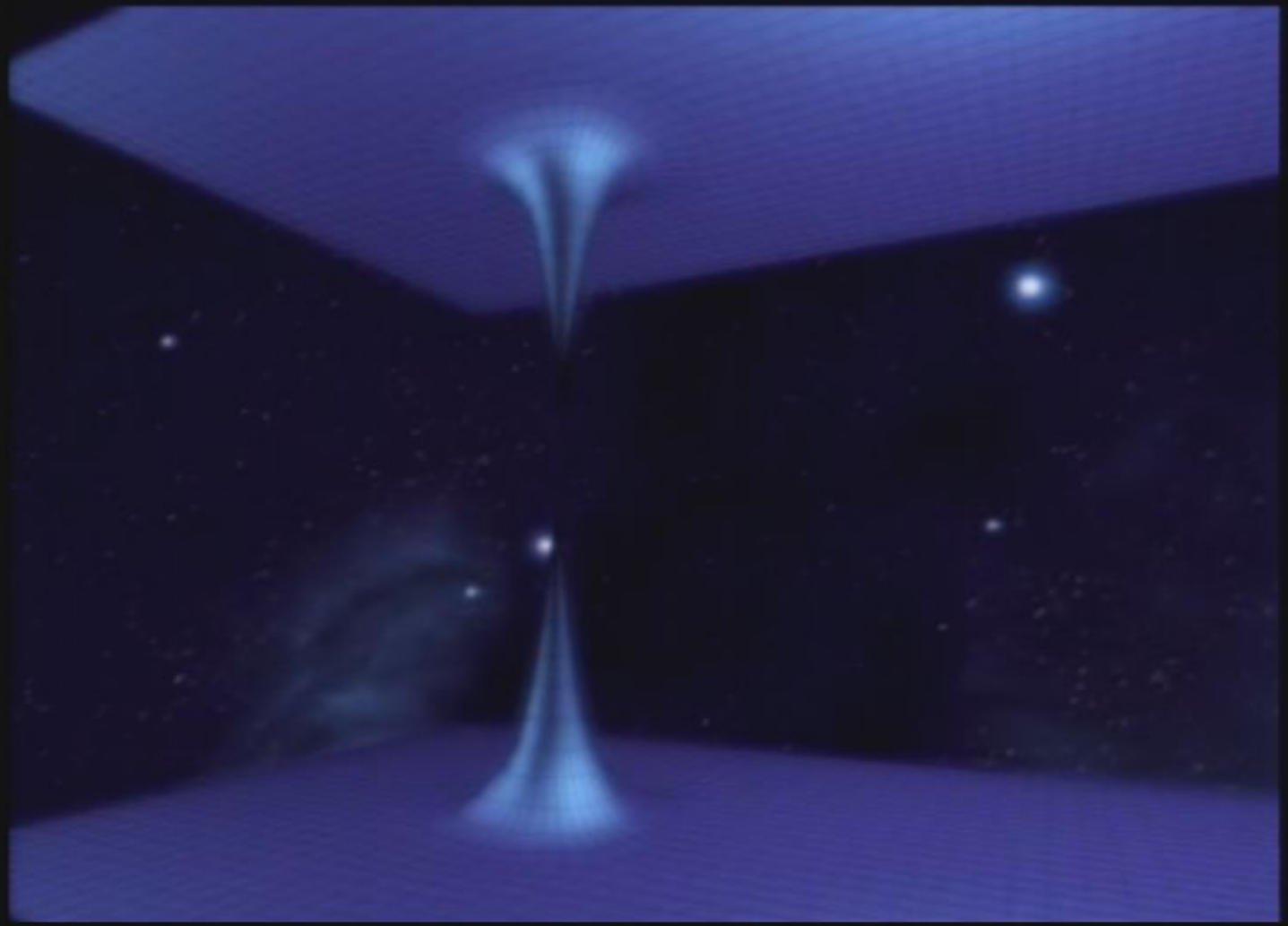

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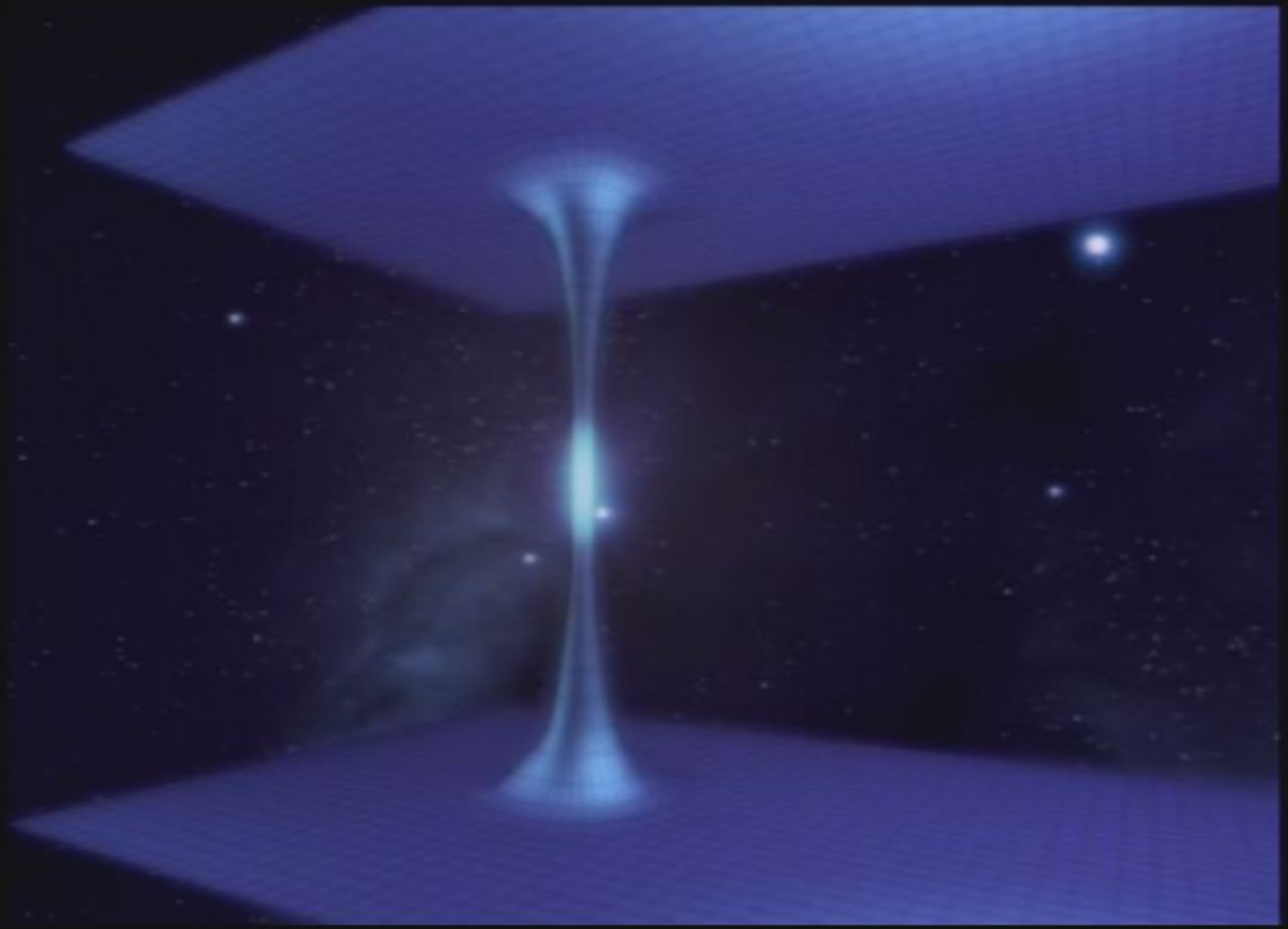

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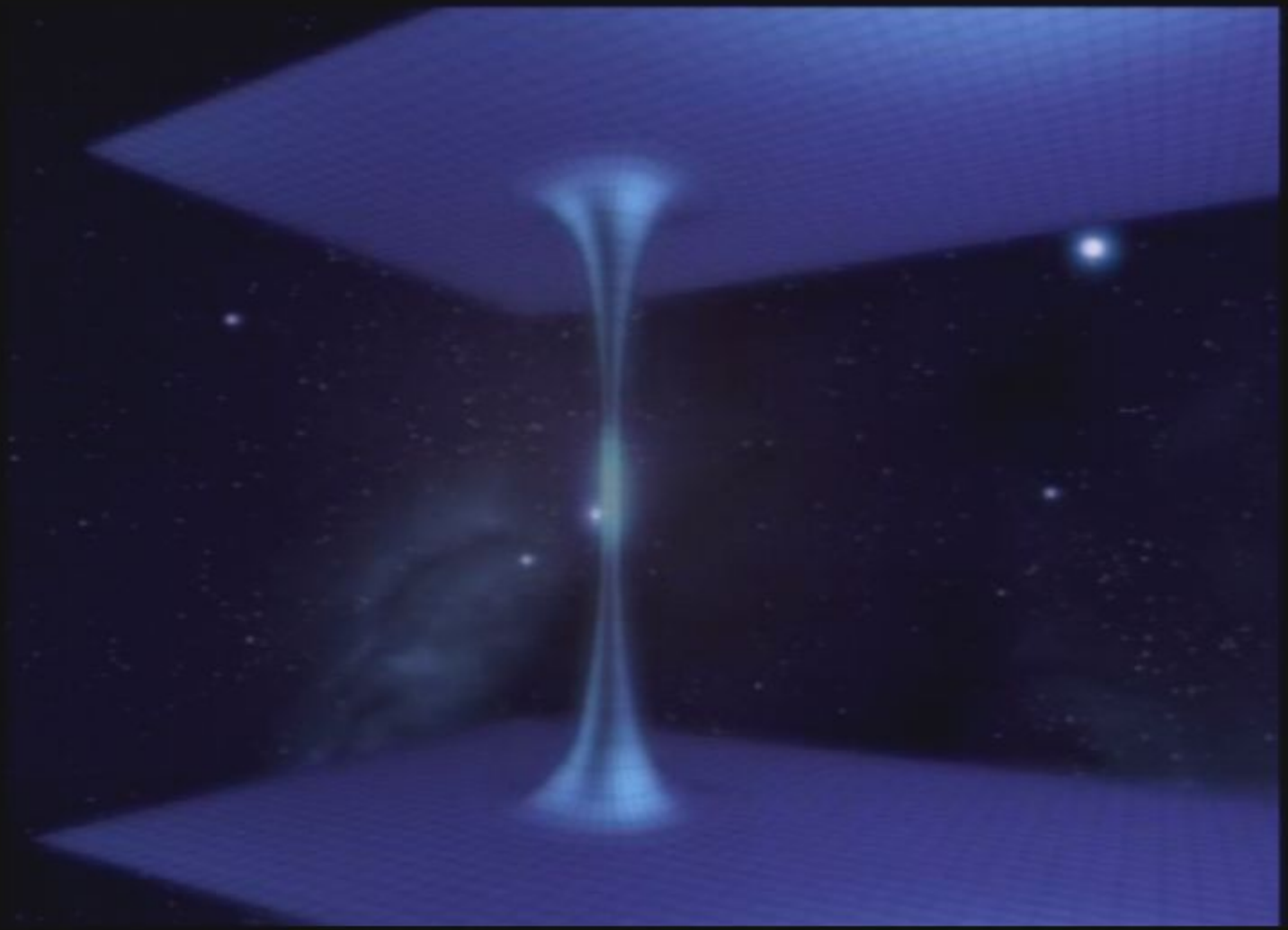

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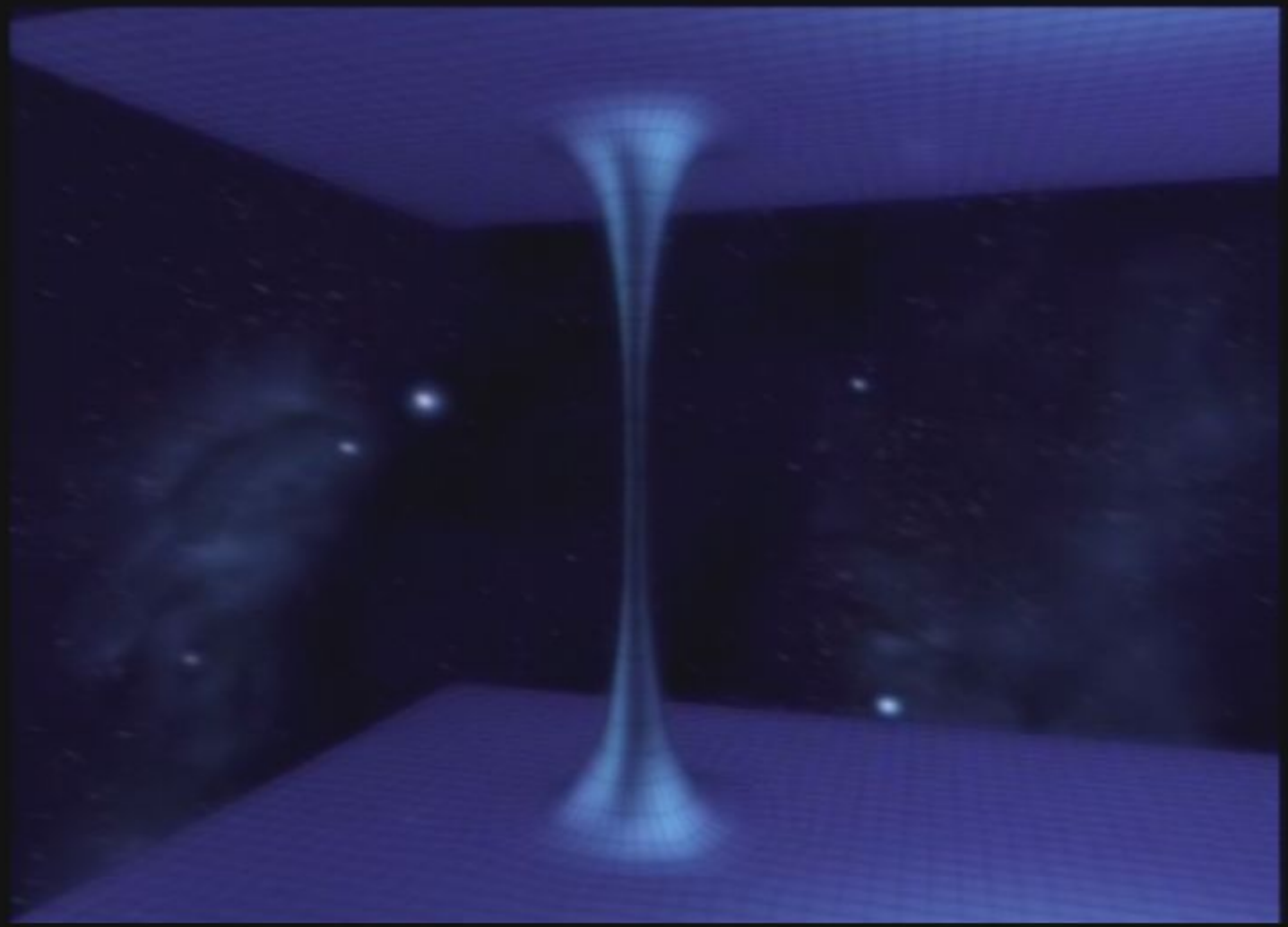

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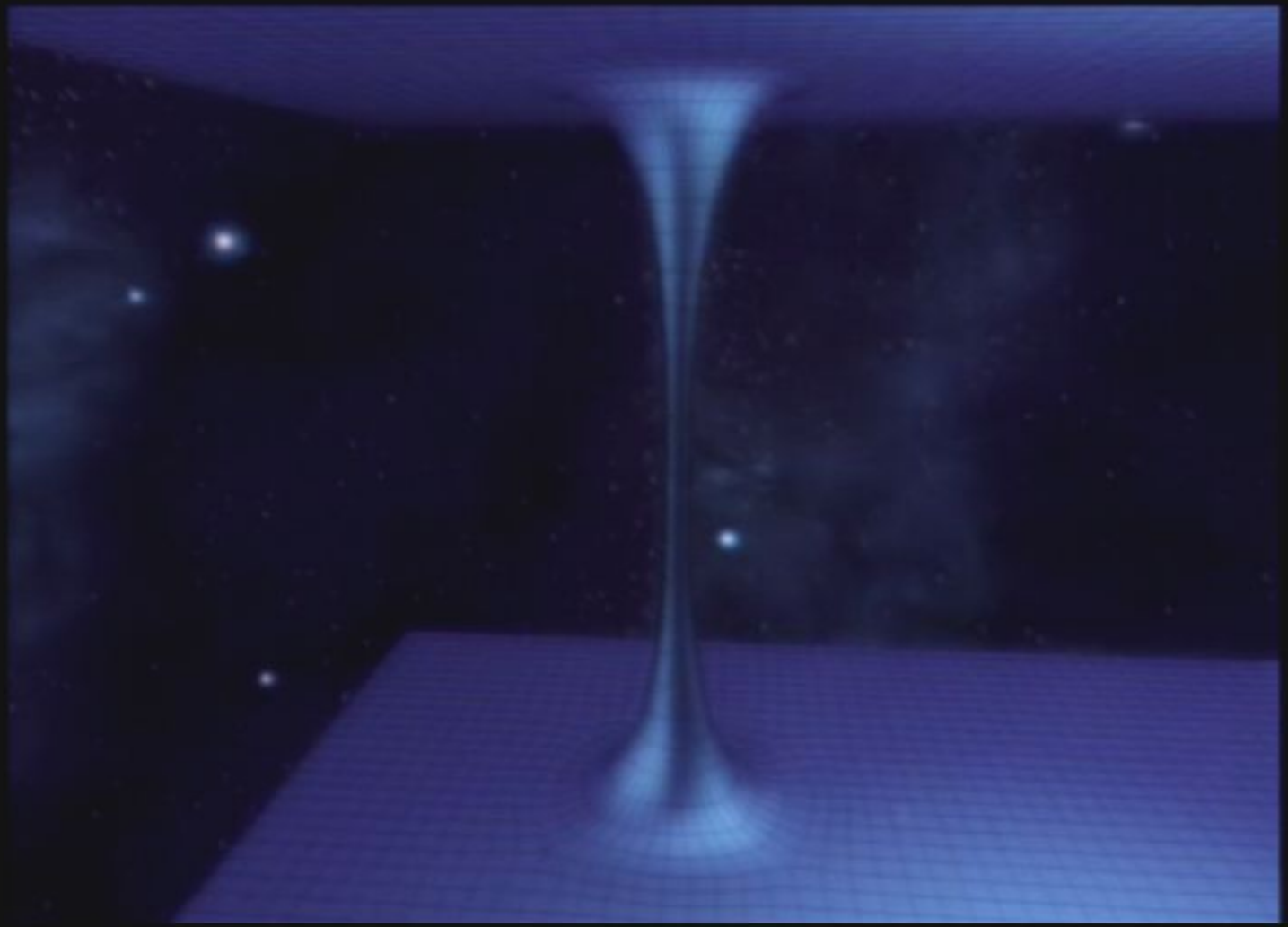

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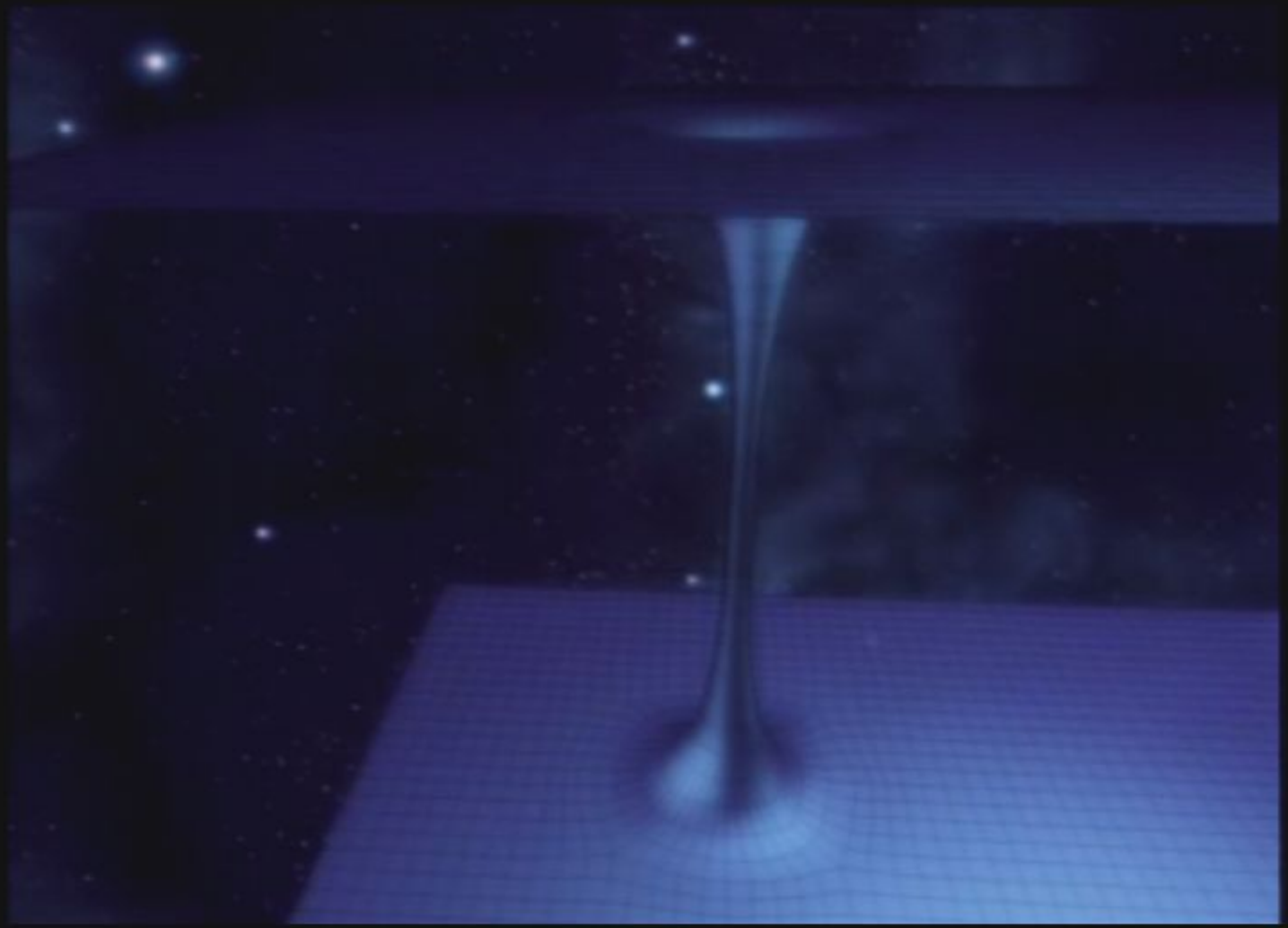

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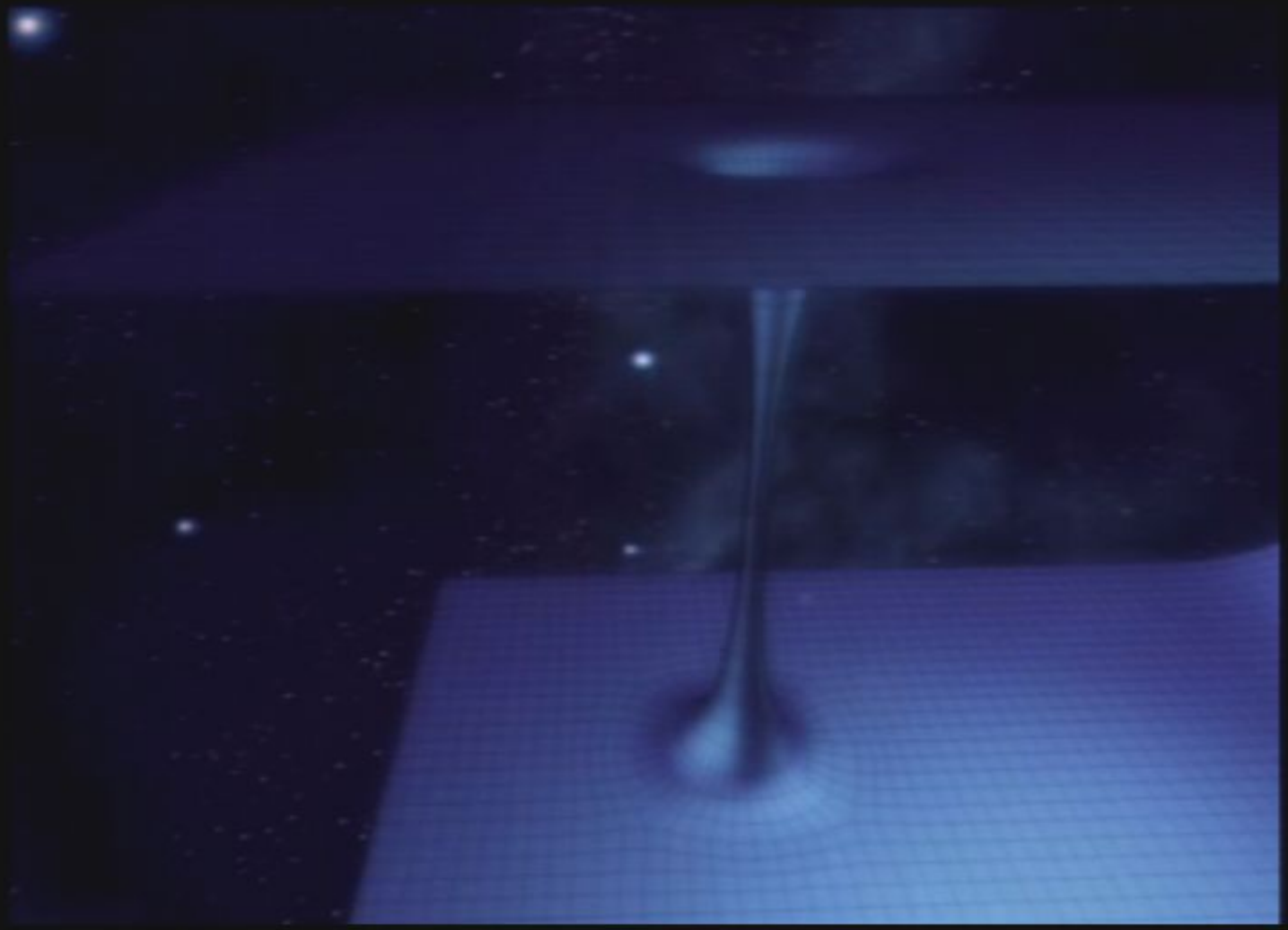

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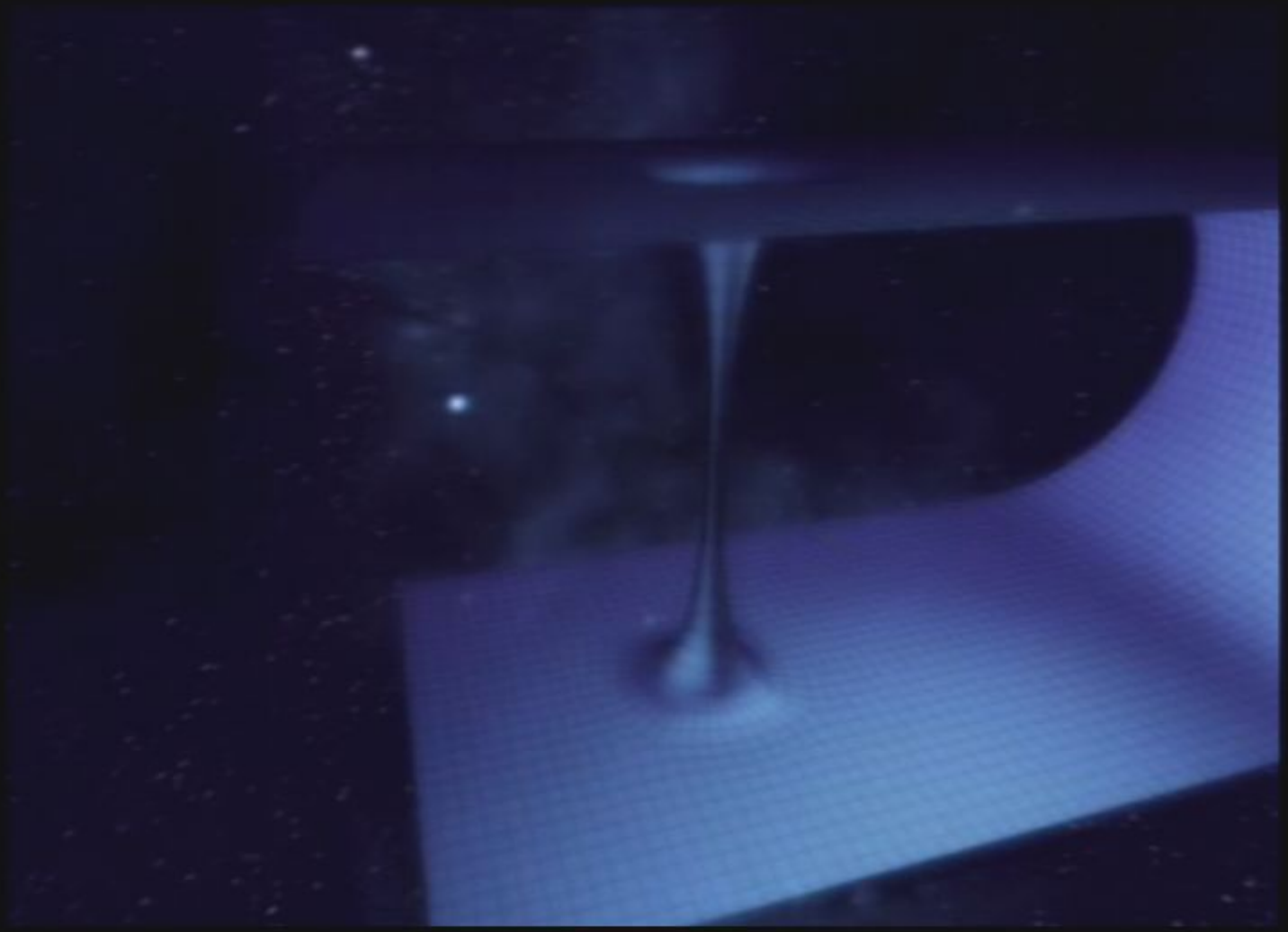

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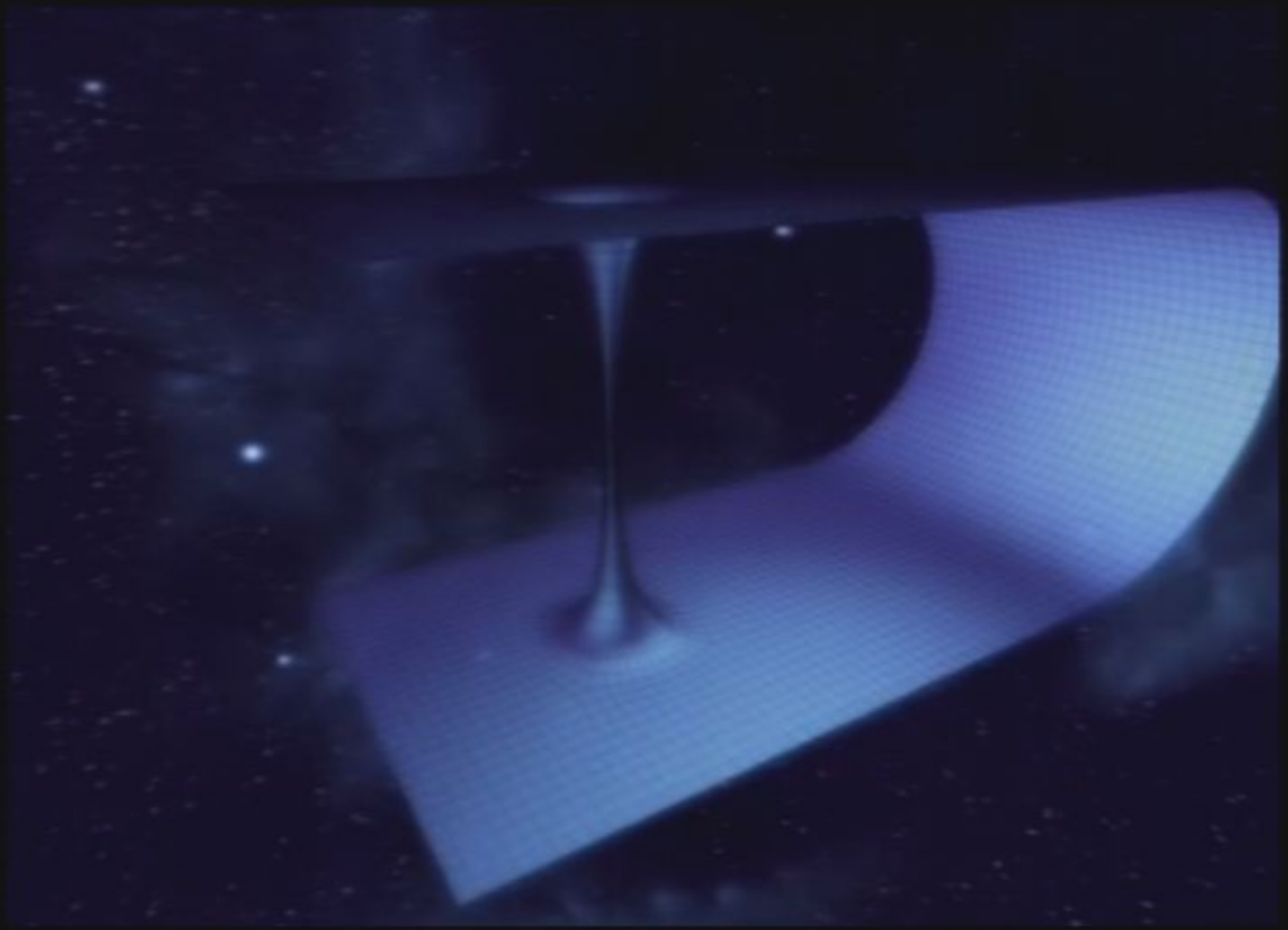

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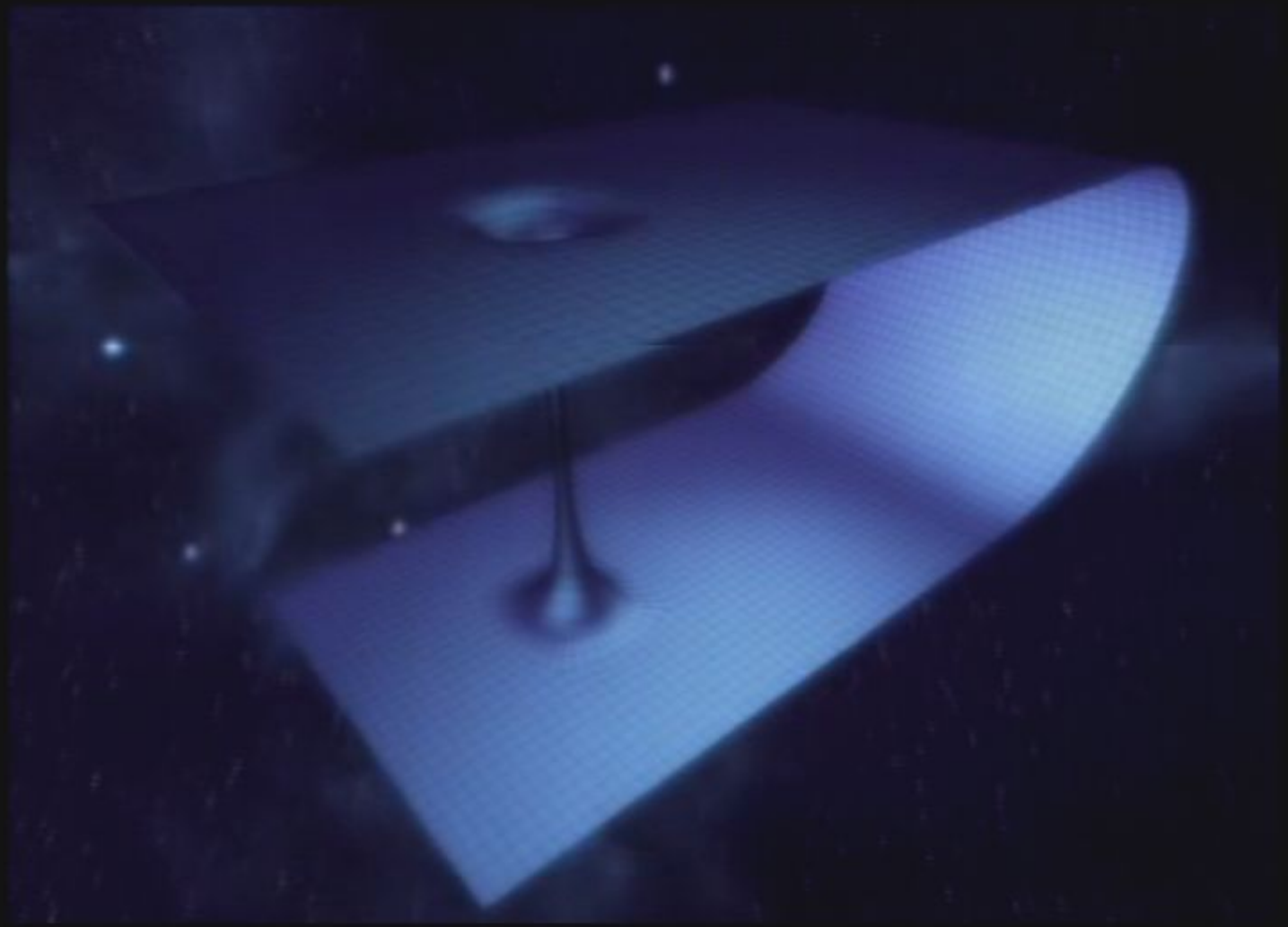

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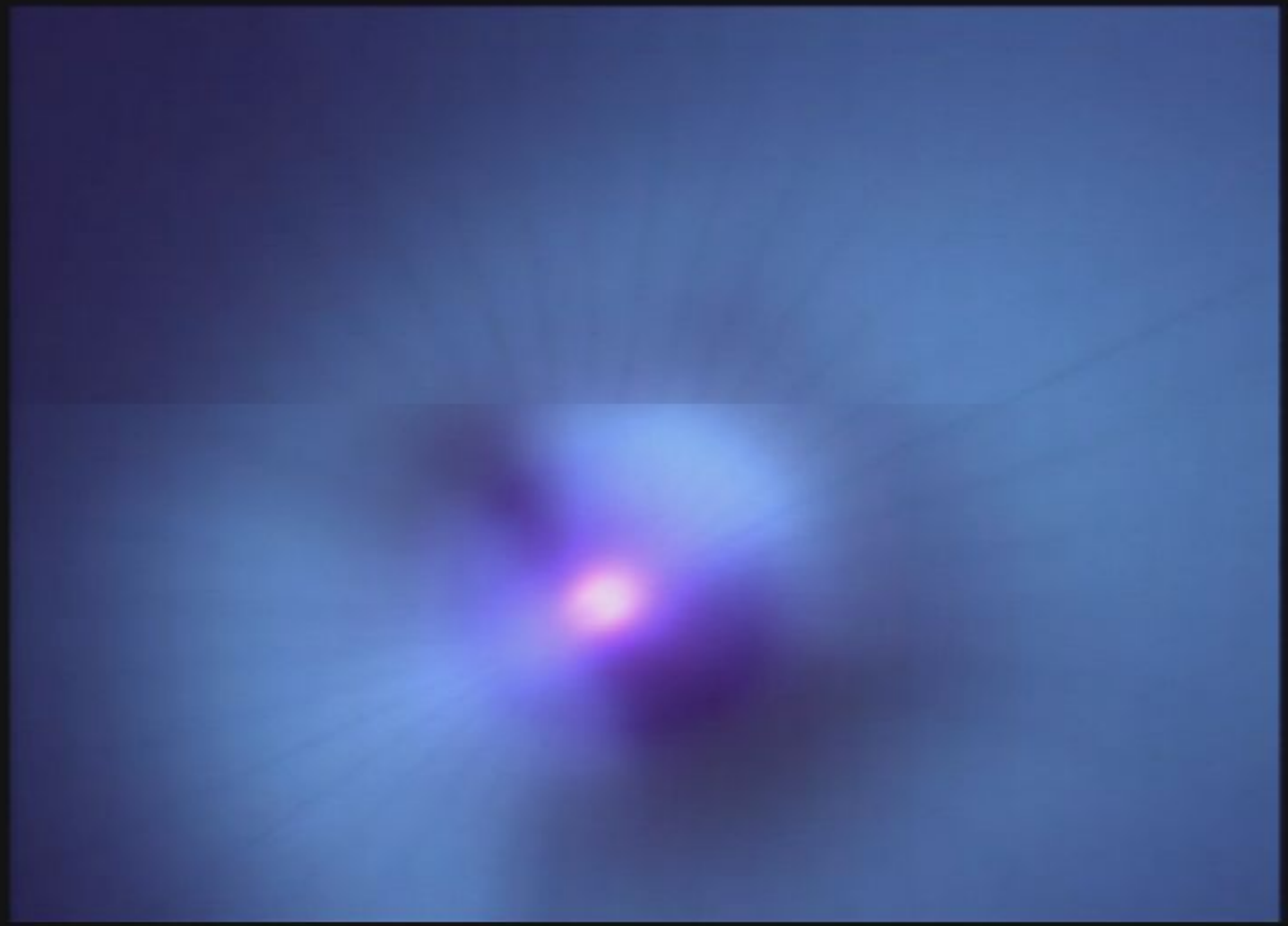

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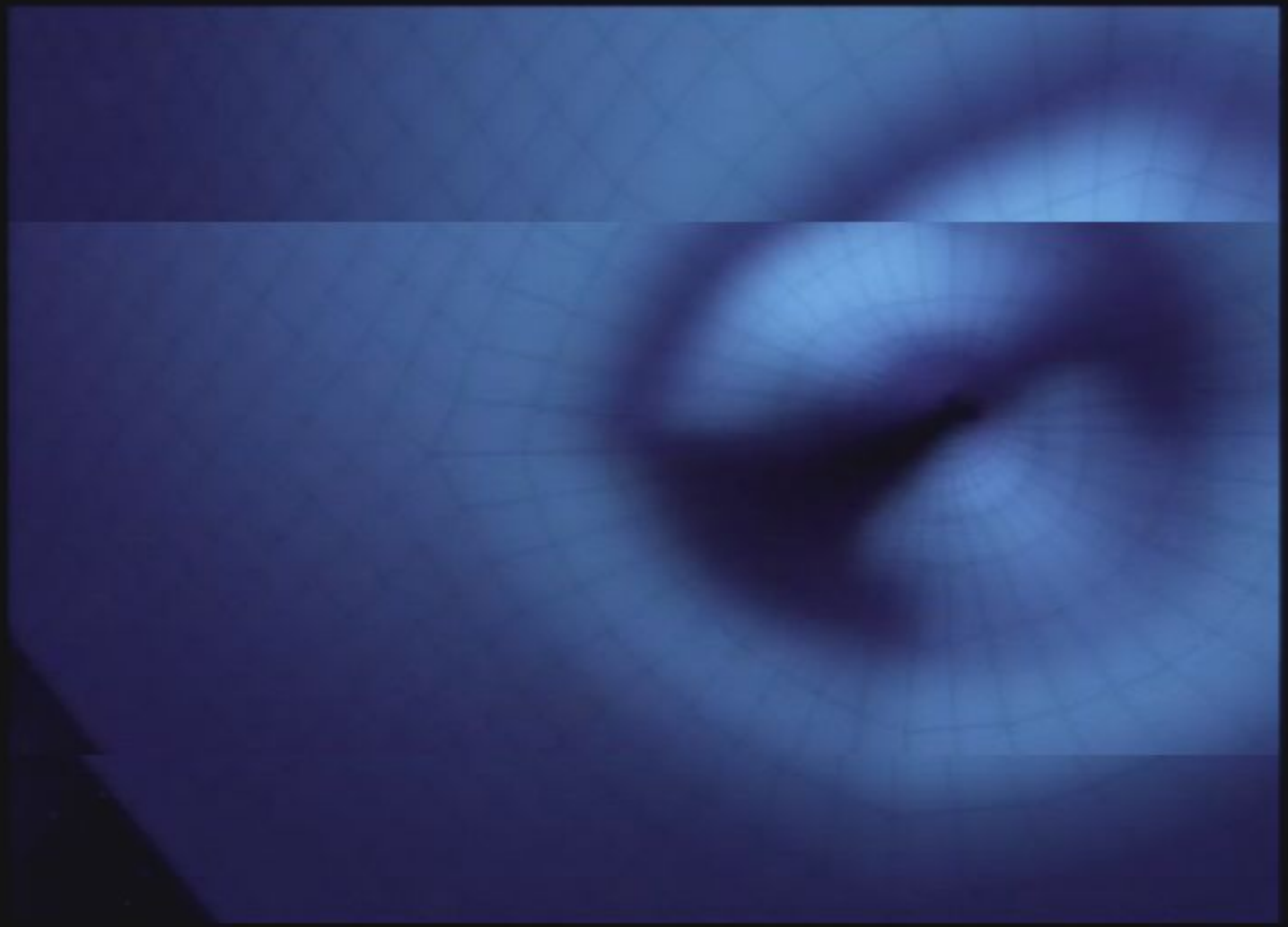

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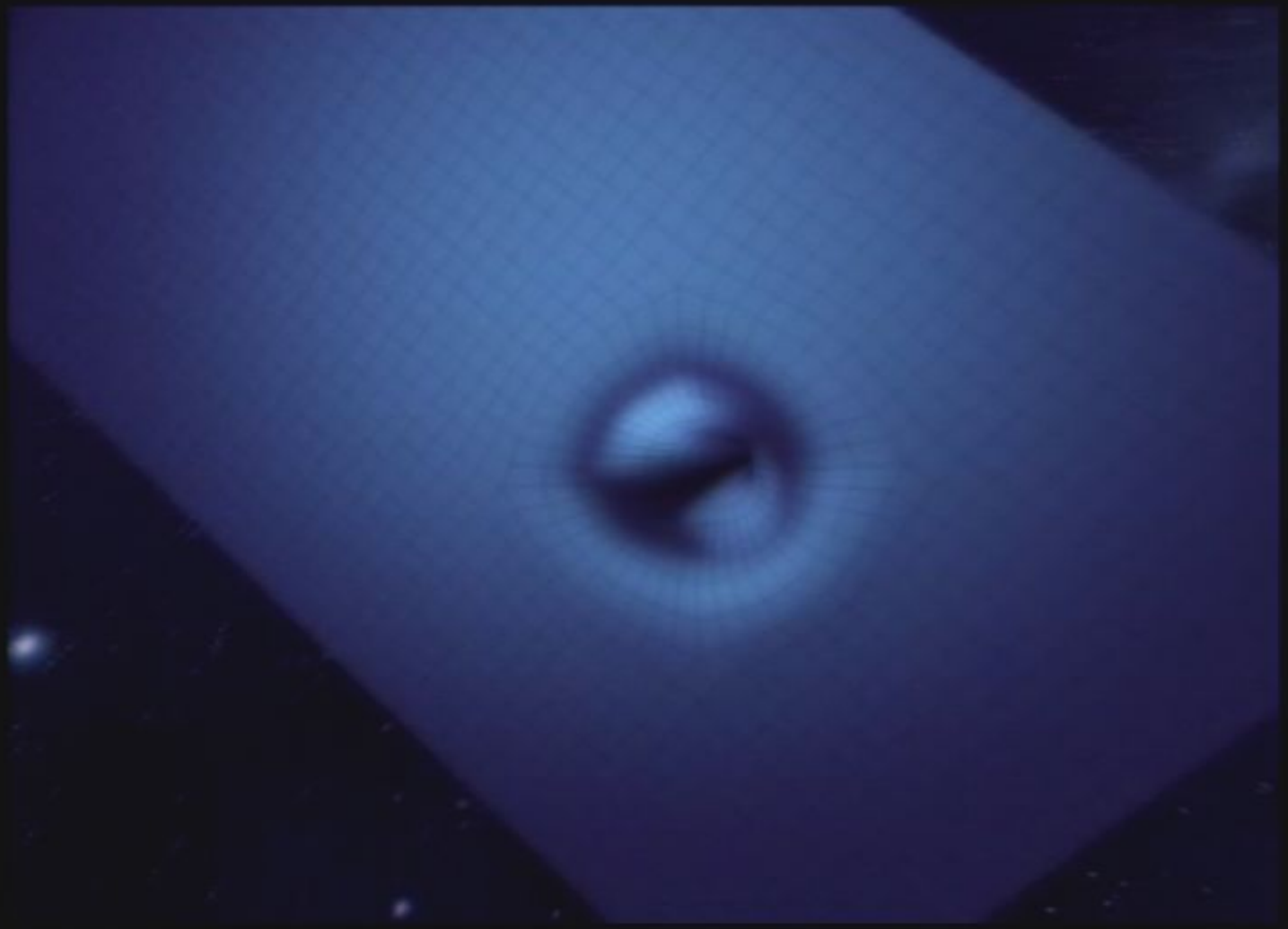

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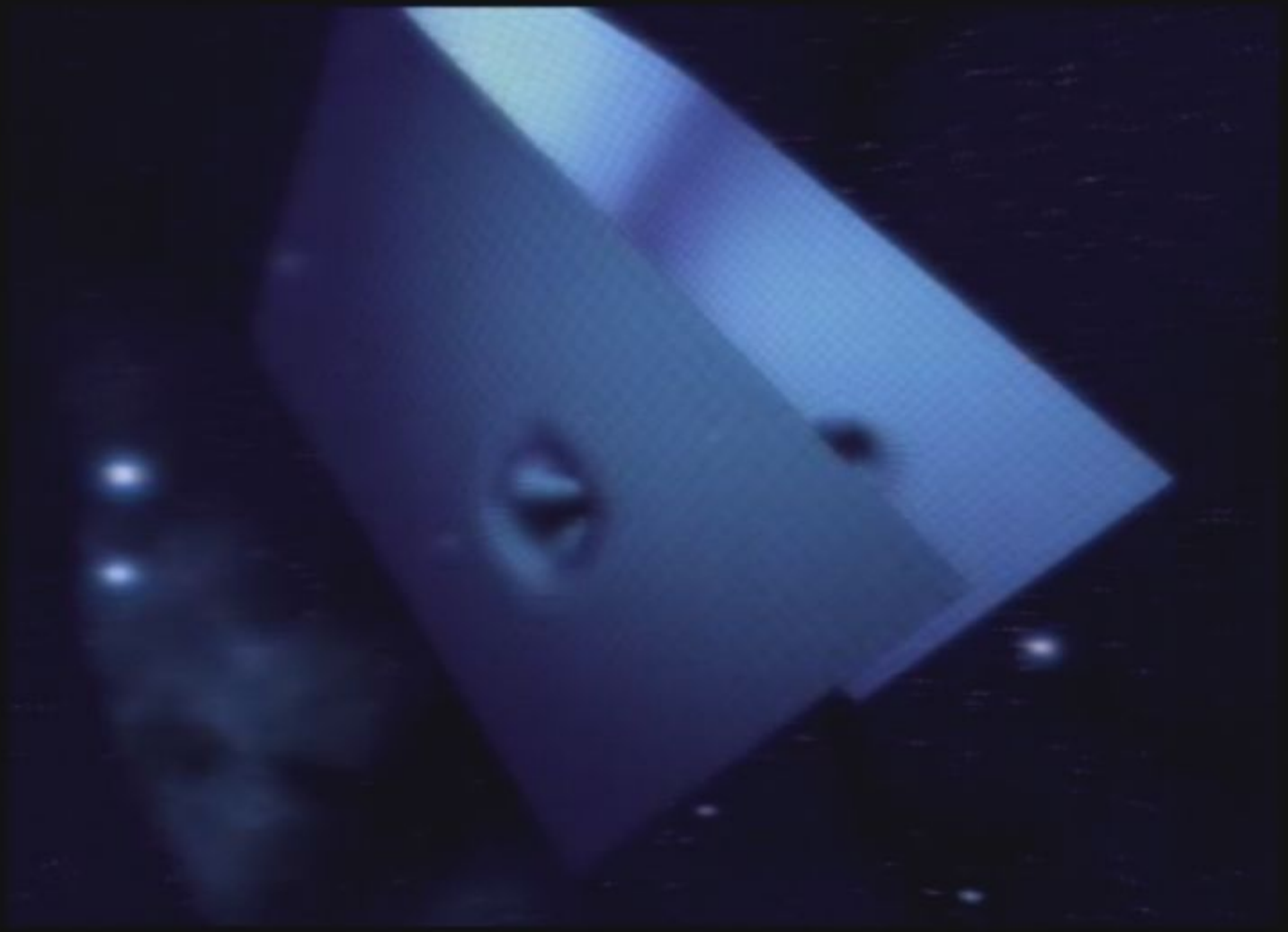

Wormholes (the traveler's view)

Naked Singularity

Such a naked singularity would be a breakdown in the laws of physics. After that, you could no longer guess what would come out of the black hole--it could be anything (to quote William H. Press) "from television sets to busts of Abraham Lincoln."

A singularity that is not inside a black hole (not surrounded by an event horizon), and therefore can be seen by someone outside it.

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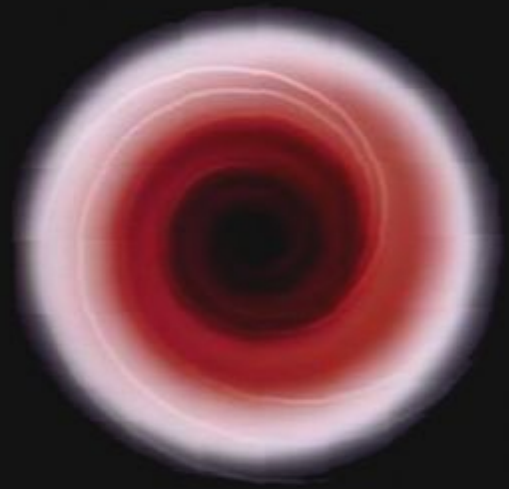

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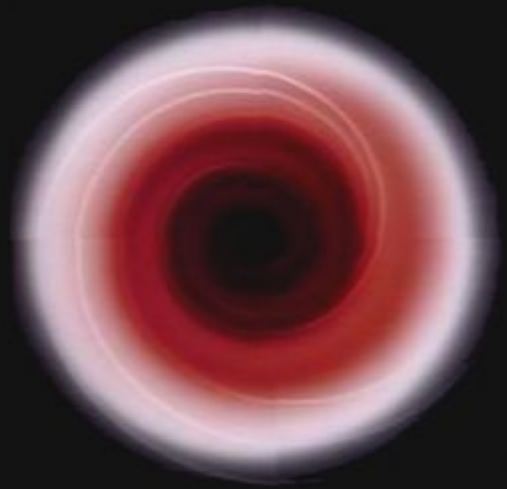

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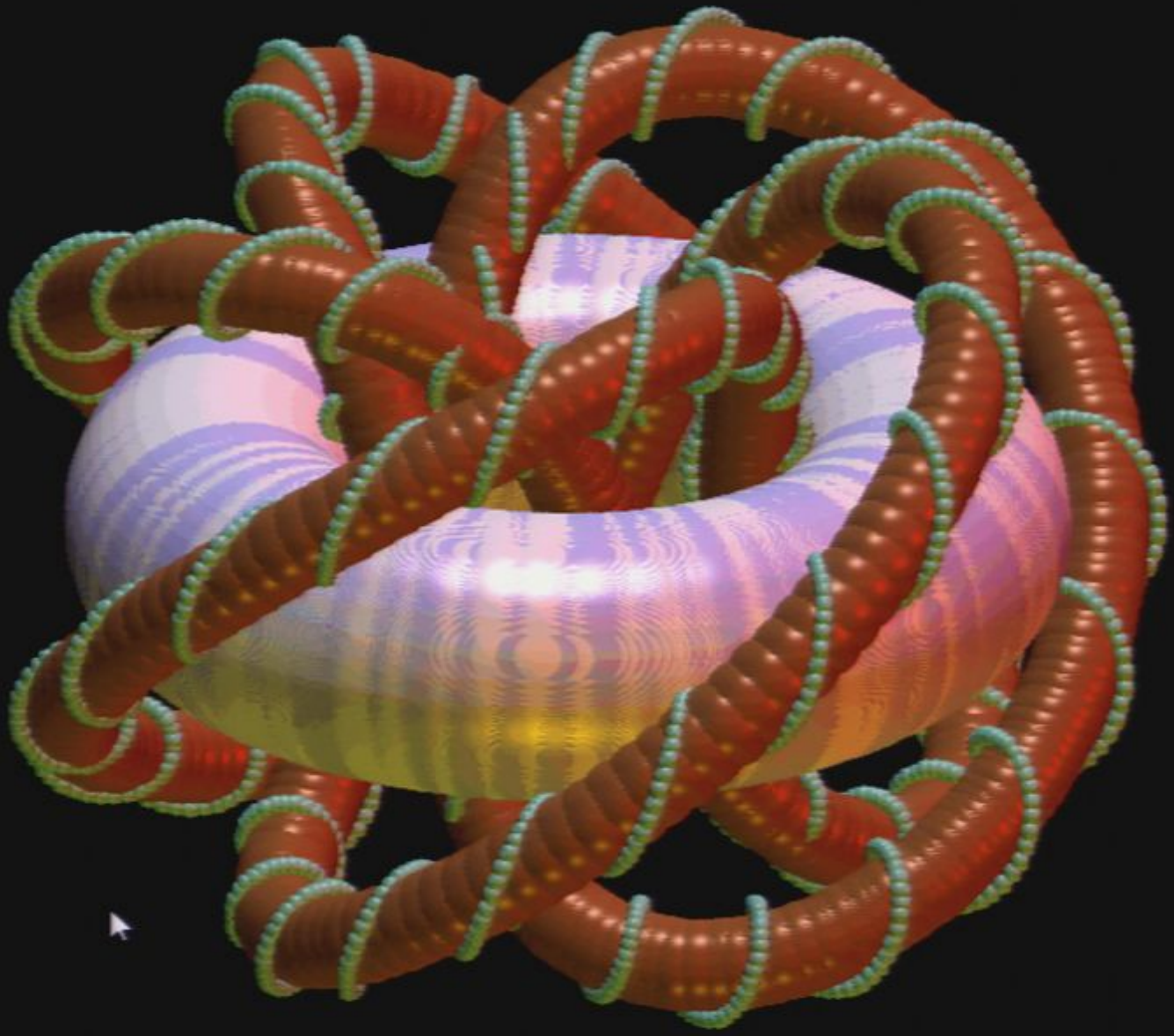
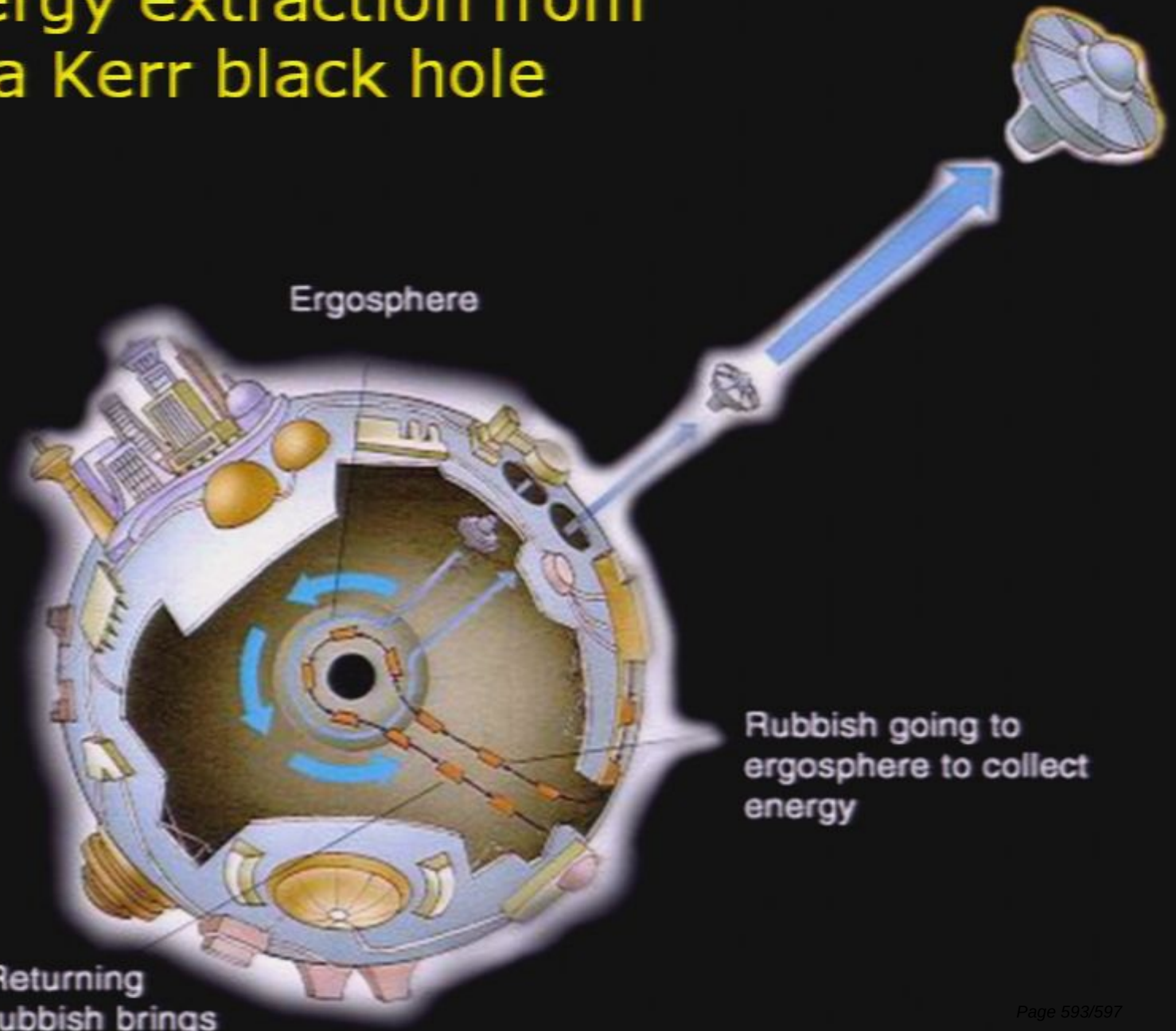
Time Travel



Energy extraction from a Kerr black hole

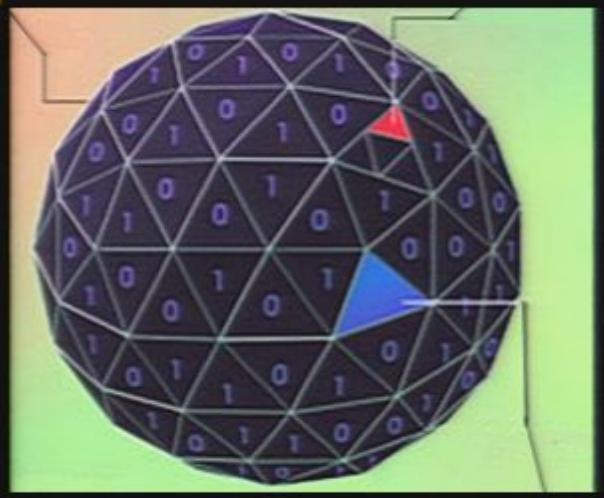


Holographic Universe

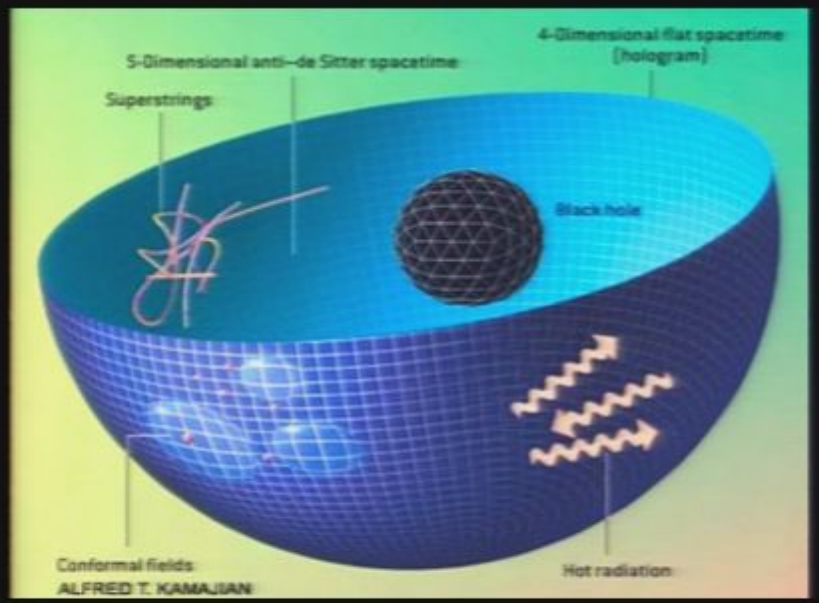
- *An astonishing theory called the holographic principle holds that the universe is just like a hologram.*
- *The physics of Black Holes demonstrates that the maximum entropy or information content of any region of space is defined not by its volume but by its surface area*

Black Hole event horizon

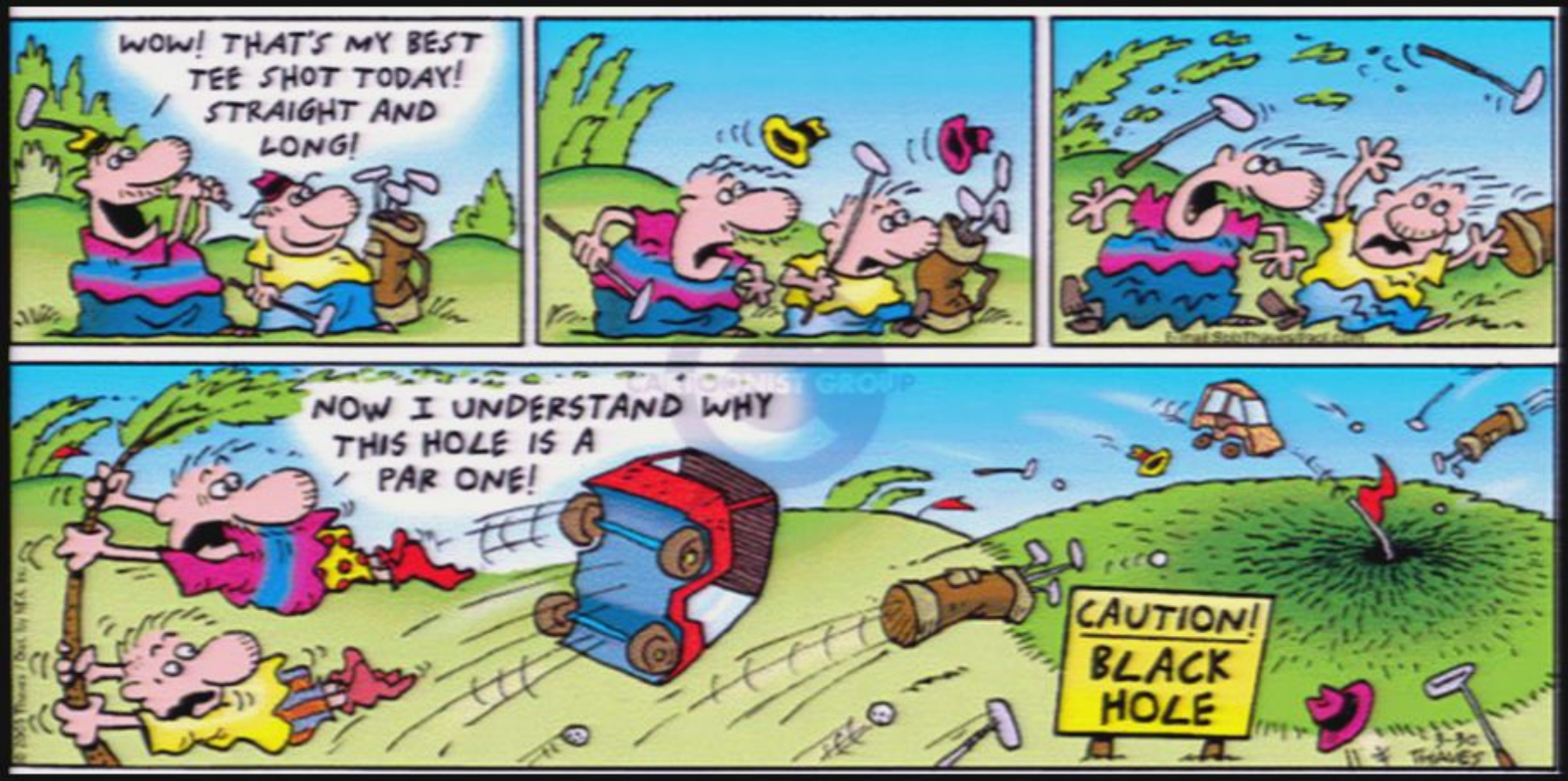
One Planck Area



One unit of entropy



WOW! THAT'S MY BEST TEE SHOT TODAY! STRAIGHT AND LONG!
NOW I UNDERSTAND WHY THIS HOLE IS A PAR ONE!
CAUTION! BLACK HOLE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