Title: General Relativity 5 - The Black Hole

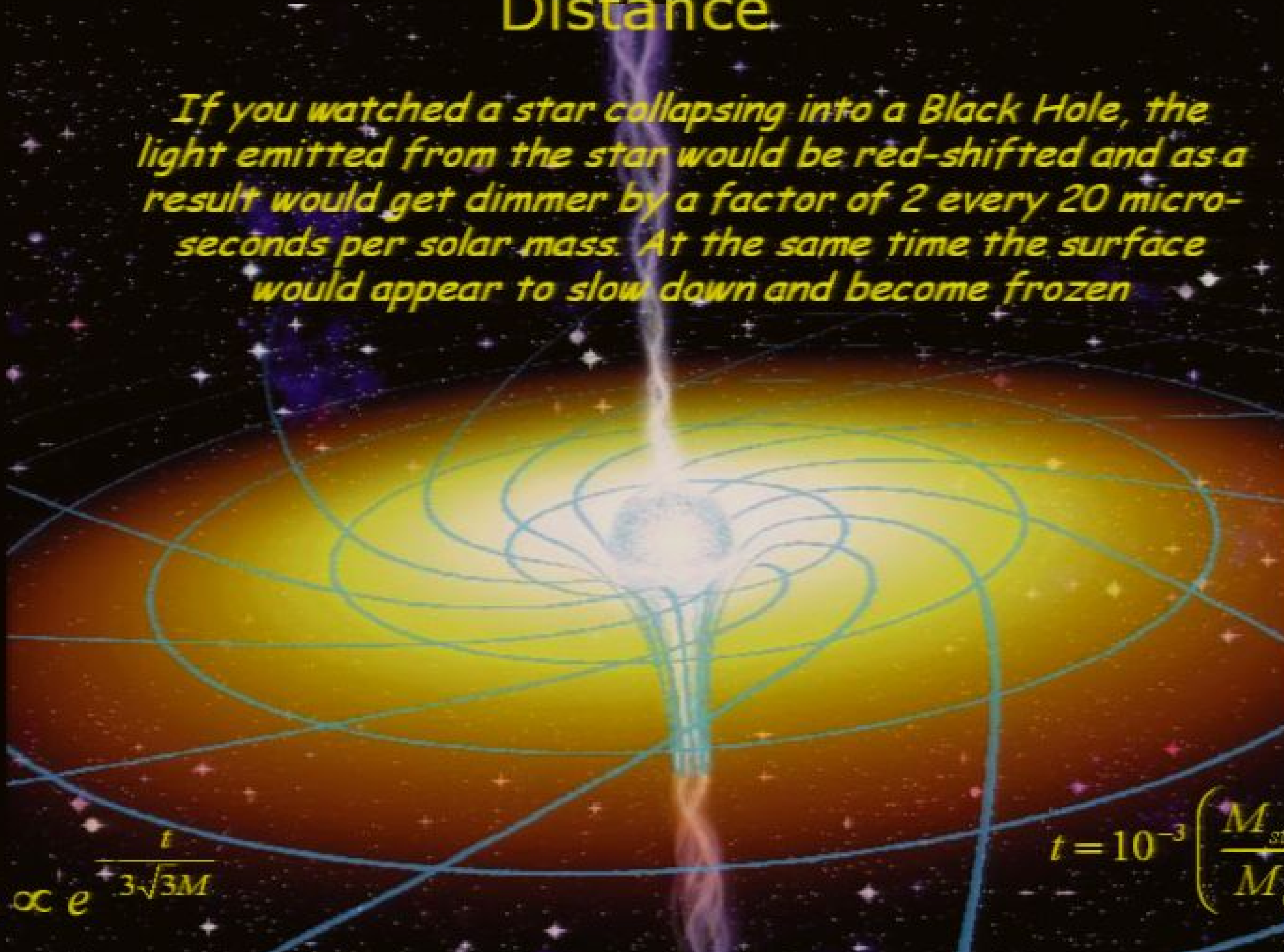
Date: Aug 02, 2006 09:15 AM

URL: http://pirsa.org/08080075

Abstract: The anatomy of a black hole.
Learning Outcomes:
â€¢ What are the mass requirements for a star to become a black hole?
â€¢ The anatomy of a Schwarzschild black hole, including the singularity and the event horizon.
â€¢ What a traveller would experience if he orbited a black hole, or had the bad luck to fall through the event horizon.

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

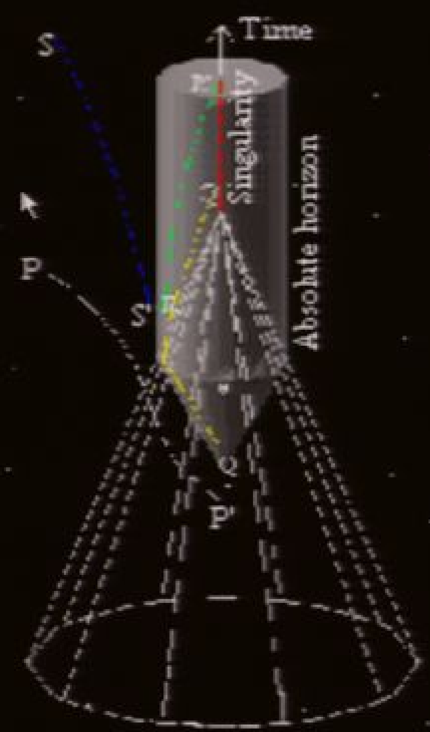


$$L \propto e^{-\frac{t}{3\sqrt{3}M}}$$

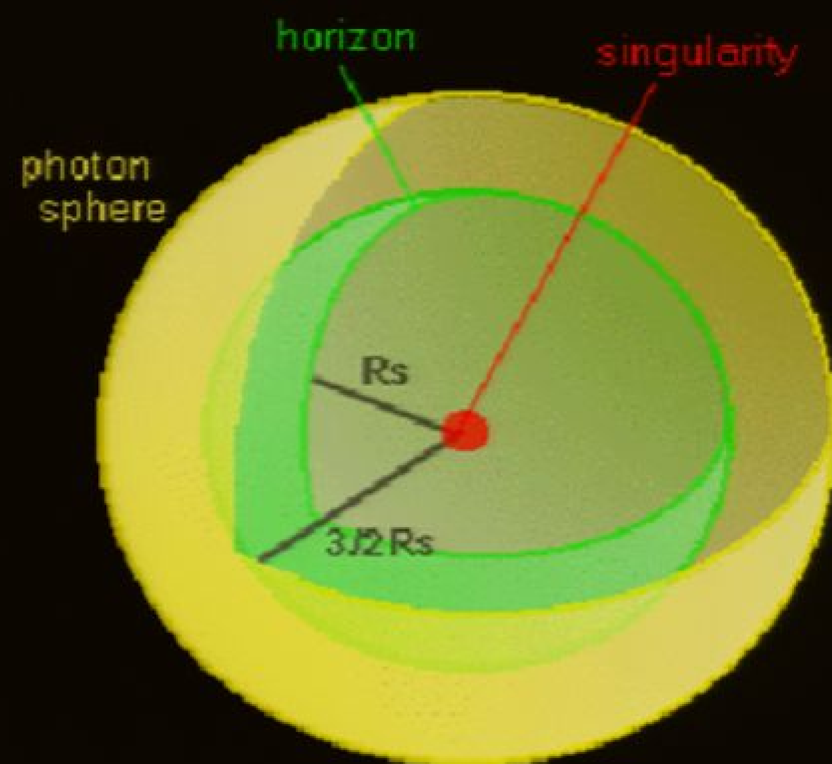
$$t = 10^{-3}\left(\frac{M_{star}}{M_{\odot}}\right)$$

Riding the Surface Down

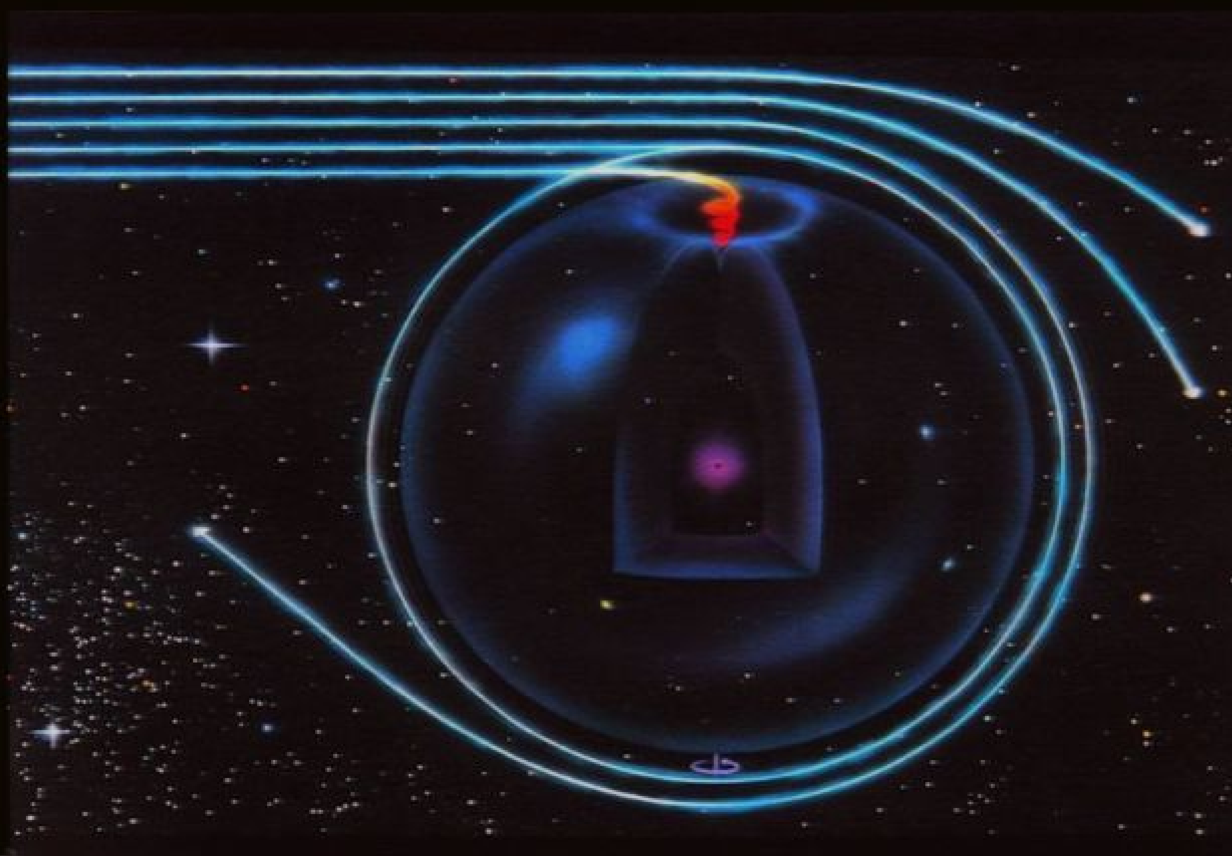
- *When the star passes the critical circumference creating an apparent horizon around itself, the star continues to implode to infinite density and zero volume, where upon it creates and merges into a space time singularity.*
- *The location where photons trying to escape get "bent" back in is the "apparent horizon"*
- *The "absolute horizon" is the boundary between where events can send signals to the outside world and where events cannot, this grows why star undergoes its dynamics process until it coincides with the suddenly created apparent horizon.*



Structure of a black hole



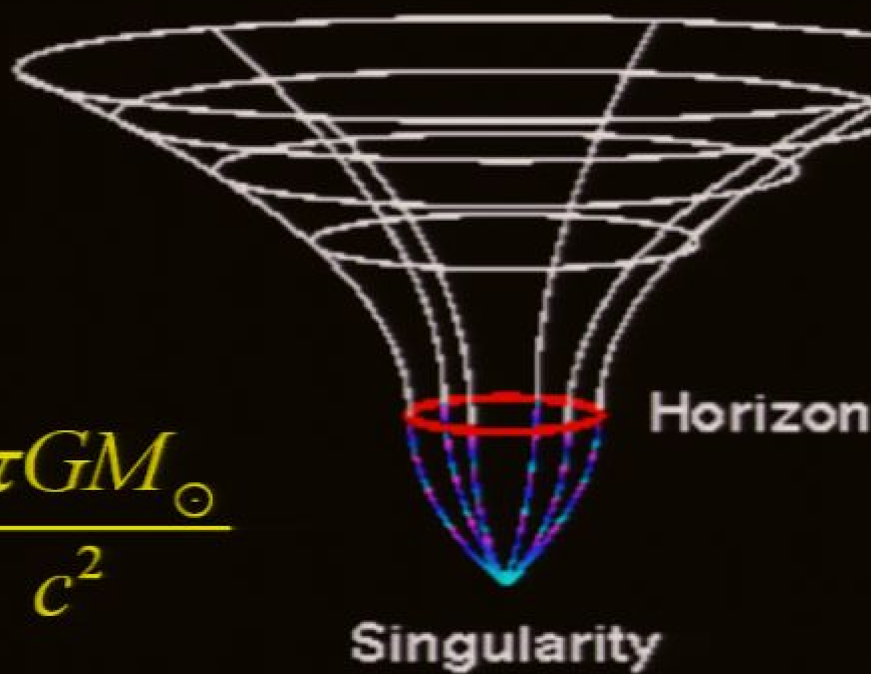
Photon orbits around a black hole



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.*

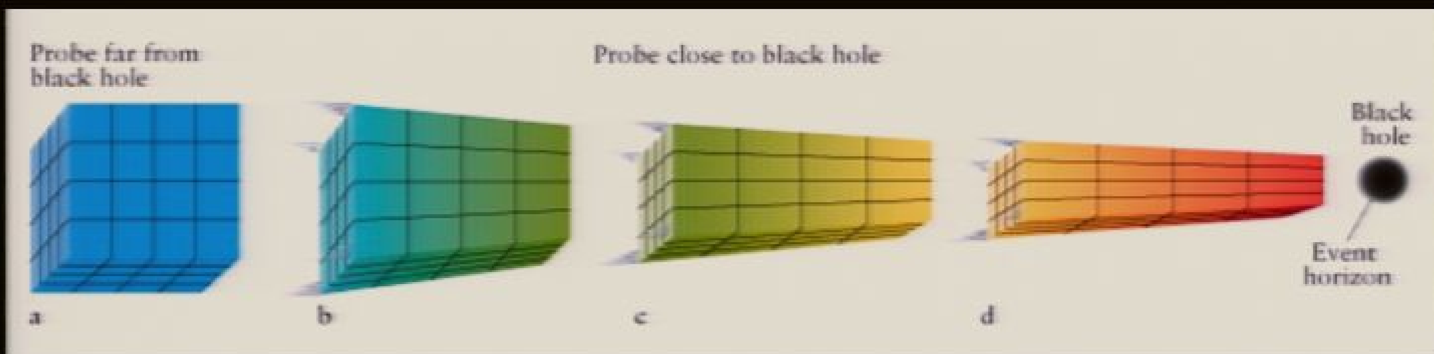
Embedding Structure



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

$$r_s = \frac{2 G M_\odot}{c^2}$$

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
- The ship will appear to hover forever at the edge of the hole to us - an effect of the time dilation
- In the ship though, you do go into the black hole.
- Nothing can leave a singularity (cosmic censorship).

Time Dilation and Blueshift

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

If you hovered at 1.000 0001 times the event horizon circumference, then one day for you would mean …

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

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

1024 days for the rest of the universe.

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

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1.6×10^{-9} m (x-ray)

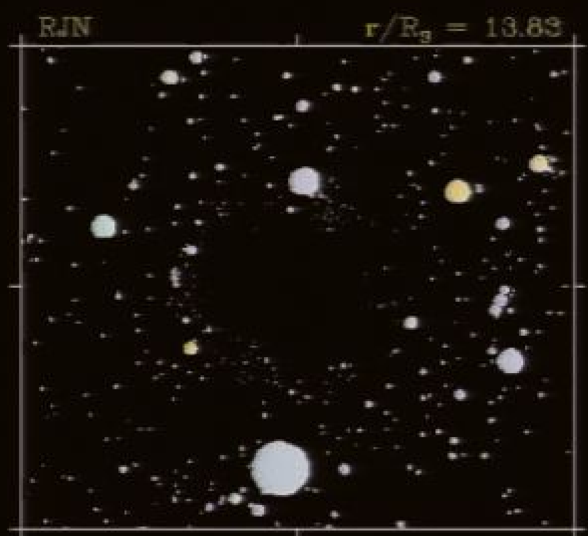
Visiting a Black Hole

Spaghettification!

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

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

Approaching



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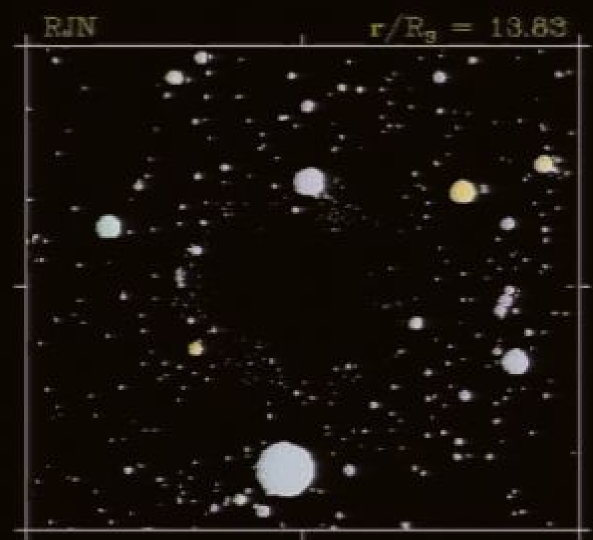

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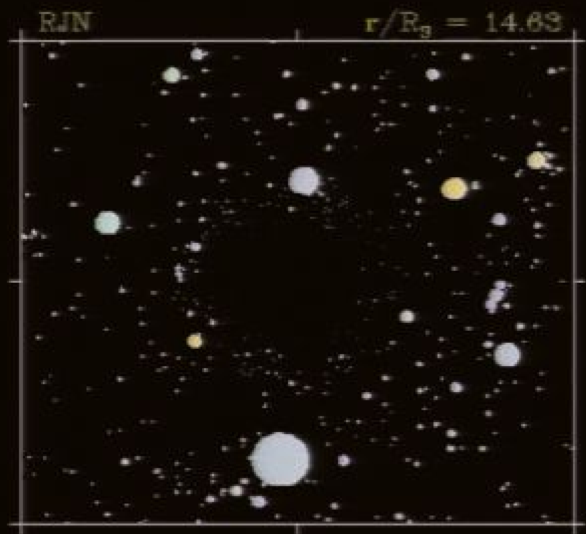

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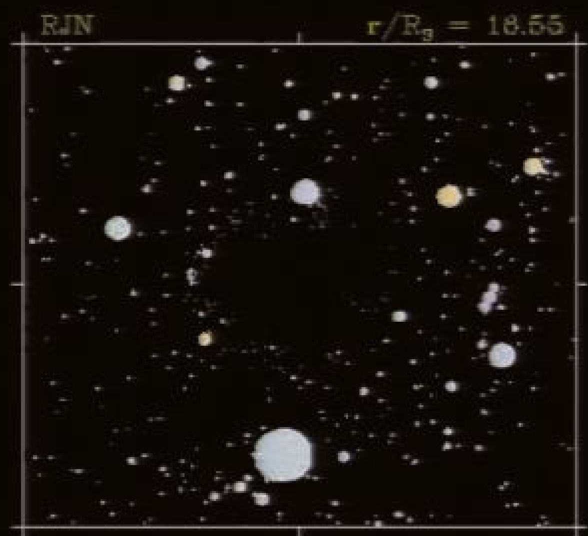

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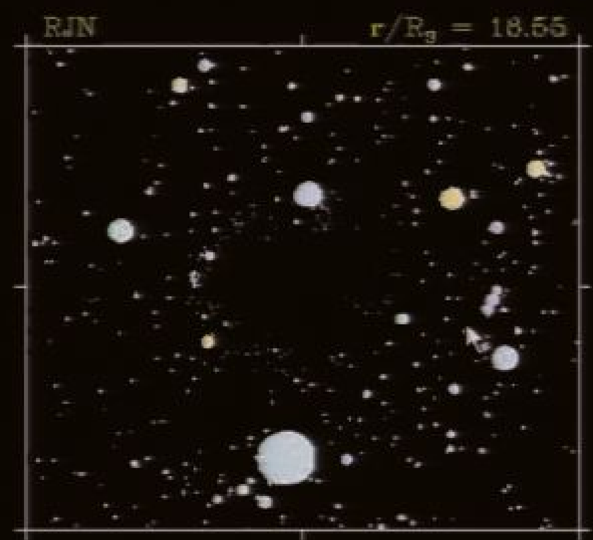

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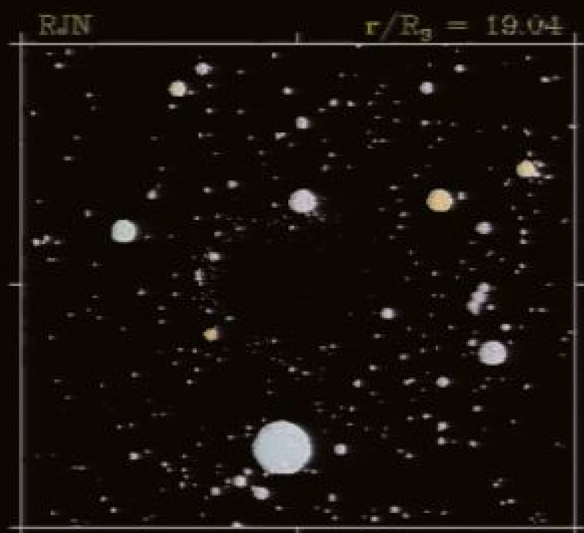

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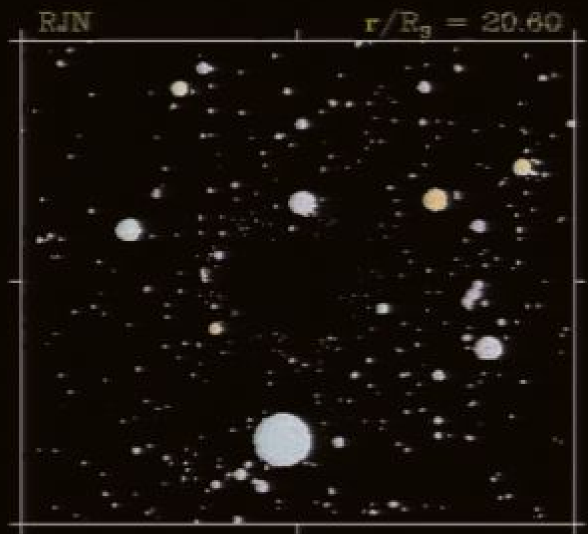

Orbiting Black Hole Looking Down