Title: Songs of the Stars: the Real Music of the Spheres

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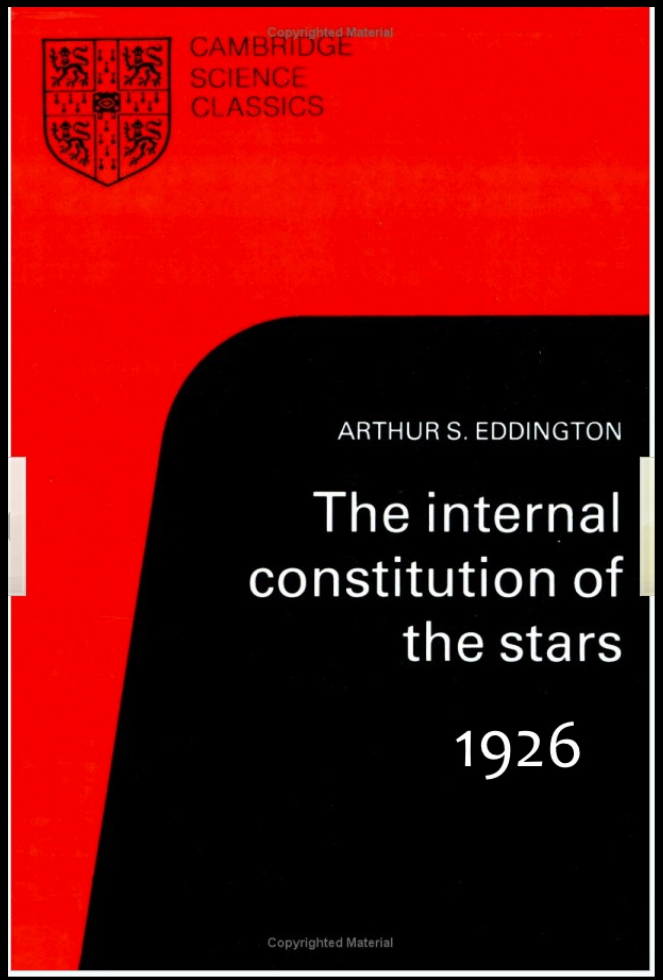
Abstract:

Songs of the Stars: the real Music of the Spheres

Professor Don Kurtz
Jeremiah Horrocks Institute
University of Central Lancashire



At first sight it would seem
that the deep interior
of the Sun and stars
is less accessible
to scientific investigation
than any other region of the universe.

Our telescopes may probe
farther and farther
into the depths of space;
but how can we ever obtain
certain knowledge
of that which is hidden
behind substantial barriers?

What appliance
can pierce through
the outer layers of a star
and test
the conditions within?

Asteroseismology

Asteroseismology

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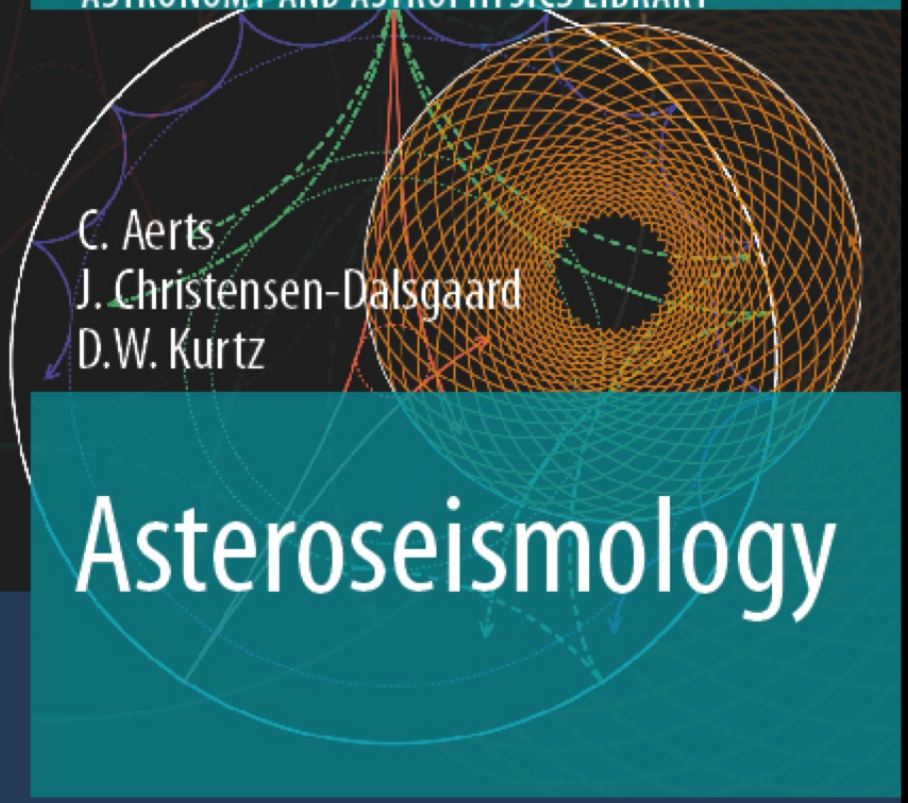

C. Aerts
J. Christensen-Dalsgaard
D.W. Kurtz

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Aerts
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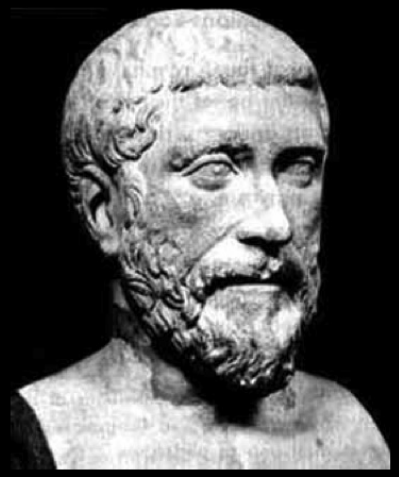
The Music of the Spheres

Pythagoras of Samos
(c.569 - 475 BC)

2:1 ratio

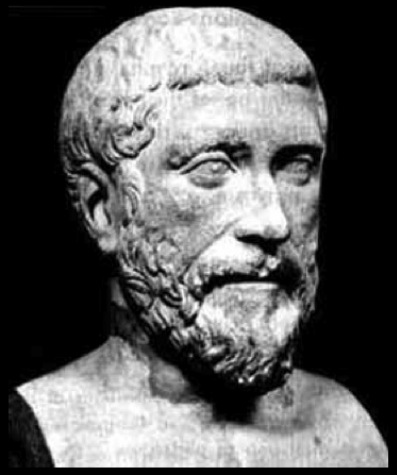


Plato said that a siren sits on each planet, who carols a most sweet song, agreeing to the motion of her own particular planet, but harmonising with all the others.

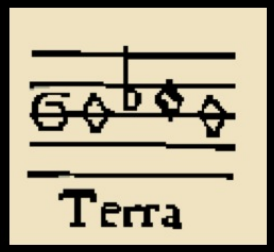
The Music of the Spheres

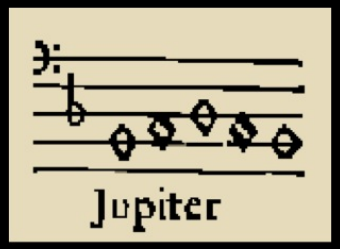
Pythagoras of Samos
(c.569 - 475 BC)

2:1 ratio



Johannes Kepler
(1571 – 1630)

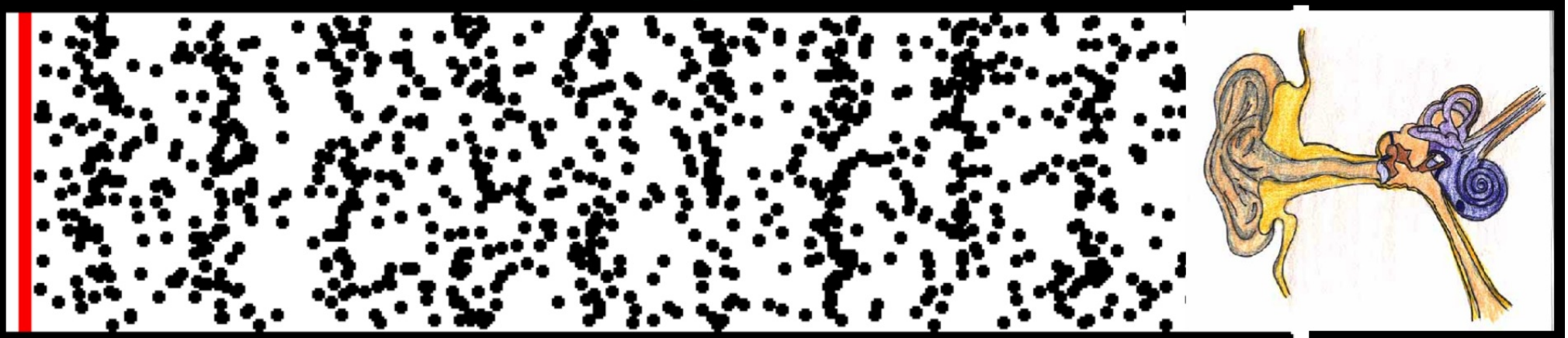




There’s not the smallest orb which thou beholdest
but in his motion like an angel sings
Still quiring to the young-eyed cherubim
(Merchant of Venice, v. 1)

Seeing with sound

Sound is a pressure wave



- More frequent collisions = faster sound speed
  - Higher temperature = faster sound speed
  - Lighter gases = faster sound speed

The range of human hearing

30 Hz to 18,000 Hz

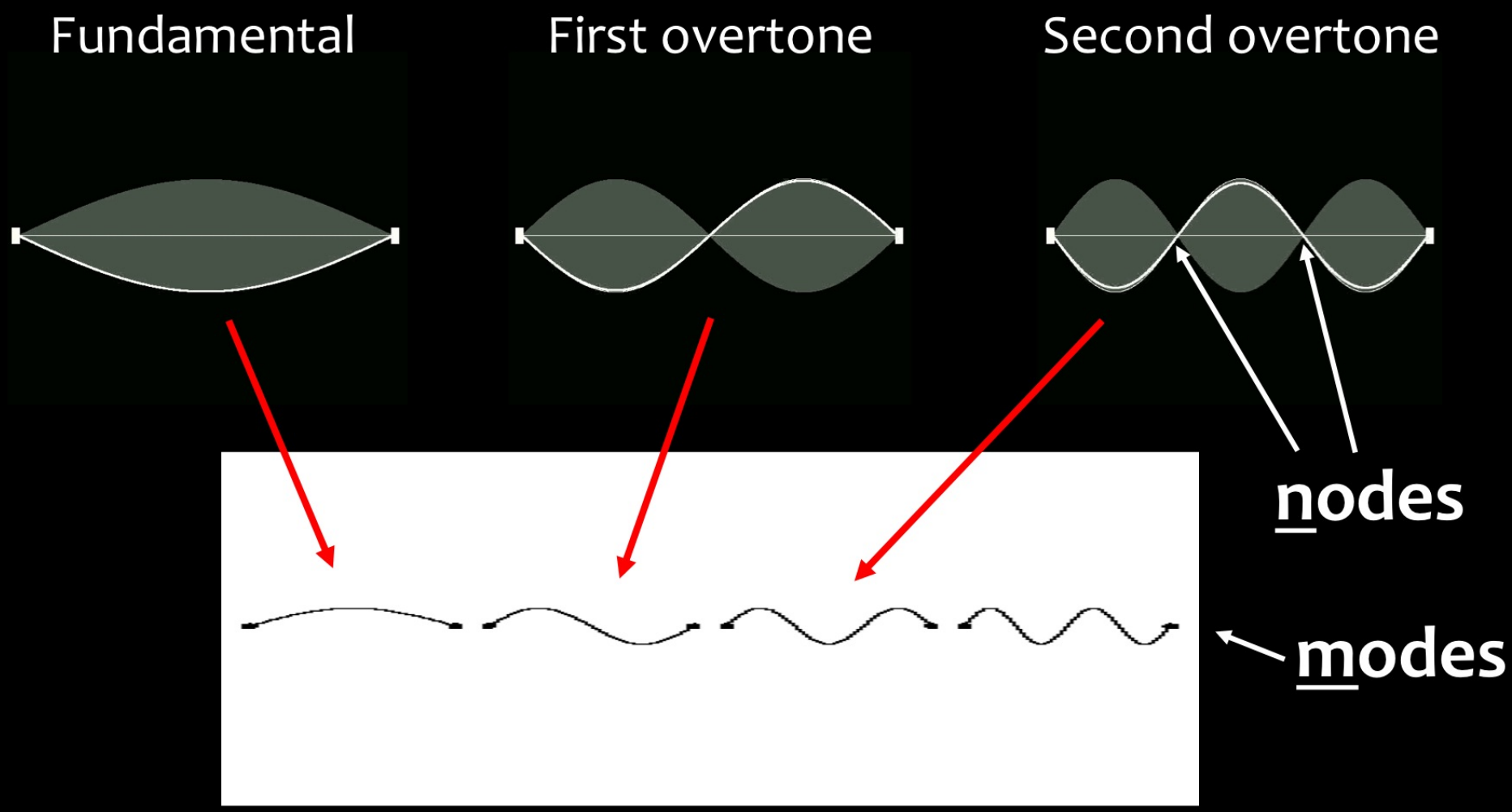
1 cycle per second = 1 Hertz = 1 Hz

Bats echo-locate at 50,000 Hz

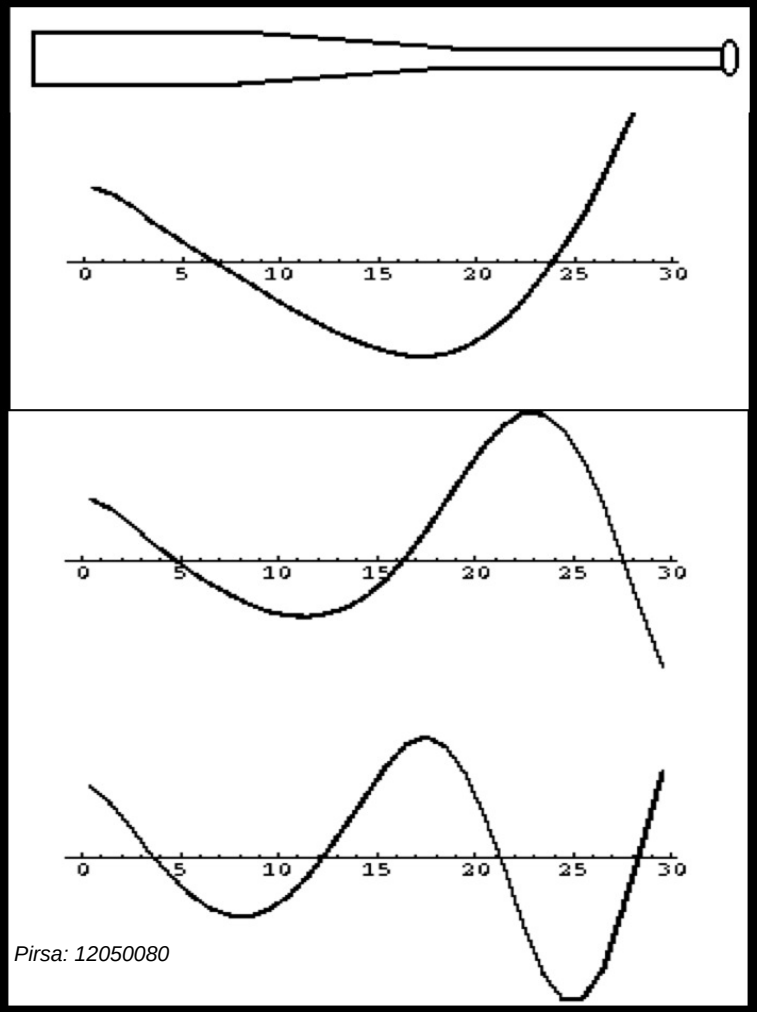
Bats echo-locate at 50,000 Hz

Blue Whales “sing” at 12-200 Hz

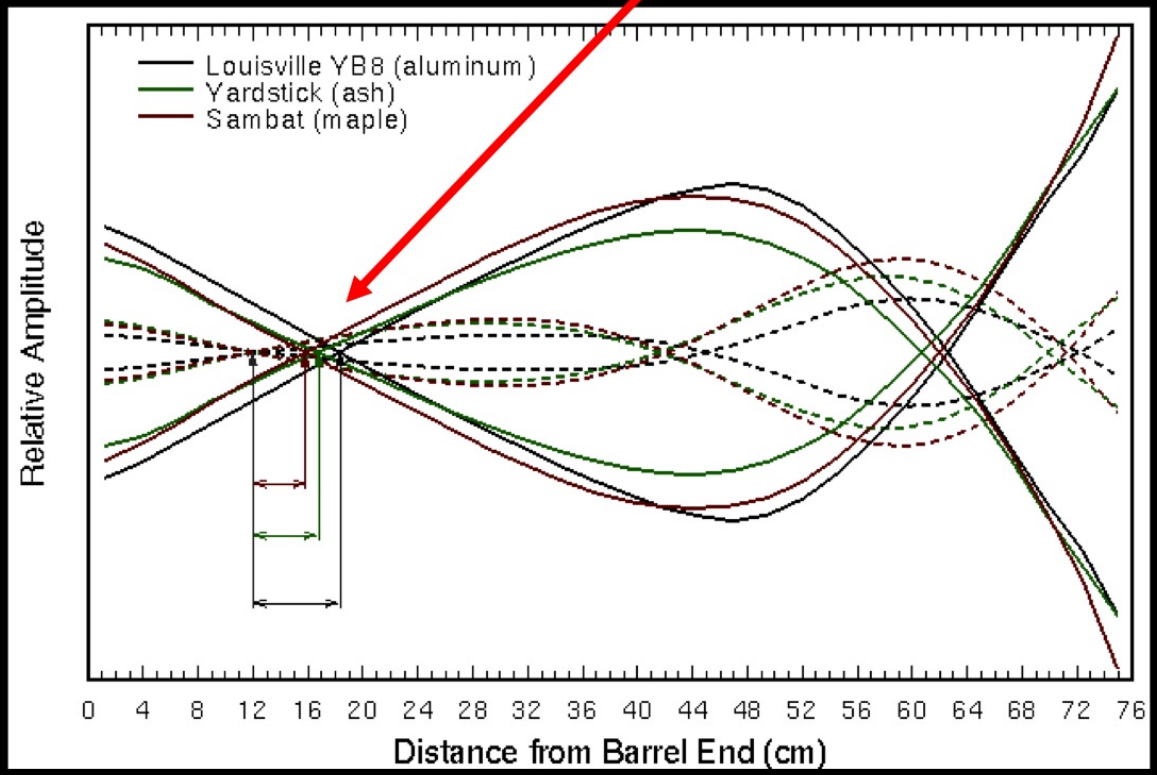
1D oscillations



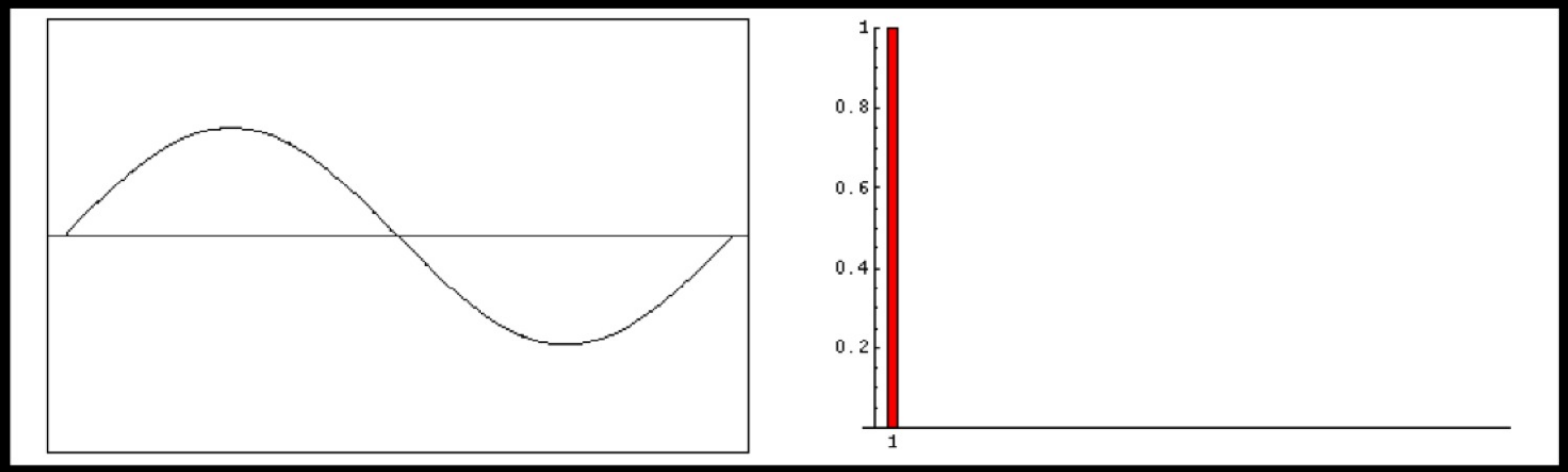
1D oscillations: The baseball bat



The "sweet spot"



pressure

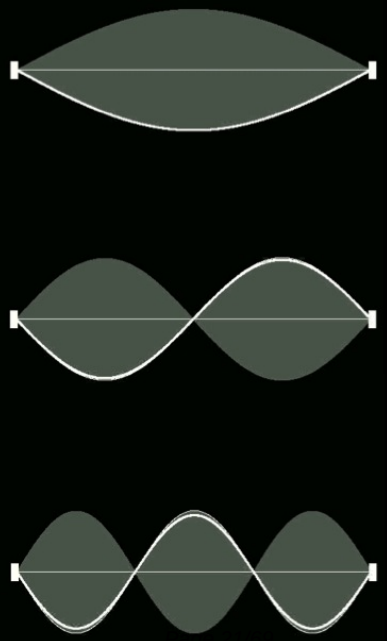


loudness

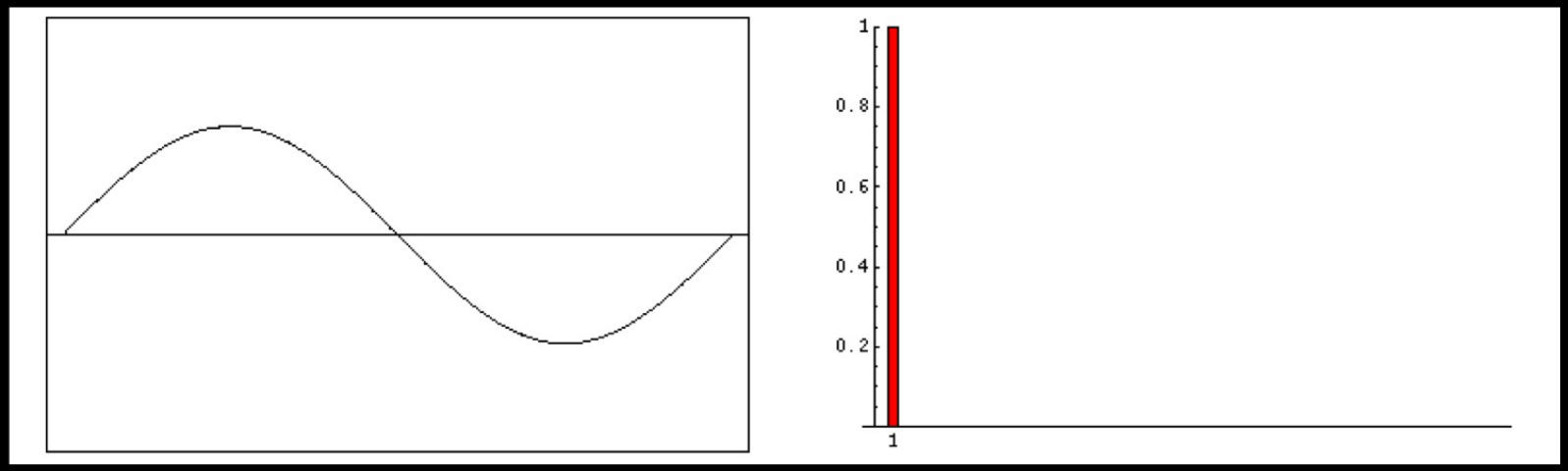
time

frequency

Harmonics



pressure

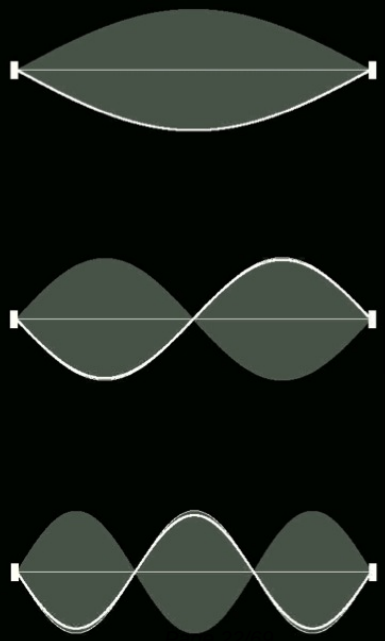


loudness

time

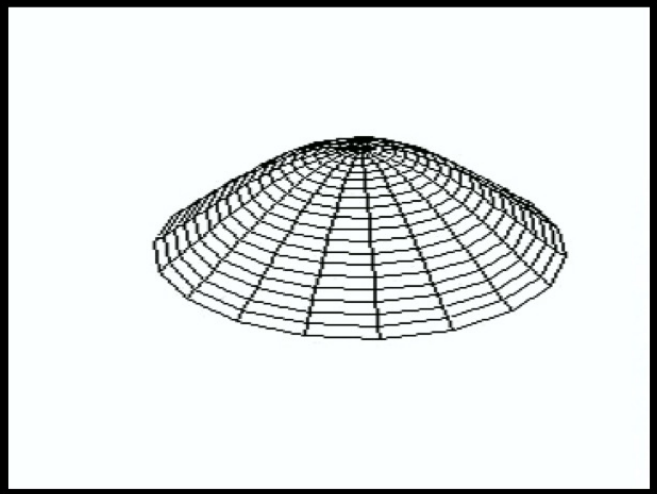
frequency

Harmonics

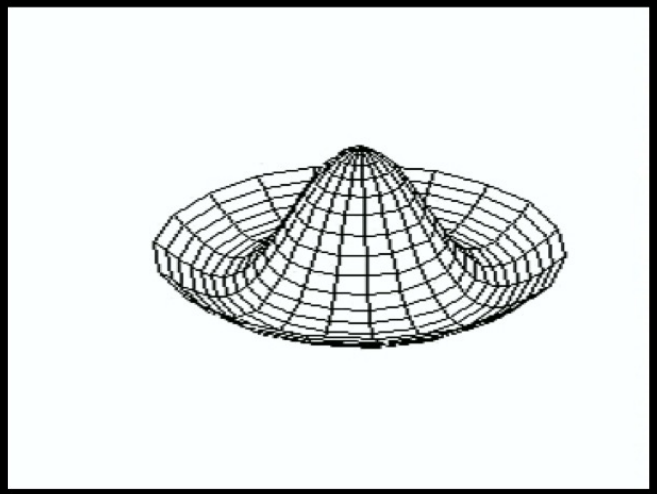


2D oscillation – drums
the radial modes

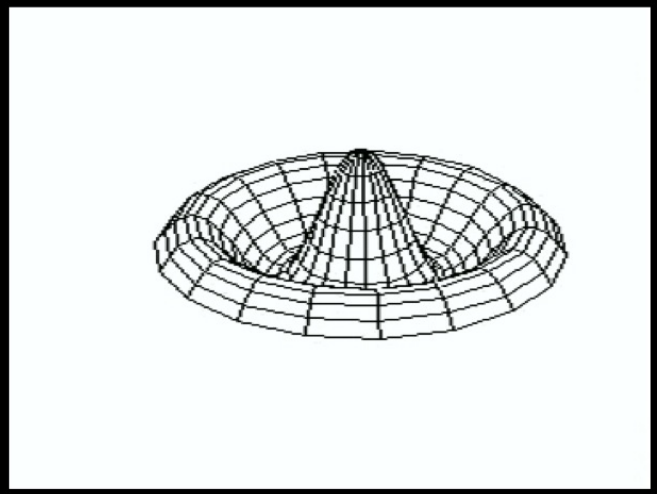
fundamental mode



1st-overtone mode

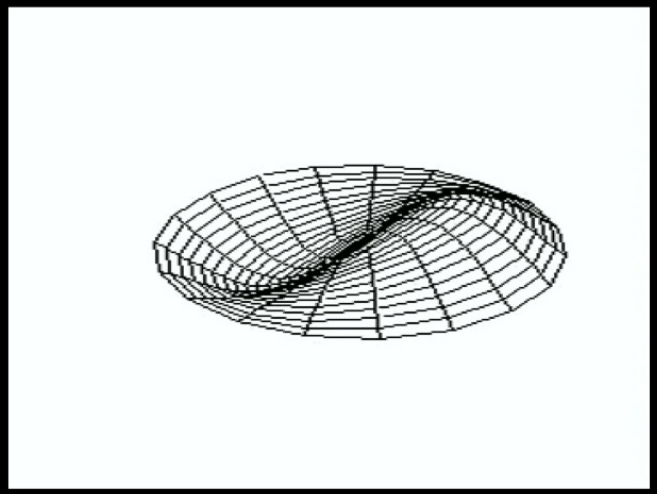


2nd-overtone mode

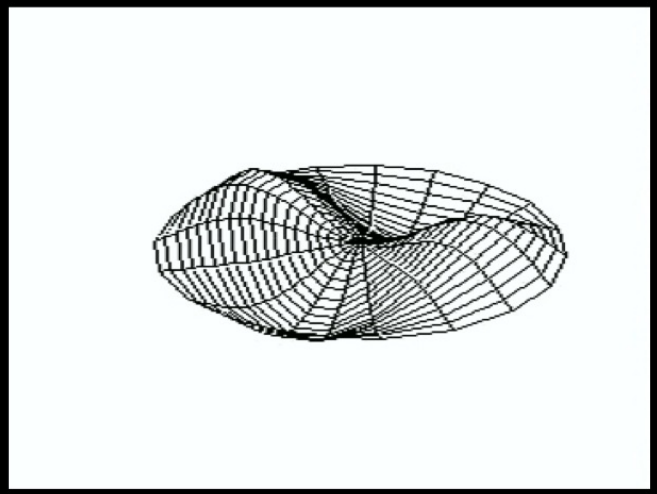


2D oscillation – drums the non-radial modes

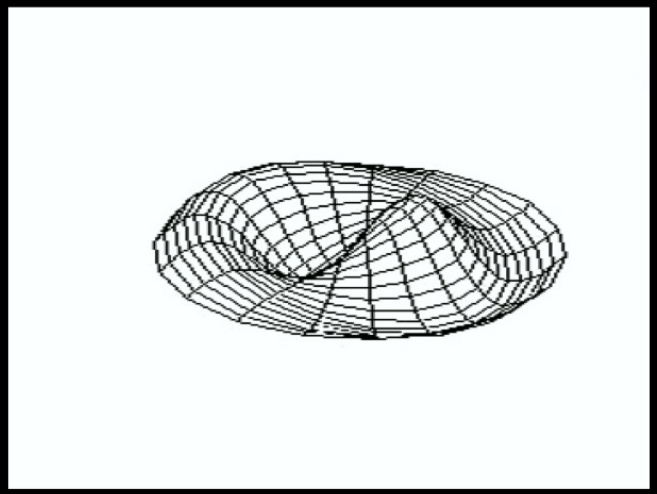
dipole mode



quadrupole mode



first overtone dipole mode



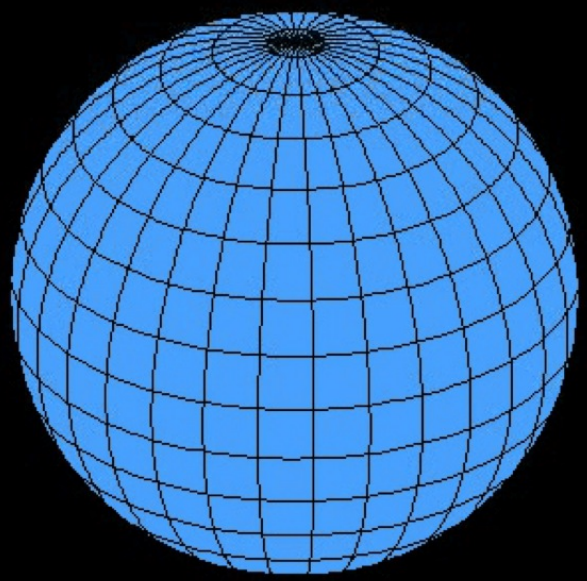
2D oscillations violins

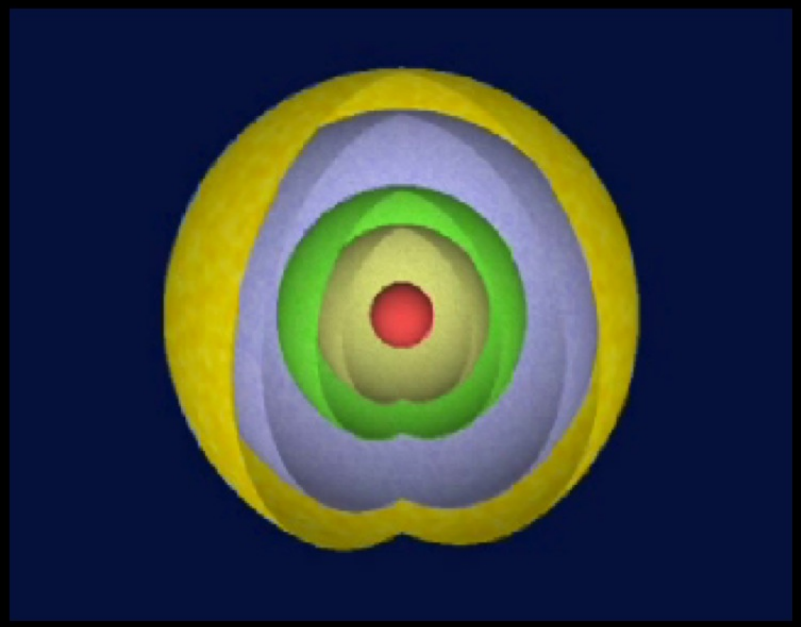
Emmanuel Rossy, Renaud Carpentier, Joe Wolfe, University of New South Wales

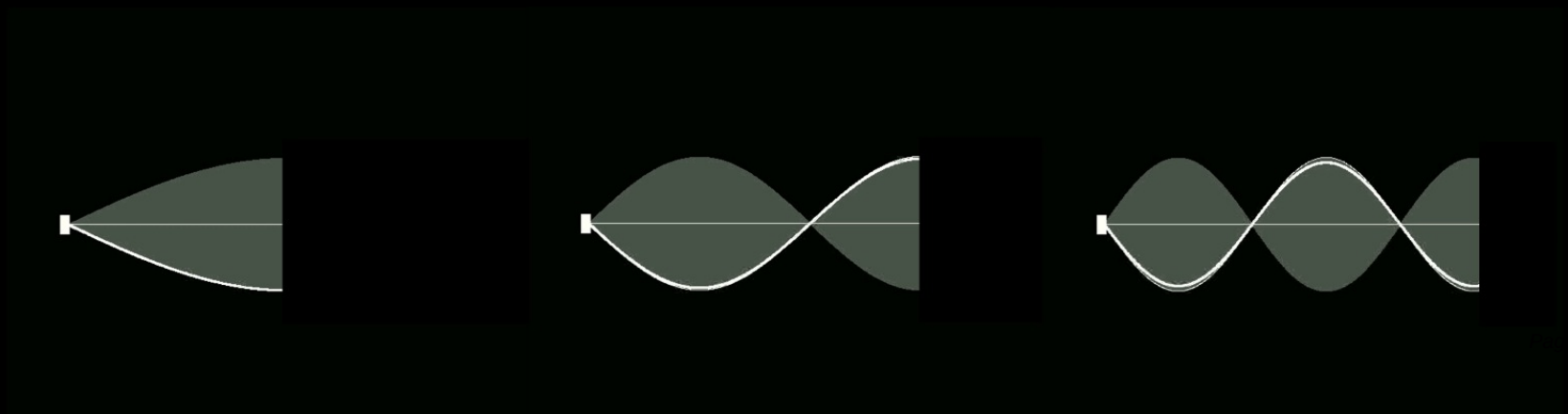
3D oscillations – stars radial modes

Rich Townsend

Zoltán Kolláth

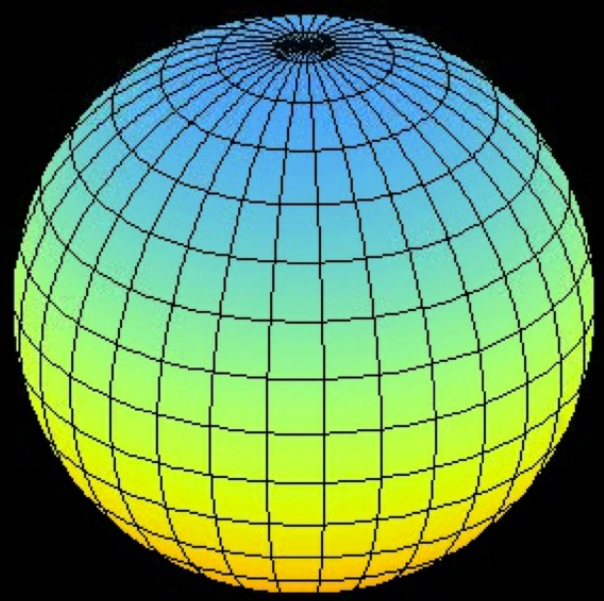






3D in stars

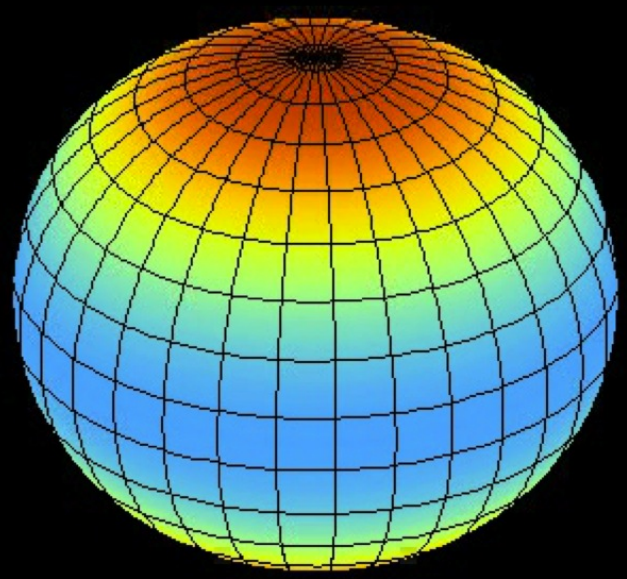
Non-radial modes: The dipole mode



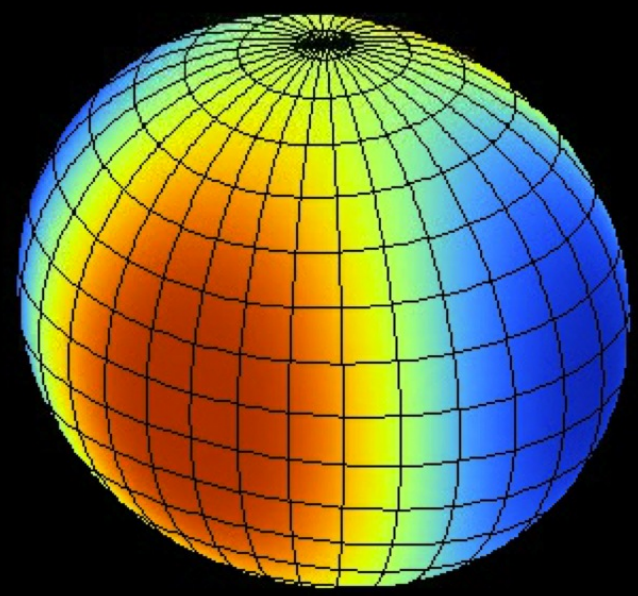
l=1, m=0

3D in stars

Non-radial modes: quadrupole modes



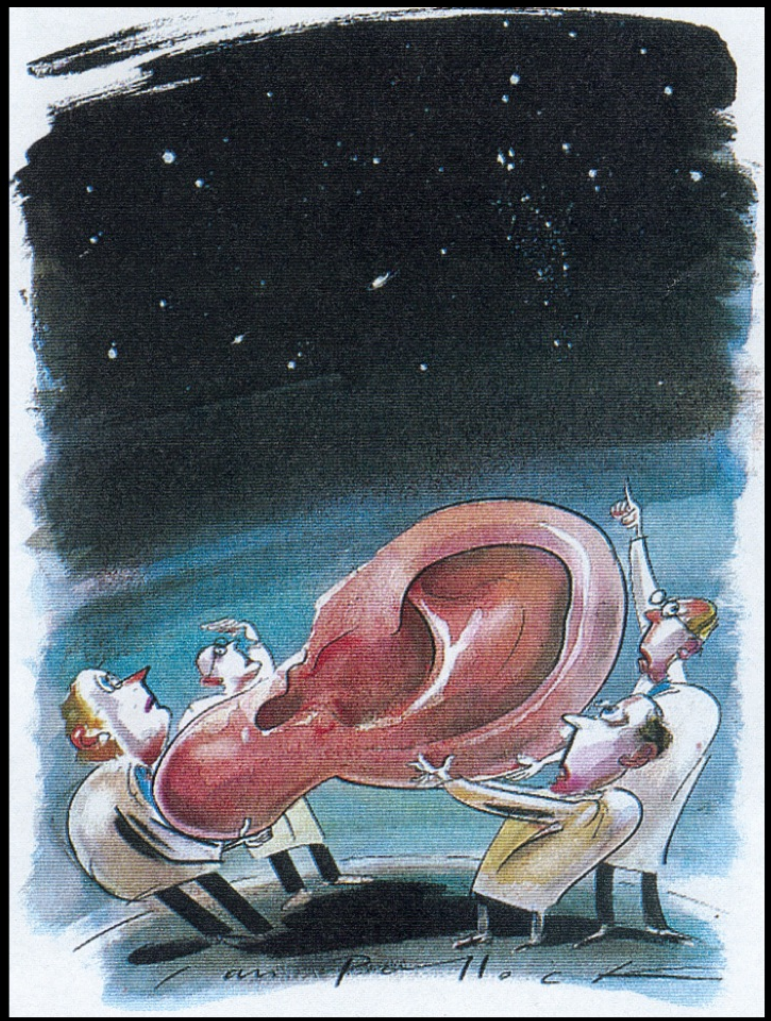
l=2, m=0



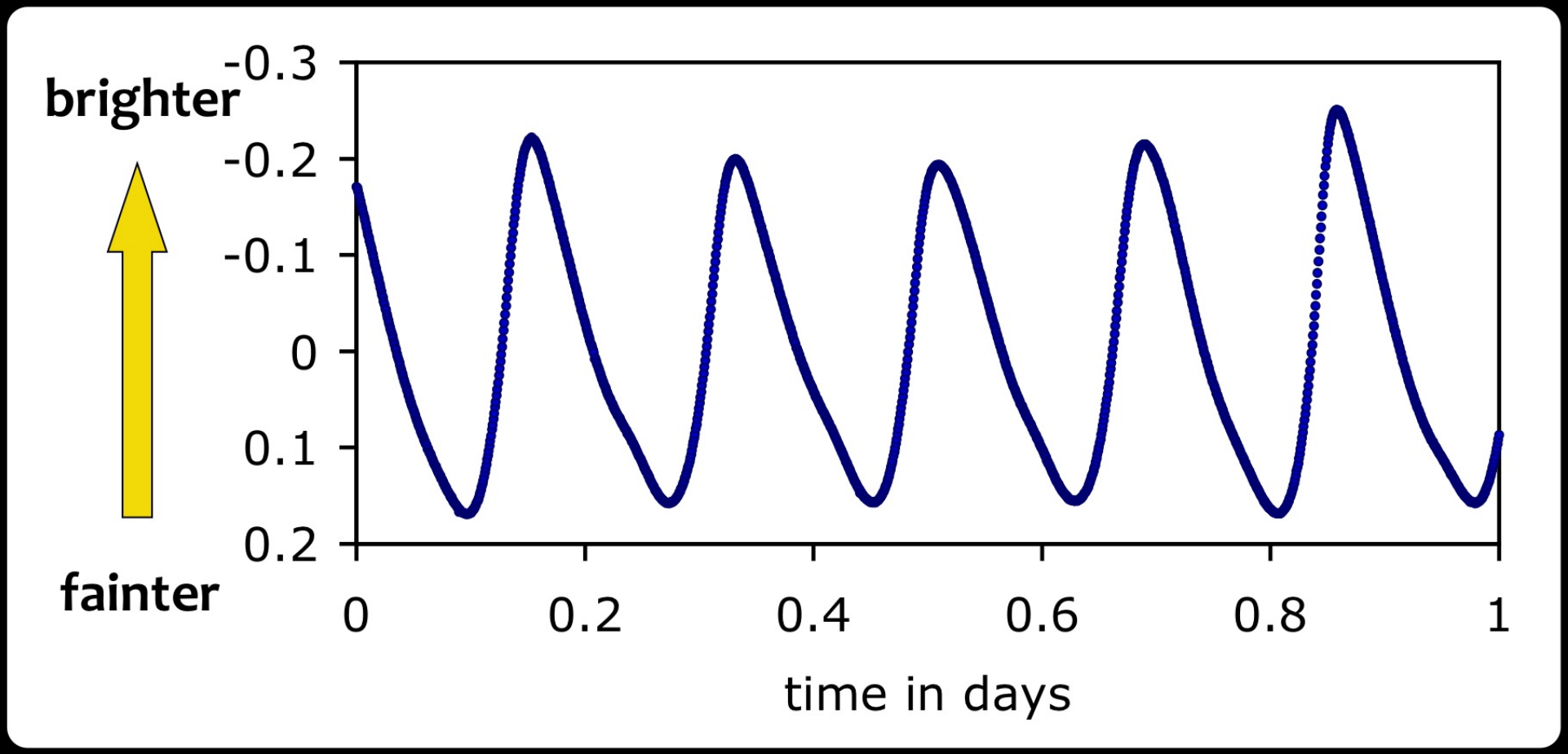
l=2, m=2

Rich Townsend

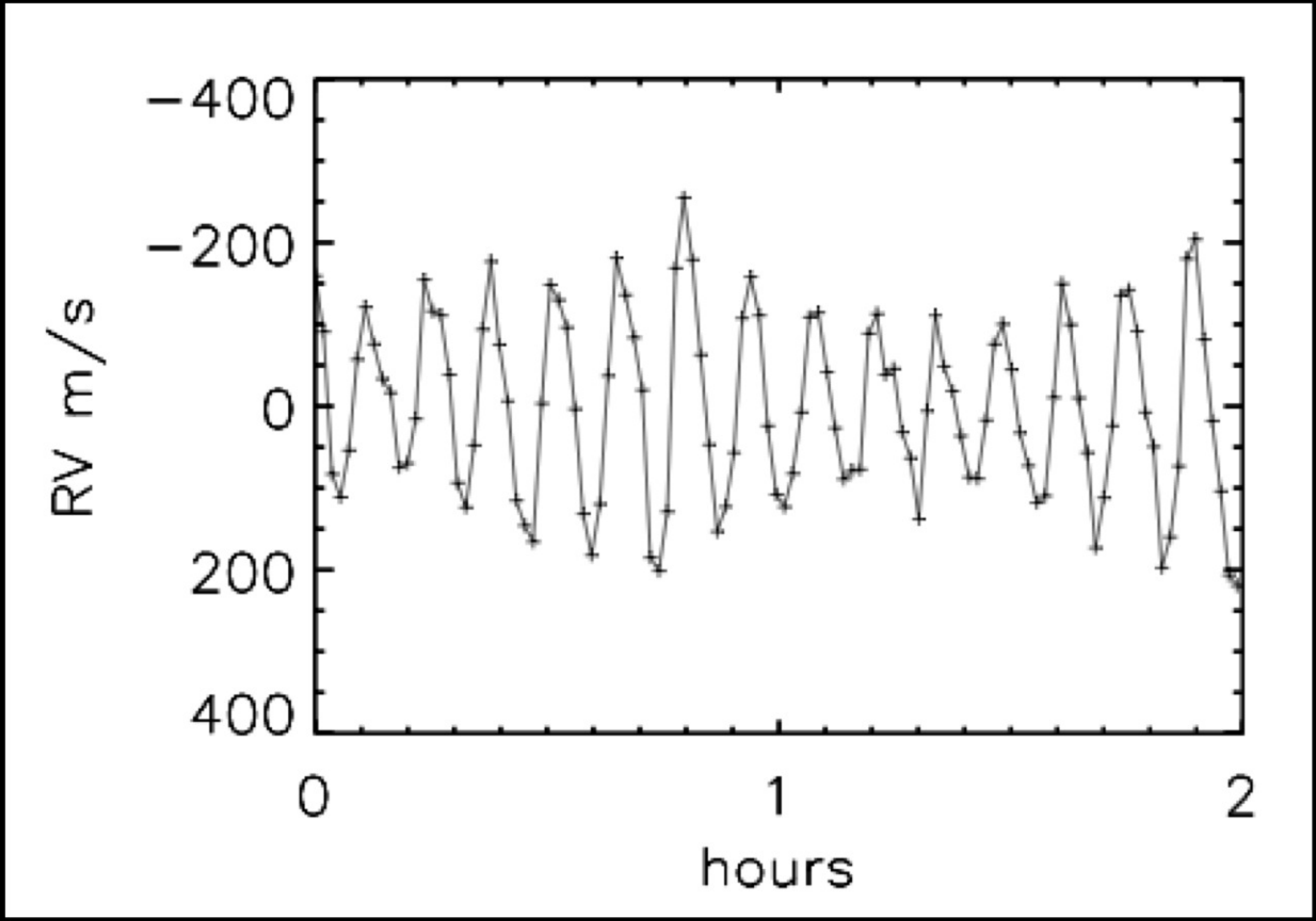
Listening to the songs of the stars



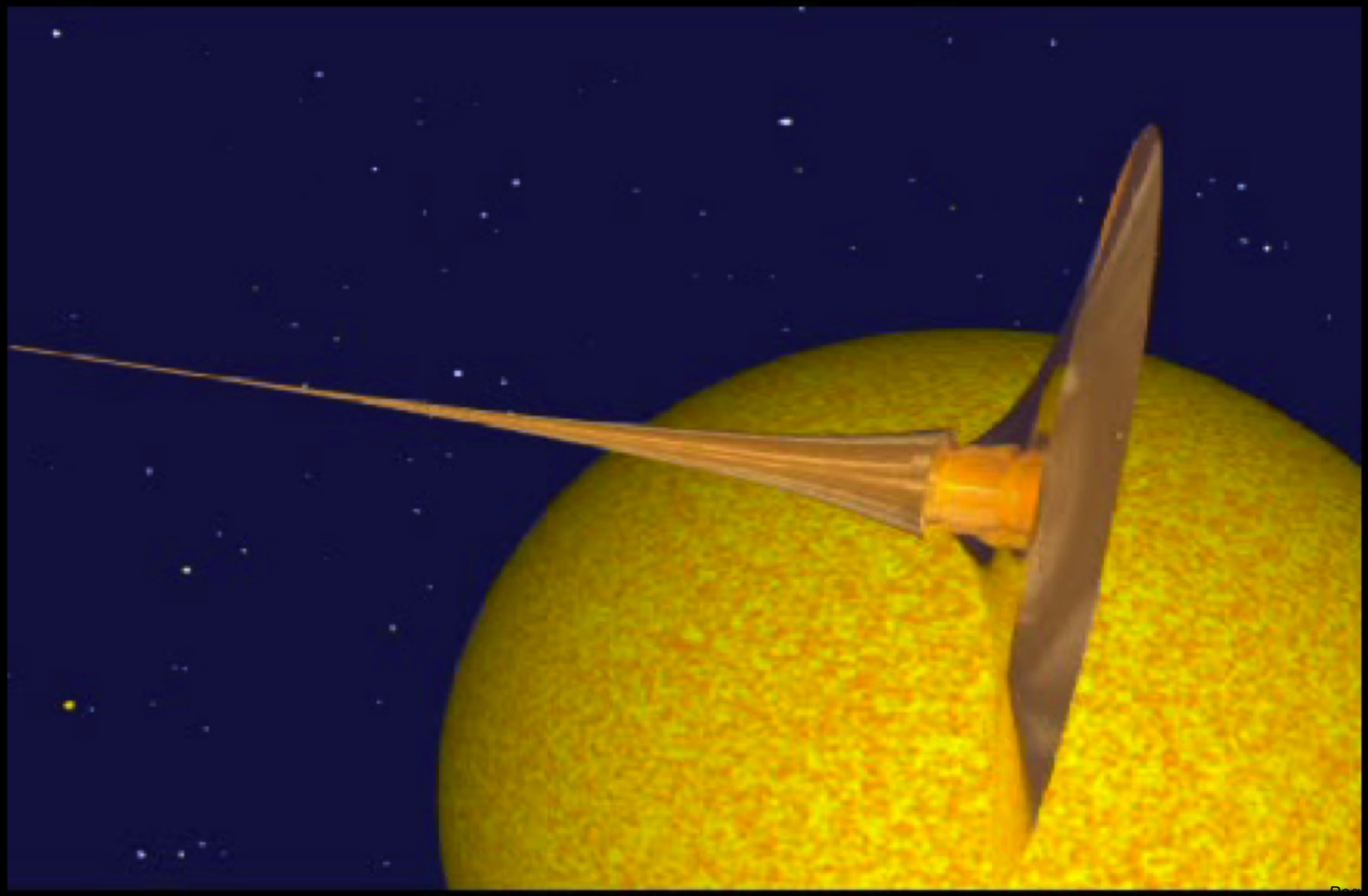
The light curve



The radial velocity curve



Cepheid variables



Zoltán Kolláth

Cepheid variables

- Henrietta Leavitt (1868-1921)
- Discovered in 1908 the <u>Period-Luminosity (PL)</u> relation for Cepheids

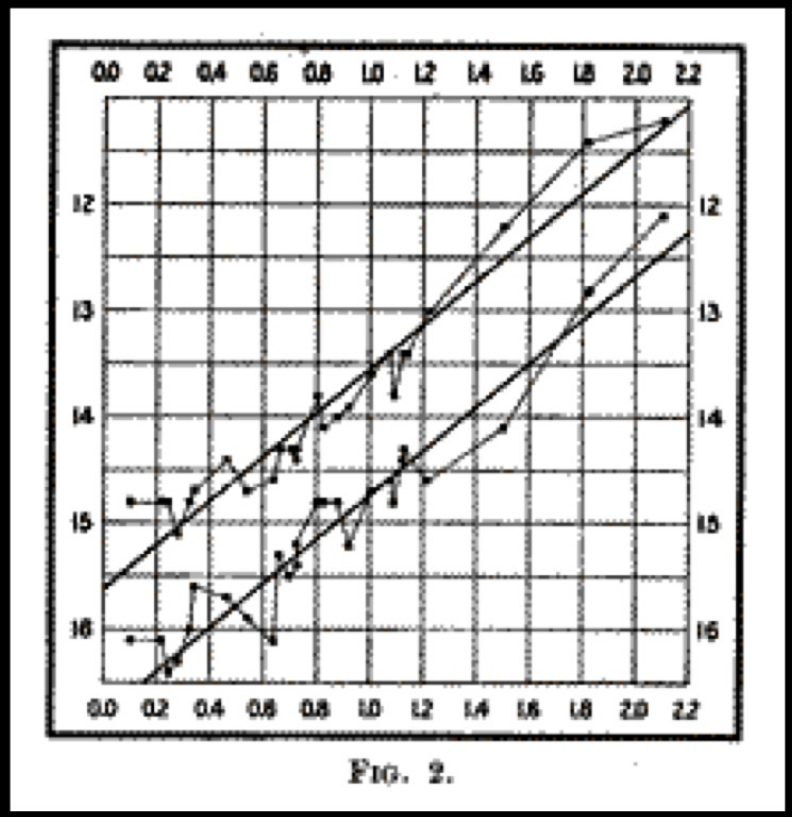
"It is worthy of notice that ...
the brighter variables have the longer periods." (Leavitt 1908)

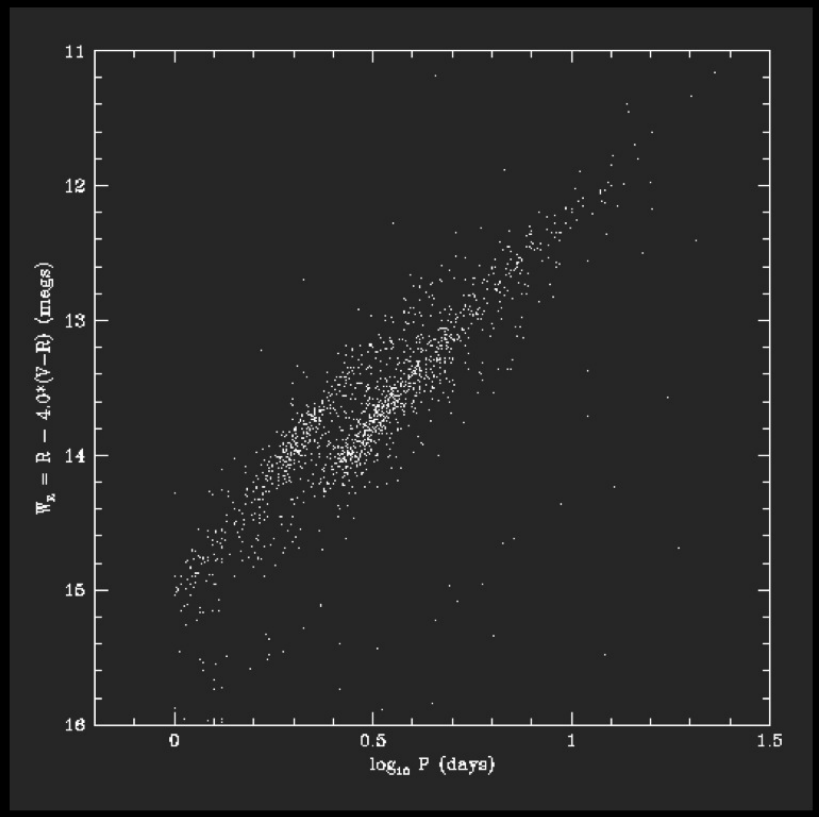
Henrietta Leavitt's PL discovery 1912

brighter

magnitude

fainter





1 10 100

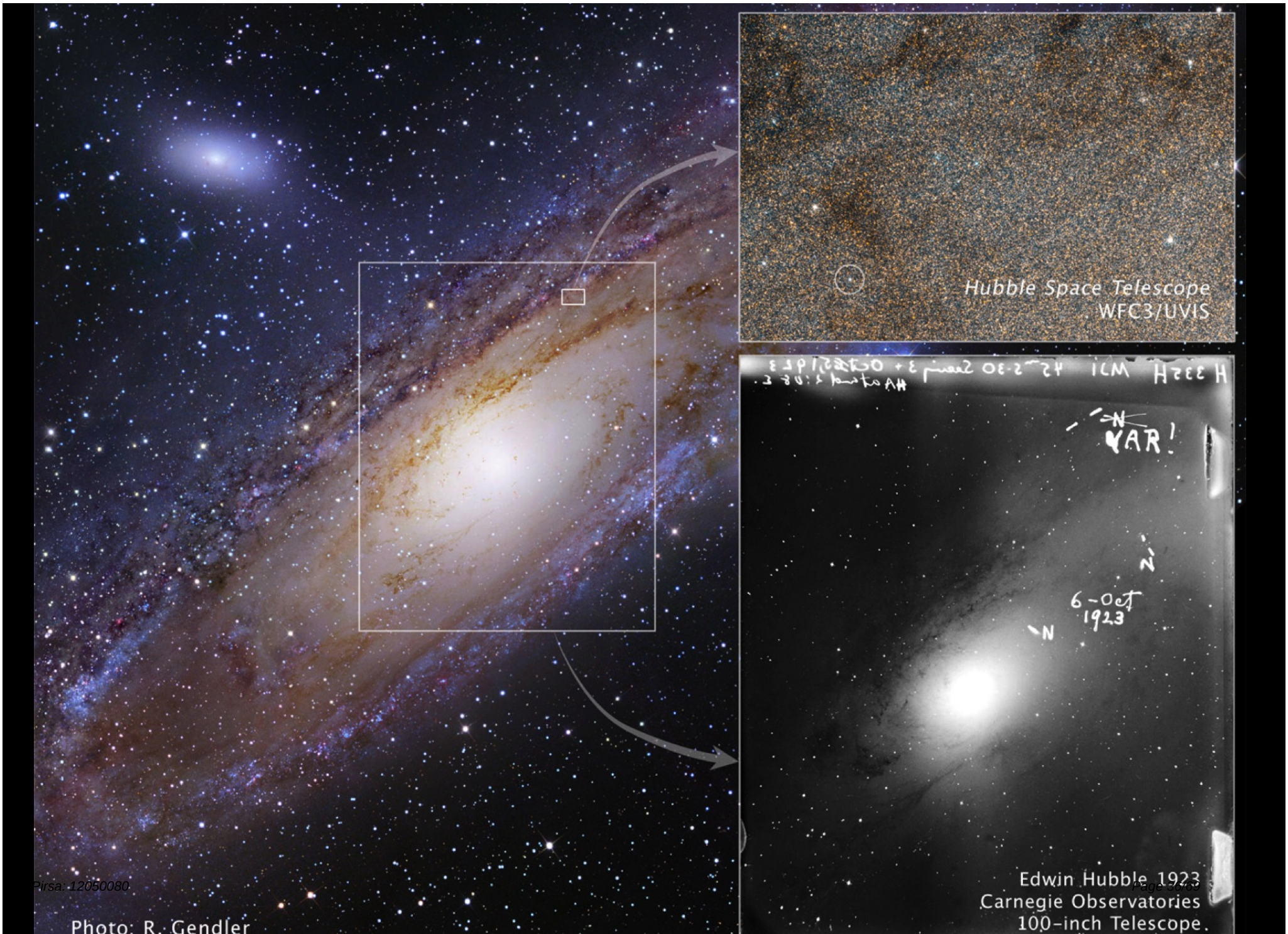
Period in days

1 10 30

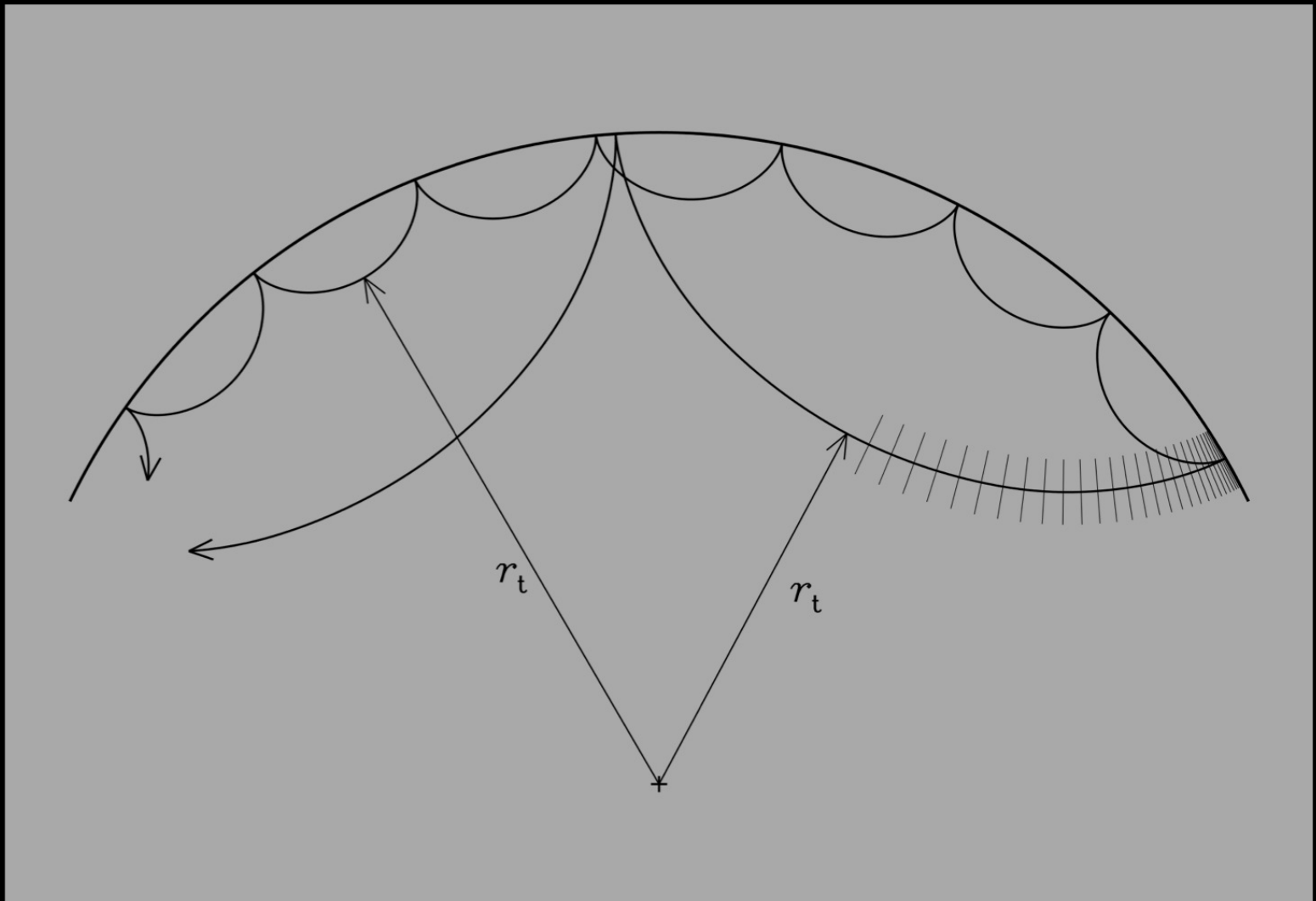
Period in days

The proof that “spiral nebulae” are galaxies - 1923

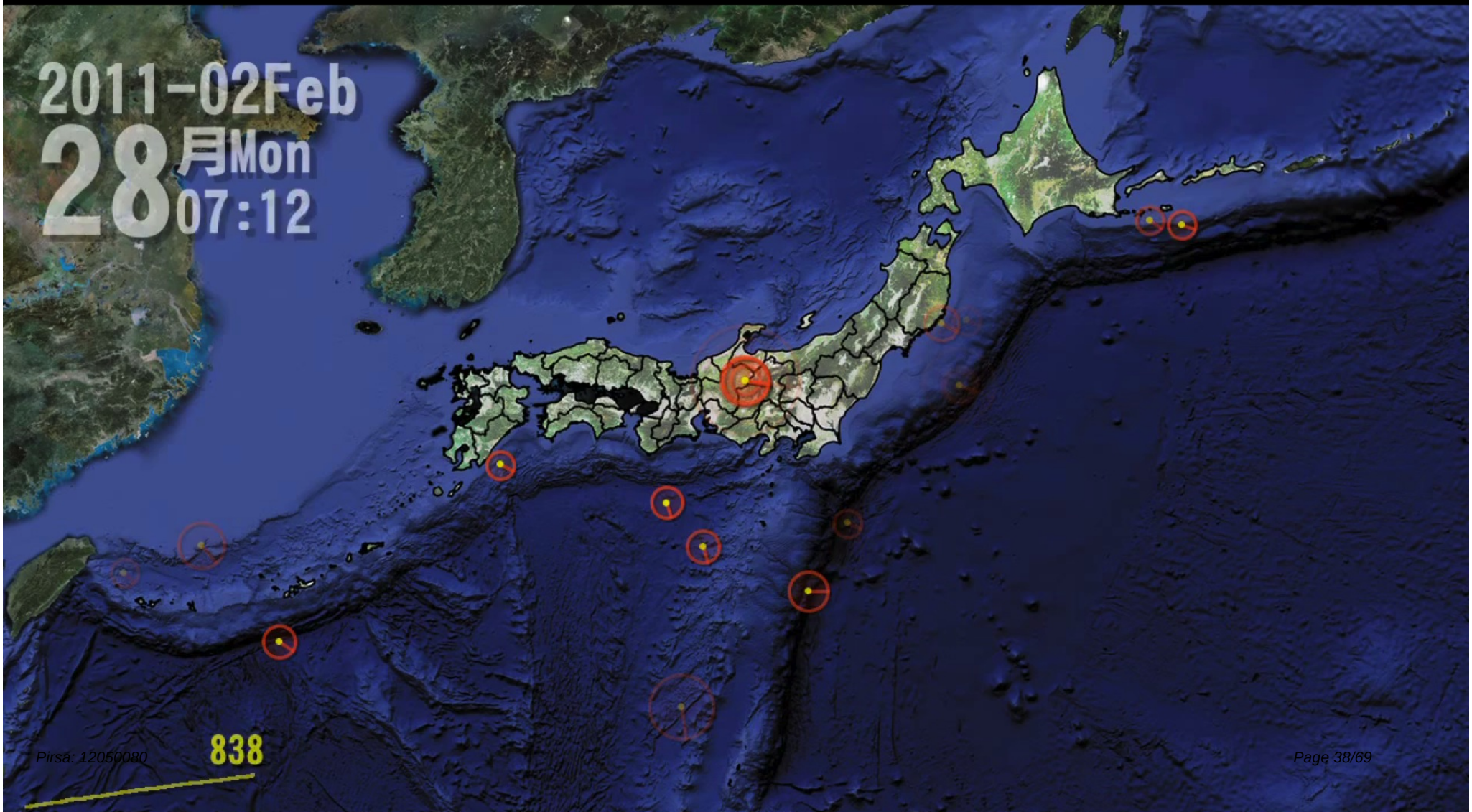
Edwin Hubble


Hubble Space Telescope
WFC3/UVIS
VAR!
6-Oct
1923
Edwin Hubble 1923
Carnegie Observatories
100-inch Telescope
Photo: R. Gendler

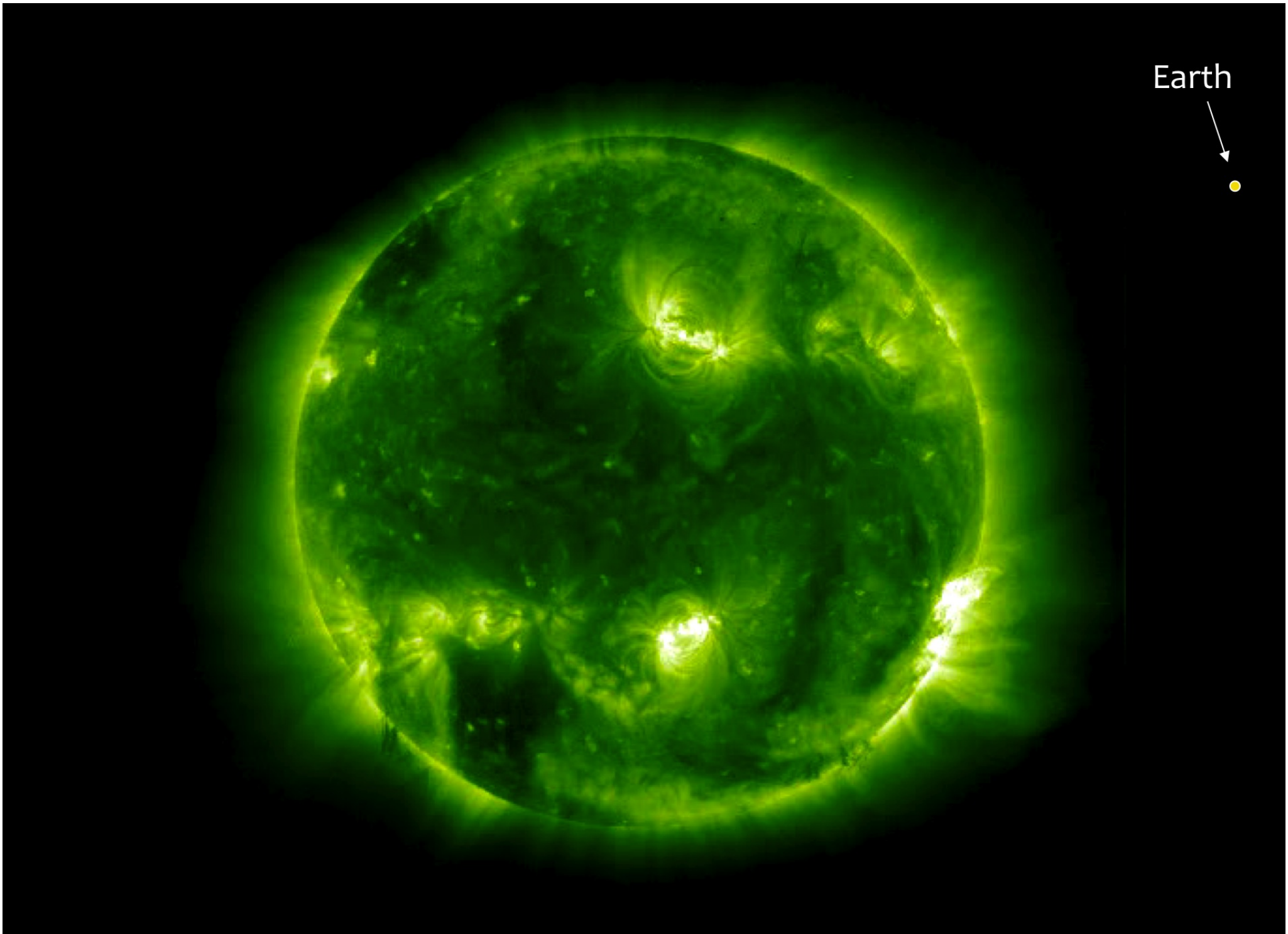
Asteroseismology – how does it work?



Earthquakes



The Sun


Earth

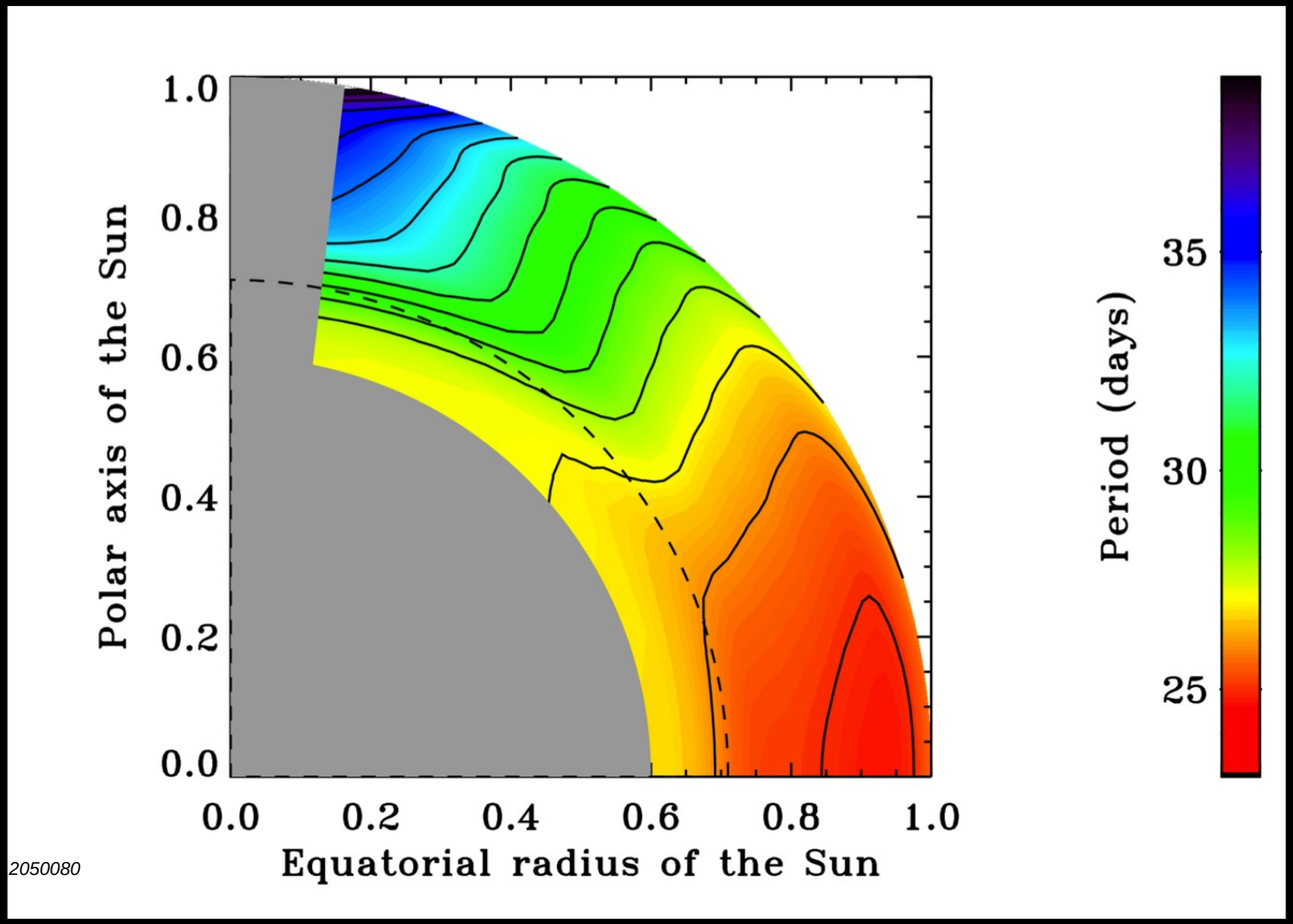
9 March 1989

“All those motorists sitting at traffic lights
cursing should realize that
it is not Hydro-Quebec's fault”

[Hydro-Quebec, 1989]

“the deep interior of the Sun and stars is less accessible than any other region of the universe.”

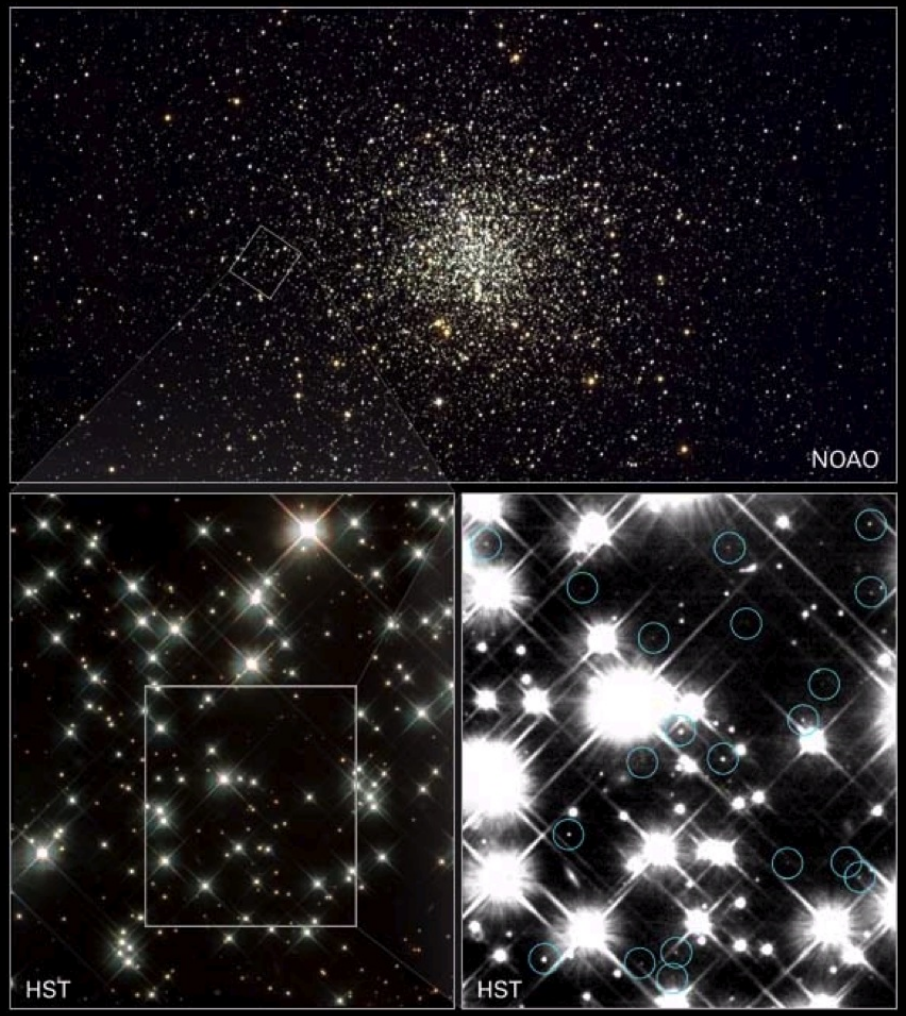
A.S. Eddington 1926



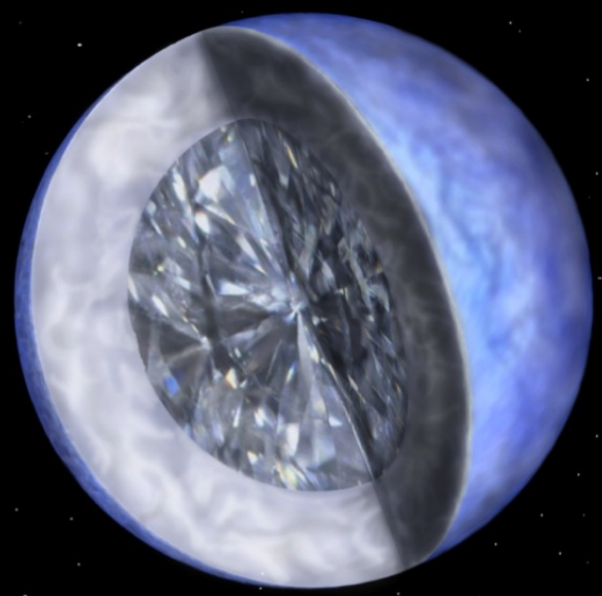
courtesy of Rachel Howe (Birmingham)

data from Jesper Schou (Stanford)

Globular cluster M4

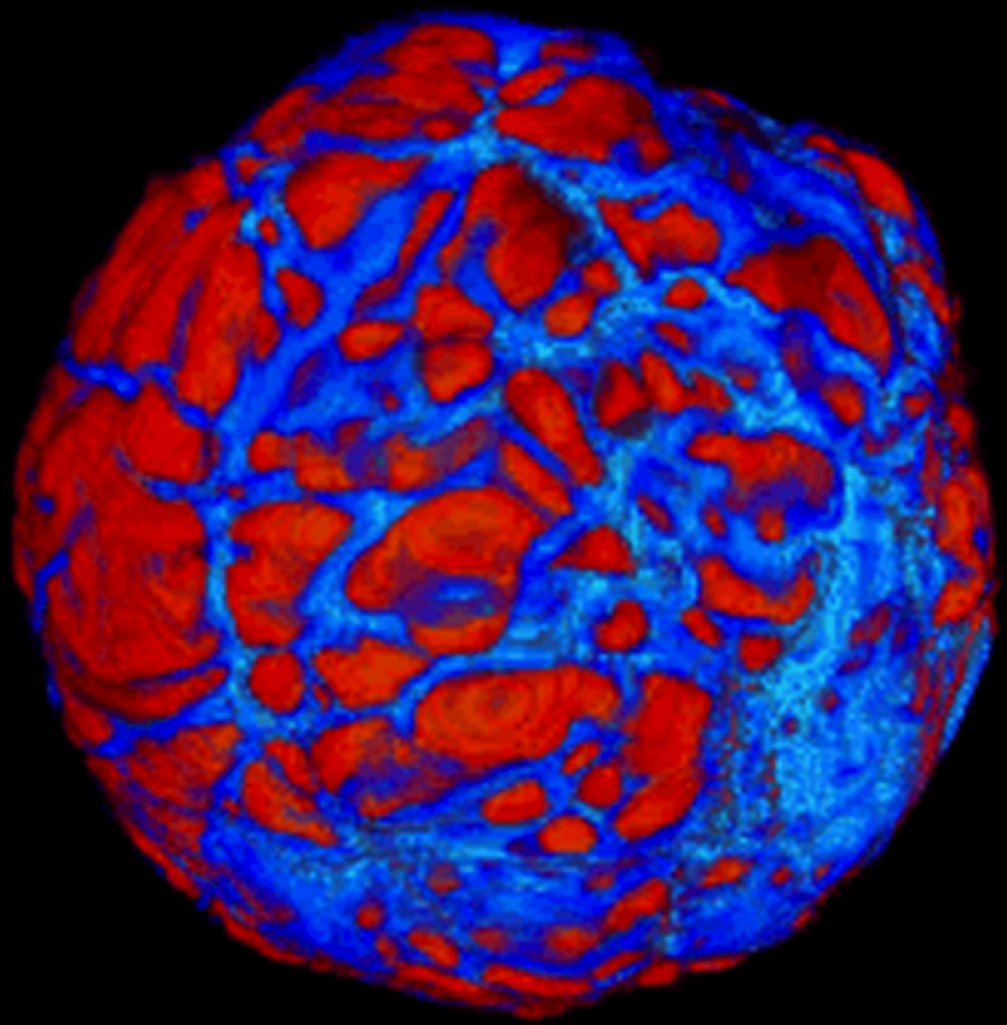


BPM 37093 “Bruce”



Travis Metcalfe, Harvard University

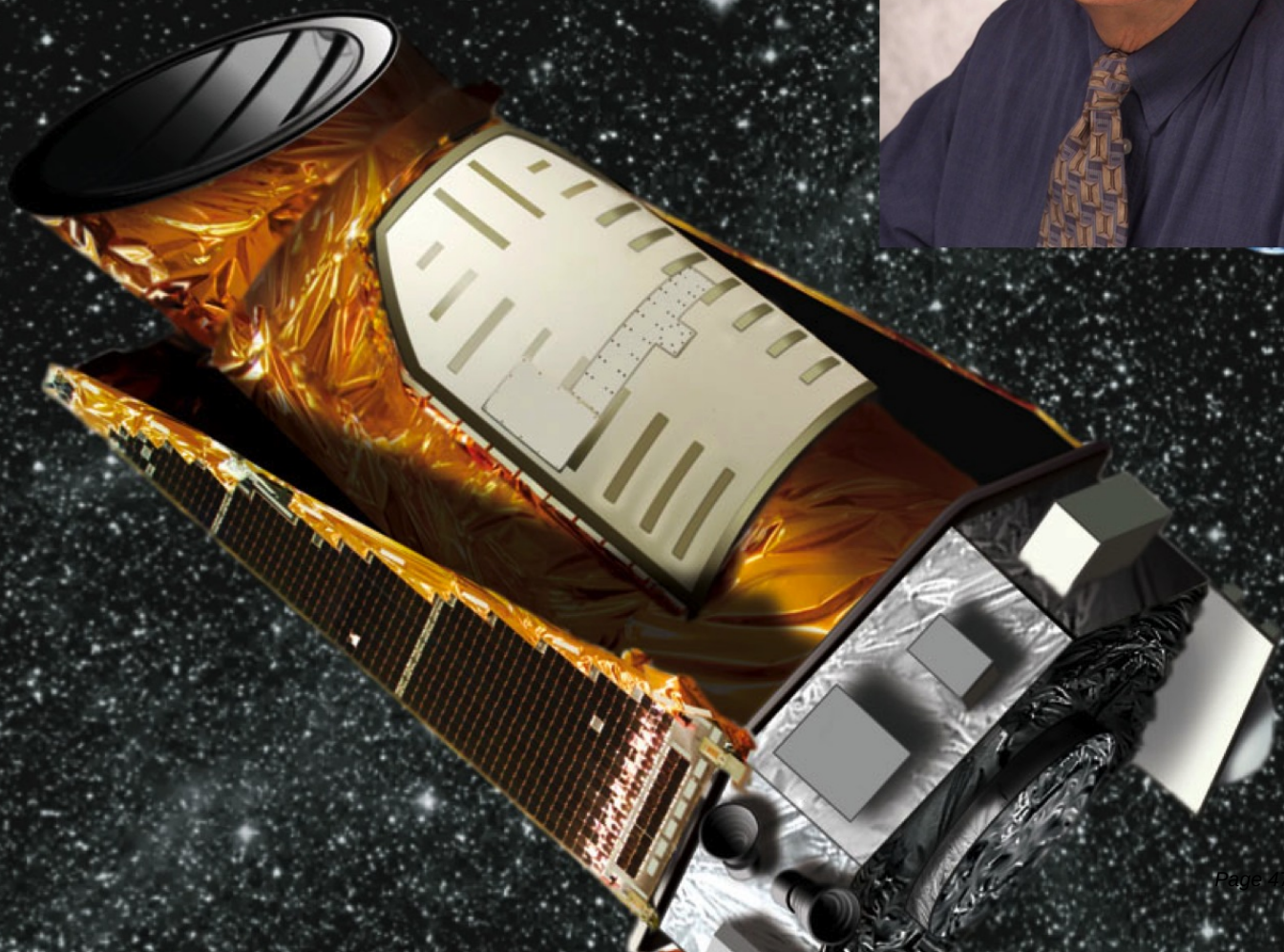
The Red Giant Star xi Hydrae



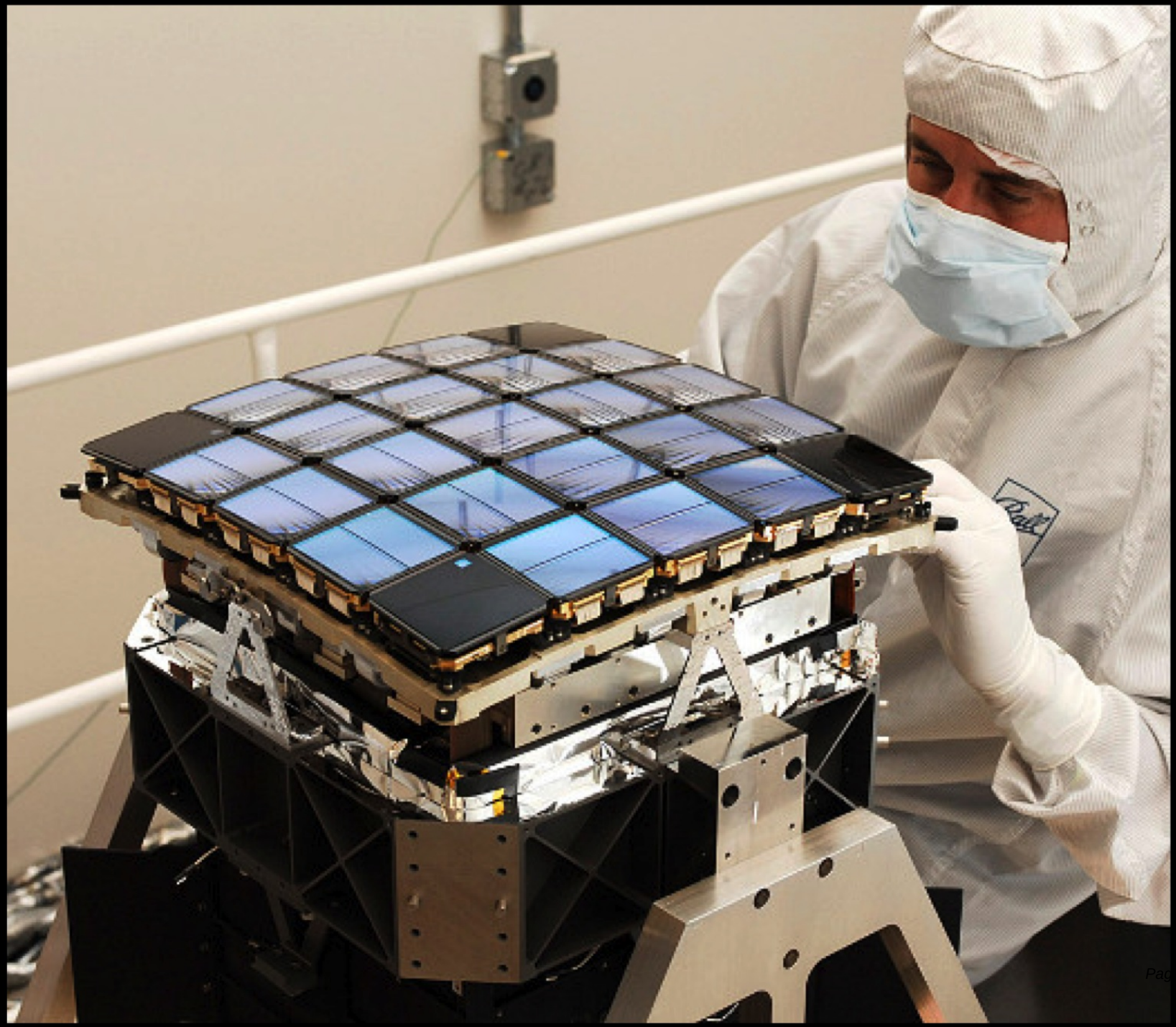
LCSE University of Minnesota


Exo-Planets
and
Pulsations
The New Keplerian
Revolution

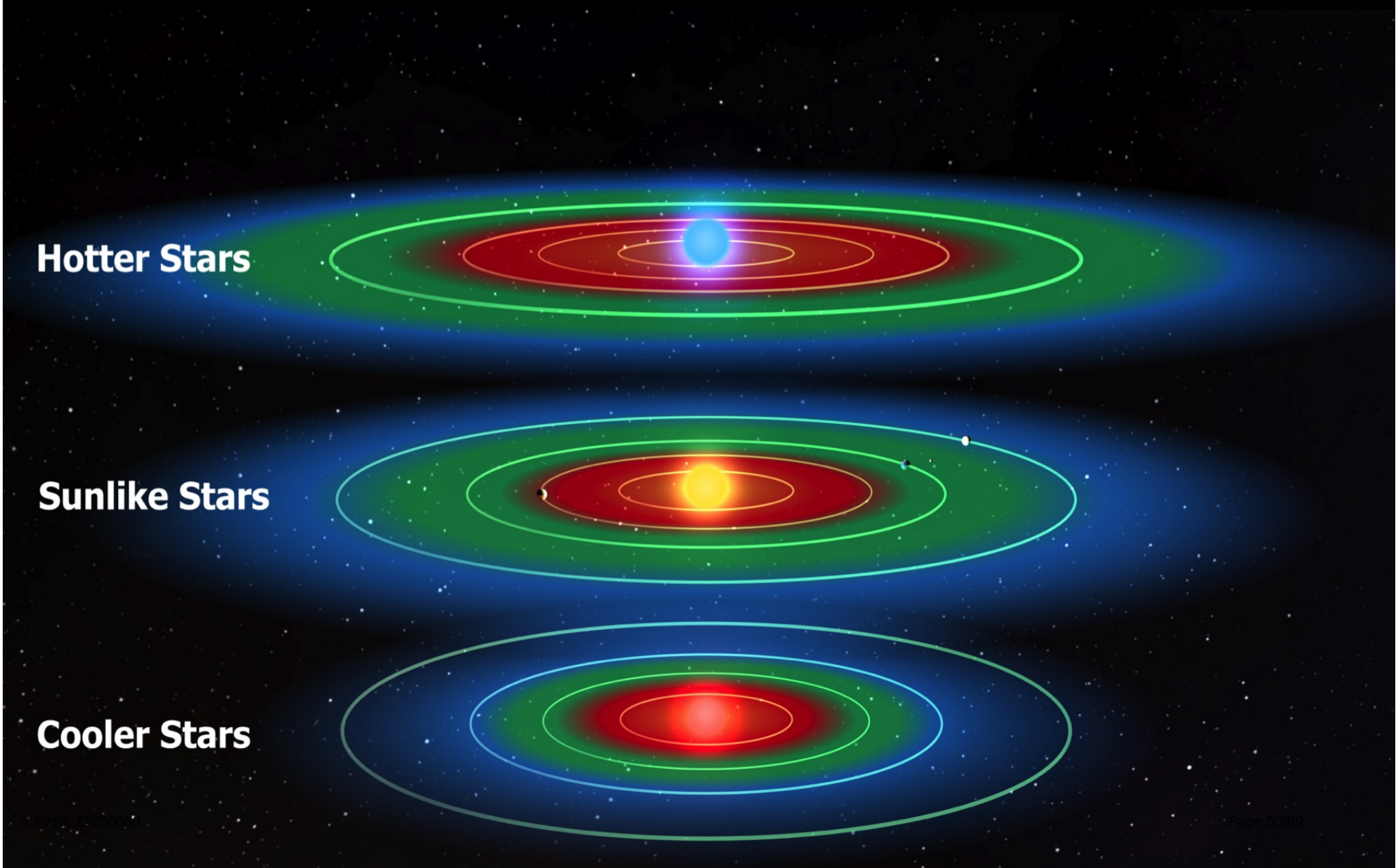
The Kepler Mission Space Telescope

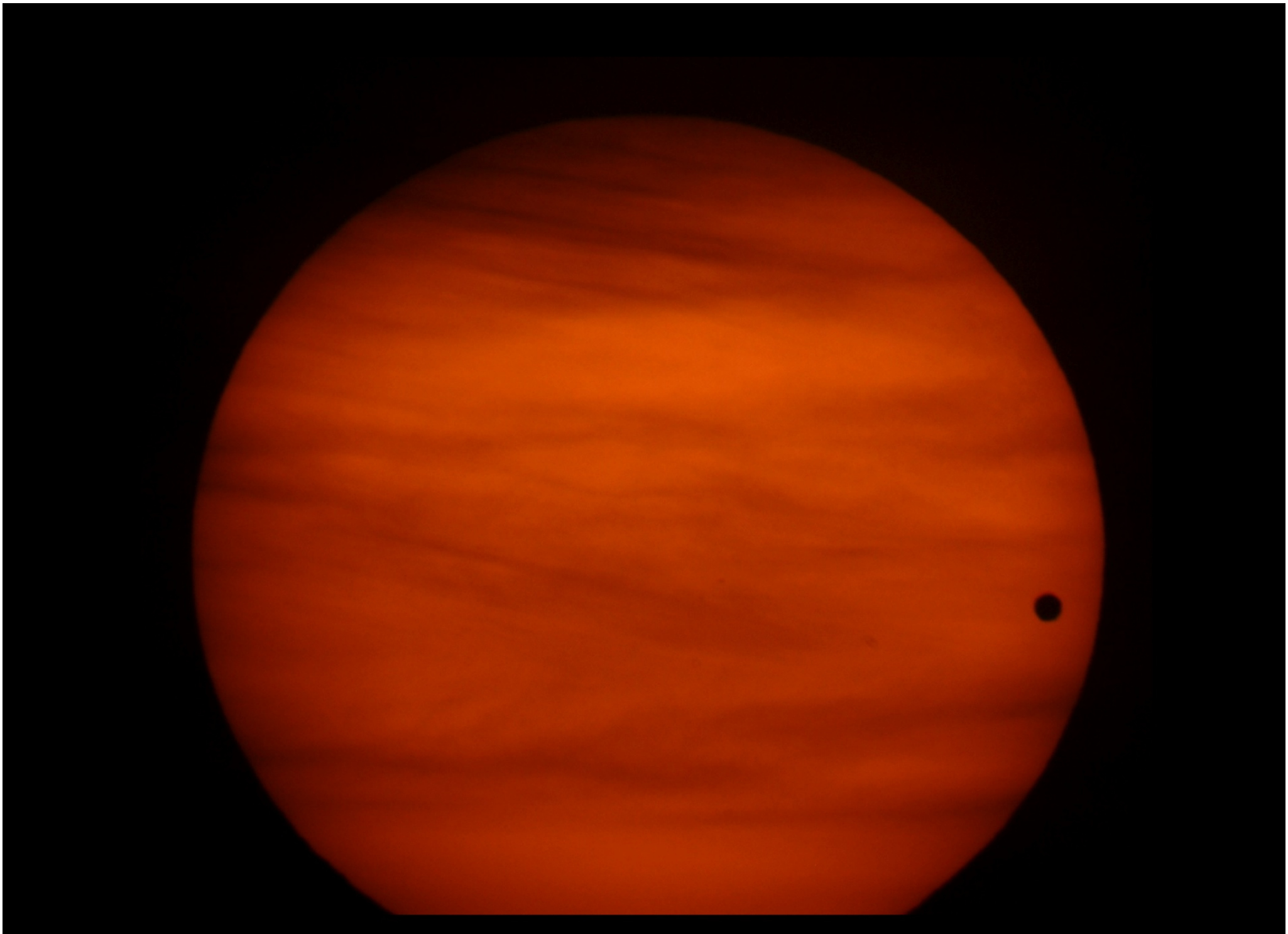


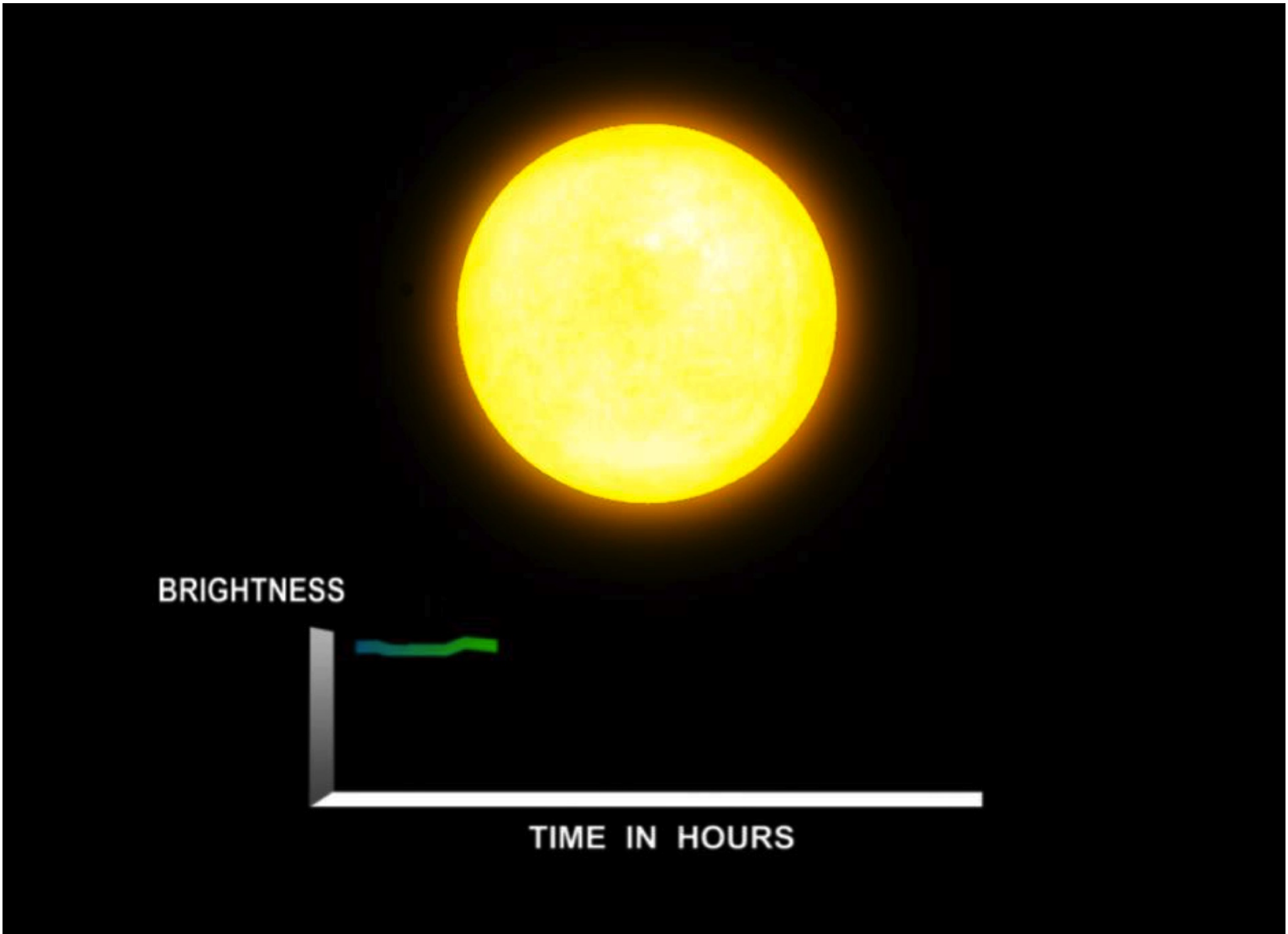

Kepler



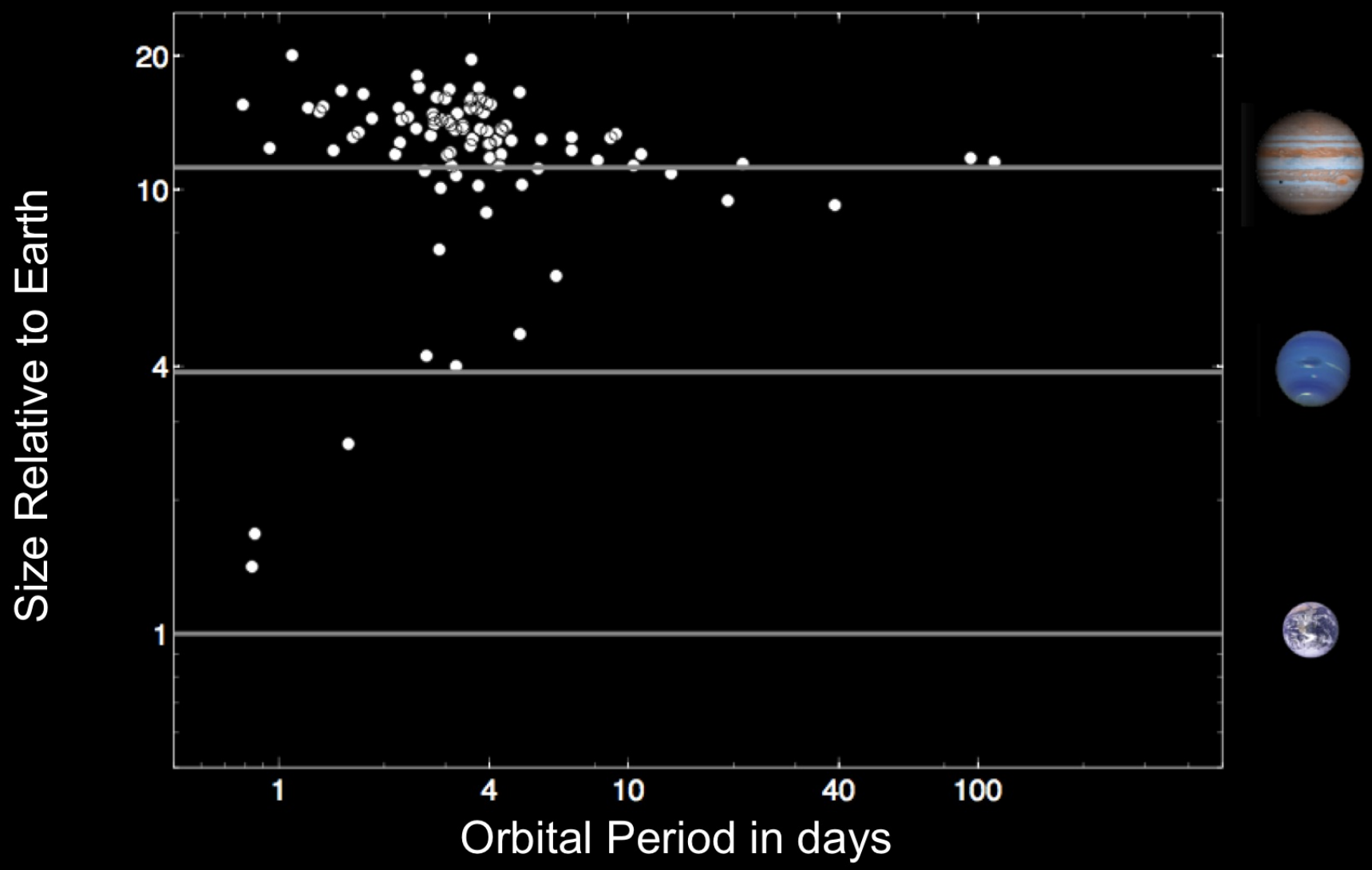
The Habitable Zone



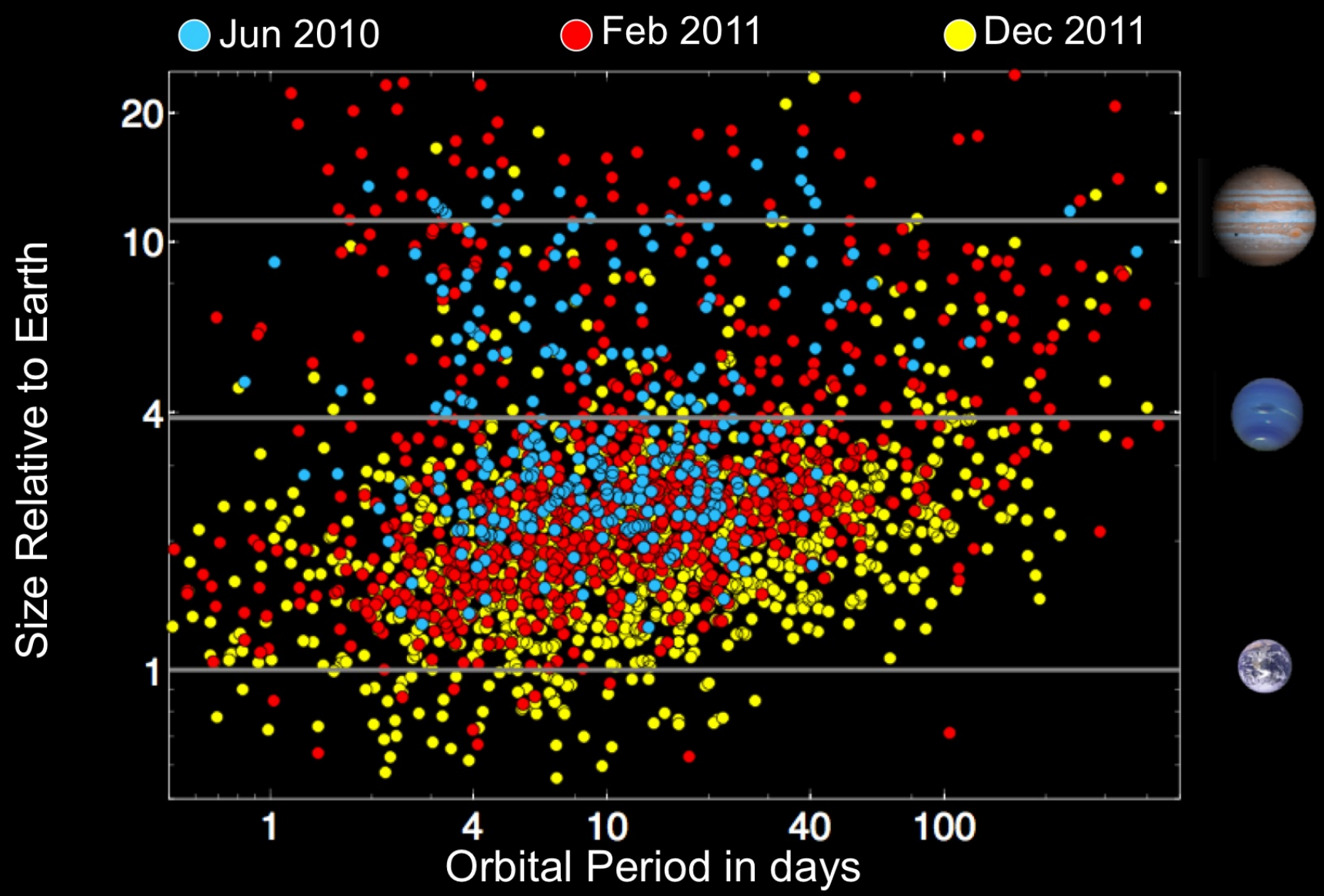


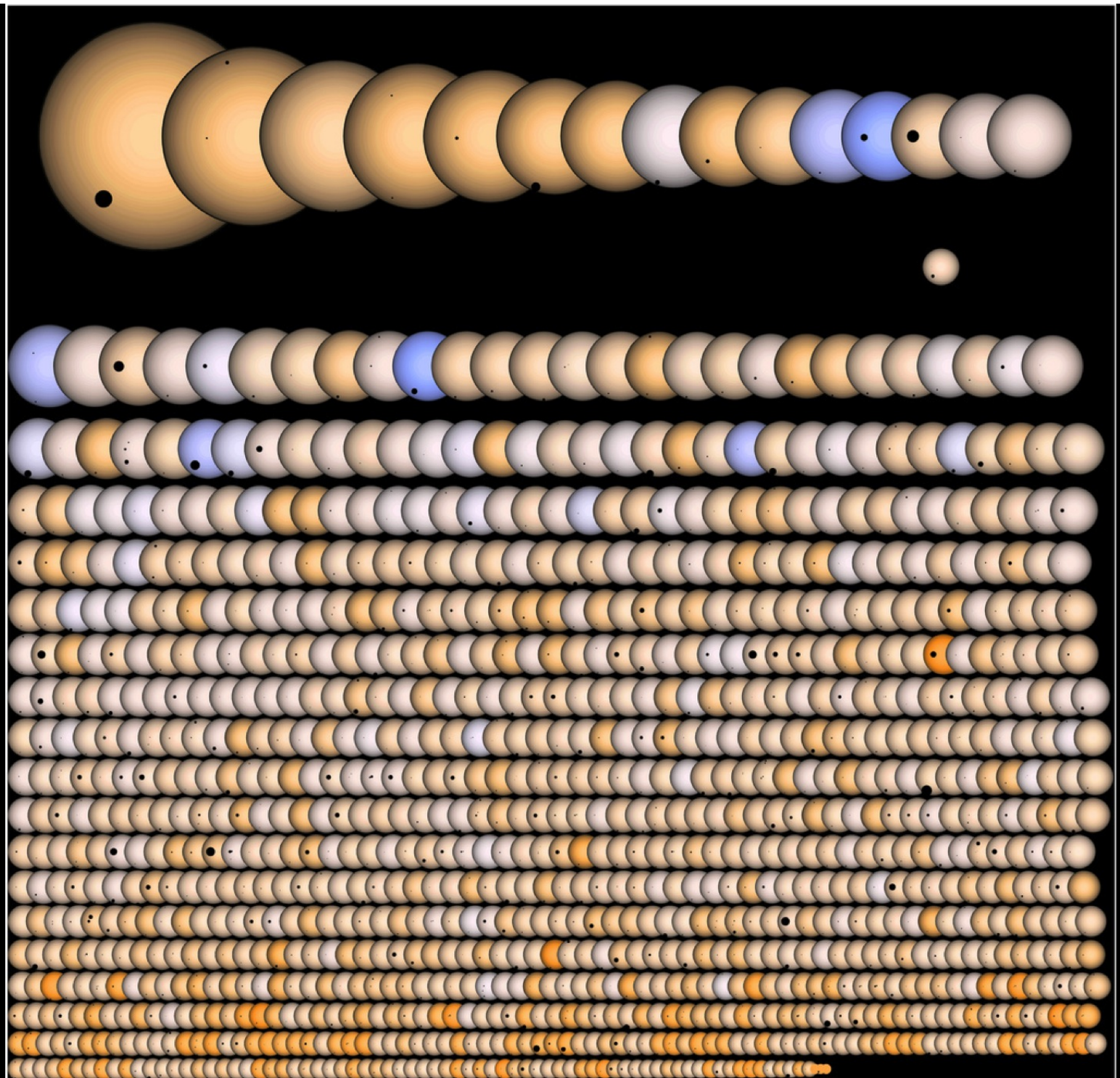

BRIGHTNESS
TIME IN HOURS

Transiting Planets pre-Kepler

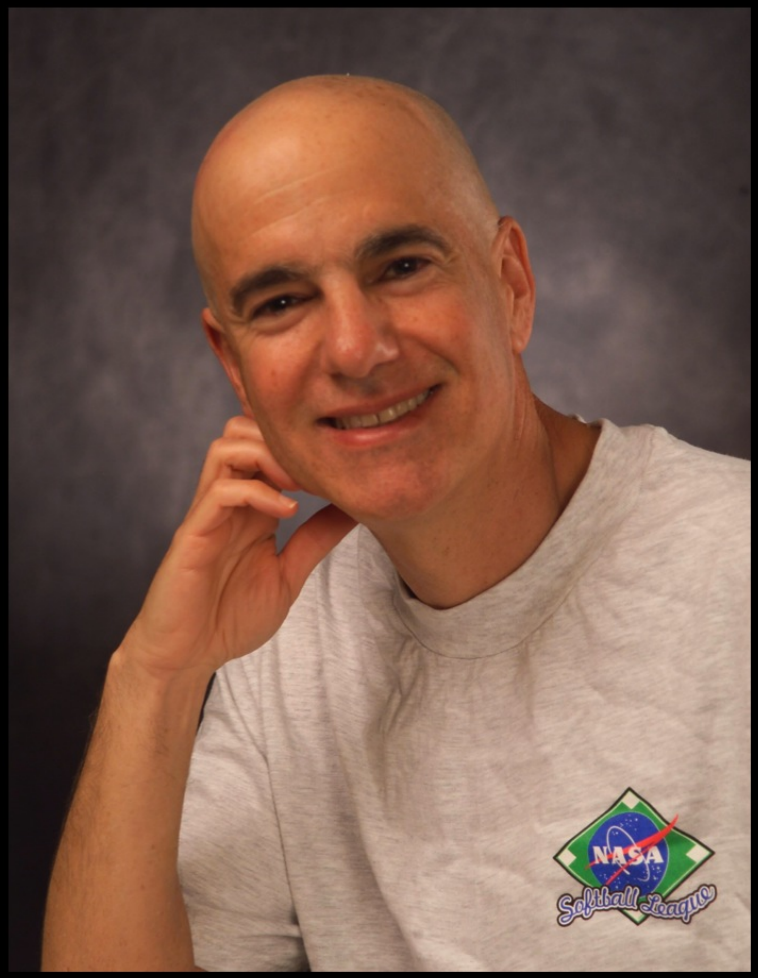


Candidates as of Dec 2011





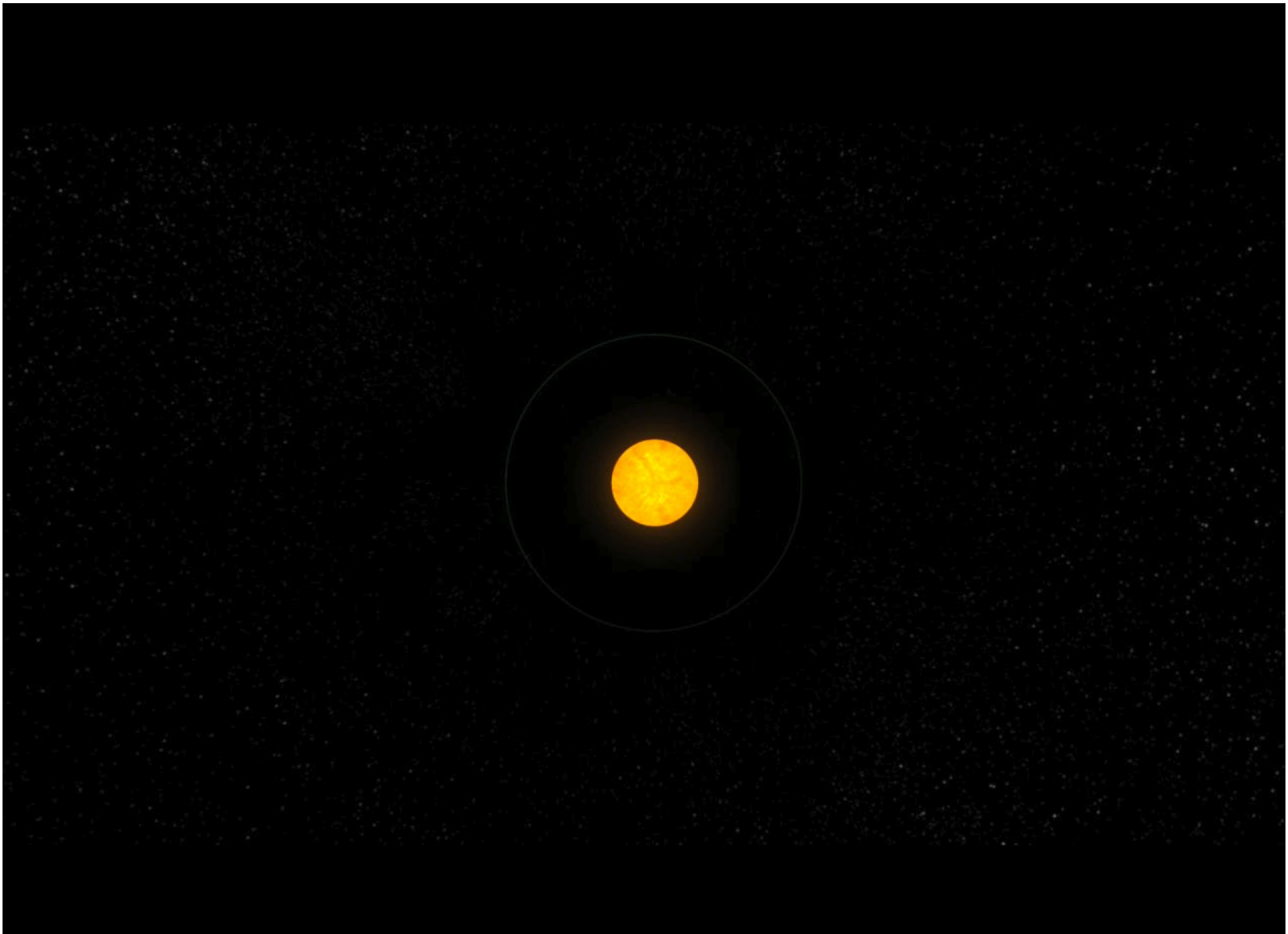
Kepler 11



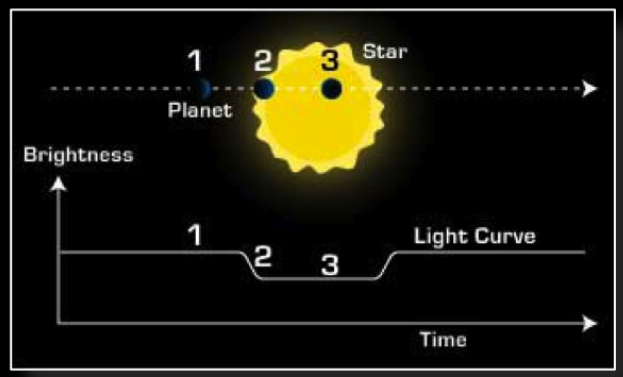
Jack Lissauer (NASA Ames)
+ Kepler team

Kepler 10b

Natalie Batalha (San Jose) + Kepler team



Transit and Doppler Measurements Yield Density



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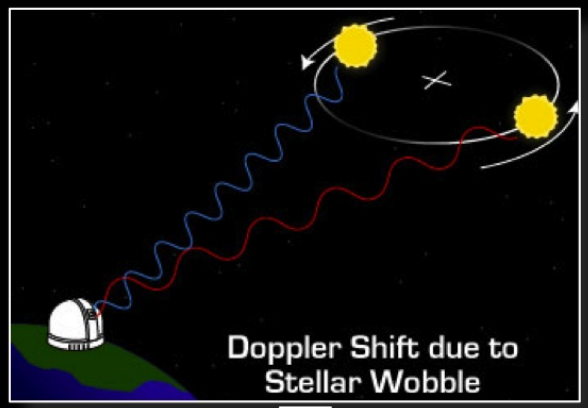
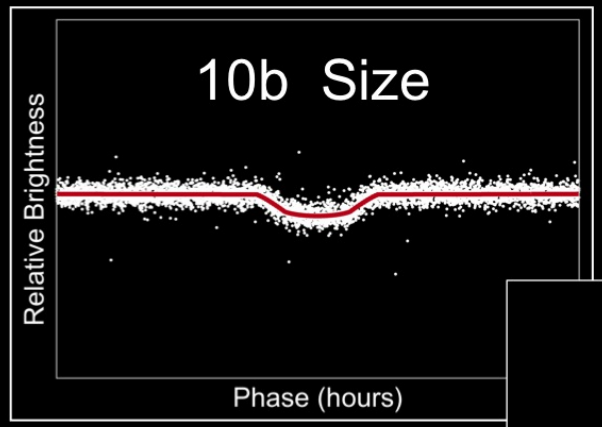
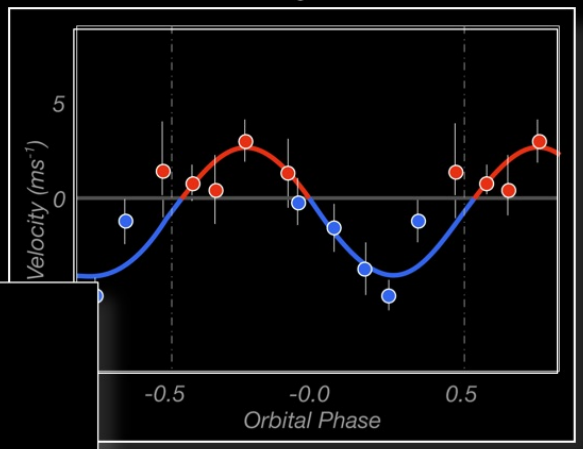


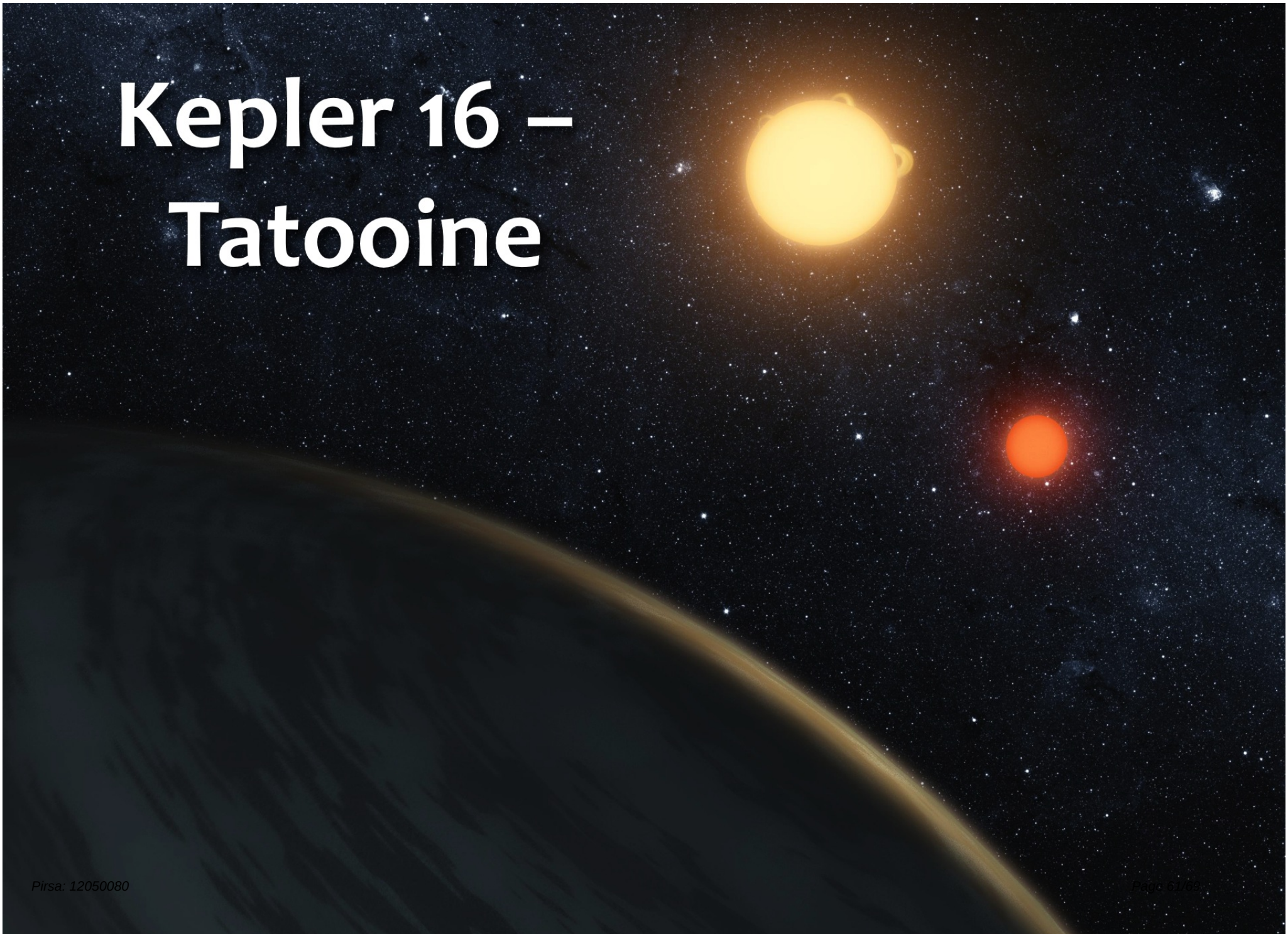




Density

$$\frac{\text{Mass}}{\text{Volume}} = 8.8\ \text{g/cm}^3$$

Kepler 16 – Tatooine



Kepler's First Planet in the Habitable Zone - Kepler-22b

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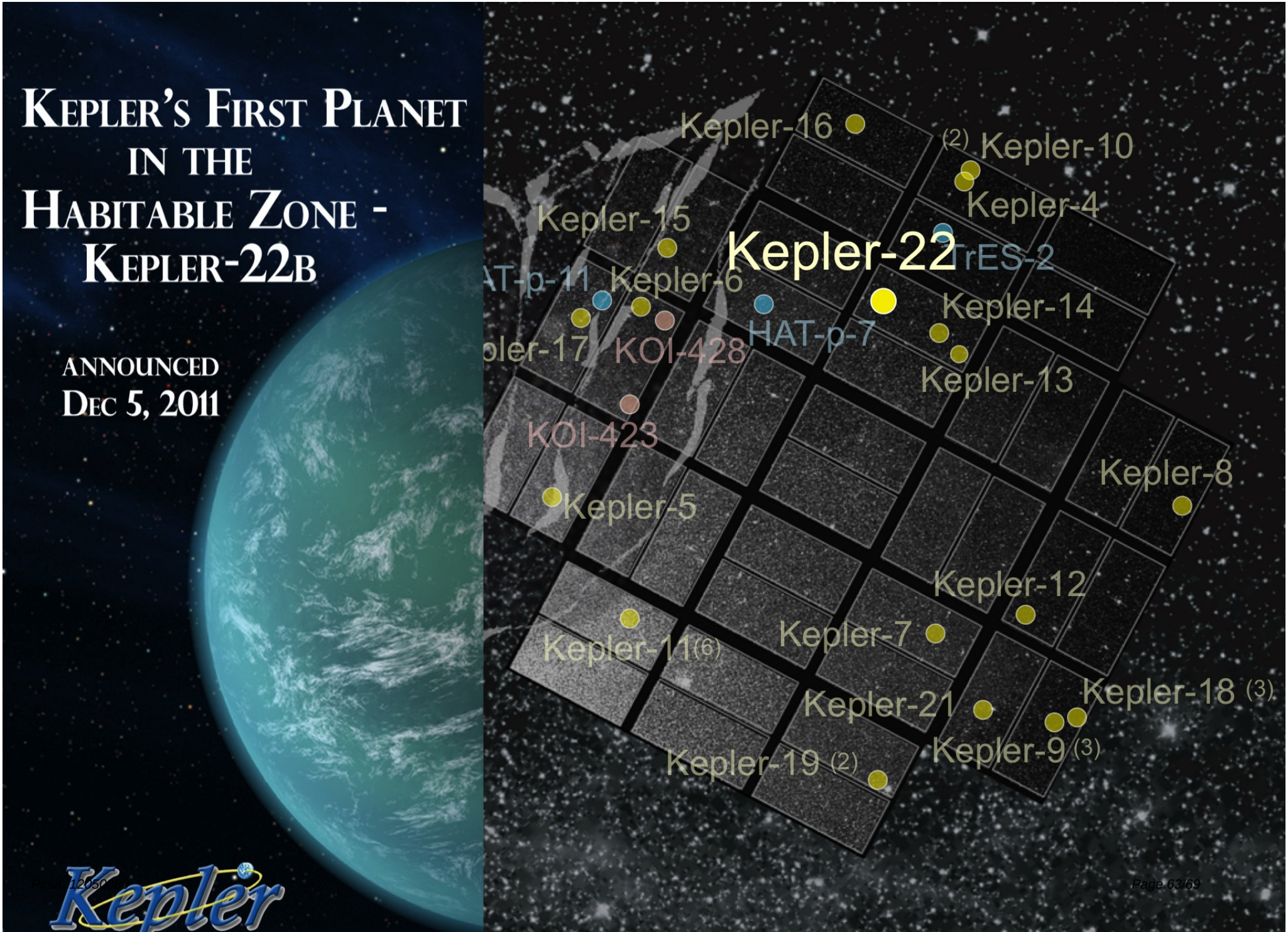
Dec 5, 2011



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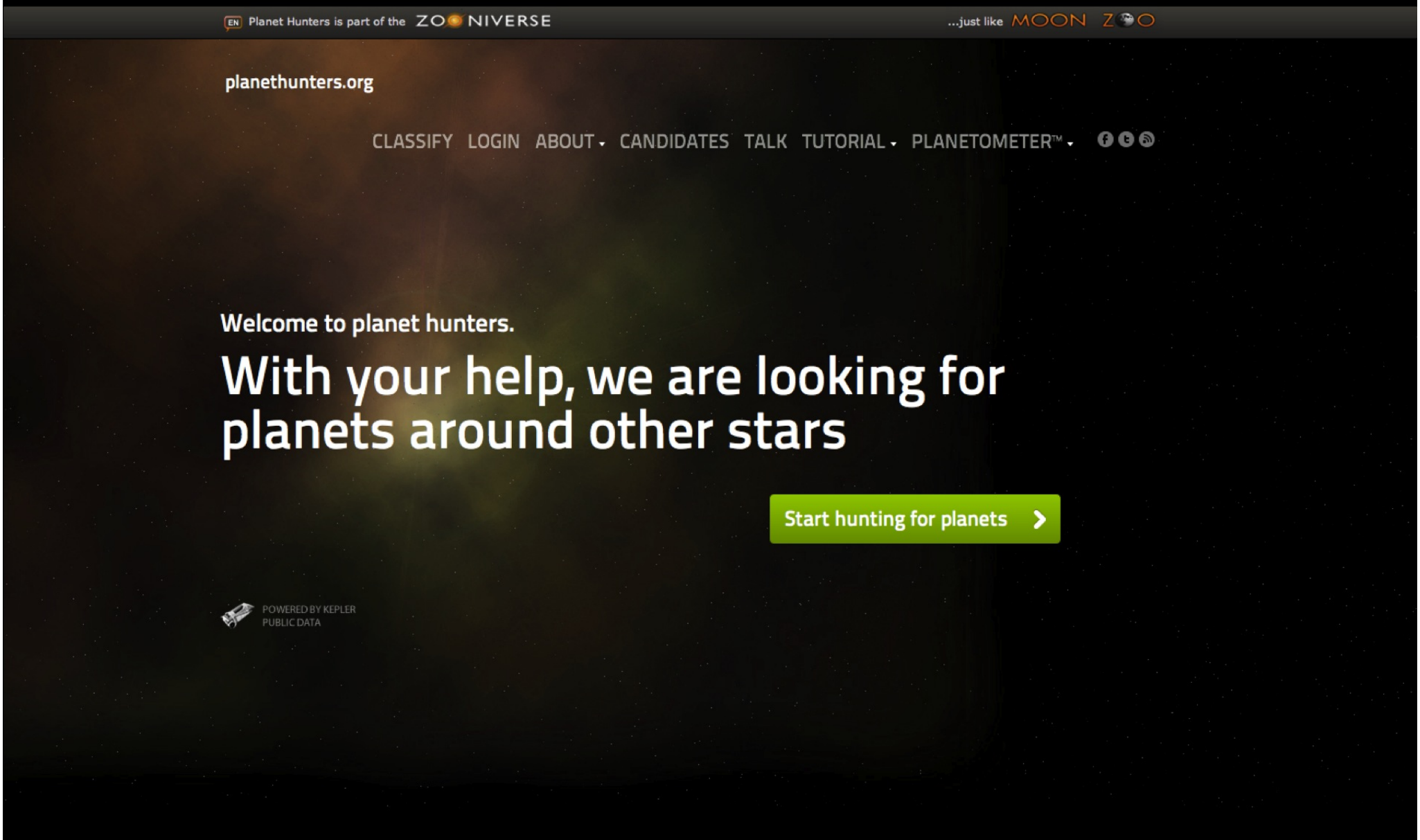

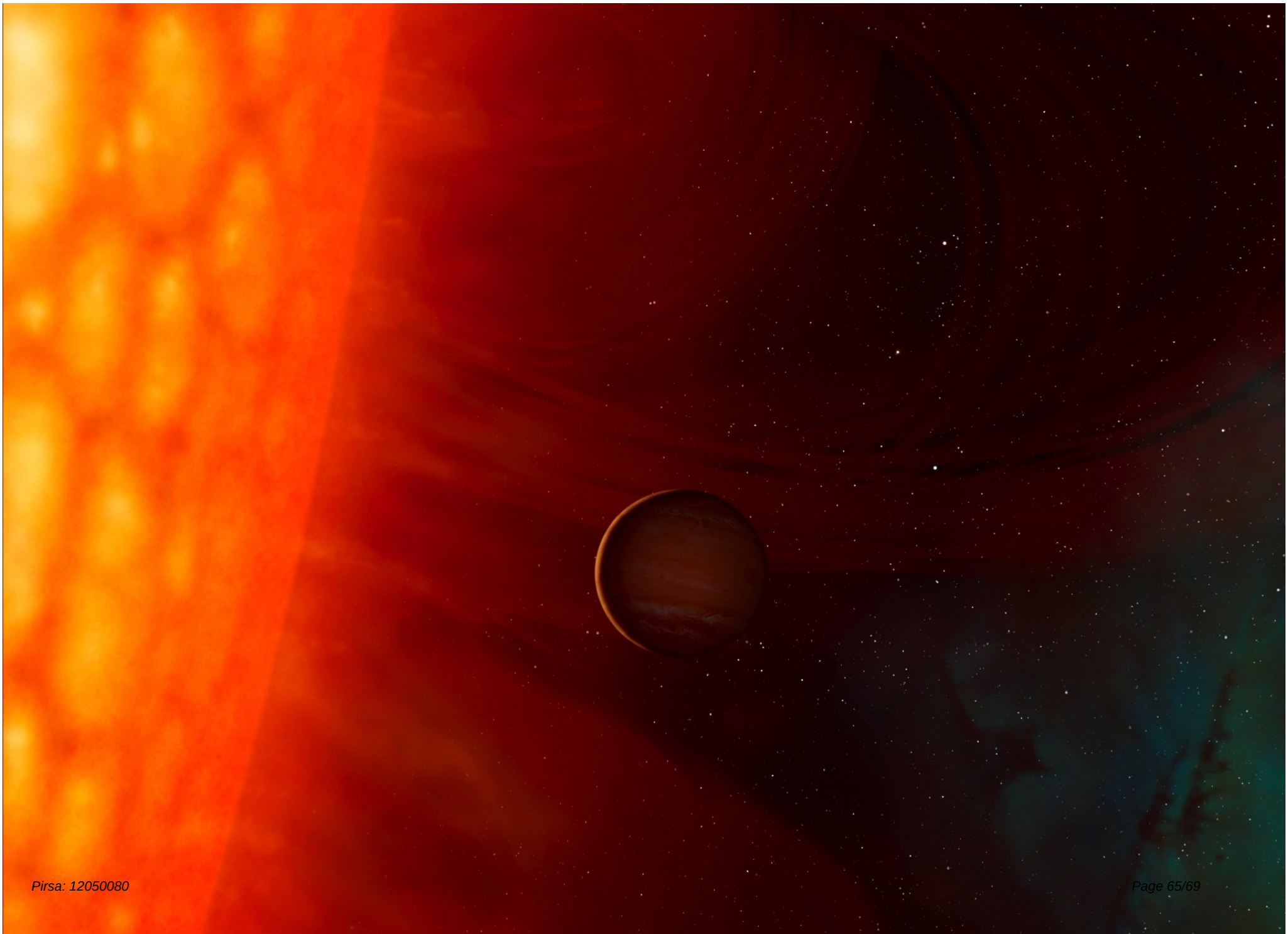

FM stars

FM stars: A Fourier view of pulsating binary stars, a new technique for measuring radial velocities photometrically

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the outer layers of a star
and test
the conditions within?


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Astronomy picture of the day = APOD