

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

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URL: <http://pirsa.org/12050080>

Abstract:



Songs of the Stars: the real Music of the Spheres

**Professor Don Kurtz
Jeremiah Horrocks Institute
University of Central Lancashire**





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ARTHUR S. EDDINGTON

The internal
constitution of
the stars

1926

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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.

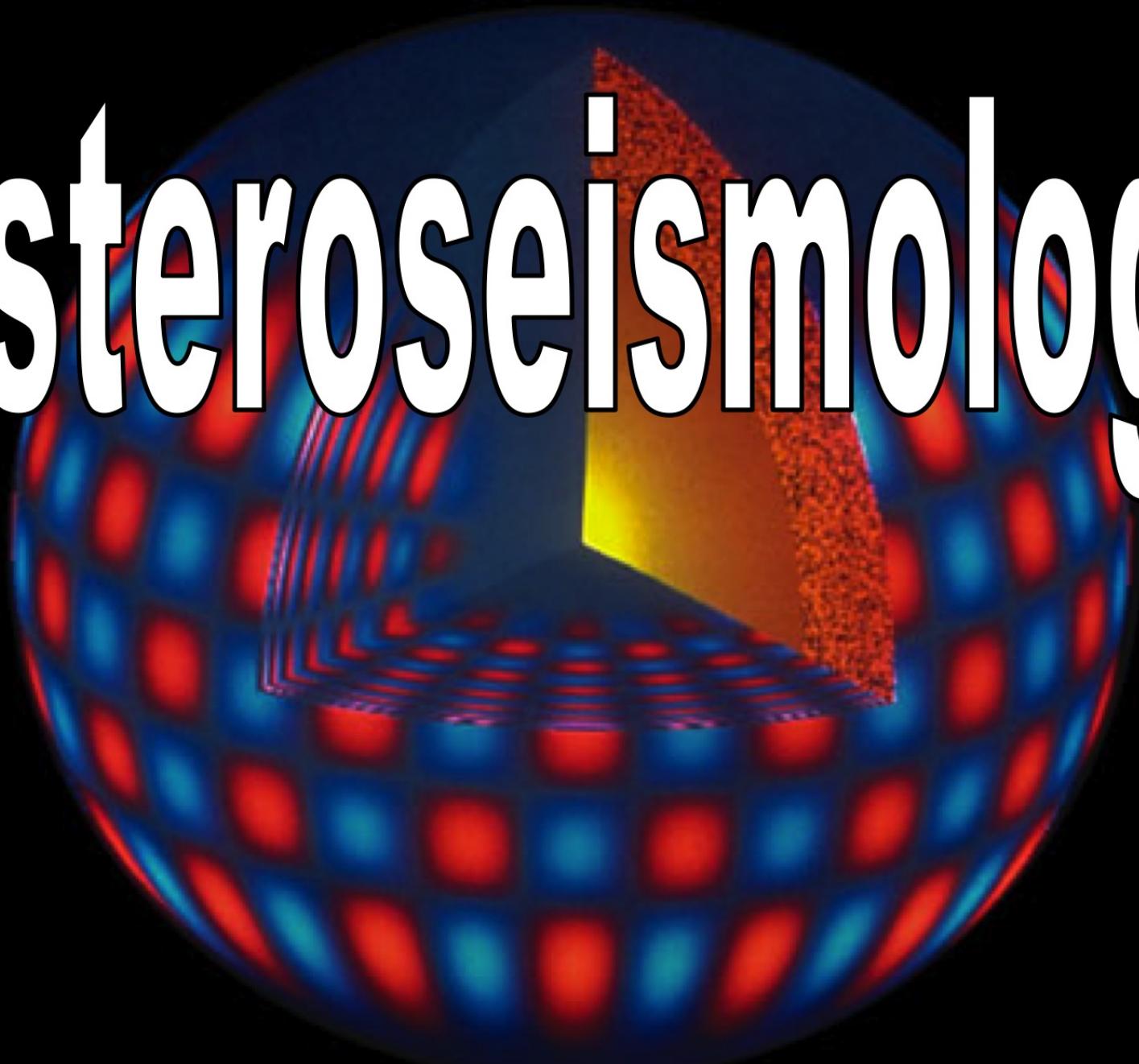
Our telescopes may probe
farther and farther
into the depths of space;
but how can we ever obtain
certain knowledge
of that which is hidden
behind substantial barriers?

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

Asteroseismology



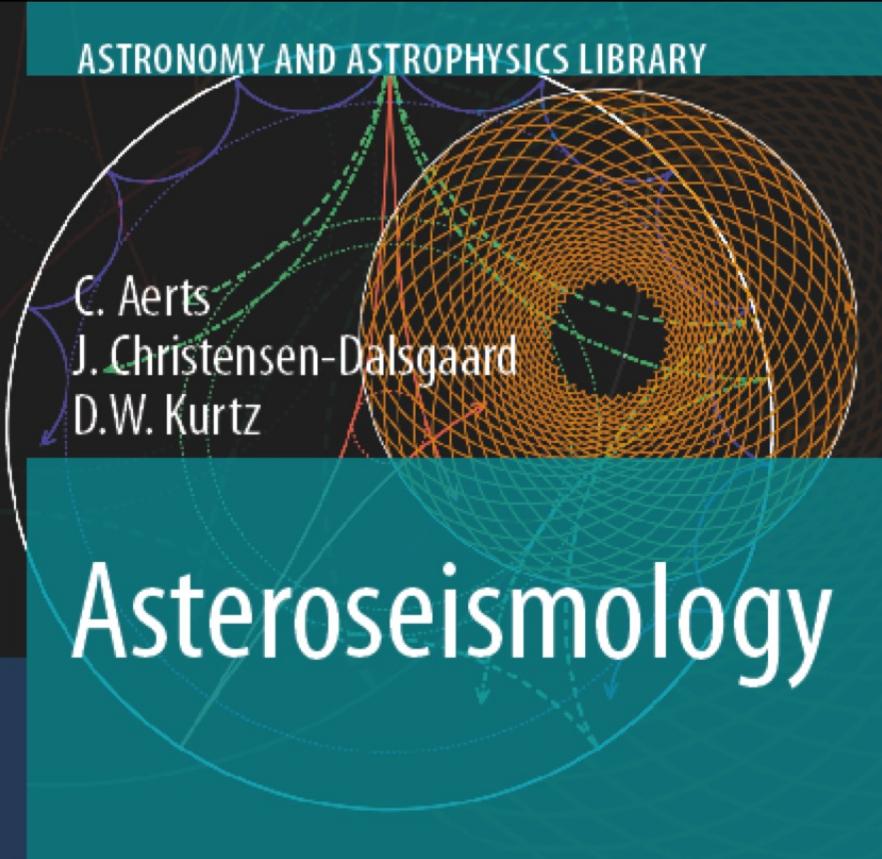
Asteroseismology



Asteroseismology



Aerts
Christensen-Dalsgaard
Kurtz

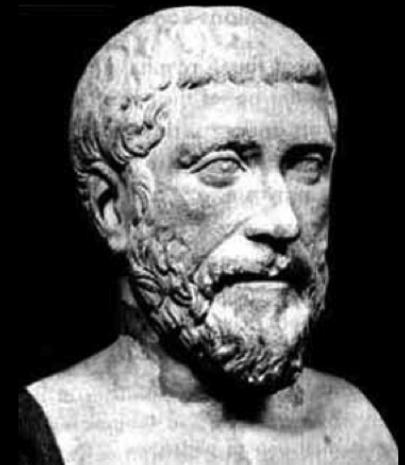


The Music of the Spheres

Pythagoras of Samos
(c.569 - 475 BC)



2:1 ratio



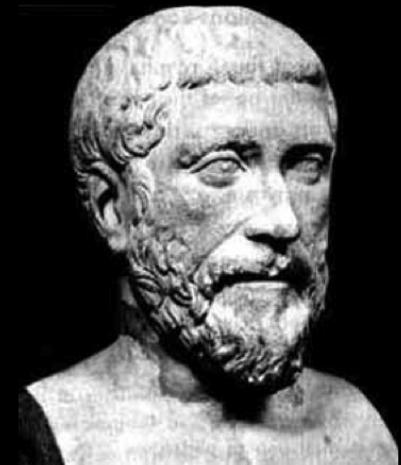
Plato said that a siren sits on each planet, who carols a most sweet song, agreeing to the motion of her own particular planet, but harmonising with all the others.

The Music of the Spheres

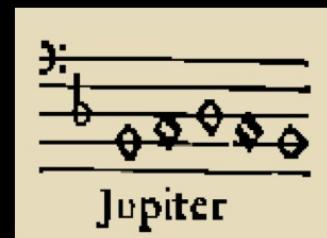
Pythagoras of Samos
(c.569 - 475 BC)



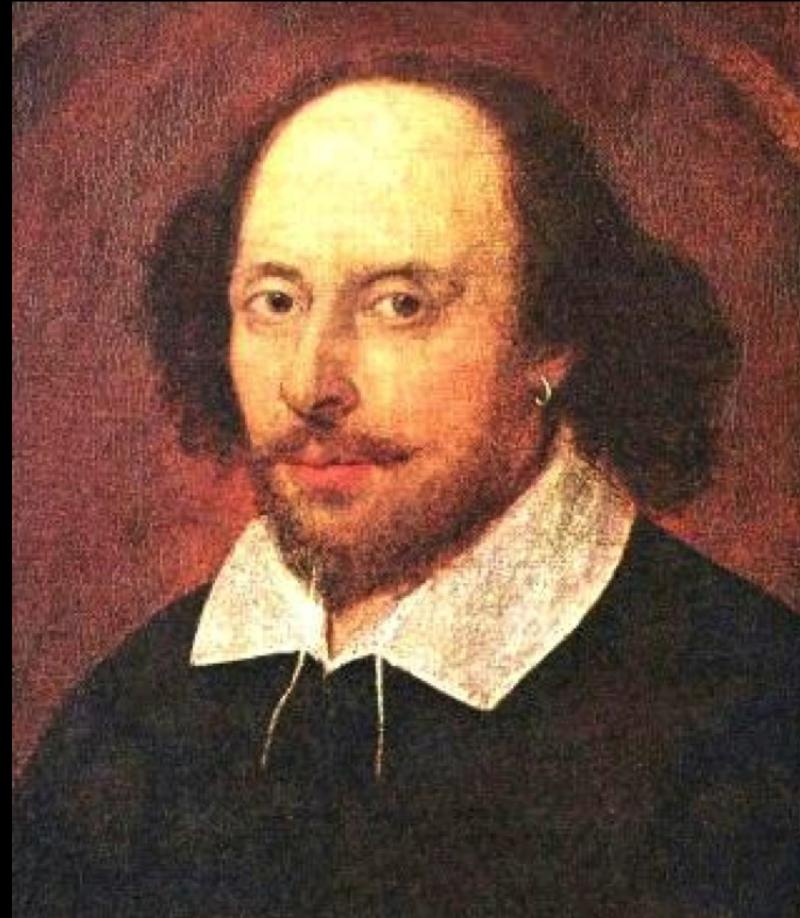
2:1 ratio



Johannes Kepler
(1571 – 1630)



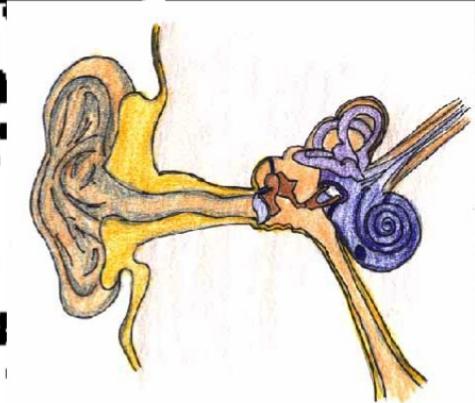
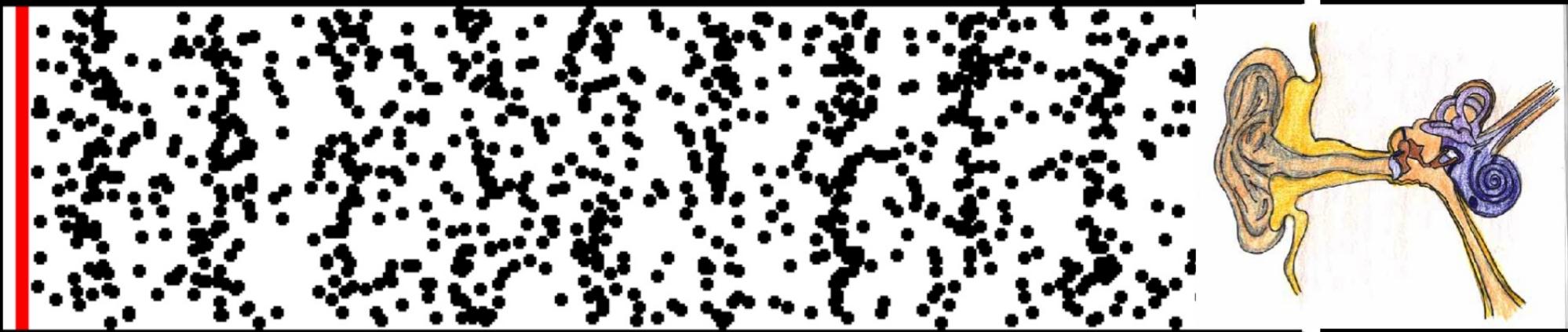
There's not the smallest orb which thou beholdest
but in his motion like an angel sings
Still quiring to the young-eyed cherubim
(Merchant of Venice, v. 1)



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

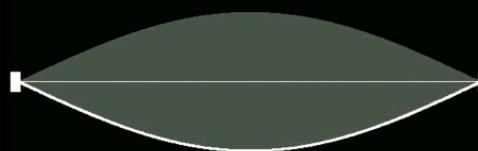


Blue Whales “sing” at 12-200 Hz

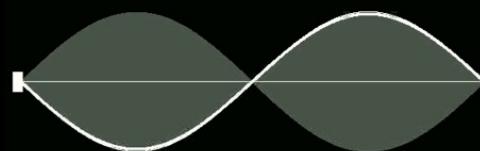


1D oscillations

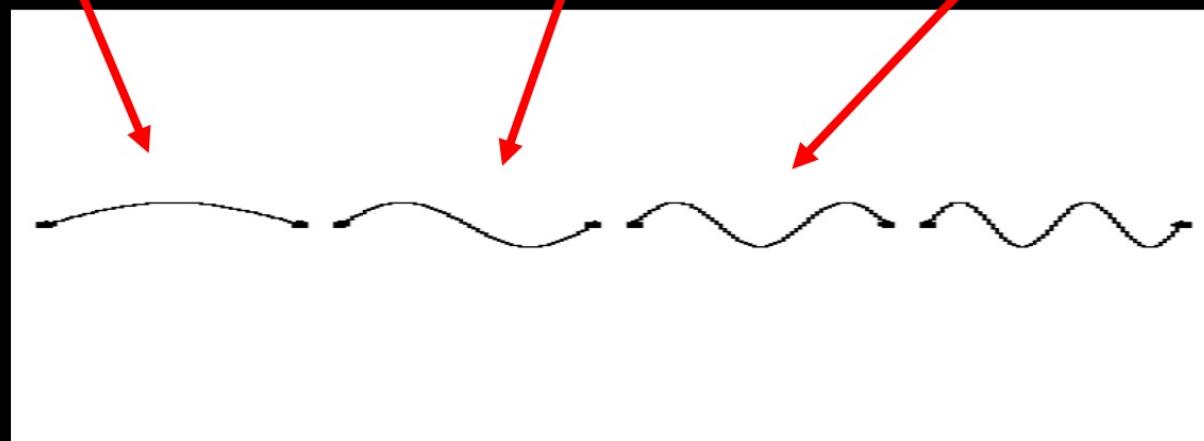
Fundamental



First overtone



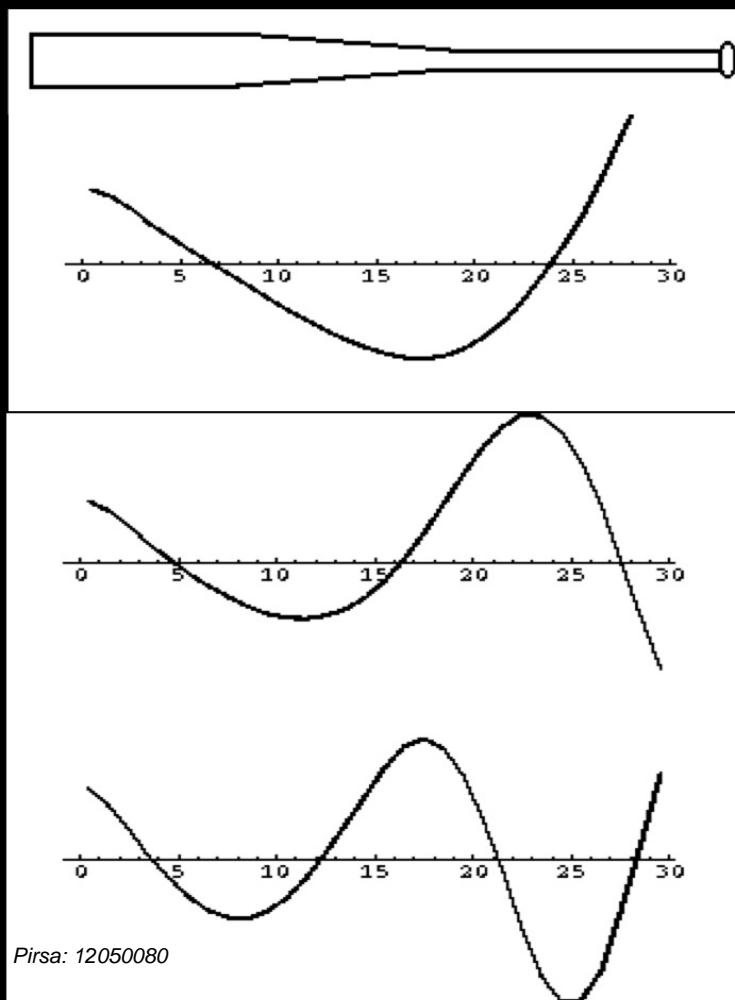
Second overtone



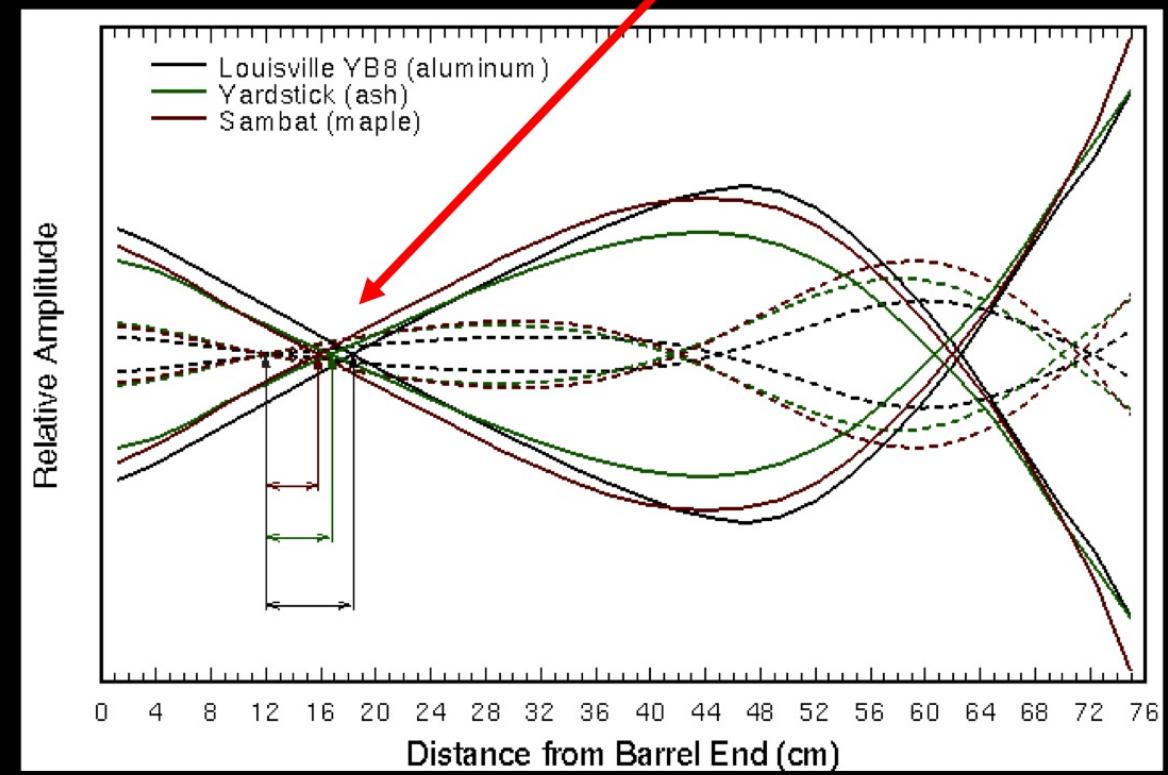
nodes

modes

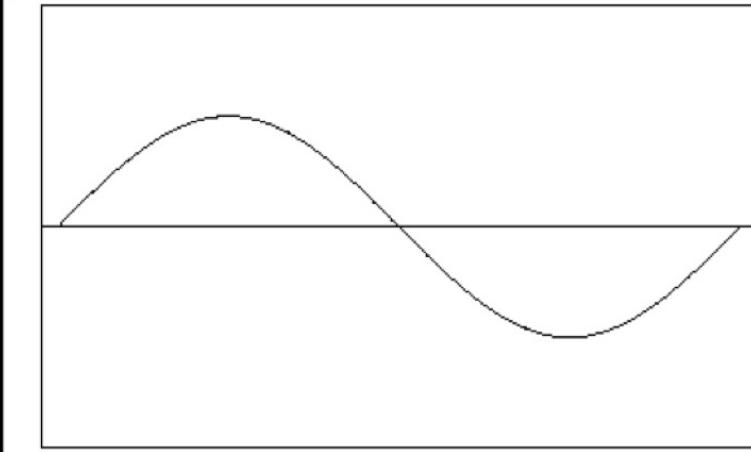
1D oscillations: The baseball bat



The “sweet spot”



pressure

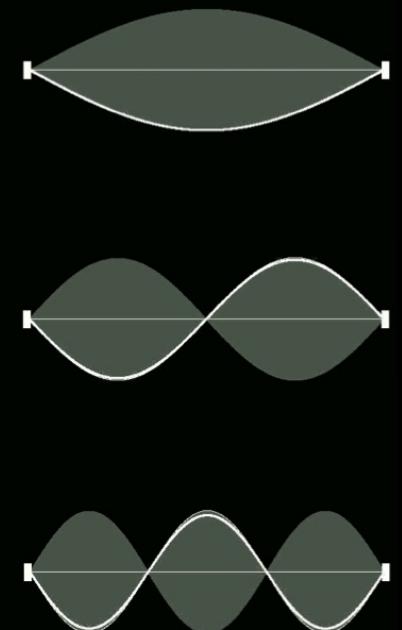


time

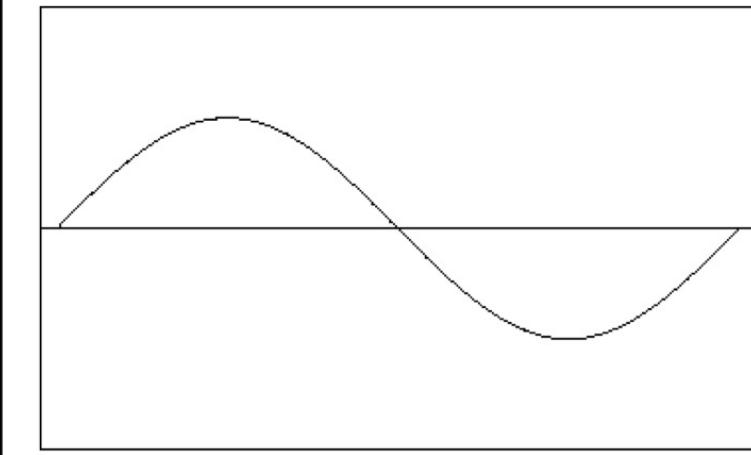


frequency

Harmonics



pressure

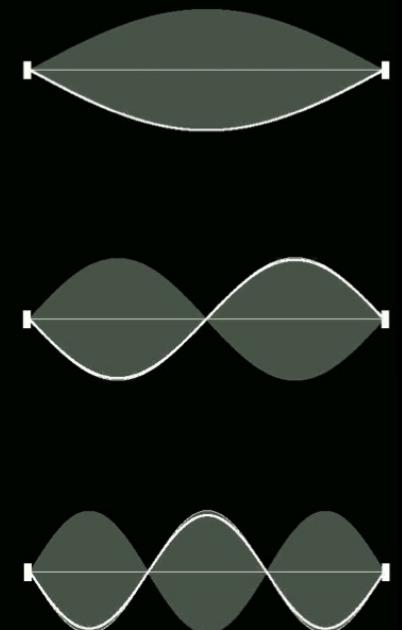


time



frequency

Harmonics

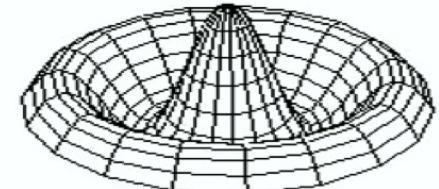
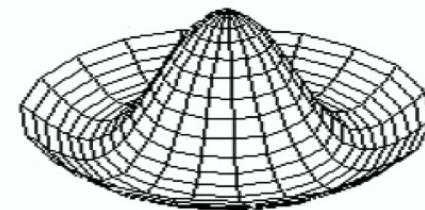


2D oscillation – drums the radial modes

fundamental mode

1st-overtone mode

2nd-overtone mode

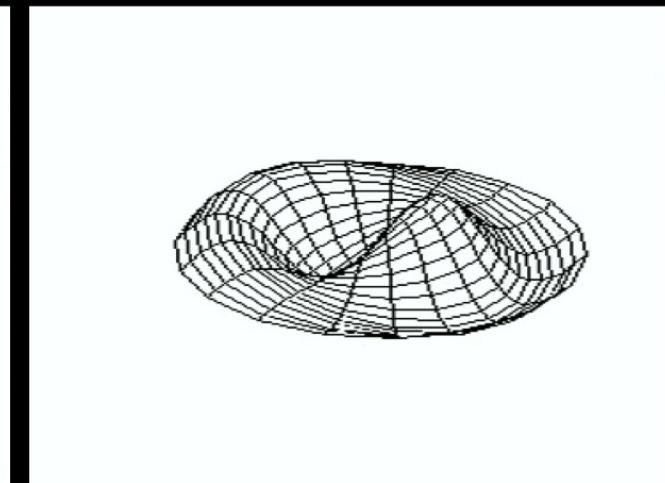
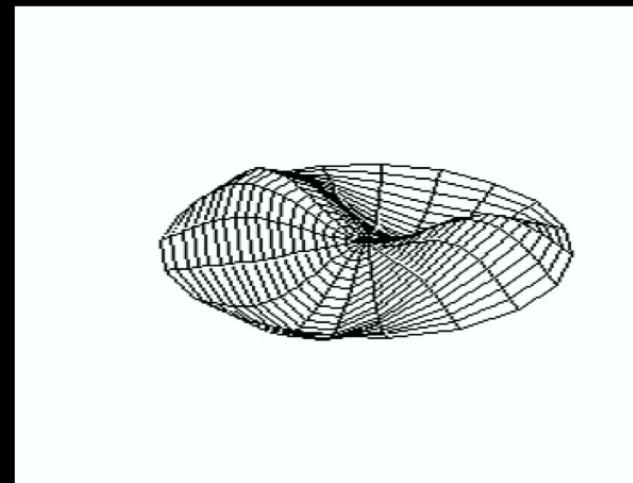
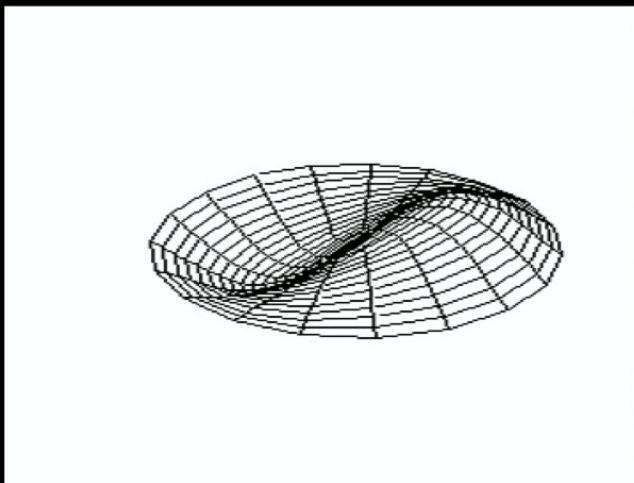


2D oscillation – drums the non-radial modes

dipole mode

quadrupole mode

first overtone
dipole mode



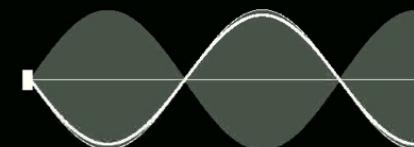
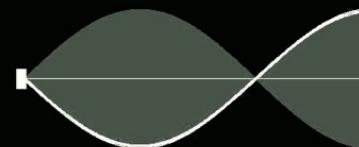
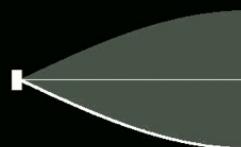
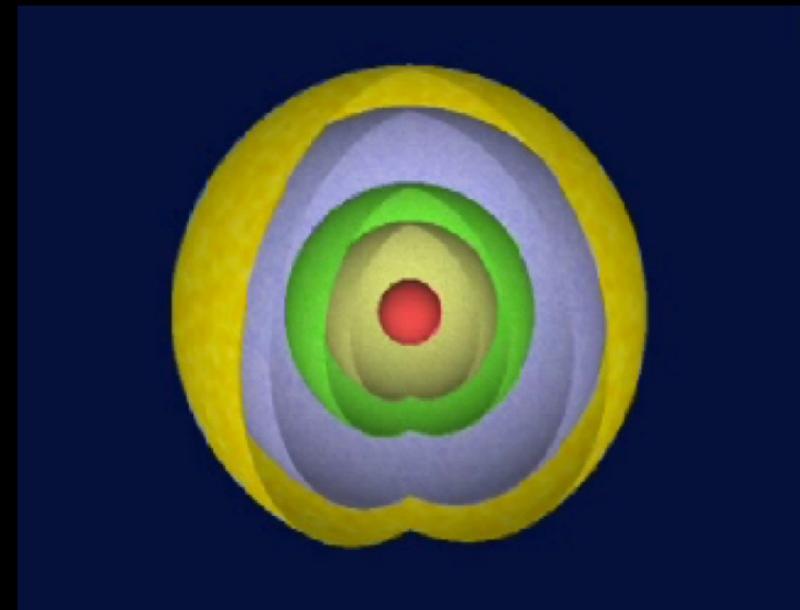
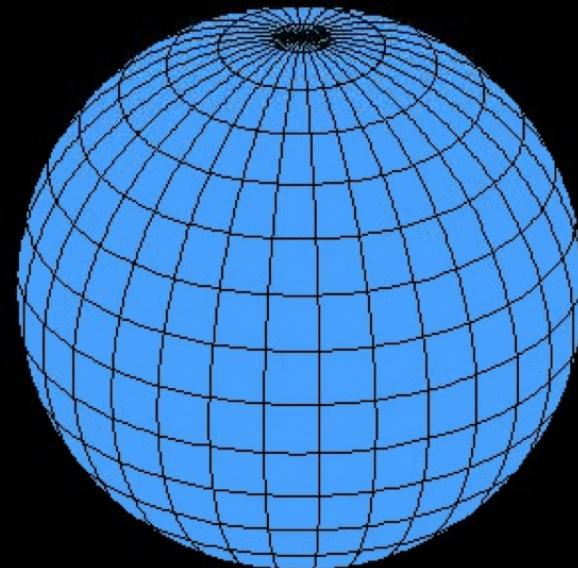
2D oscillations violins



3D oscillations – stars radial modes

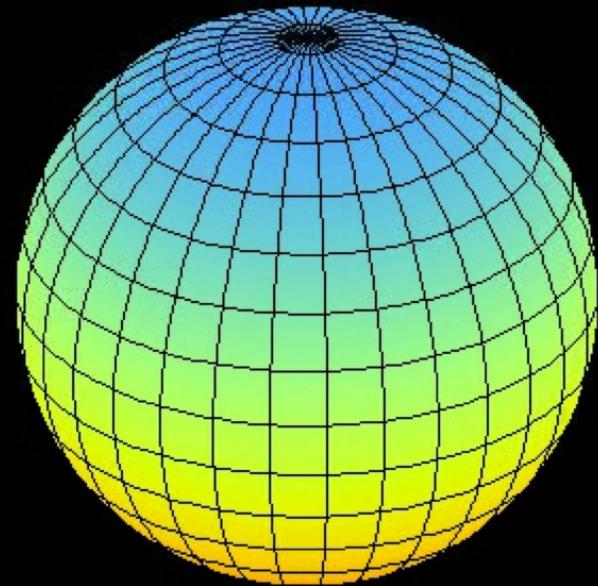
Rich Townsend

Zoltán Kolláth



3D in stars

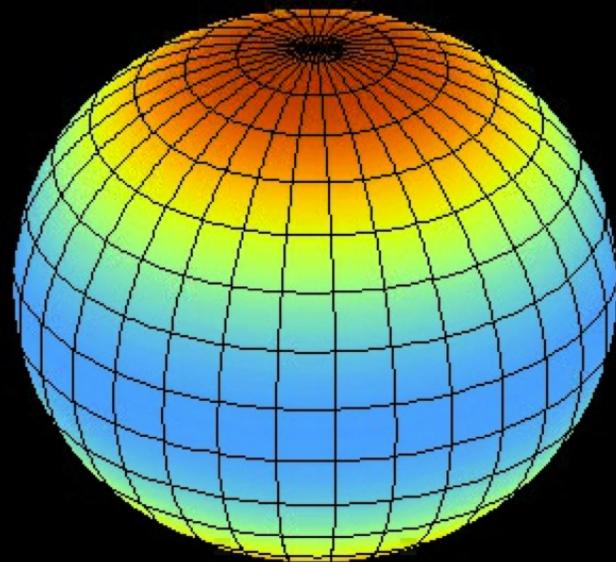
Non-radial modes: The dipole mode



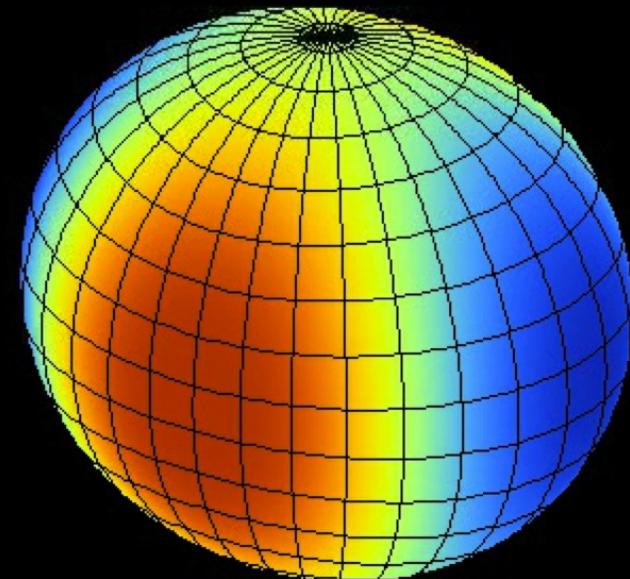
$l=1, m=0$

3D in stars

Non-radial modes: quadrupole modes

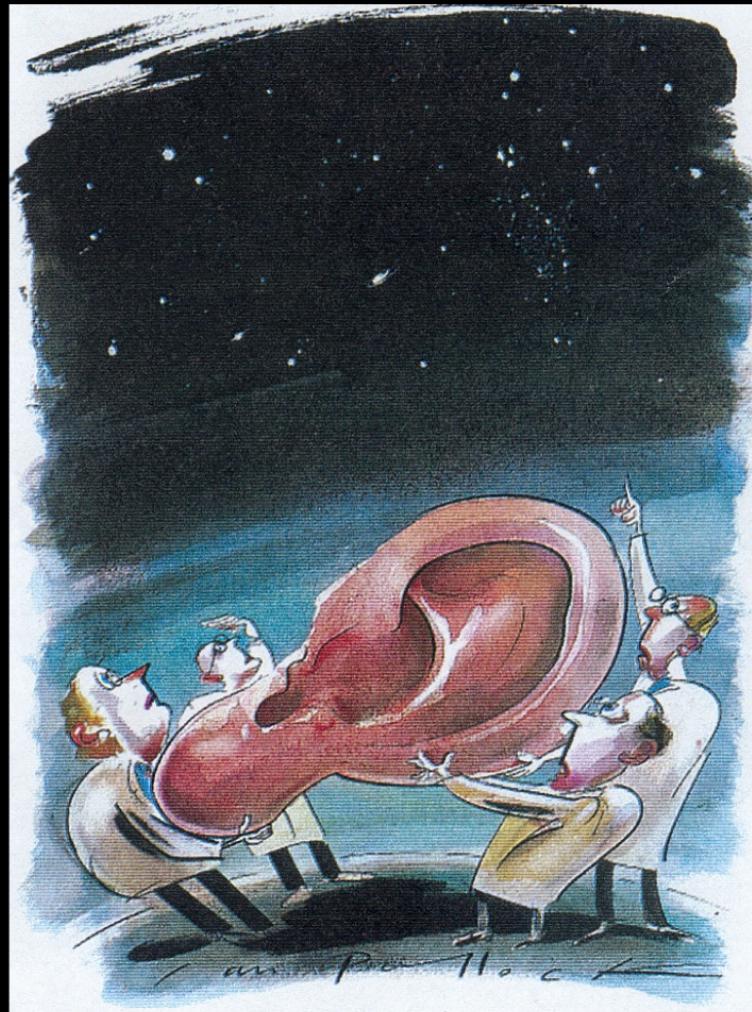


$l=2, m=0$

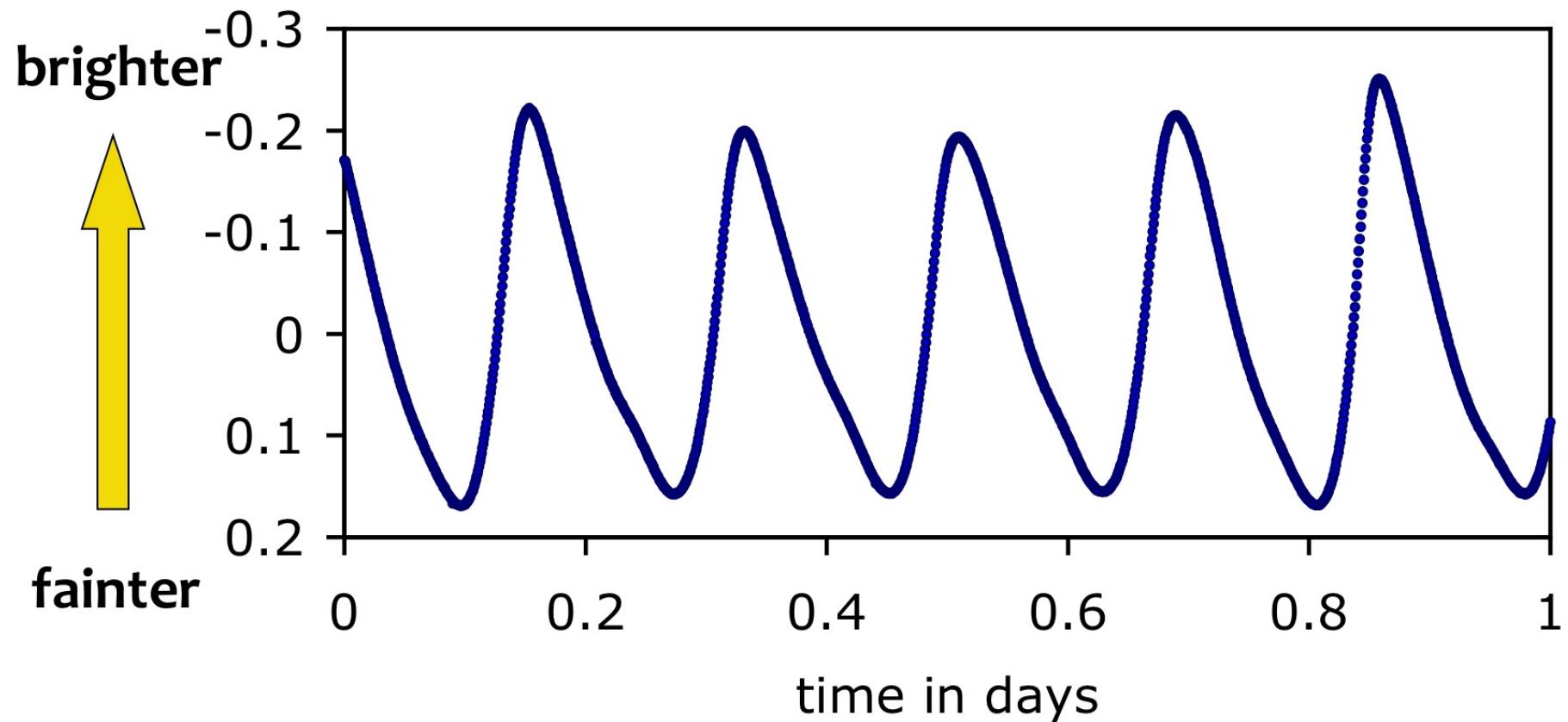


$l=2, m=2$

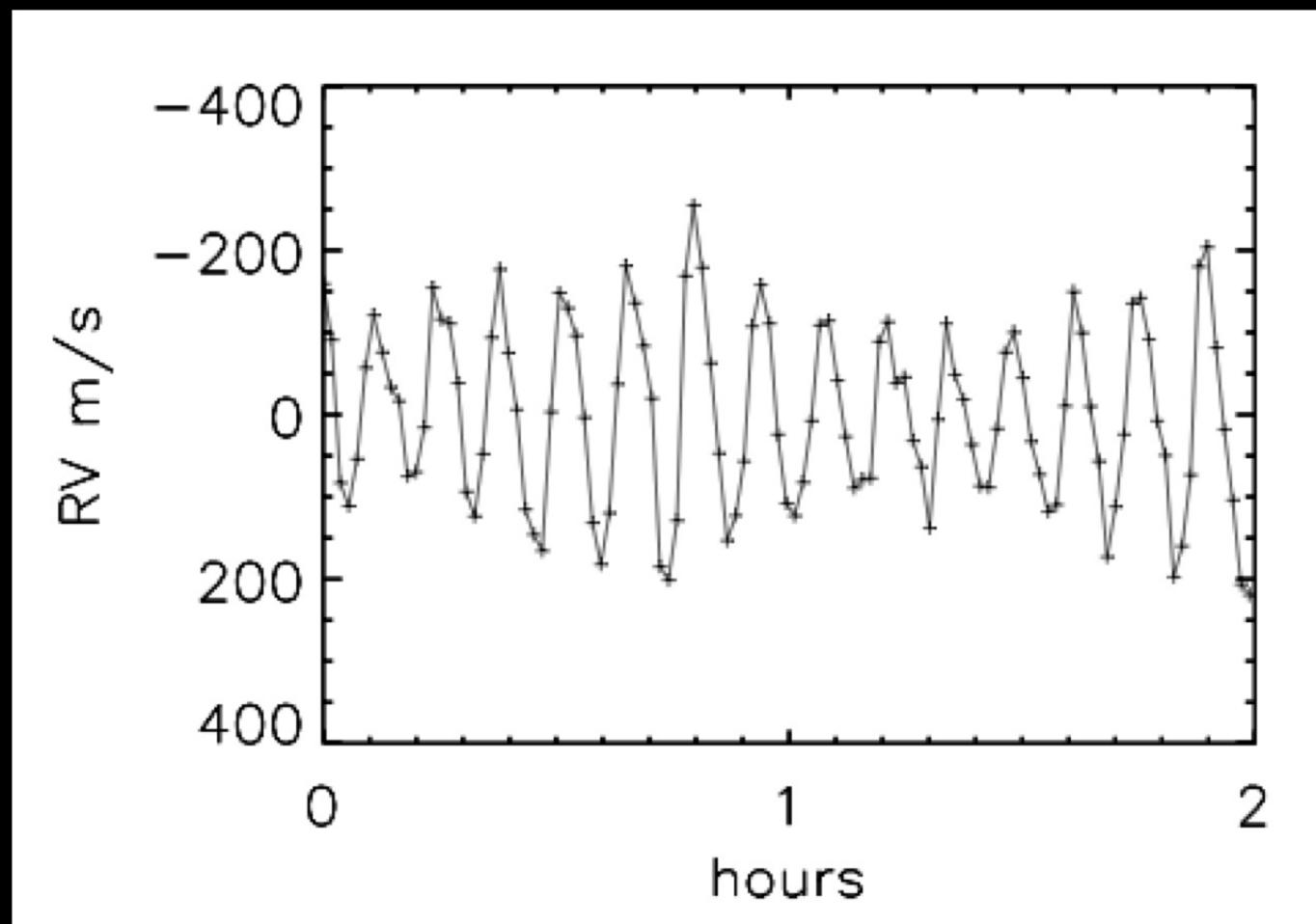
Listening to the songs of the stars



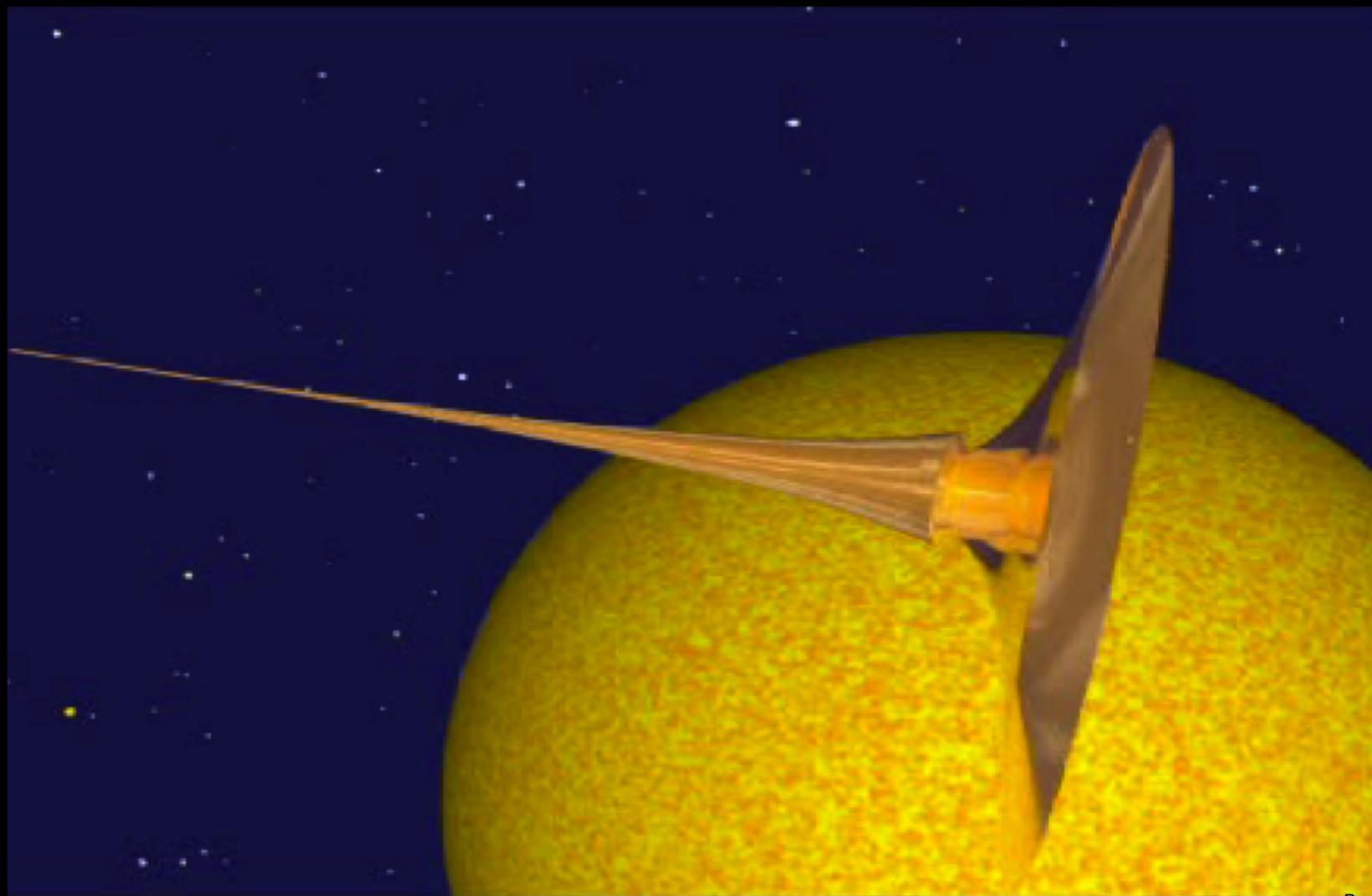
The light curve



The radial velocity curve



Cepheid variables



Cepheid variables

- **Henrietta Leavitt (1868-1921)**
- **Discovered in 1908 the Period-Luminosity (PL) relation for Cepheids**

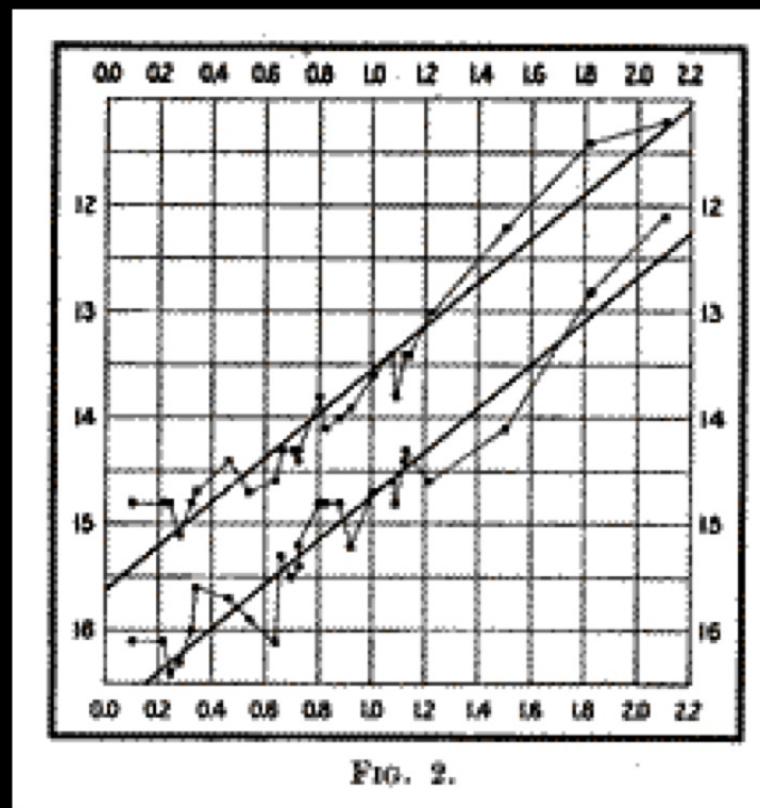


**“It is worthy of notice that ...
the brighter variables have the longer periods.” (Leavitt 1908)**

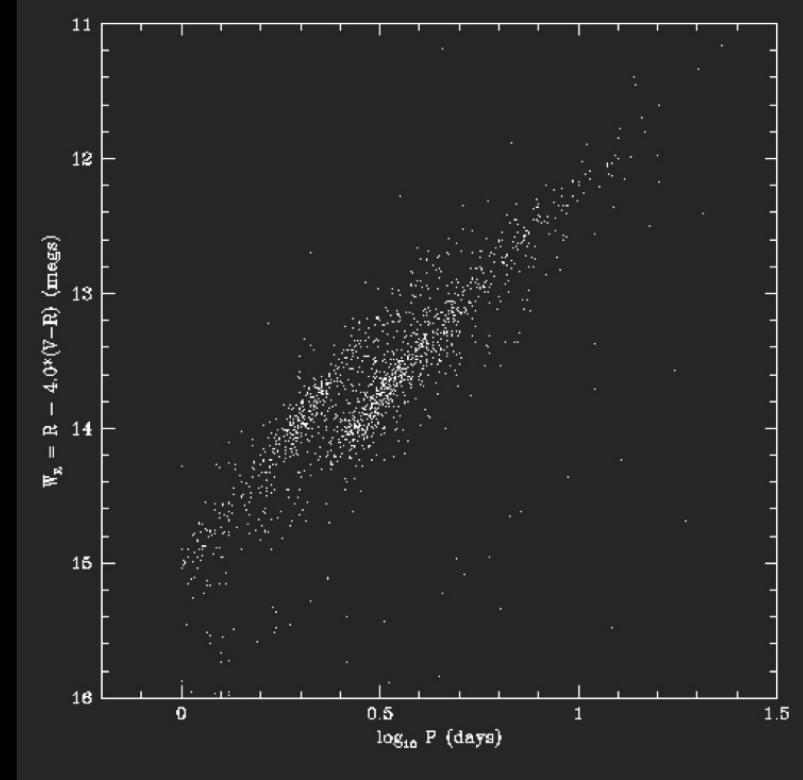
Henrietta Leavitt's PL discovery

1912

brighter
↑
magnitude
fainter



Period in days



Period in days

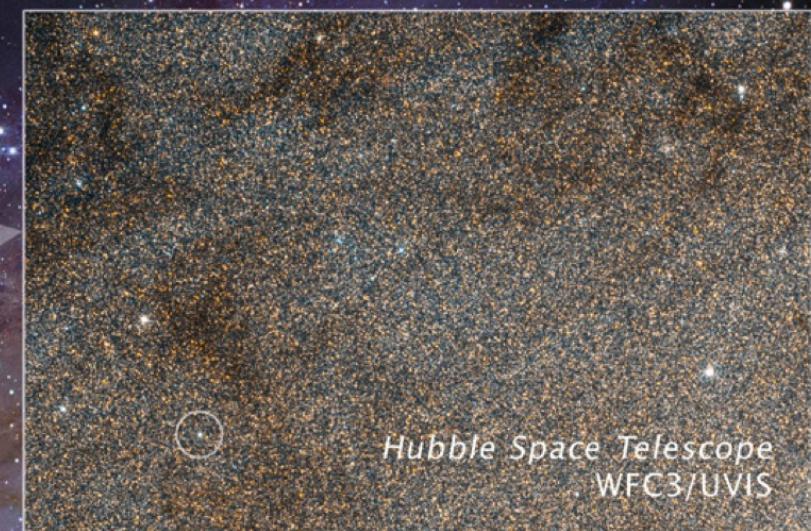
The proof that “spiral nebulae” are galaxies - 1923



Edwin Hubble

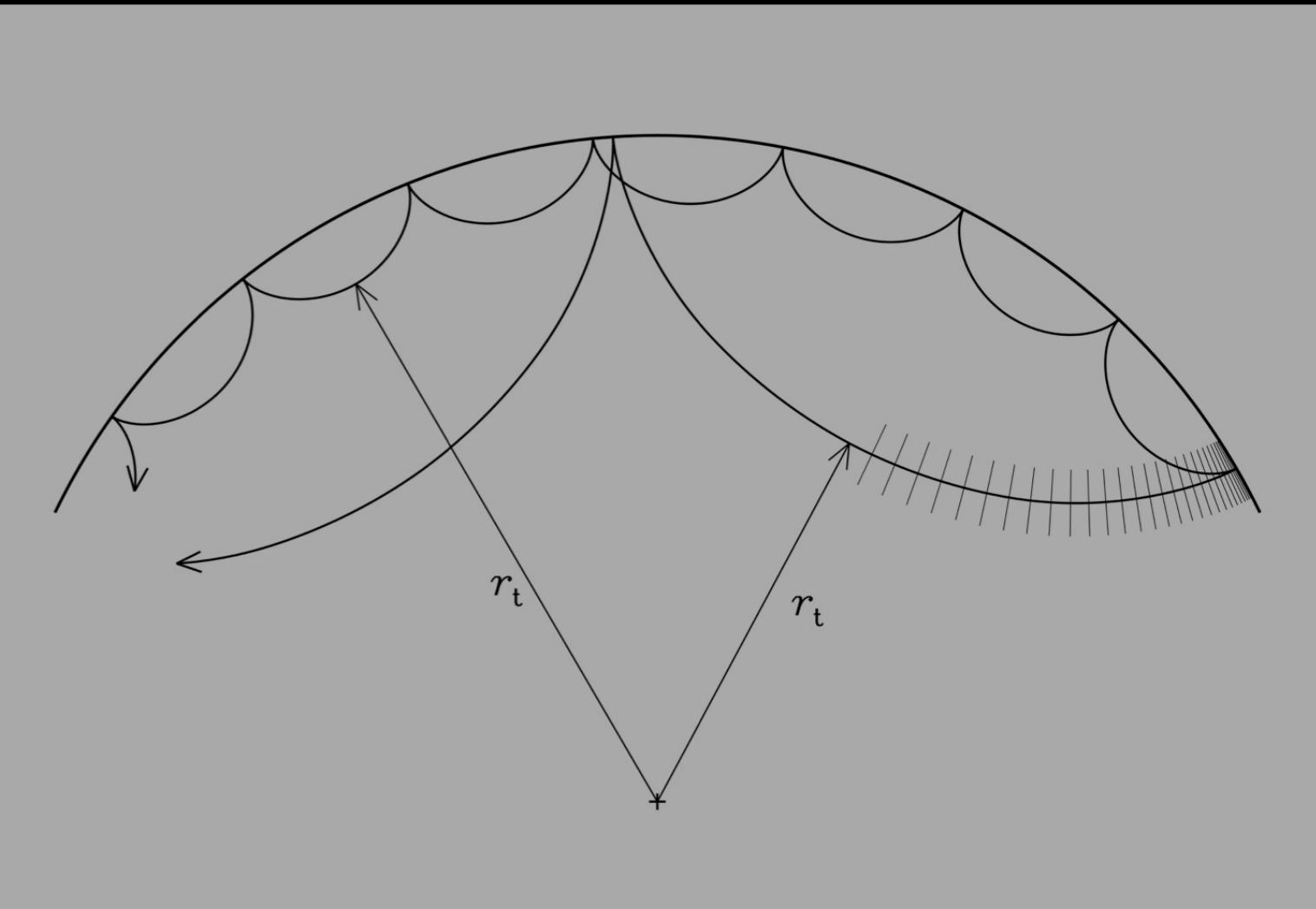
Pirsa: 12050080

Photo: R. Gendler



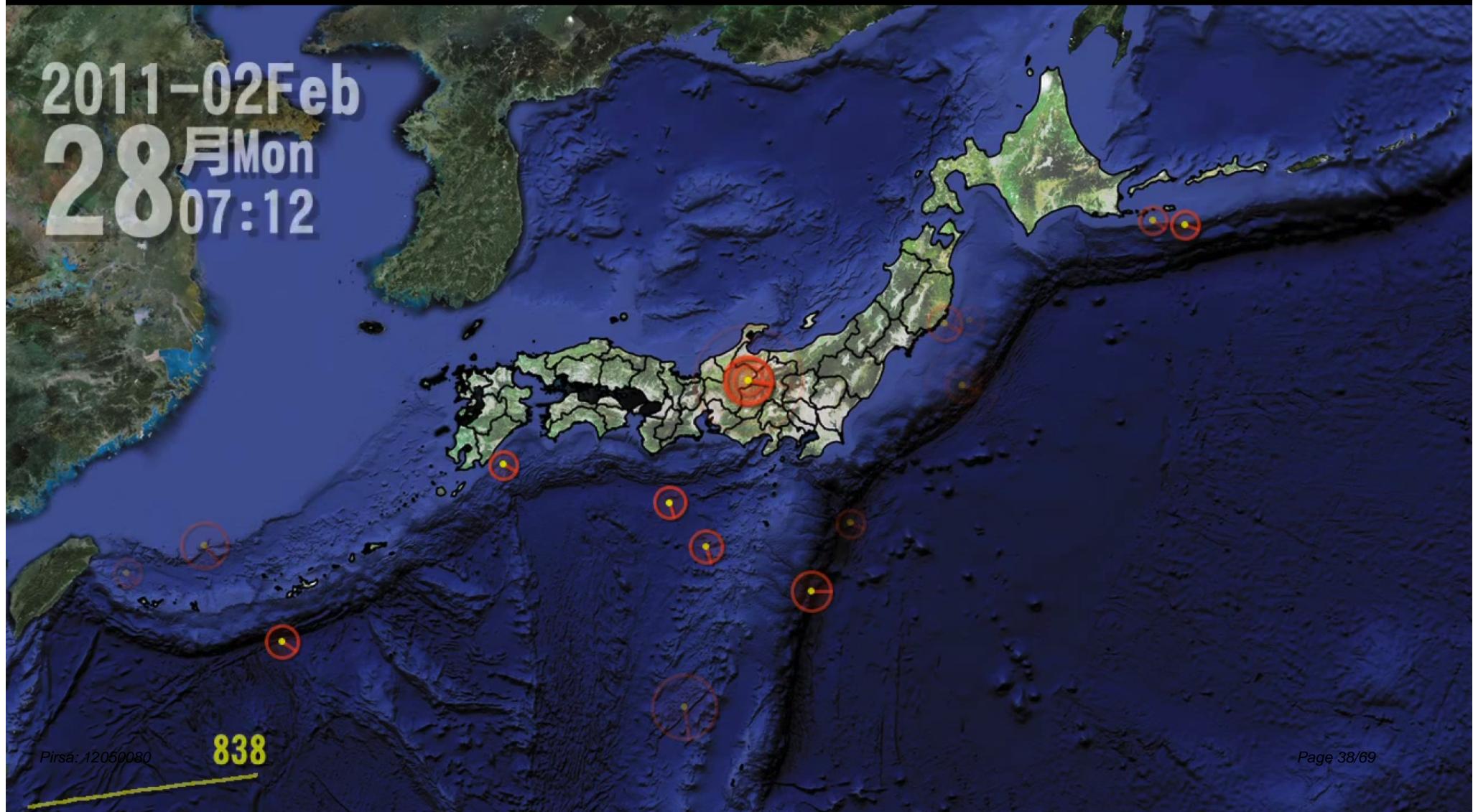
Edwin Hubble 1923
Carnegie Observatories
100-inch Telescope.

Asteroseismology – how does it work?



Earthquakes

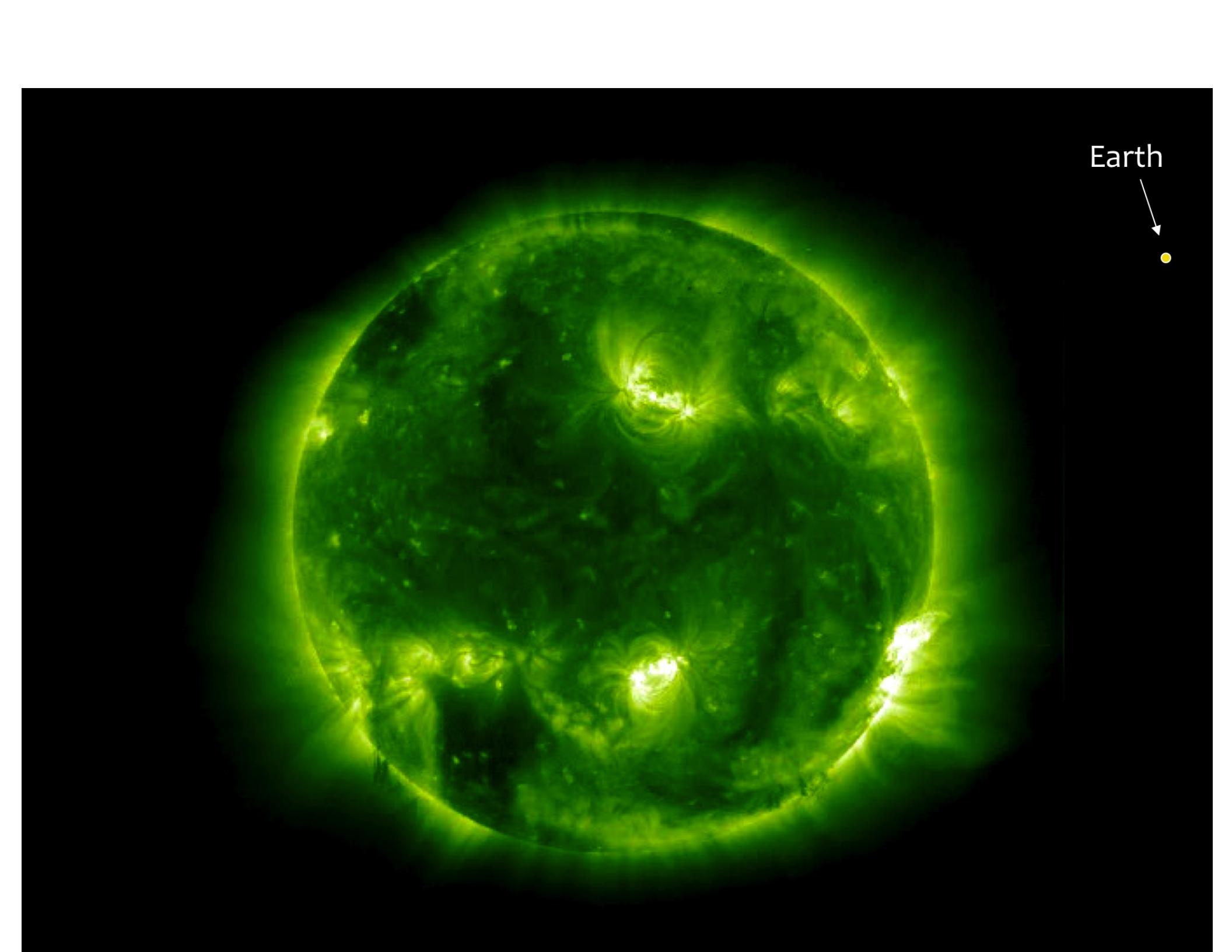
2011-02Feb
28月Mon
07:12





The Sun





Earth



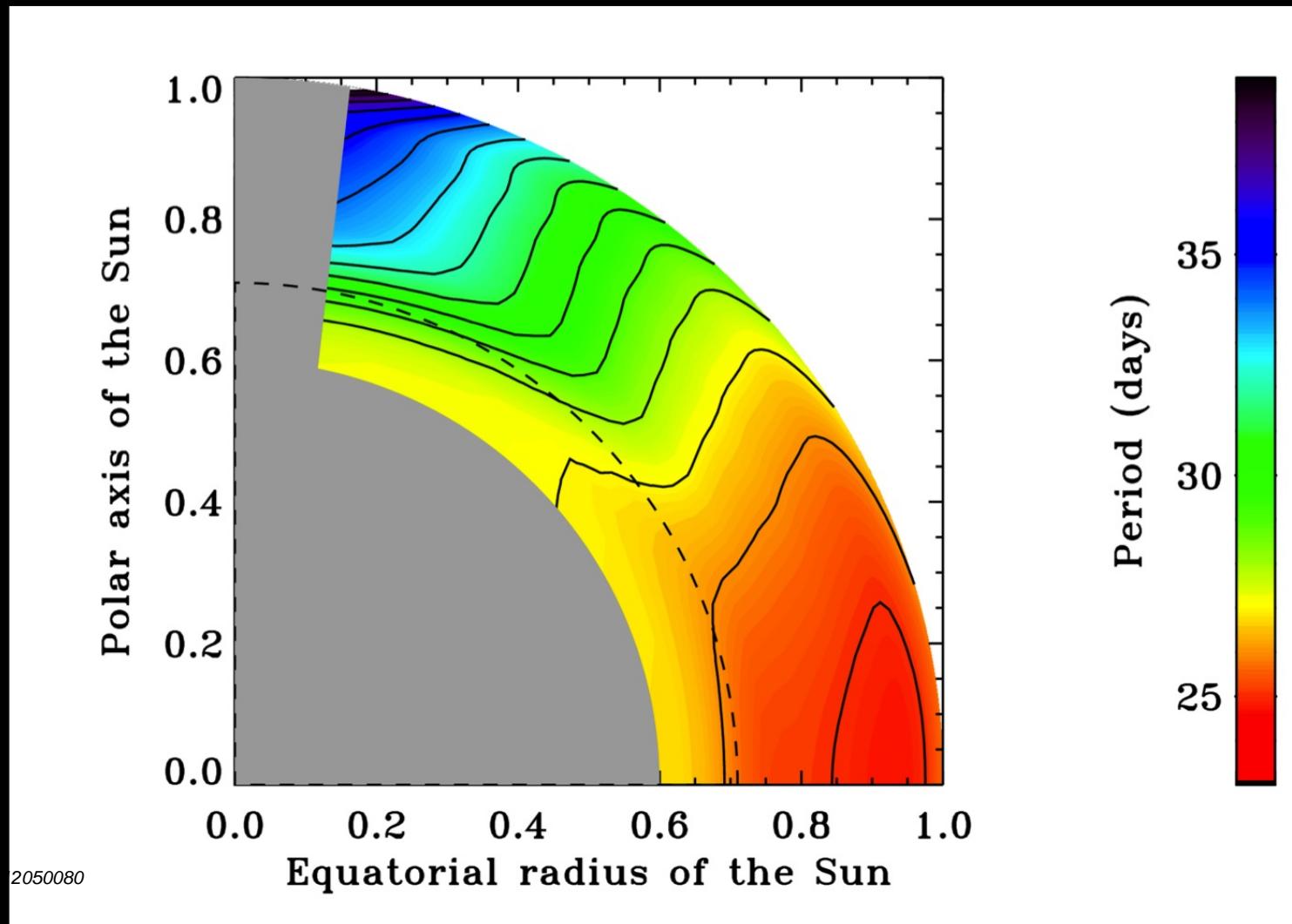
9 March 1989

“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



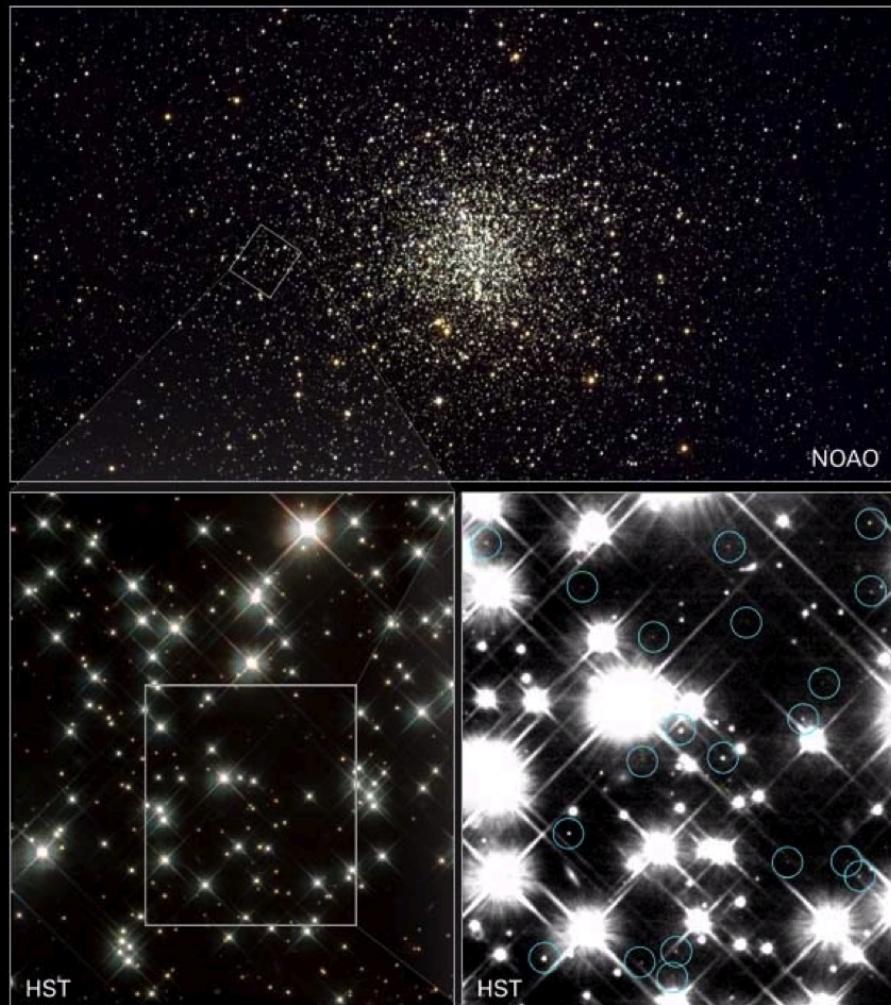
Period (days)

35
30
25

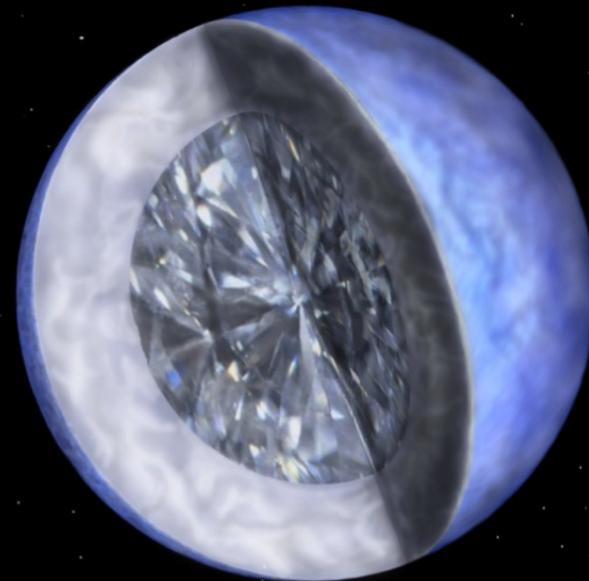
courtesy of
Rachel Howe
(Birmingham)

data from
Jesper Schou
(Stanford)

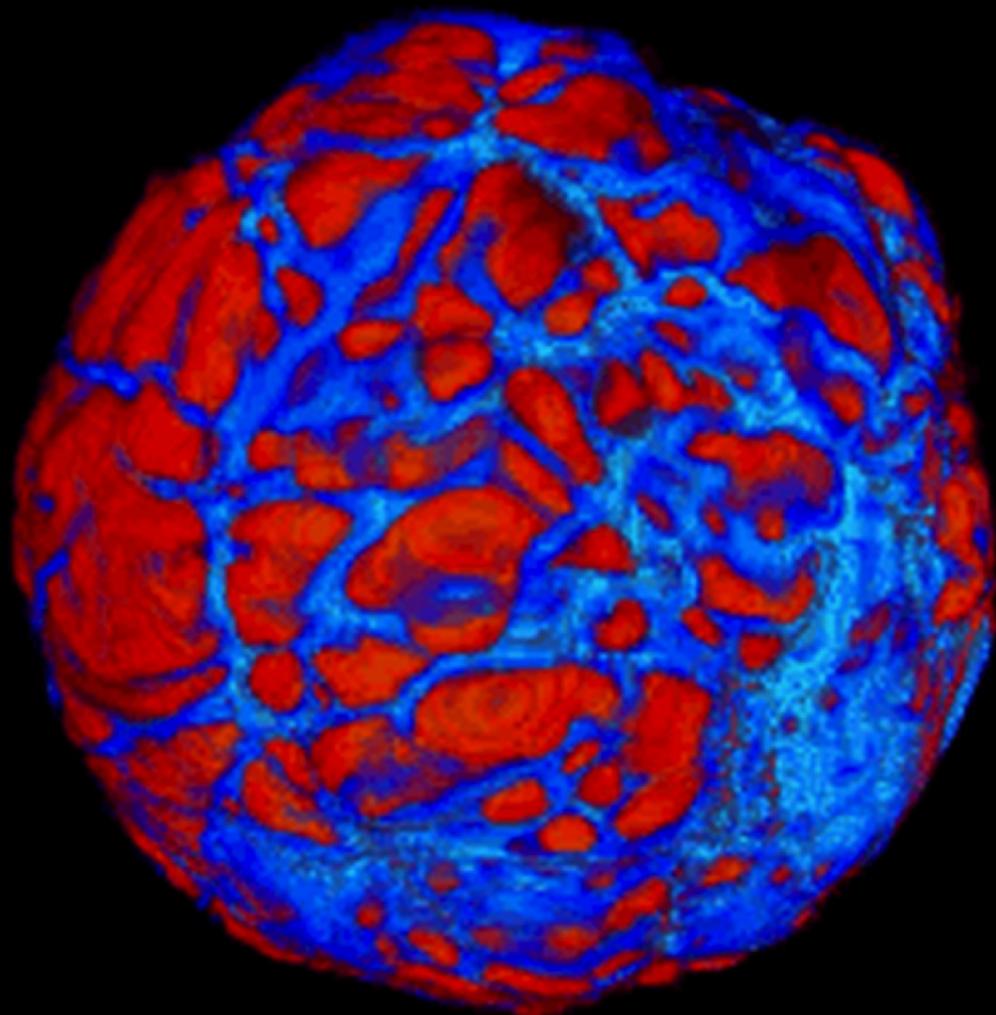
Globular cluster M4



BPM 37093 “Bruce”



The Red Giant Star xi Hydrael

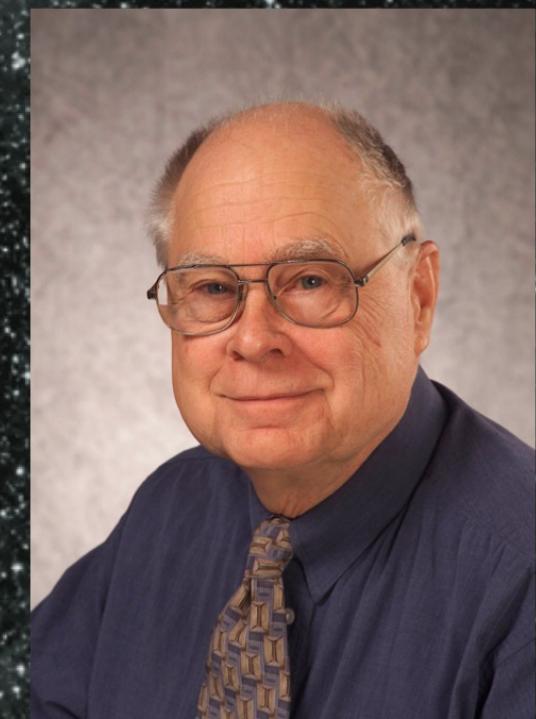
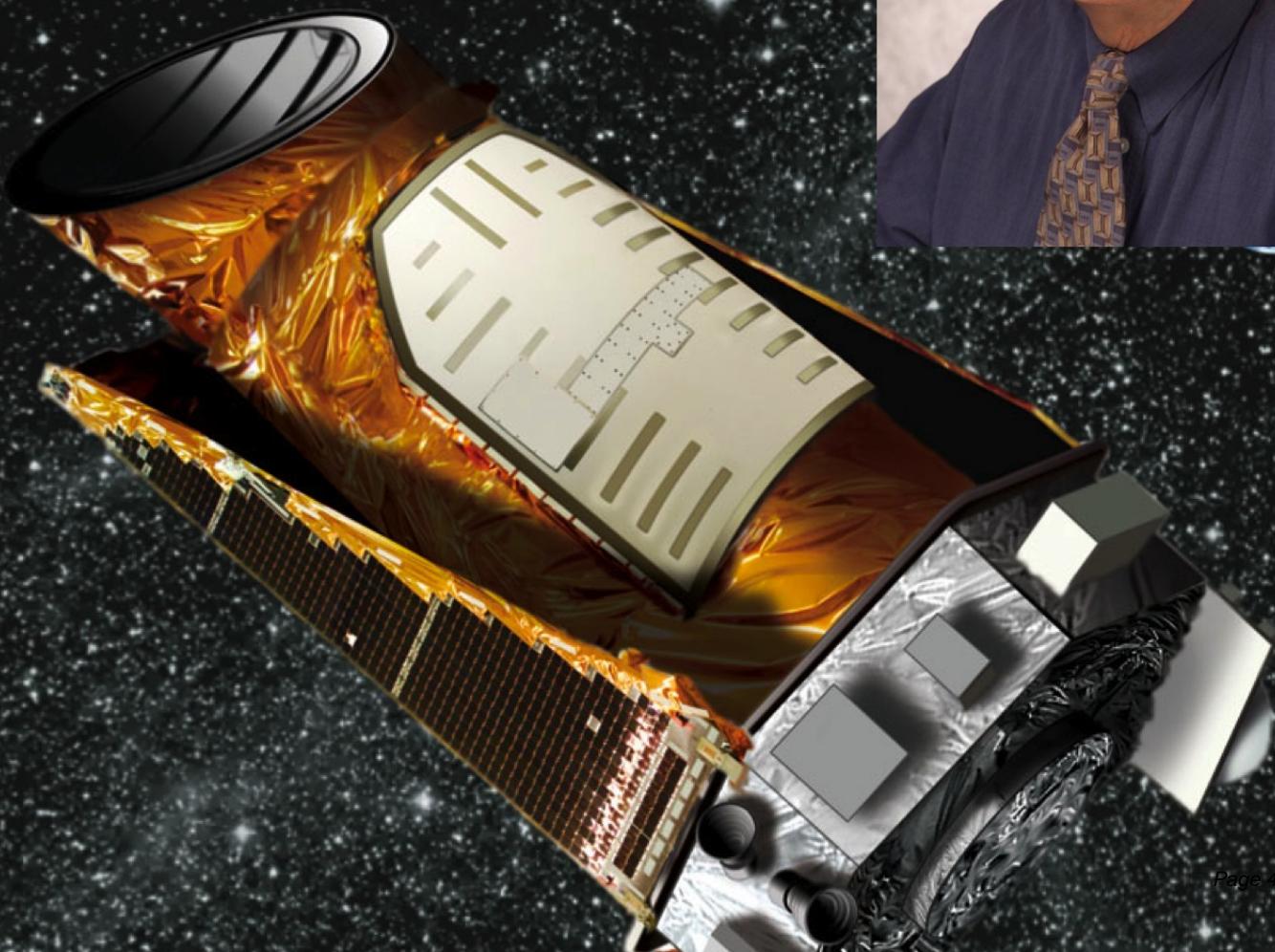


LCSE University of
Minnesota

Exo-Planets and Pulsations

The New Keplerian Revolution

The Kepler Mission Space Telescope





Kepler

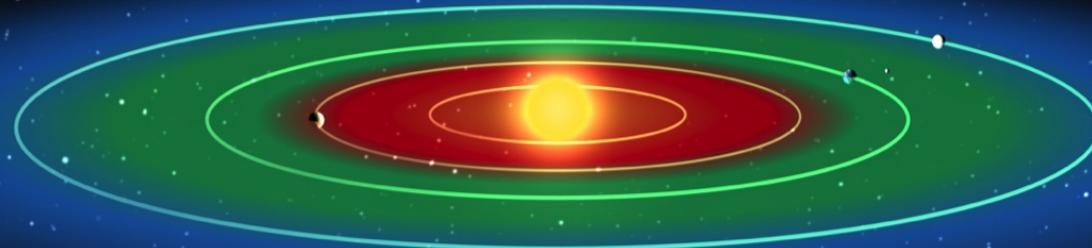


The Habitable Zone

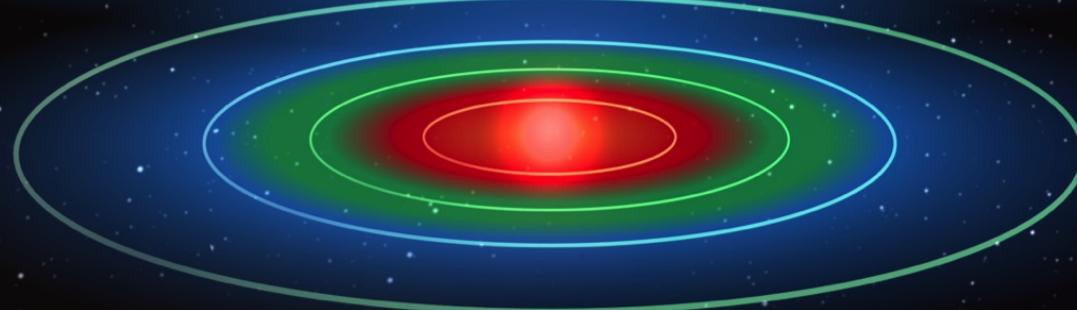
Hotter Stars



Sunlike Stars



Cooler Stars





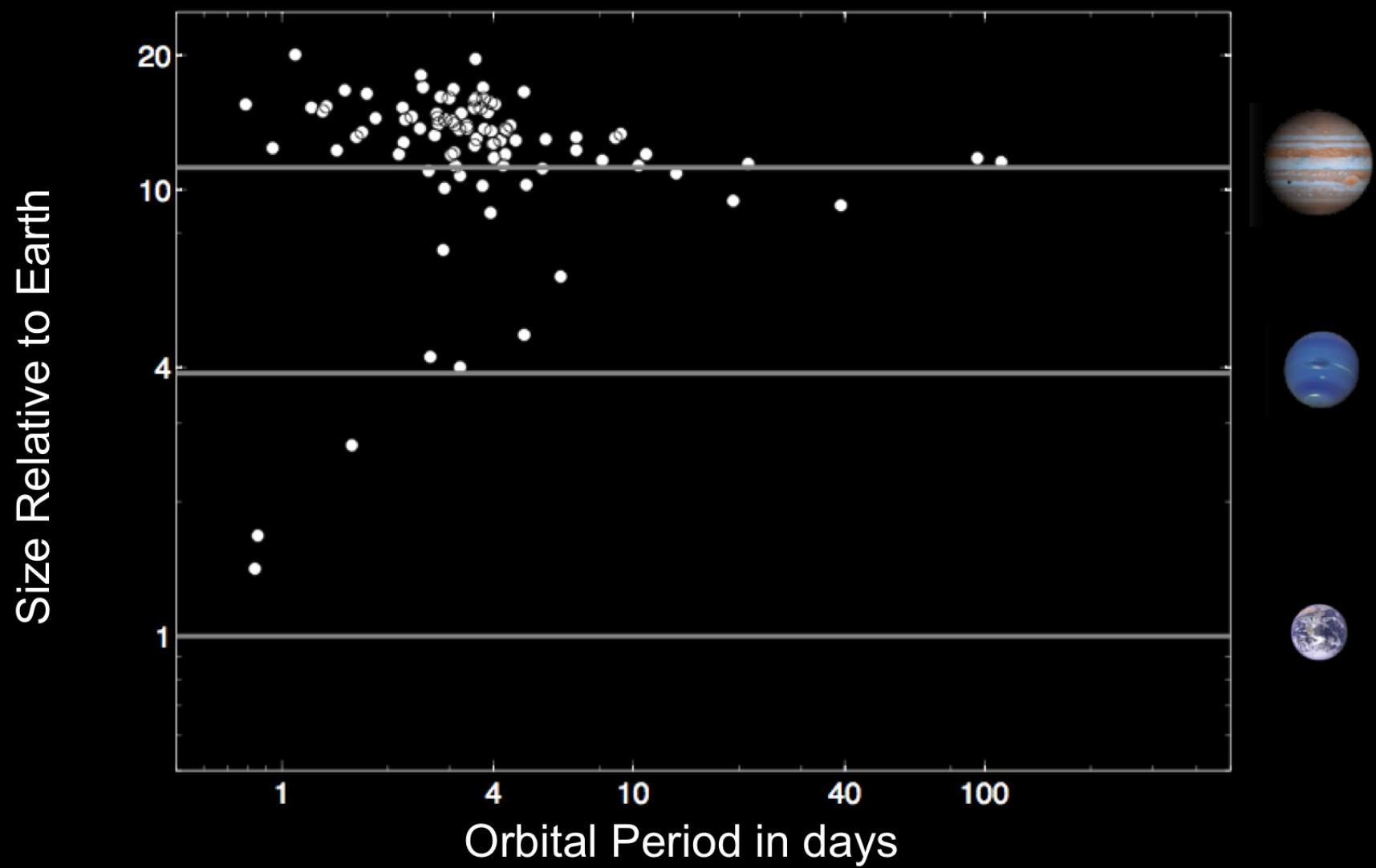


BRIGHTNESS

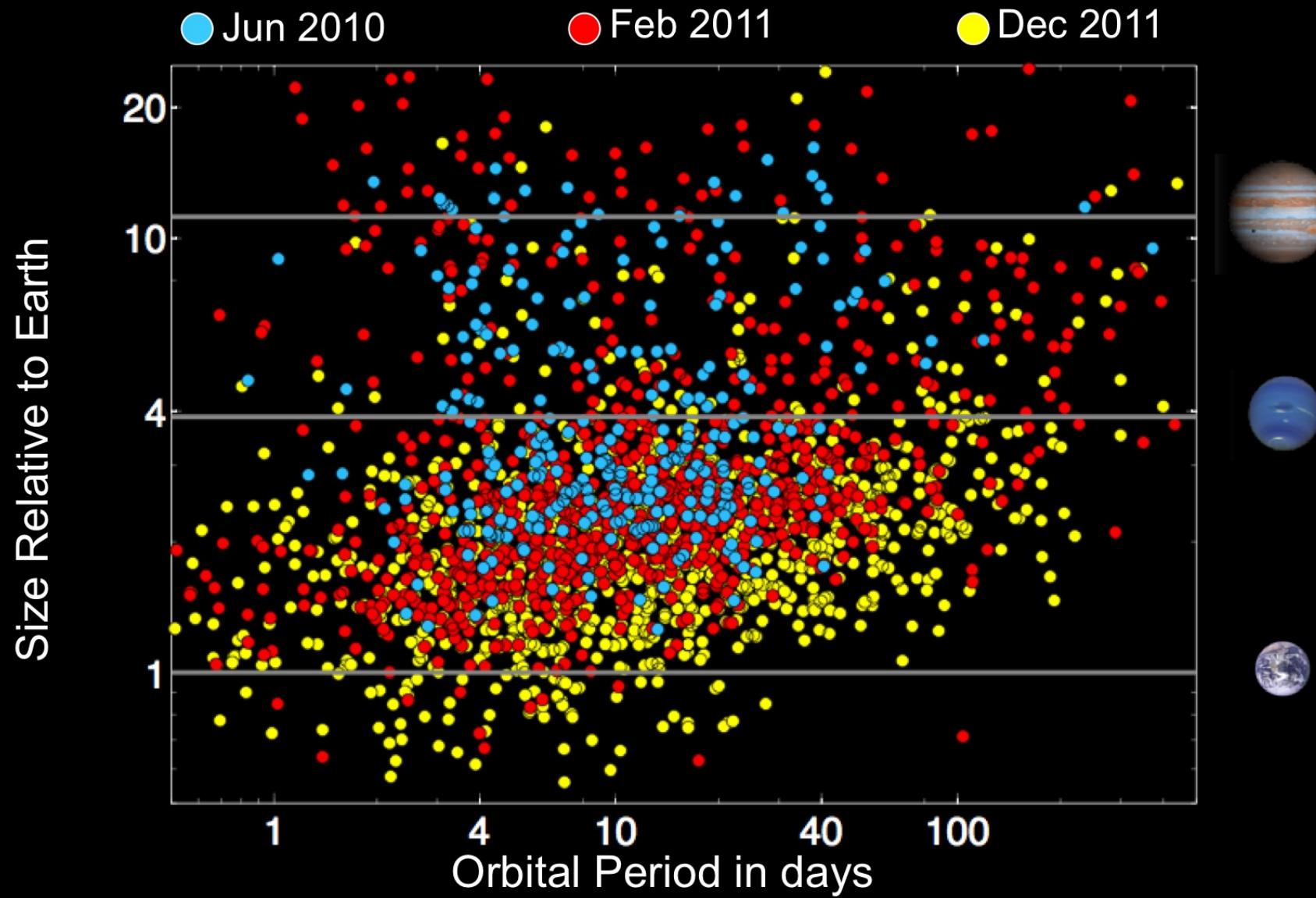


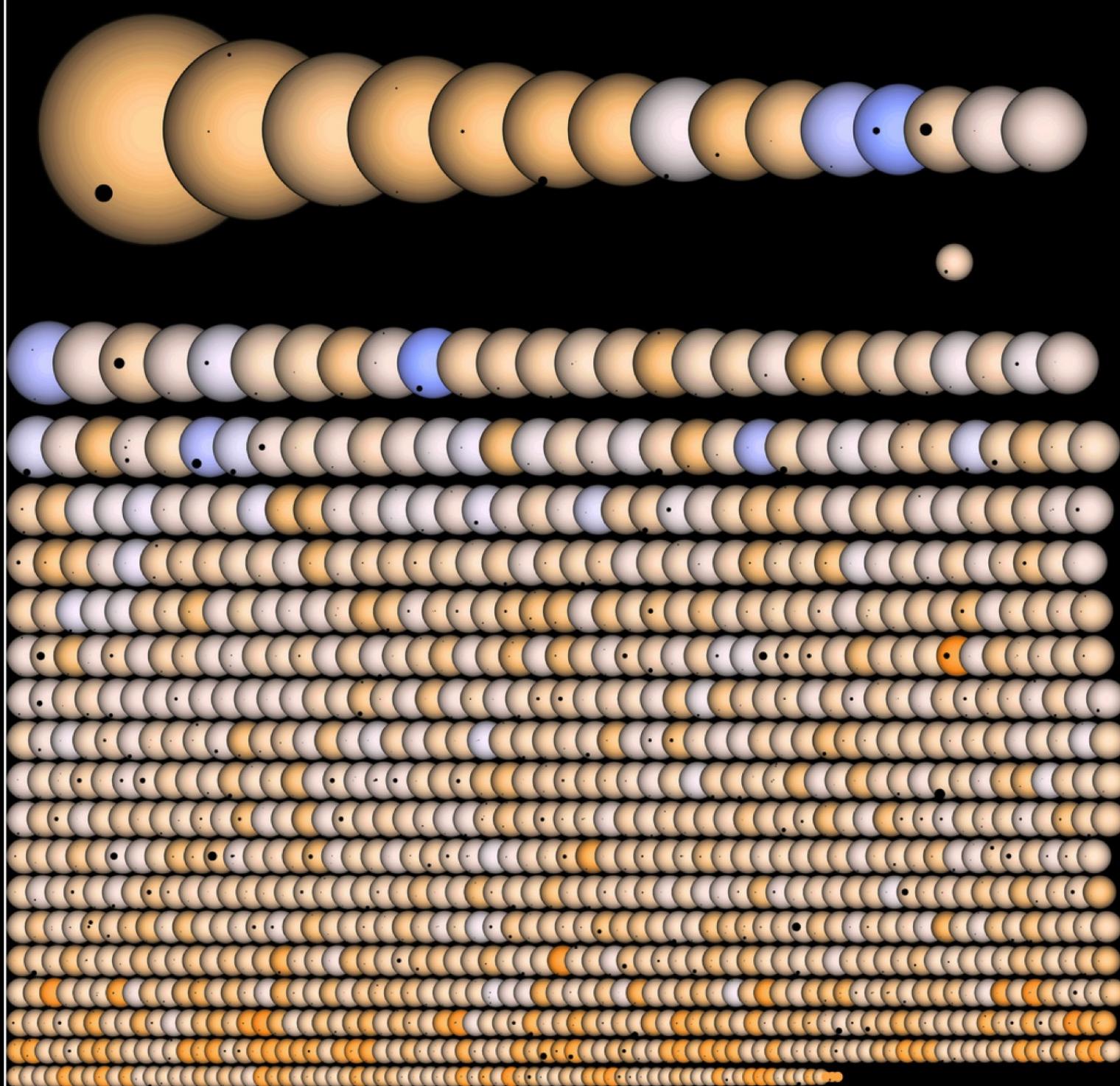
TIME IN HOURS

Transiting Planets pre-Kepler

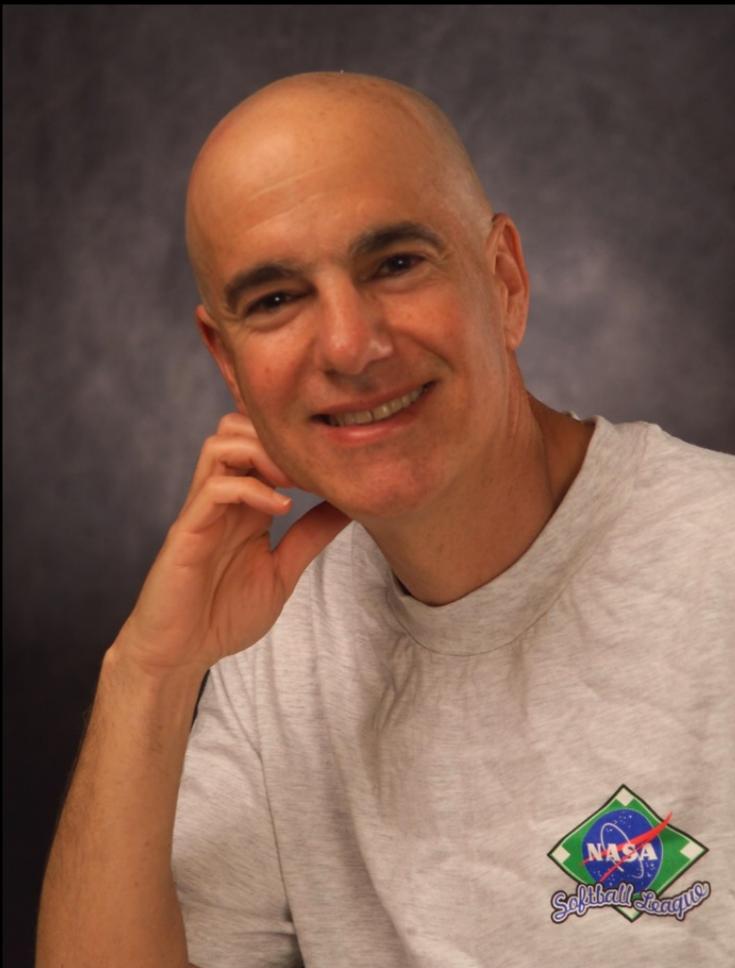


Candidates as of Dec 2011





Kepler 11



Jack Lissauer (NASA Ames)
+ Kepler team

nature
THE INTERNATIONAL WEEKLY JOURNAL OF SCIENCE

SIX NEW WORLDS

Kepler telescope gets edge-on view of compact planetary system around Sun-like star **PAGE 53**

POLICY
DEEP-SEA MINING
Regulate now to protect hydrothermal vent species
PAGE 31

DRUG DISCOVERY
TAKING THE LEAD
Debating how to keep the pipelines flowing
PAGE 42

ADAPTIVE IMMUNITY
EARLY ORIGIN FOR A 'THYMUS'
Gill-based thymus found in living fossil lampreys
PAGE 50

NATURE.COM/NATURE
3 February 2011 \$10
Vol. 470, No. 7302

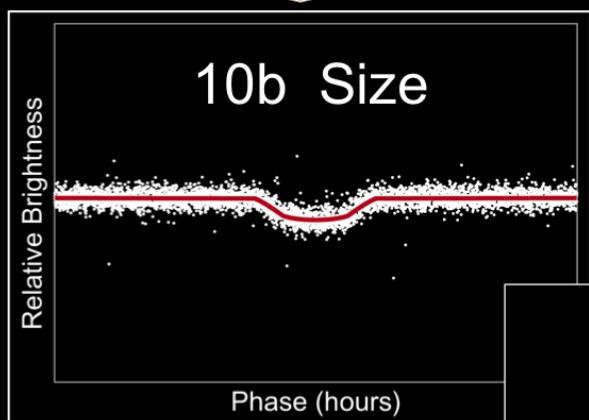
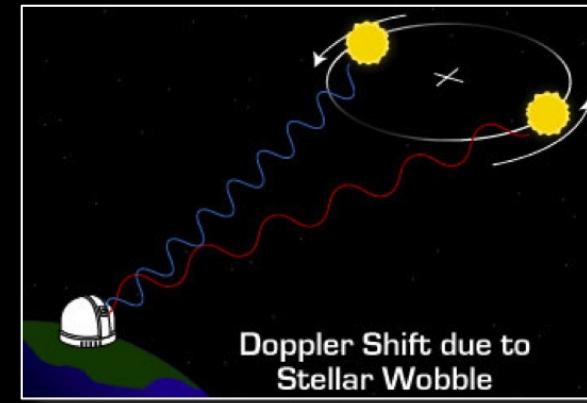
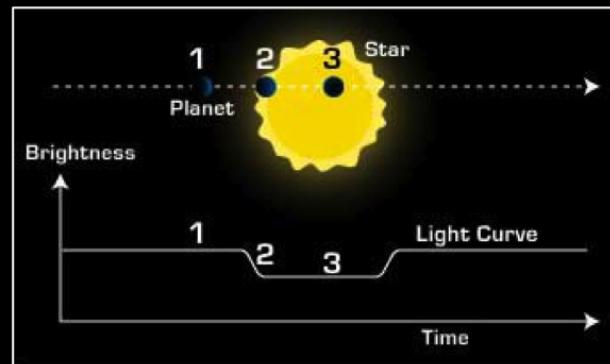
Page 56/69

Kepler 10b

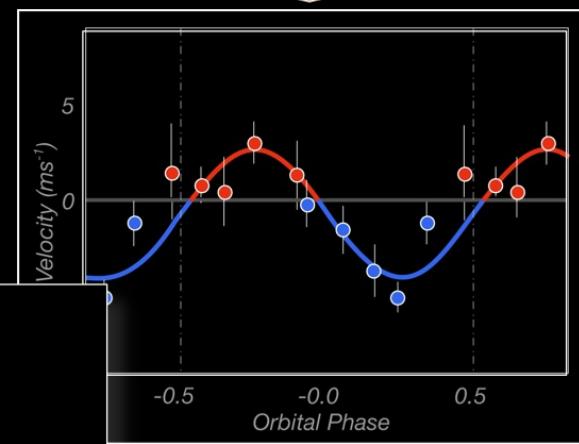




Transit and Doppler Measurements Yield Density

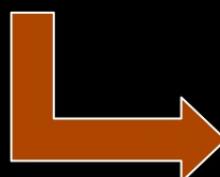


+



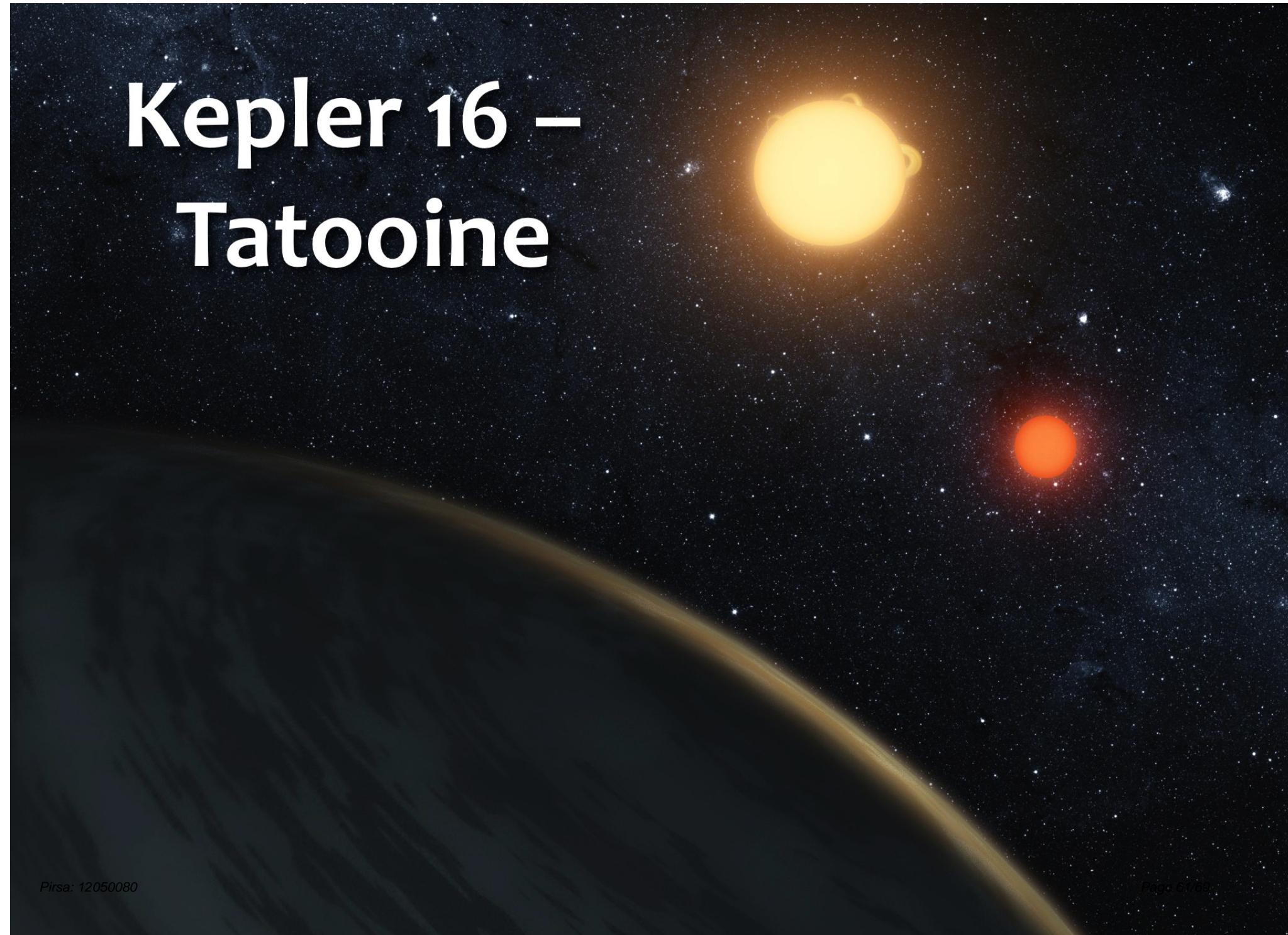
Density

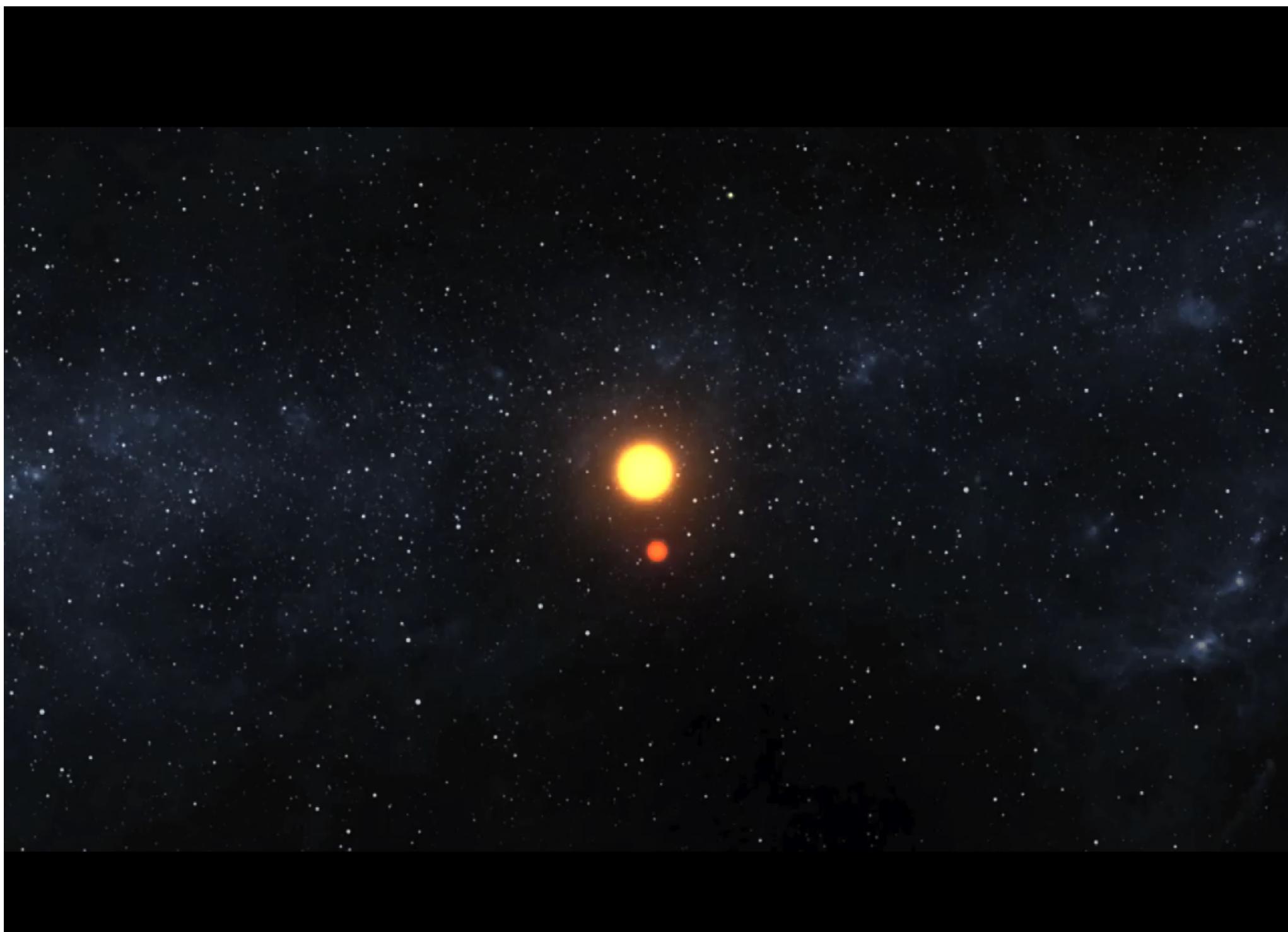
$$\frac{\text{Mass}}{\text{Volume}} = 8.8 \text{ g/cm}^3$$





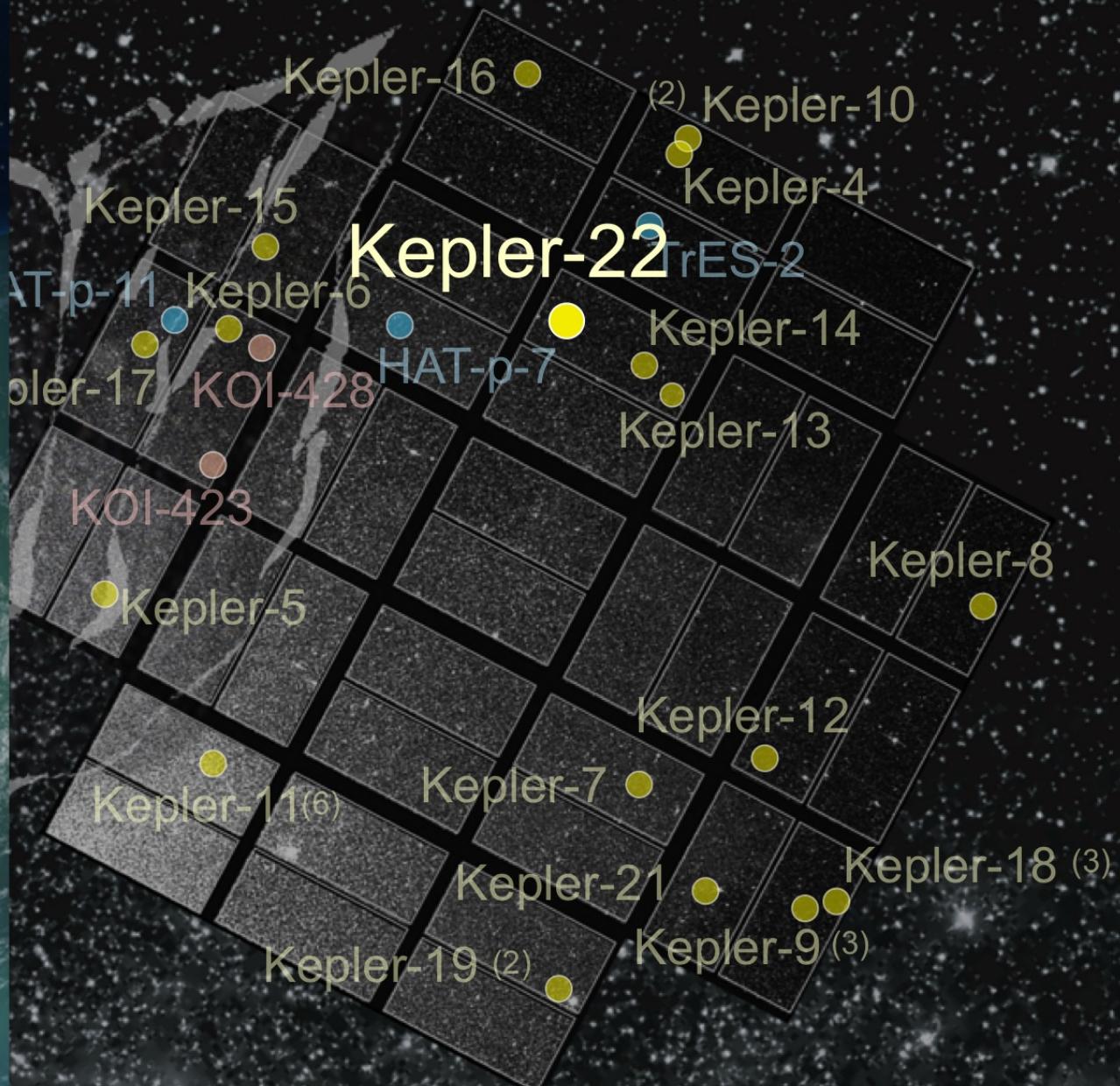
Kepler 16 – Tatooine





KEPLER'S FIRST PLANET IN THE HABITABLE ZONE - KEPLER-22B

**ANNOUNCED
DEC 5, 2011**



planethunters.org

 Planet Hunters is part of the ZOO NIVERSE

...just like MOON ZOO

planethunters.org

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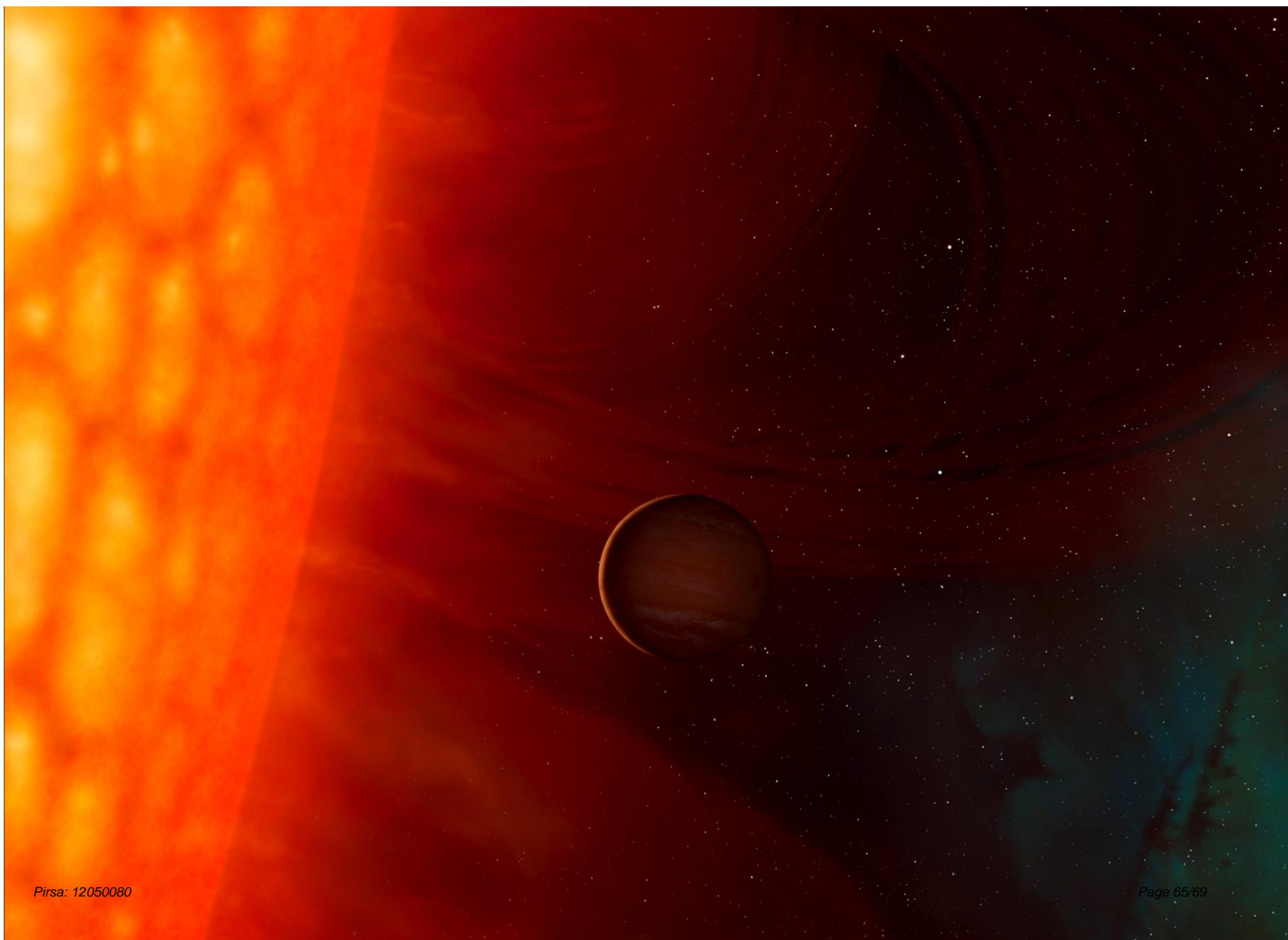
Welcome to planet hunters.

With your help, we are looking for
planets around other stars

[Start hunting for planets >](#)



POWERED BY KEPLER
PUBLIC DATA



FM stars

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

Hiromoto Shibahashi¹ and Donald W. Kurtz²

¹*Department of Astronomy, The University of Tokyo, Tokyo 113-0033, Japan*

²*Jeremiah Horrocks Institute of Astrophysics, University of Central Lancashire, Preston PR1 2HE, UK*



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

The background of the slide is a reproduction of Vincent van Gogh's famous painting "The Starry Night". It depicts a dark, swirling night sky filled with stars of various sizes and colors, from small white dots to large, luminous yellow and orange spirals. Below the sky, a small town with houses and a church steeple is nestled among rolling hills and fields. The overall mood is one of celestial beauty and movement.

Asteroseismology: the real Music of the Spheres

Zoltan Kollath The Stellar Music Project

www.konkoly.hu/stellarmusic/

Kepler Space Mission
kepler.nasa.gov

asteroseismology.org

General astronomy:
Astronomy picture of the day = APOD