Asteroseismology: Probing Inside Stars Using Stellar Oscillations

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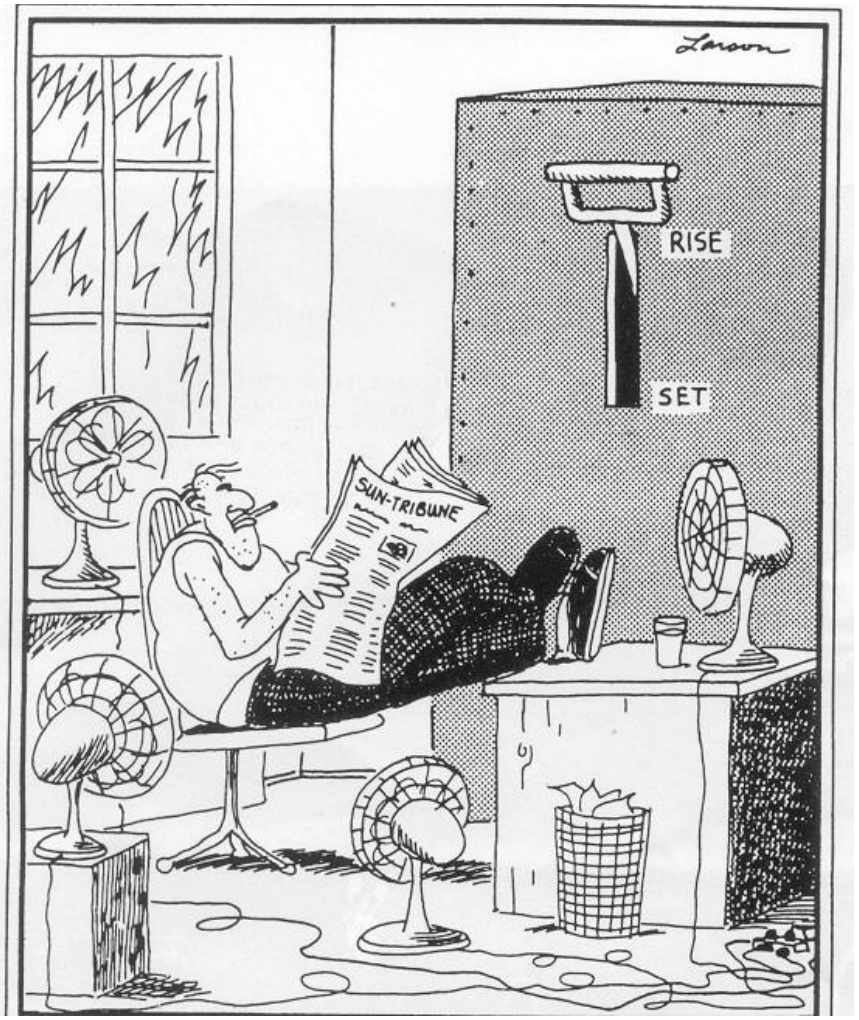
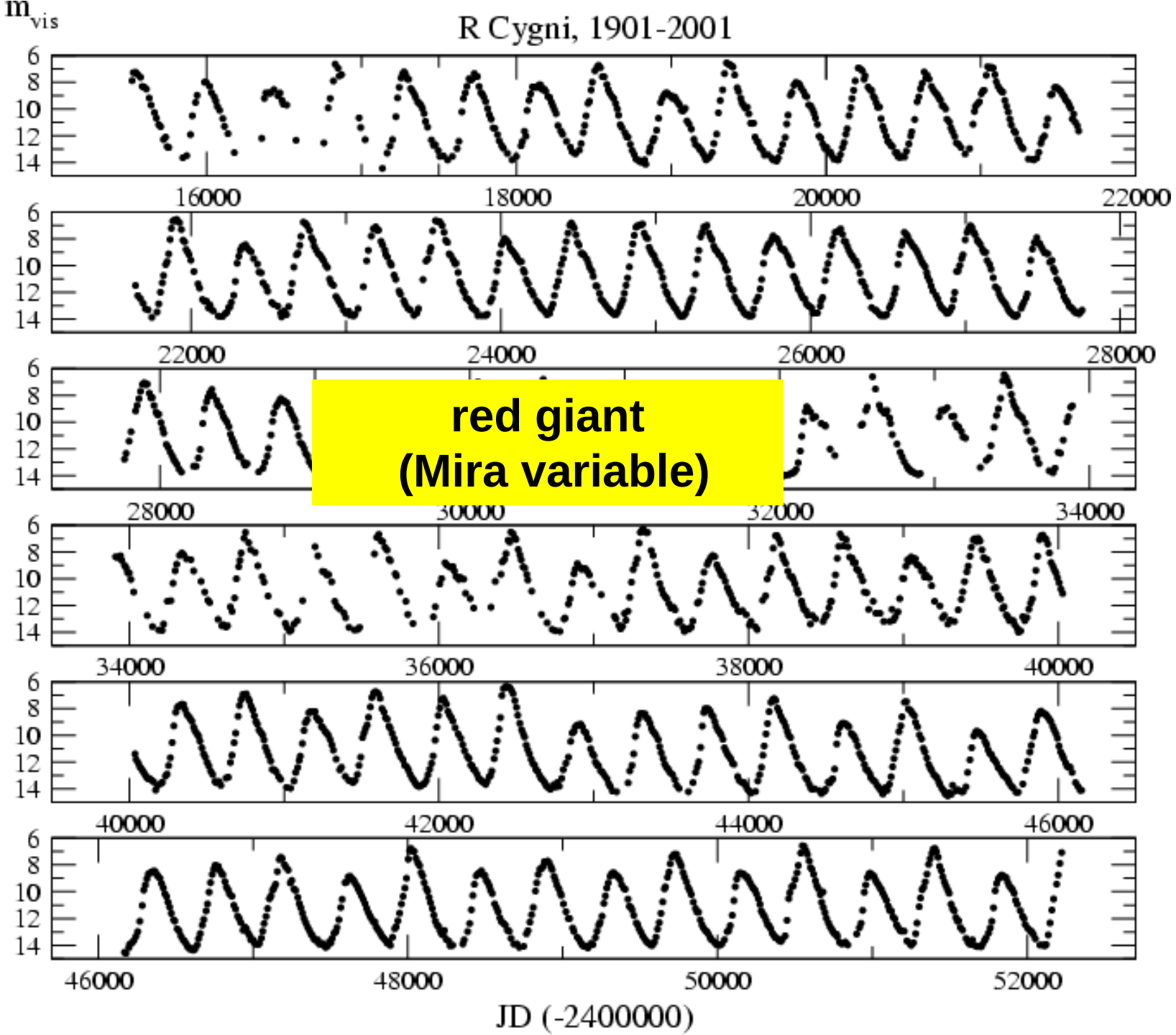
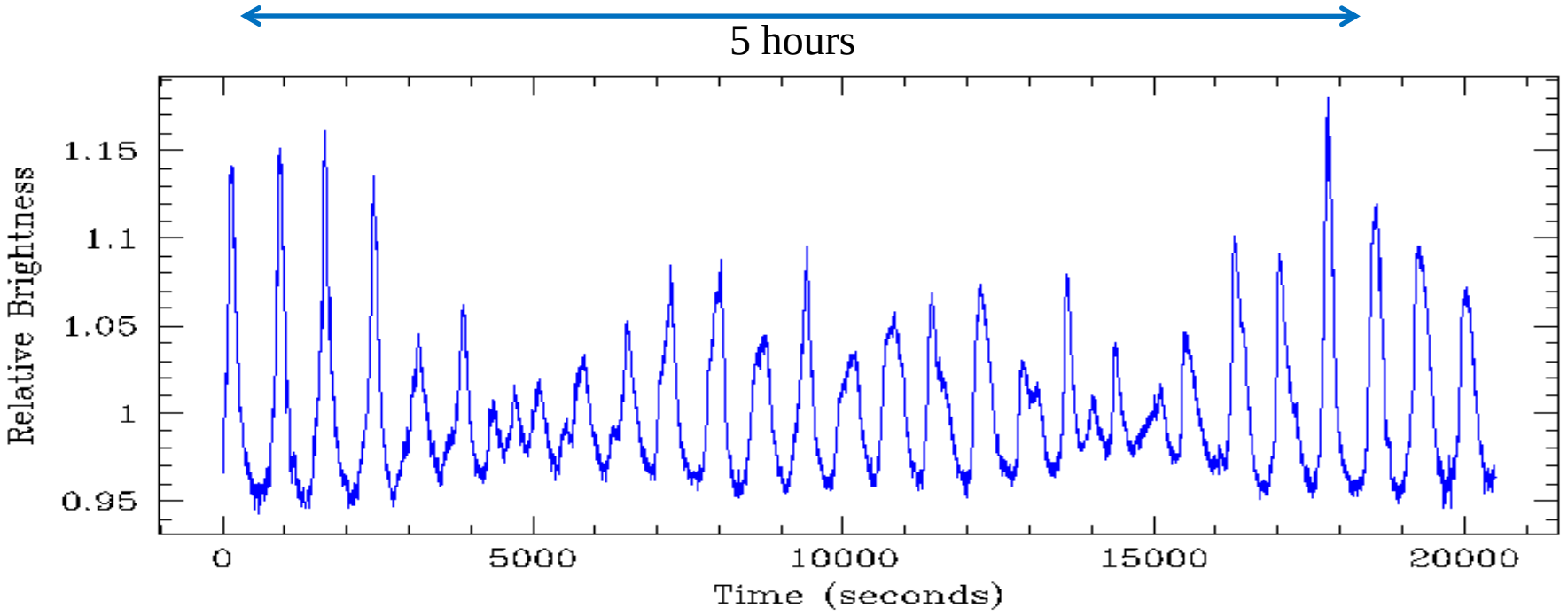
(Univ. Sydney)

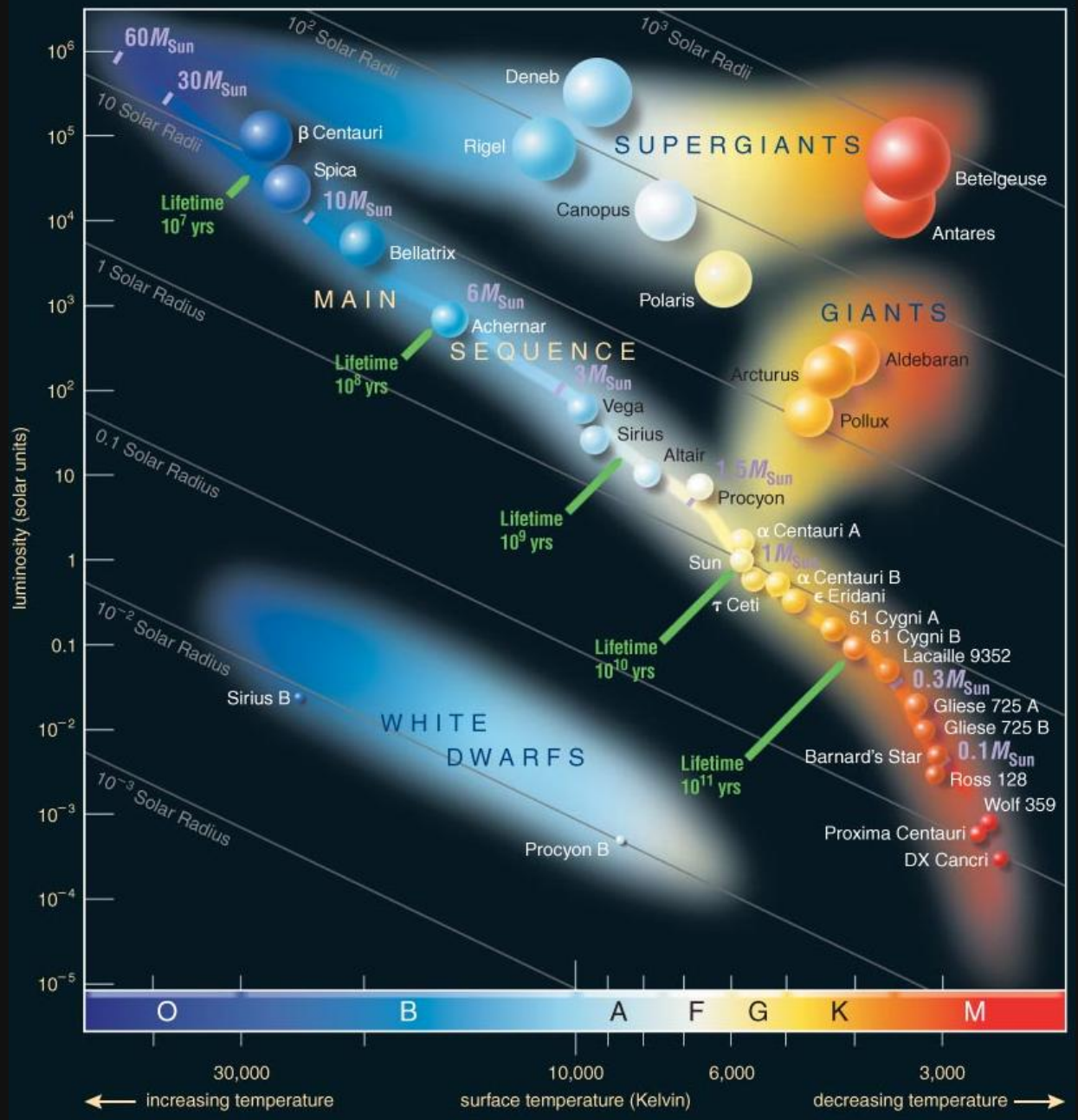


Inside the Sun


m vis
R Cygni, 1901-2001
6
8
10
12
14
16000
18000
20000
22000
24000
26000
28000
30000
32000
34000
36000
38000
40000
42000
44000
46000
48000
50000
52000
JD (-2400000)
red giant
(Mira variable)

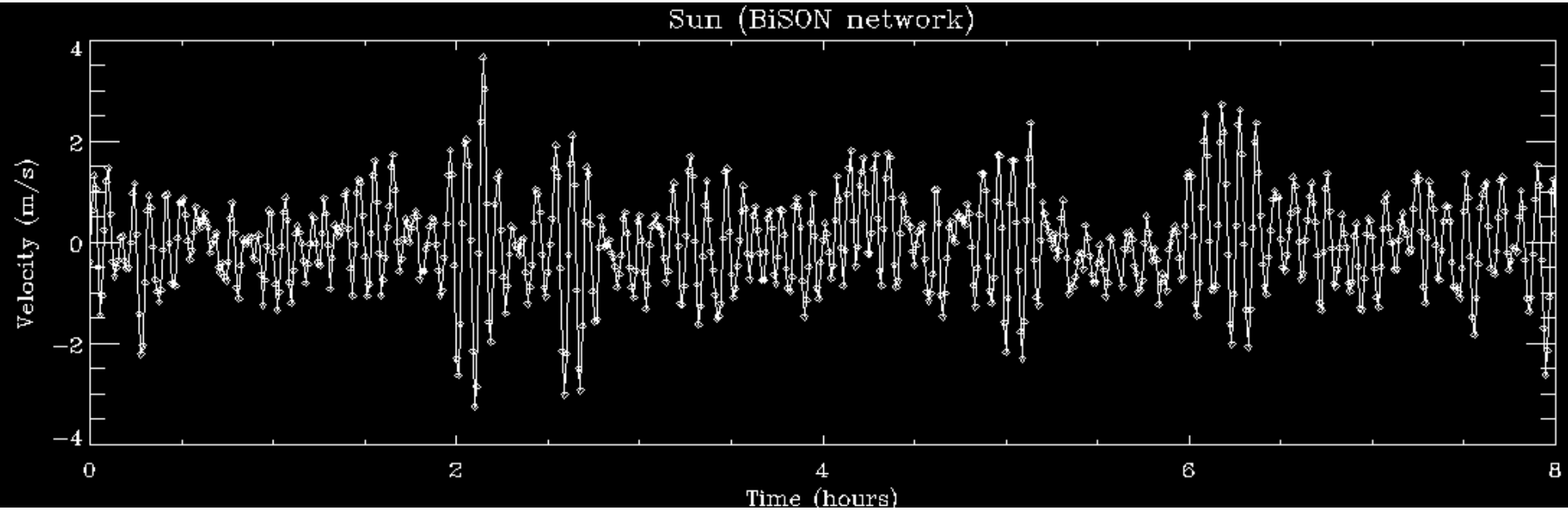
white dwarf


5 hours
Relative Brightness
1.15
1.1
1.05
1
0.95
0
5000
10000
15000
20000
Time (seconds)



Hertzsprung-Russell diagram

Oscillations in the Sun

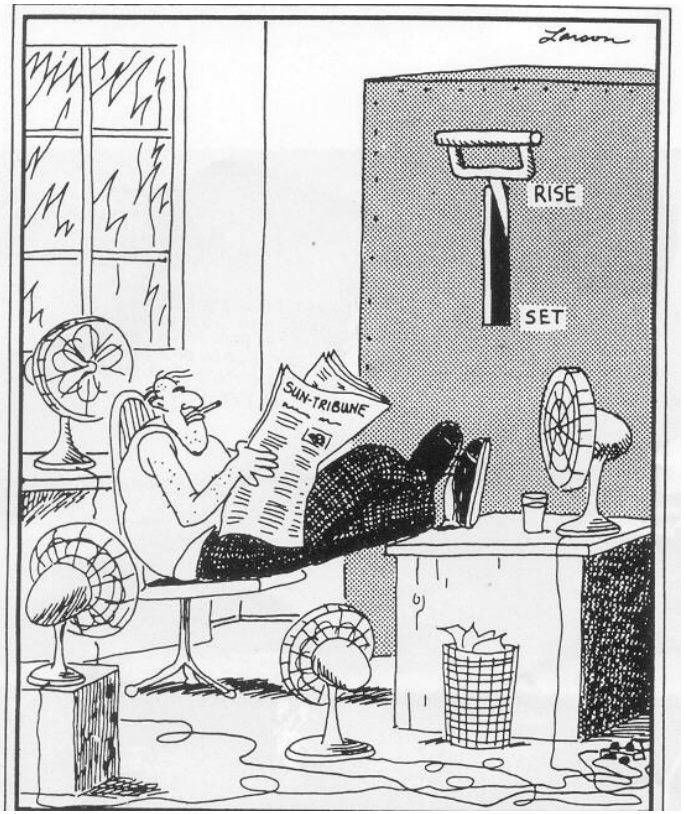


BiSON (Birmingham Solar Oscillations Network)

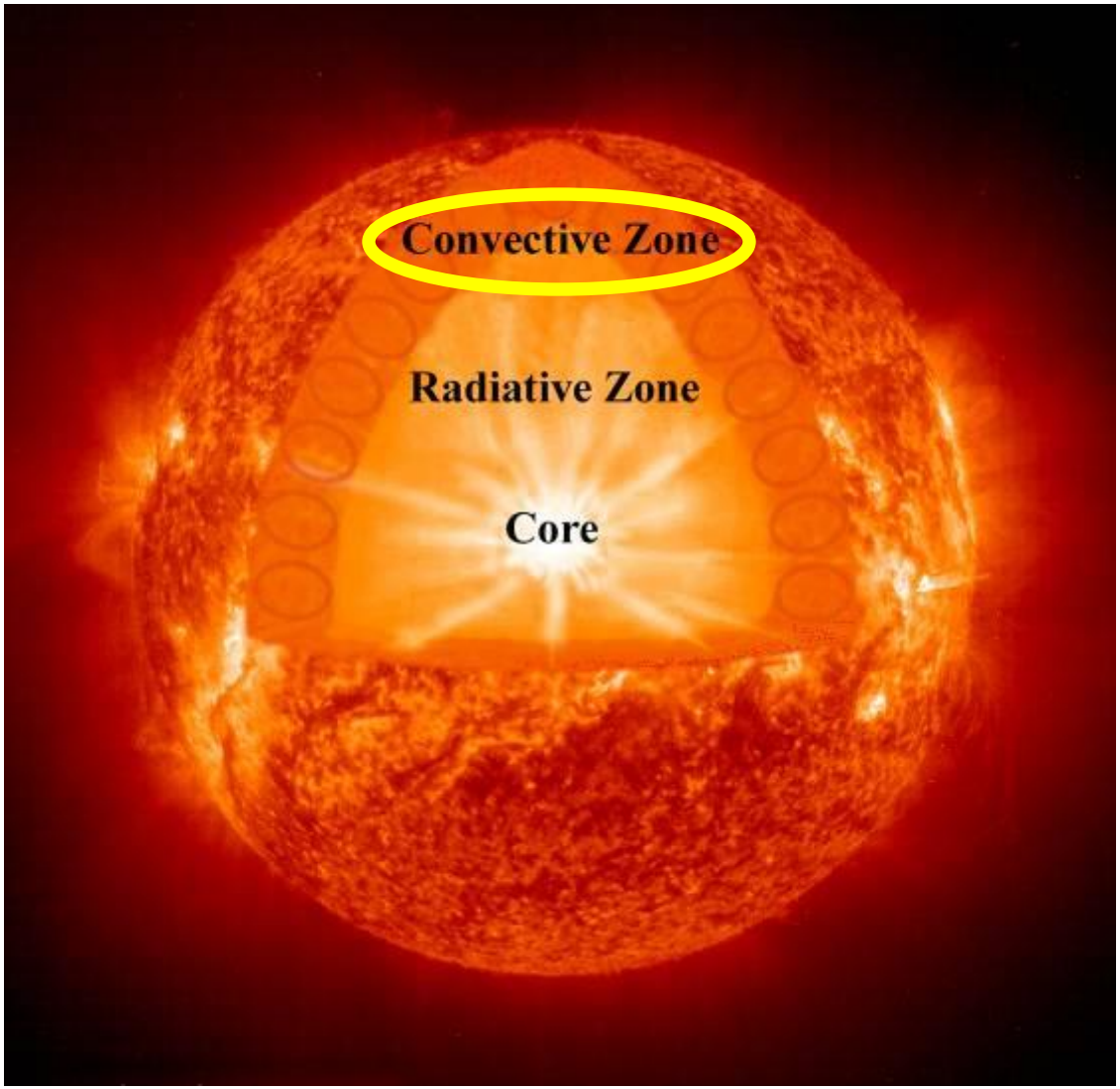
Asteroseismology: the study of stellar oscillations (“starquakes”)

1. What causes stellar oscillations?
2. How do we measure them?
3. What can we learn from them?

1. What causes stellar oscillations?

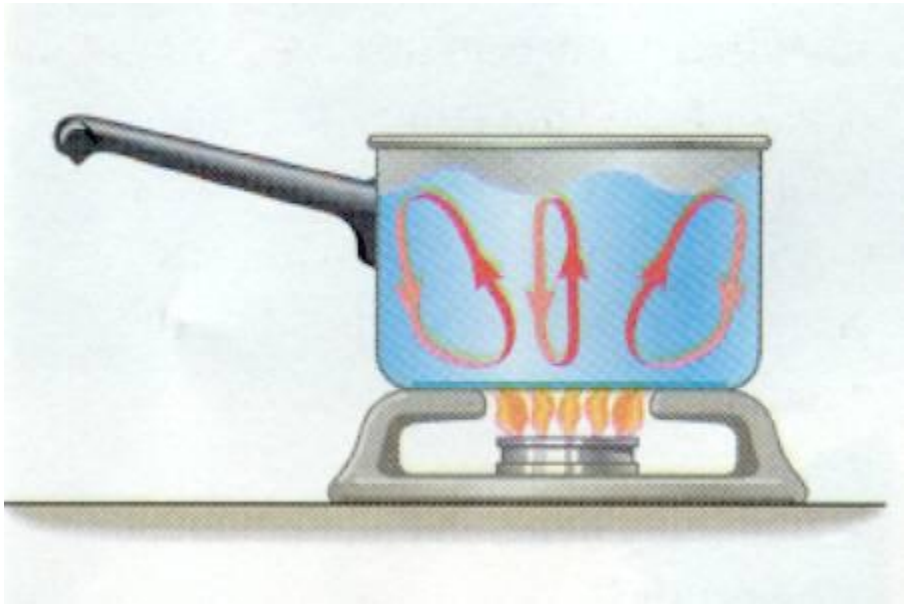


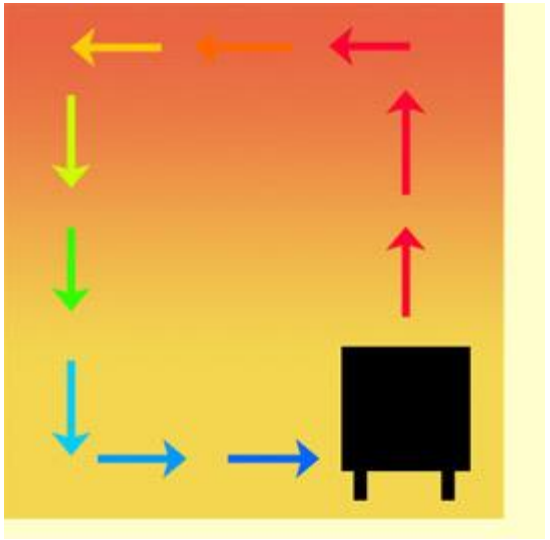
Inside the Sun



Inside the Sun

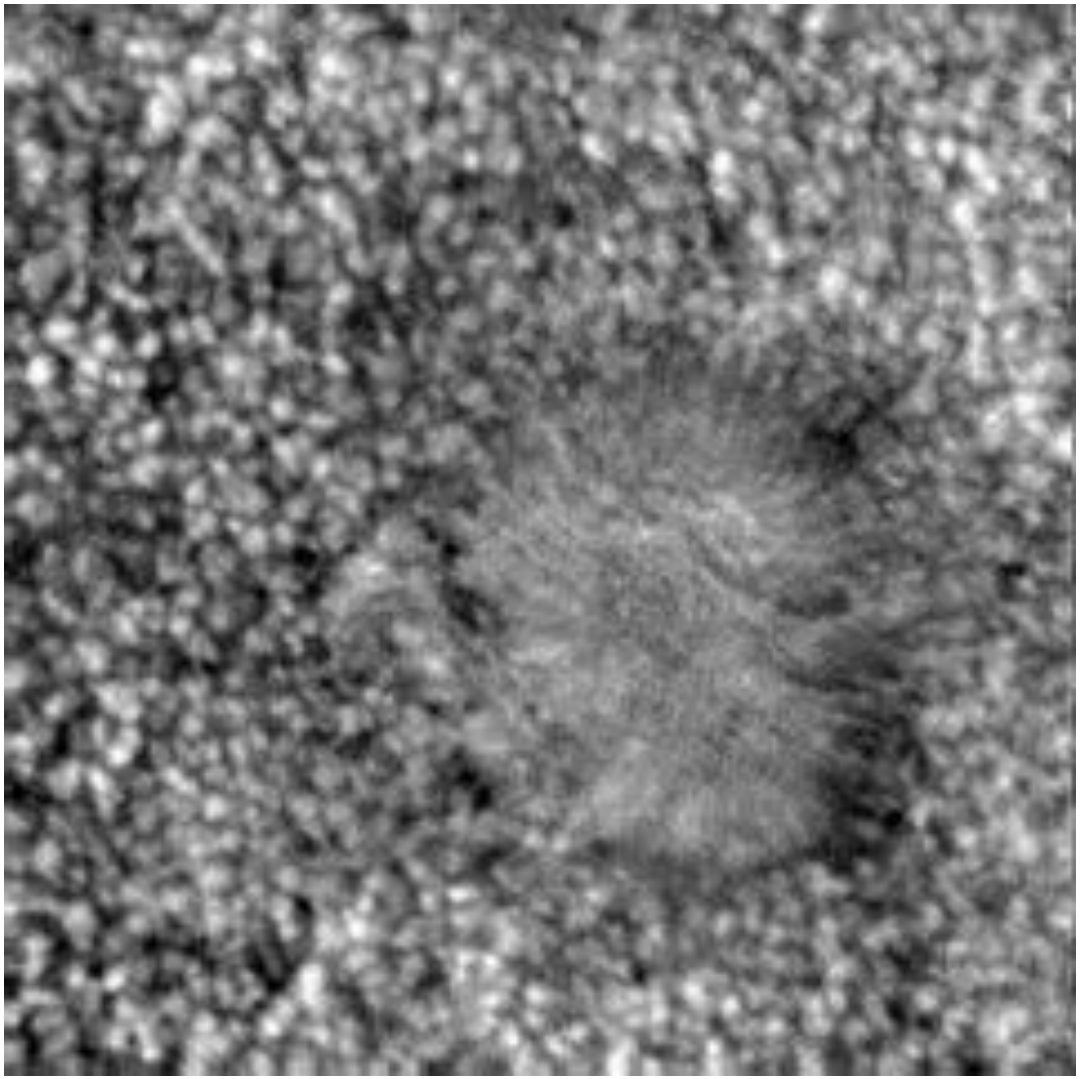
Convection excites the oscillations by shaking the star



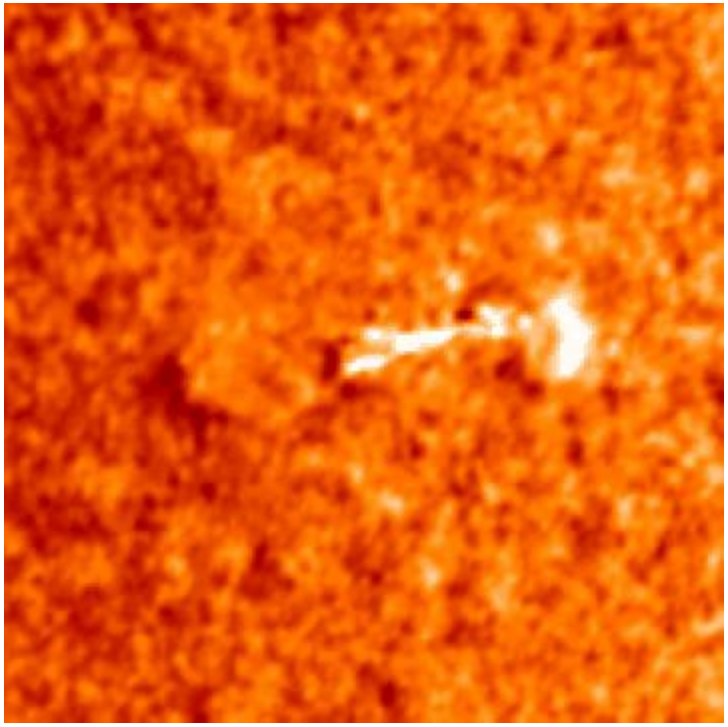


convection

Convection at the surface of the Sun



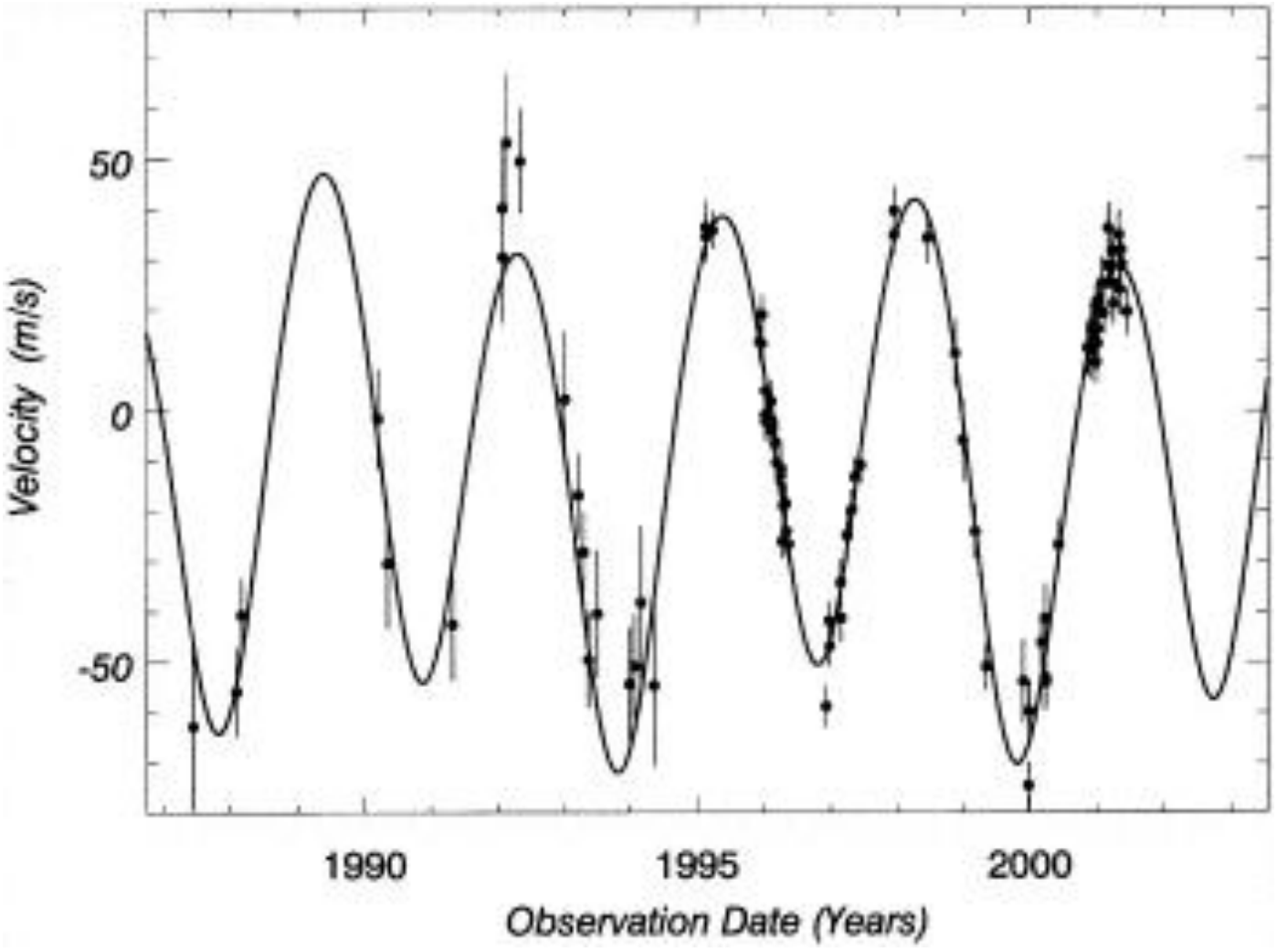
A local sunquake:



2. How do we measure stellar oscillations?

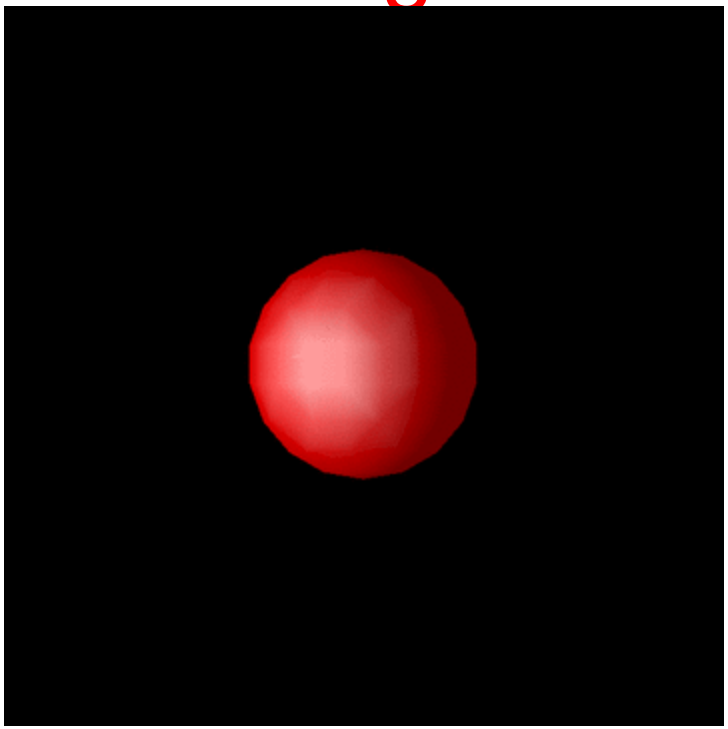
Method A: changes in velocity using the Doppler effect

Velocity variations in a star

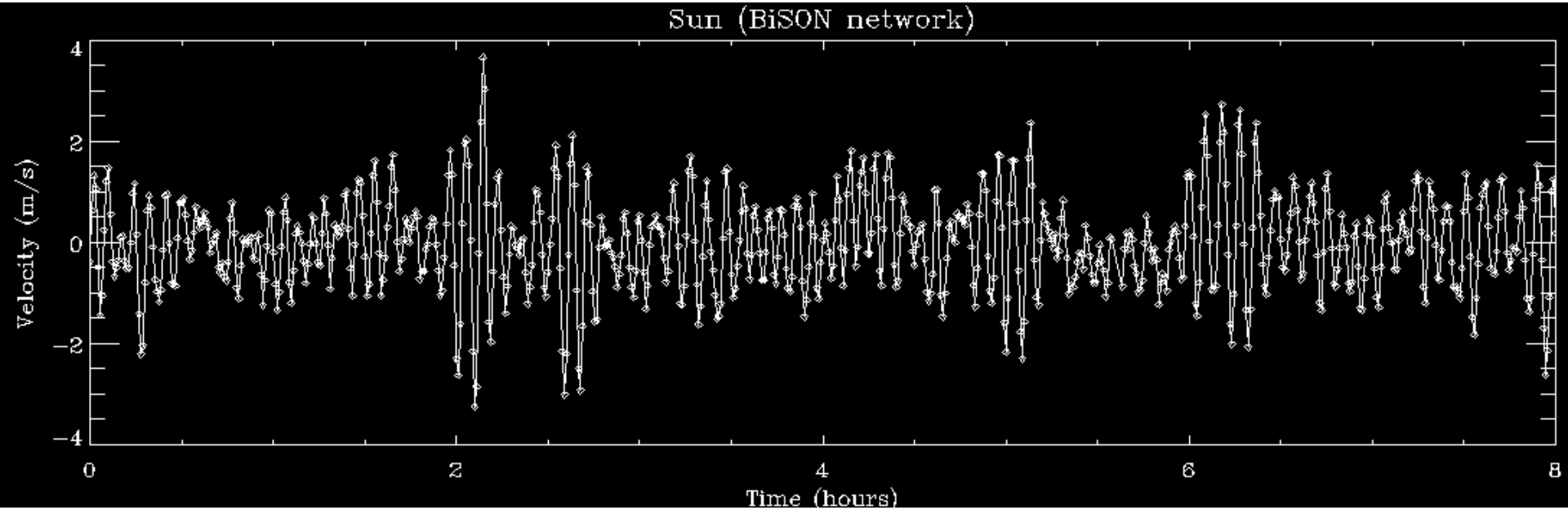


Planets around the star 47 Ursa Majoris

animation of an oscillating star

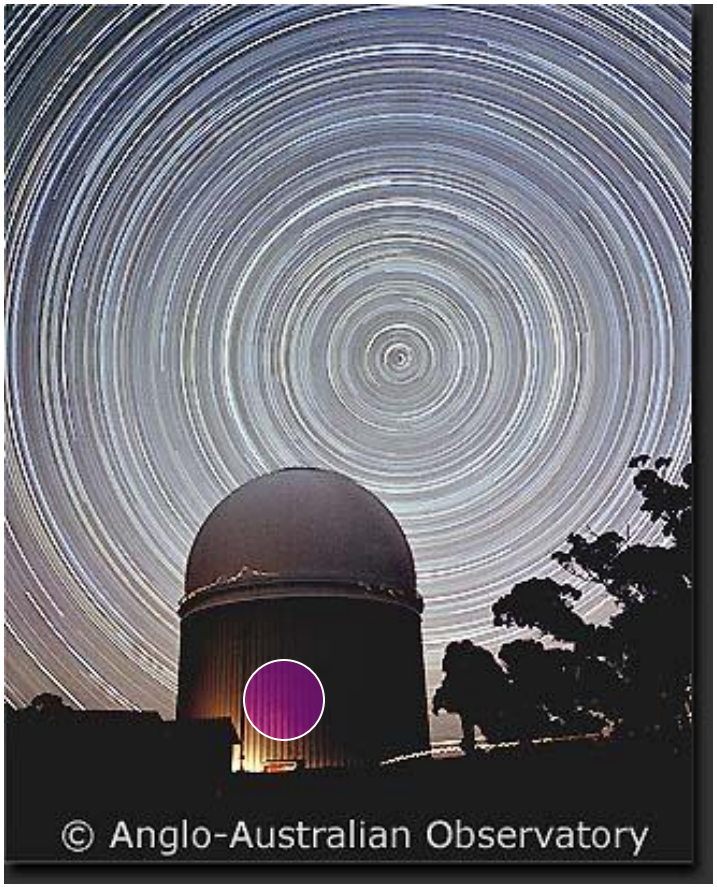


Oscillations in the Sun

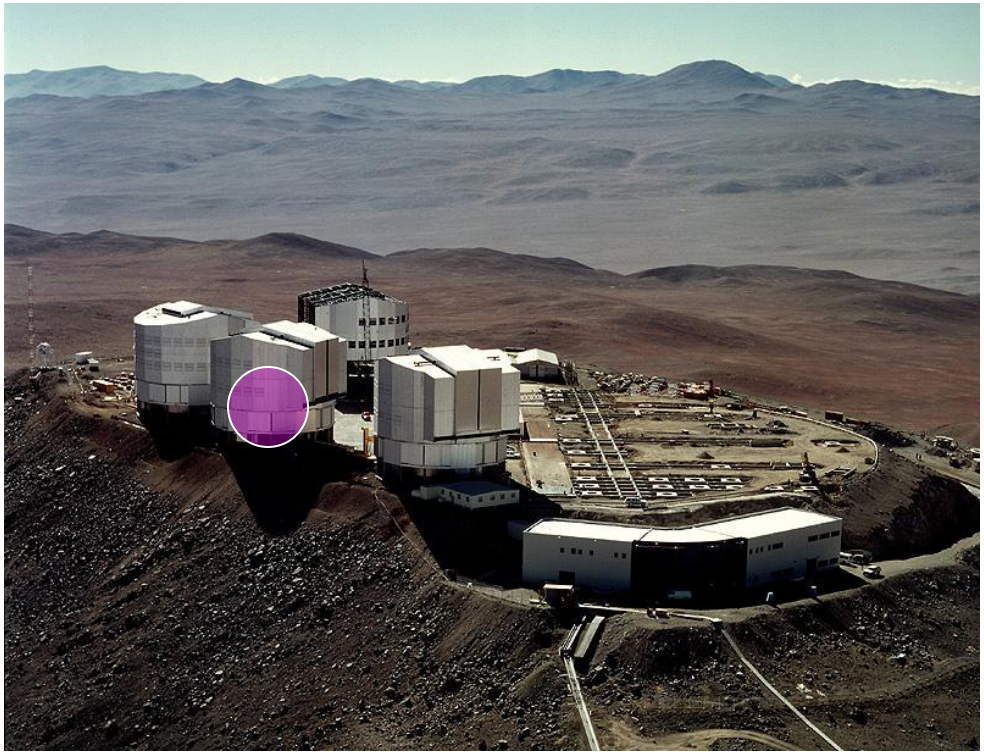


BiSON (Birmingham Solar Oscillations Network)

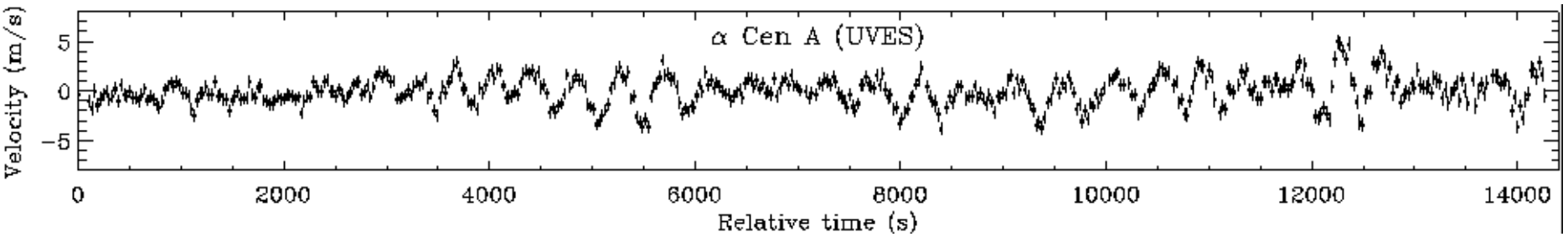
Anglo-Australian Telescope



European Southern Observatory's Very Large Telescope (Chile)



Velocities of α Centauri A with the VLT



Precision: 50-70 cm/s (exposure times 3 seconds)

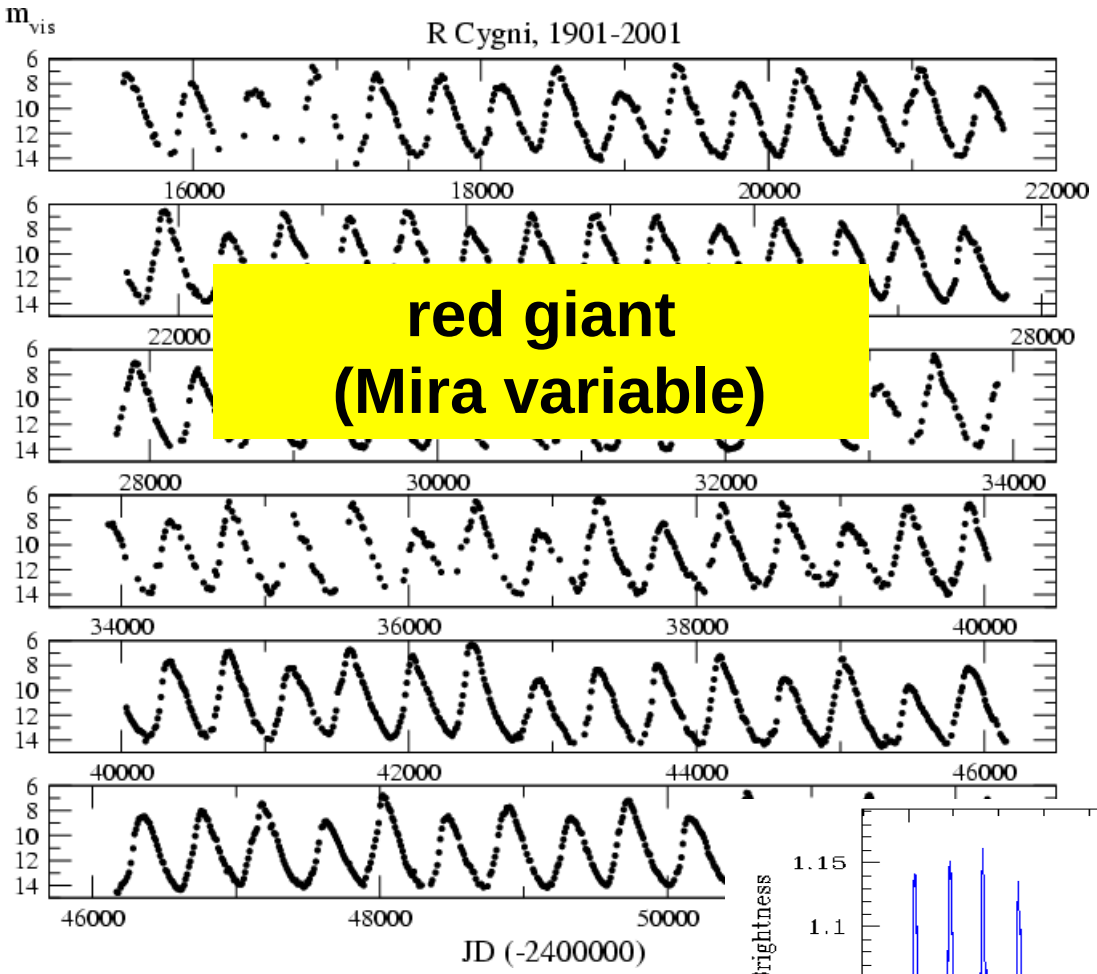
The next step: a network dedicated to asteroseismology

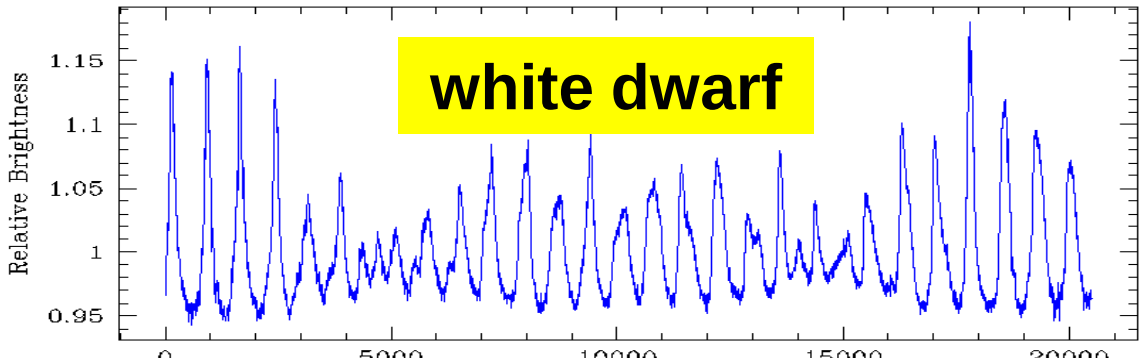
First node in Tenerife under construction

VELUX®

Carlsberg

Method B: changes in brightness

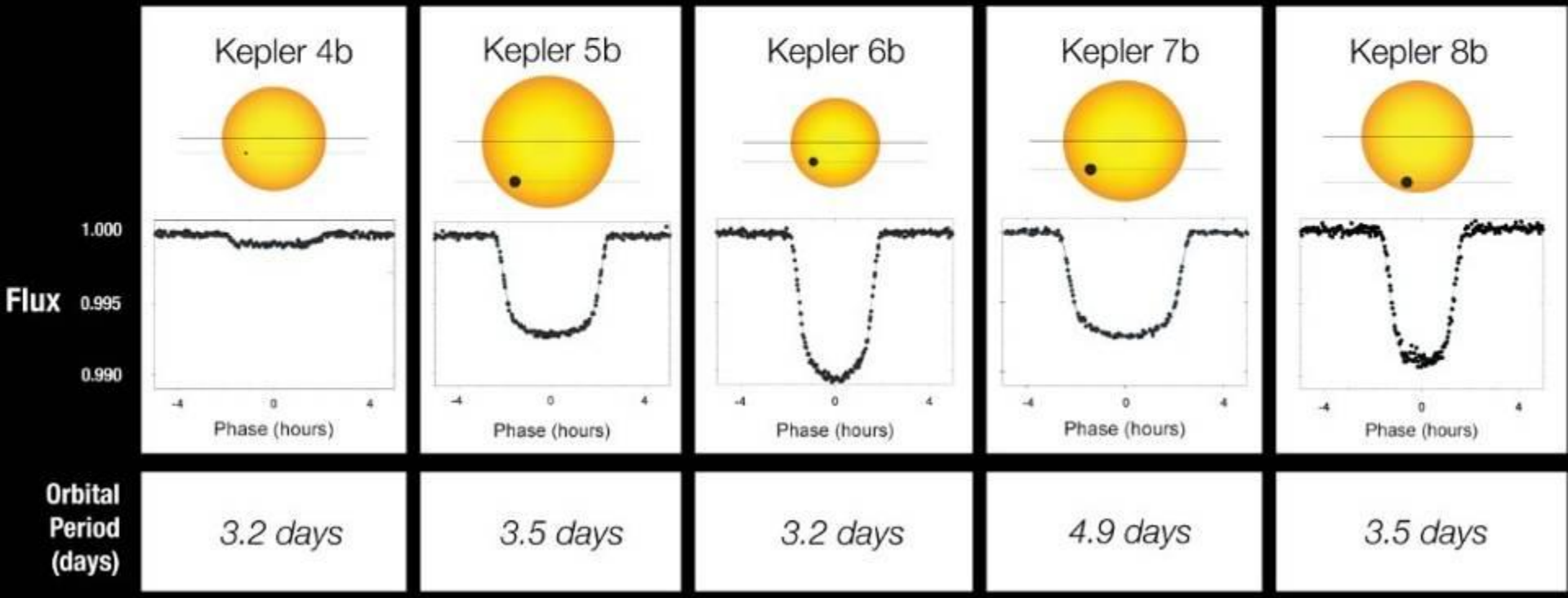




Kepler

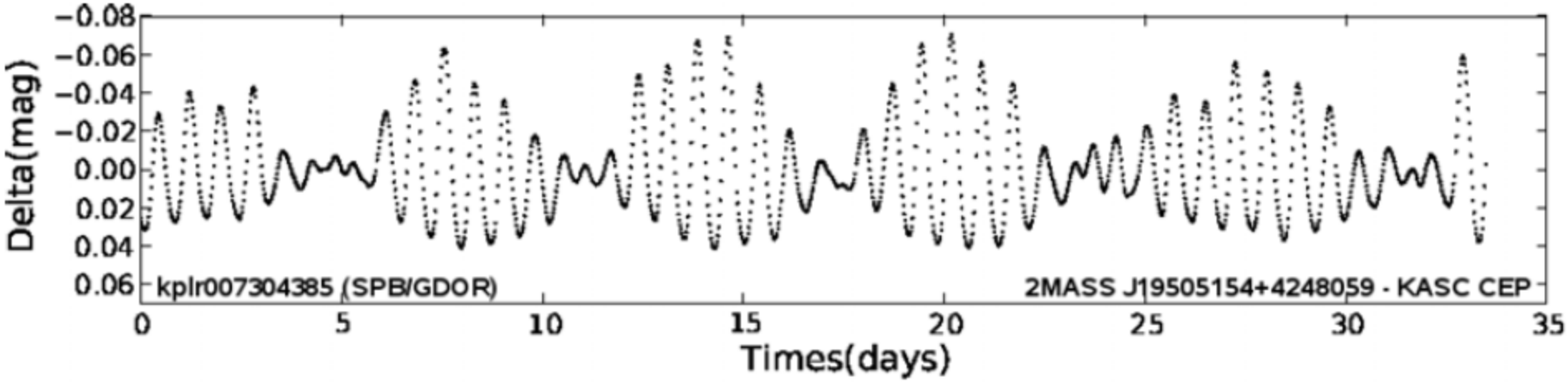
95cm telescope; Launched: 6 March 2009. Observations commenced: 1 May 2009

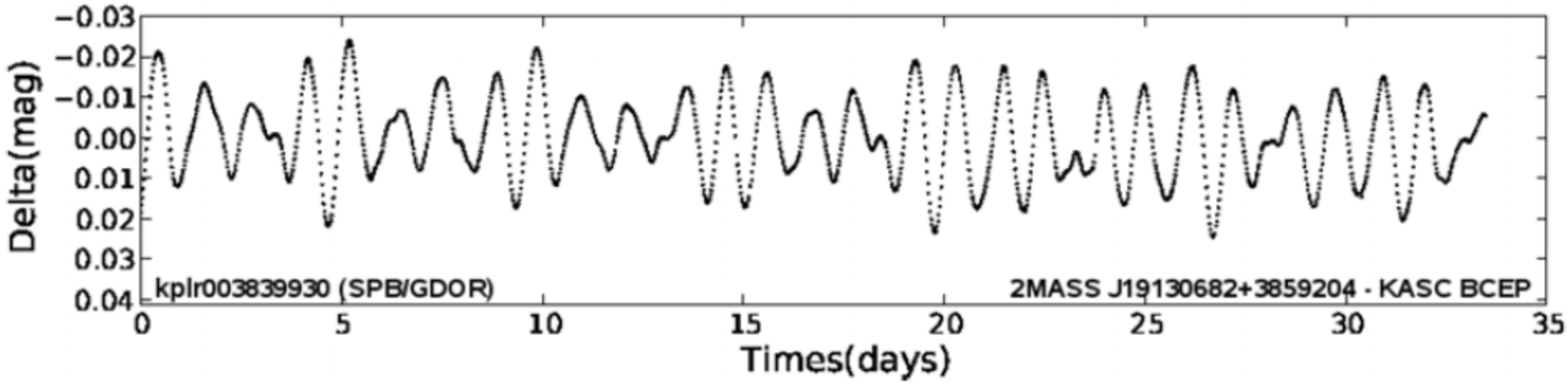
Transit Light Curves



Orbital Period (days)	3.2 days	3.5 days	3.2 days	4.9 days	3.5 days

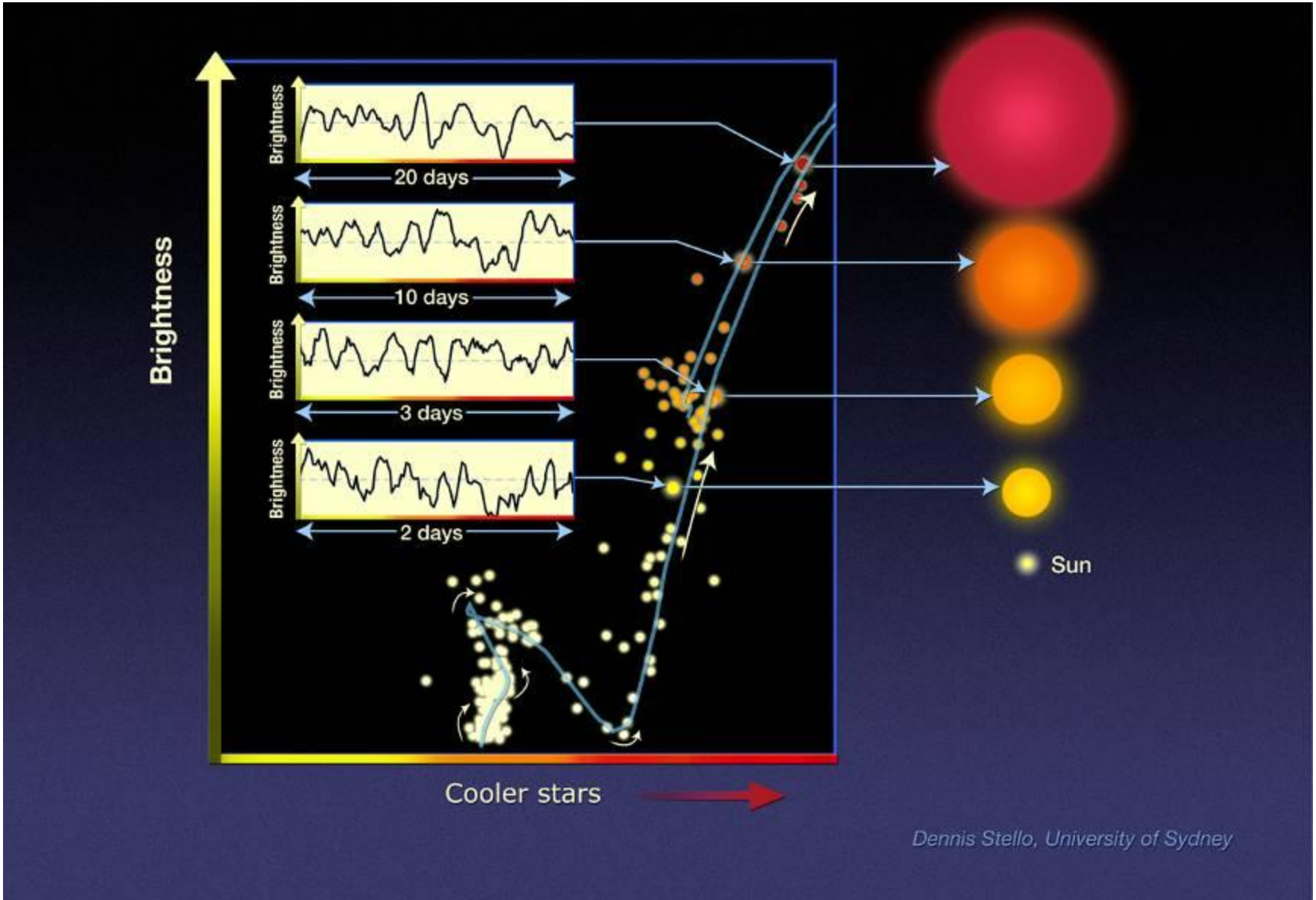
Two examples of oscillating stars discovered by Kepler



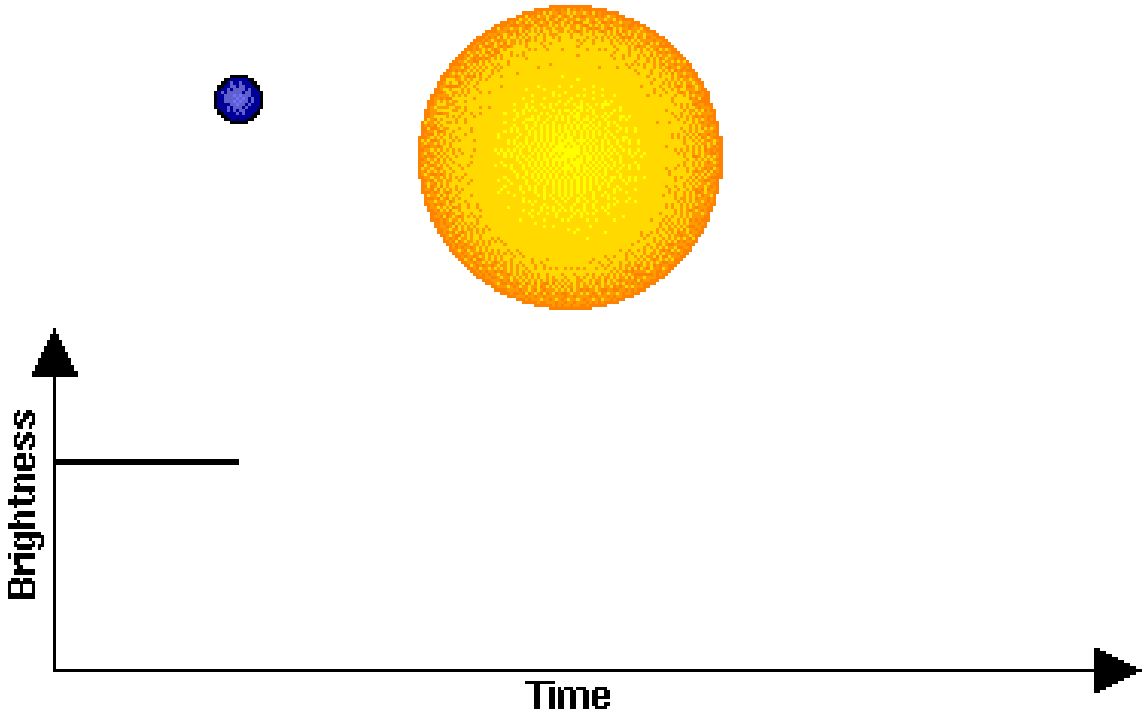


What can we learn from stellar oscillations?

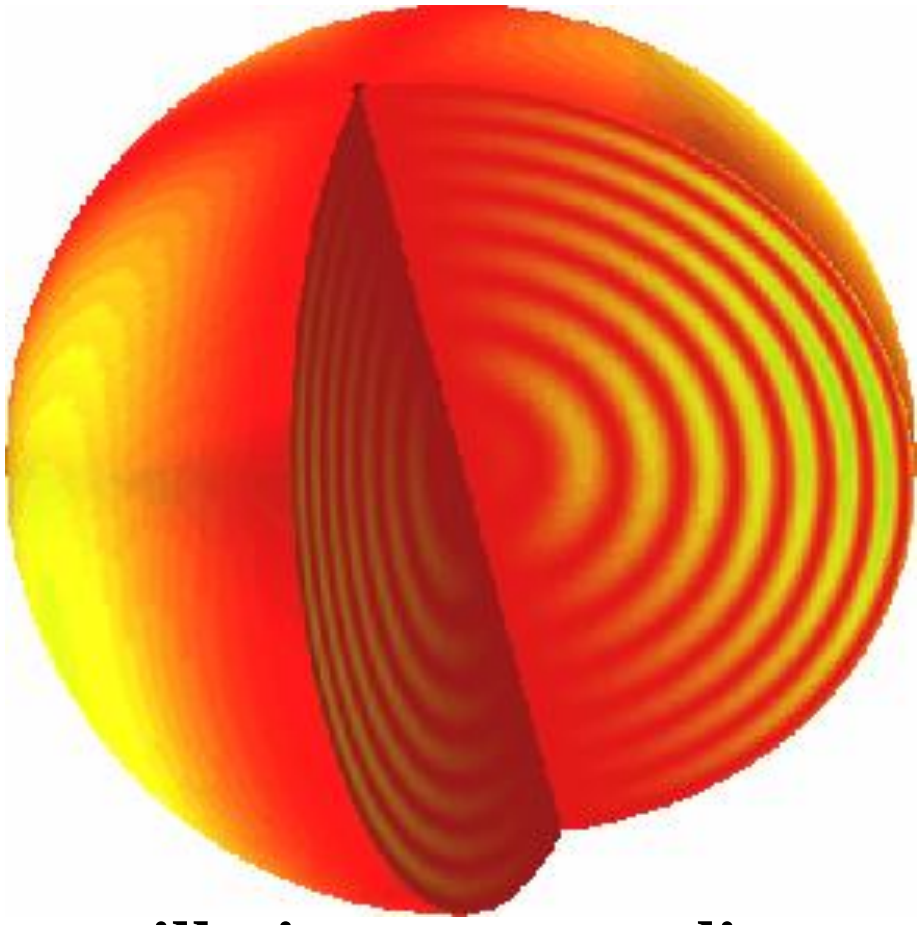
We can measure the sizes of stars



which is important for transits

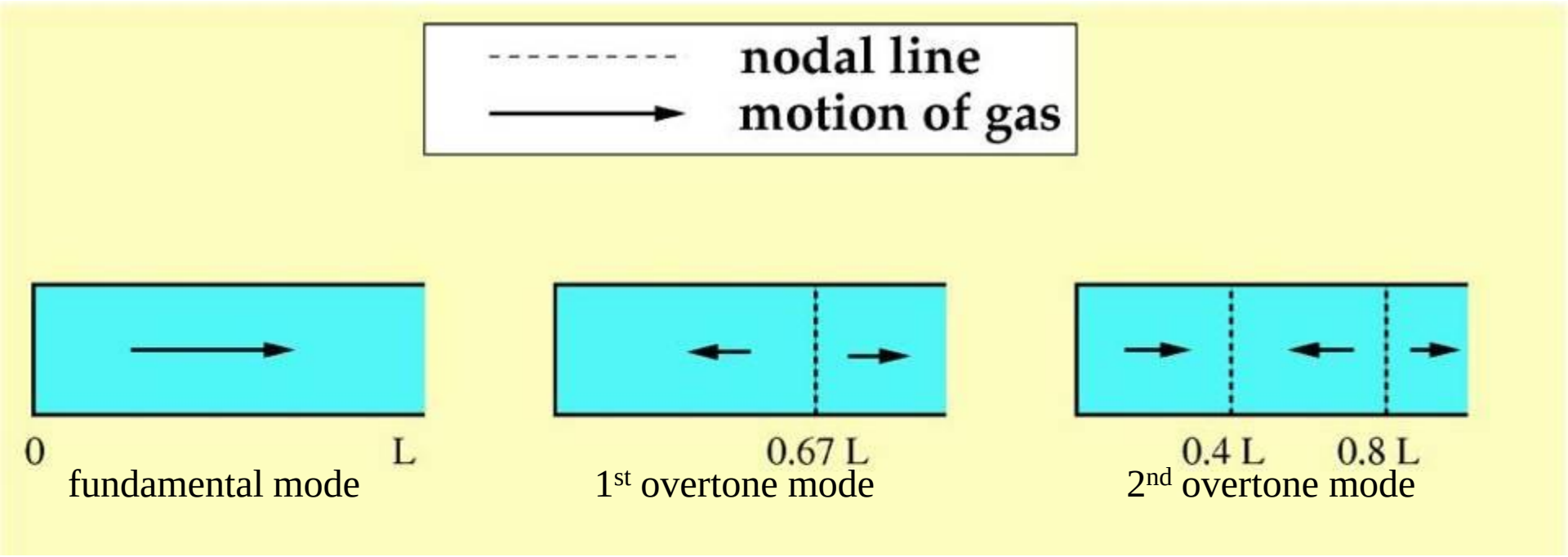


We can also measure the sound speed throughout the star.



Stellar oscillations are standing sound waves

Standing sound waves

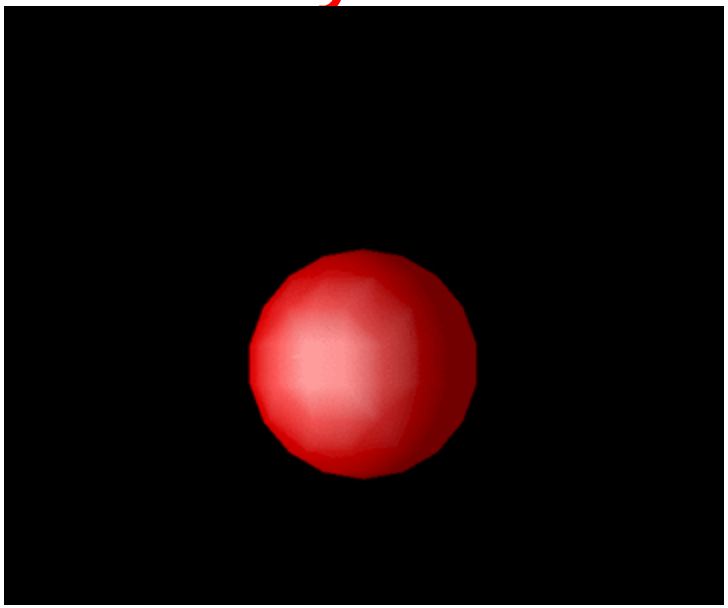


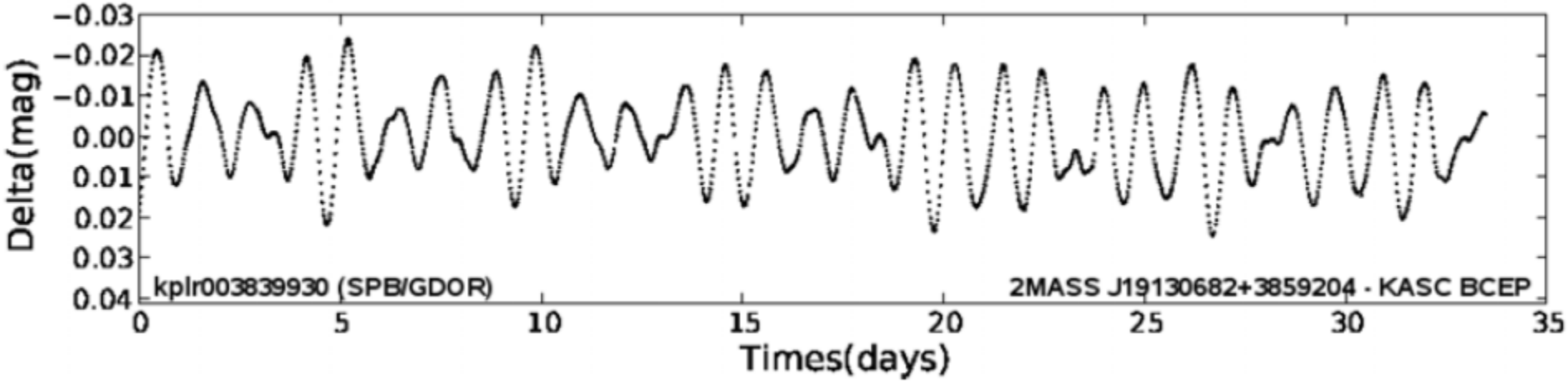
fundamental mode

1st overtone mode

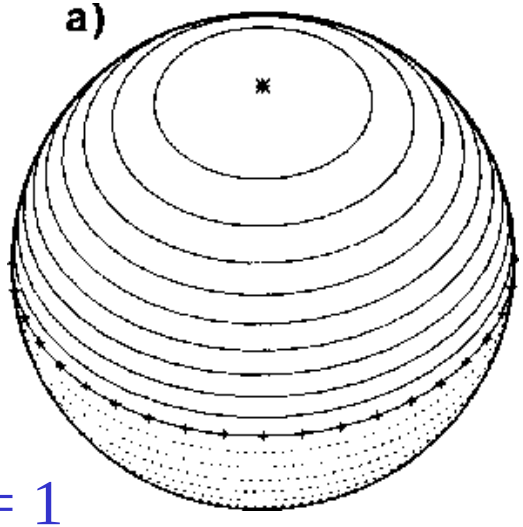
2nd overtone mode

stars can oscillate simultaneously in many modes

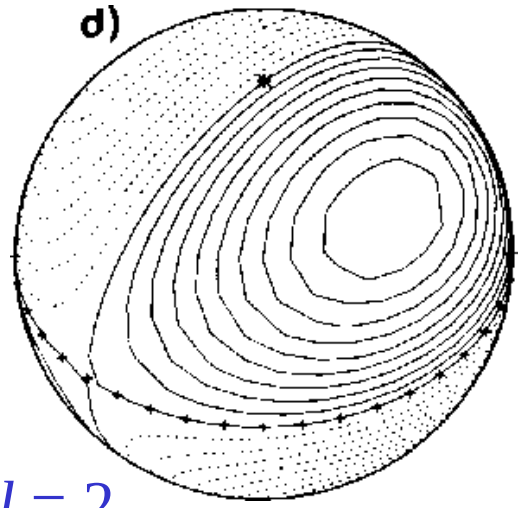




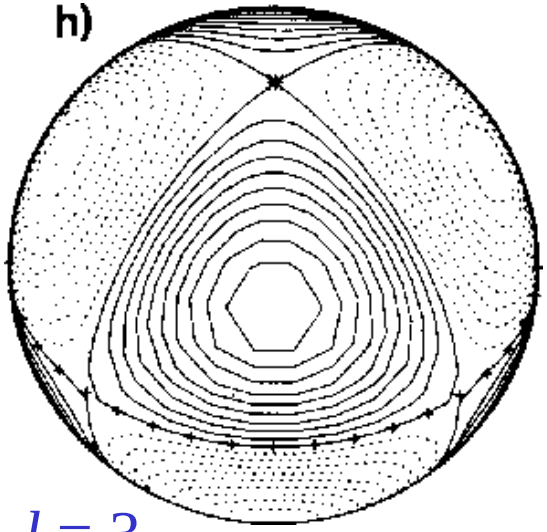
Also non-radial modes:



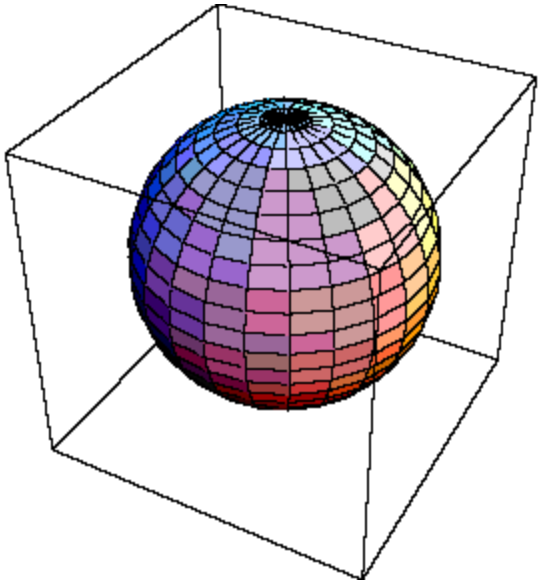
$l = 1$

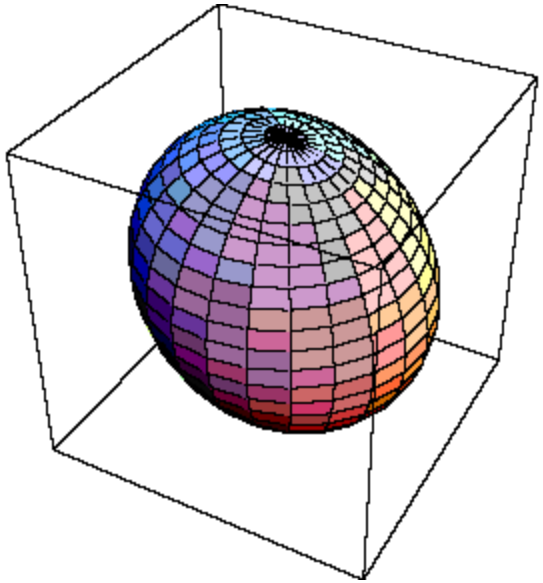


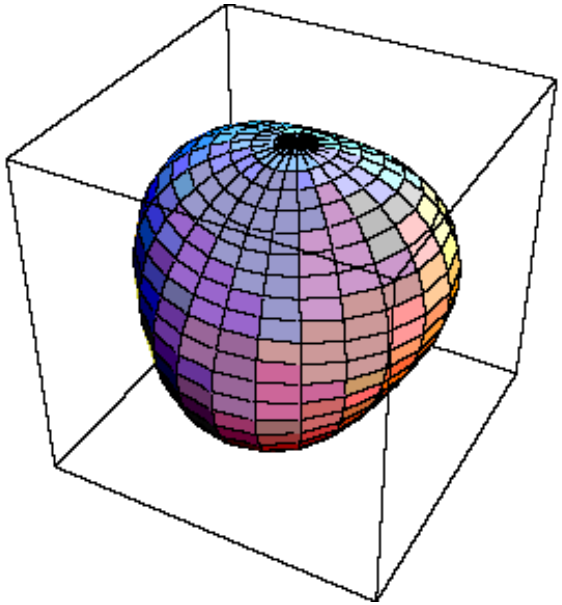
$l = 2$



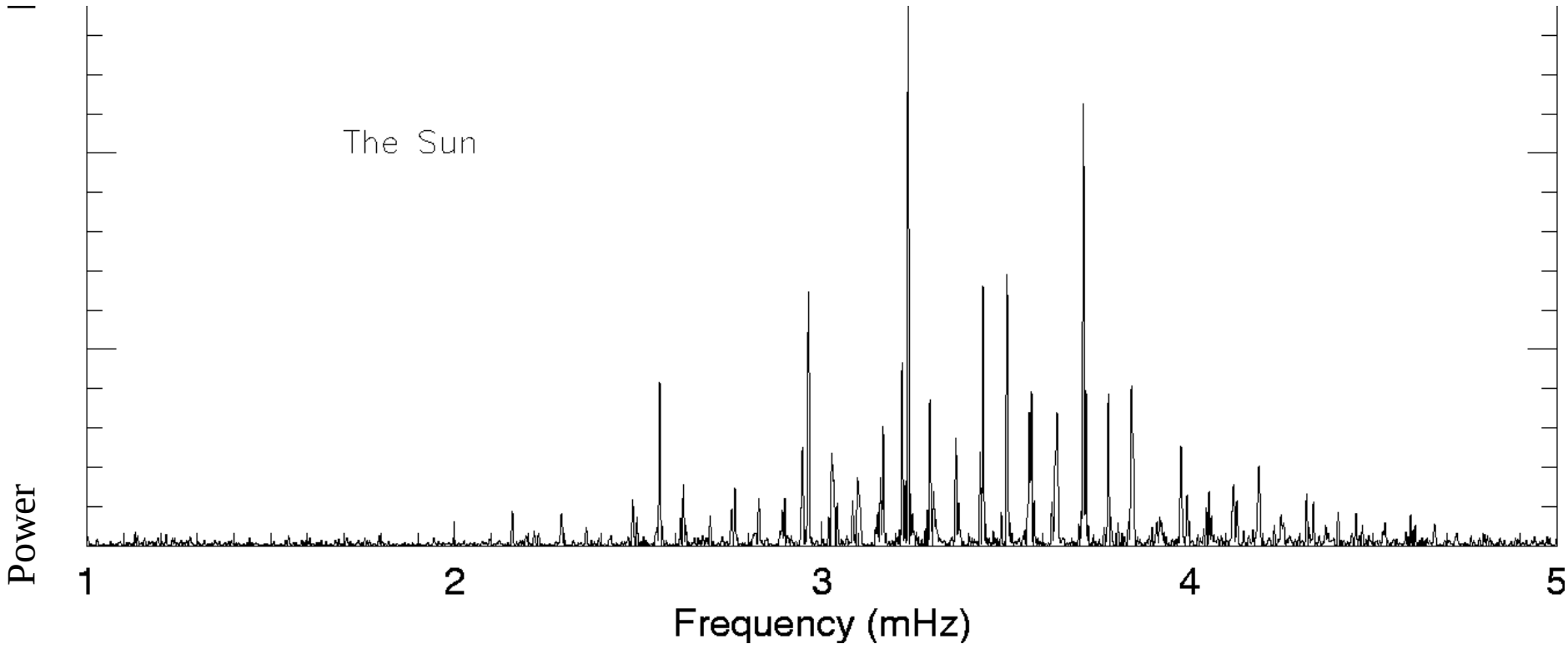
$l = 3$







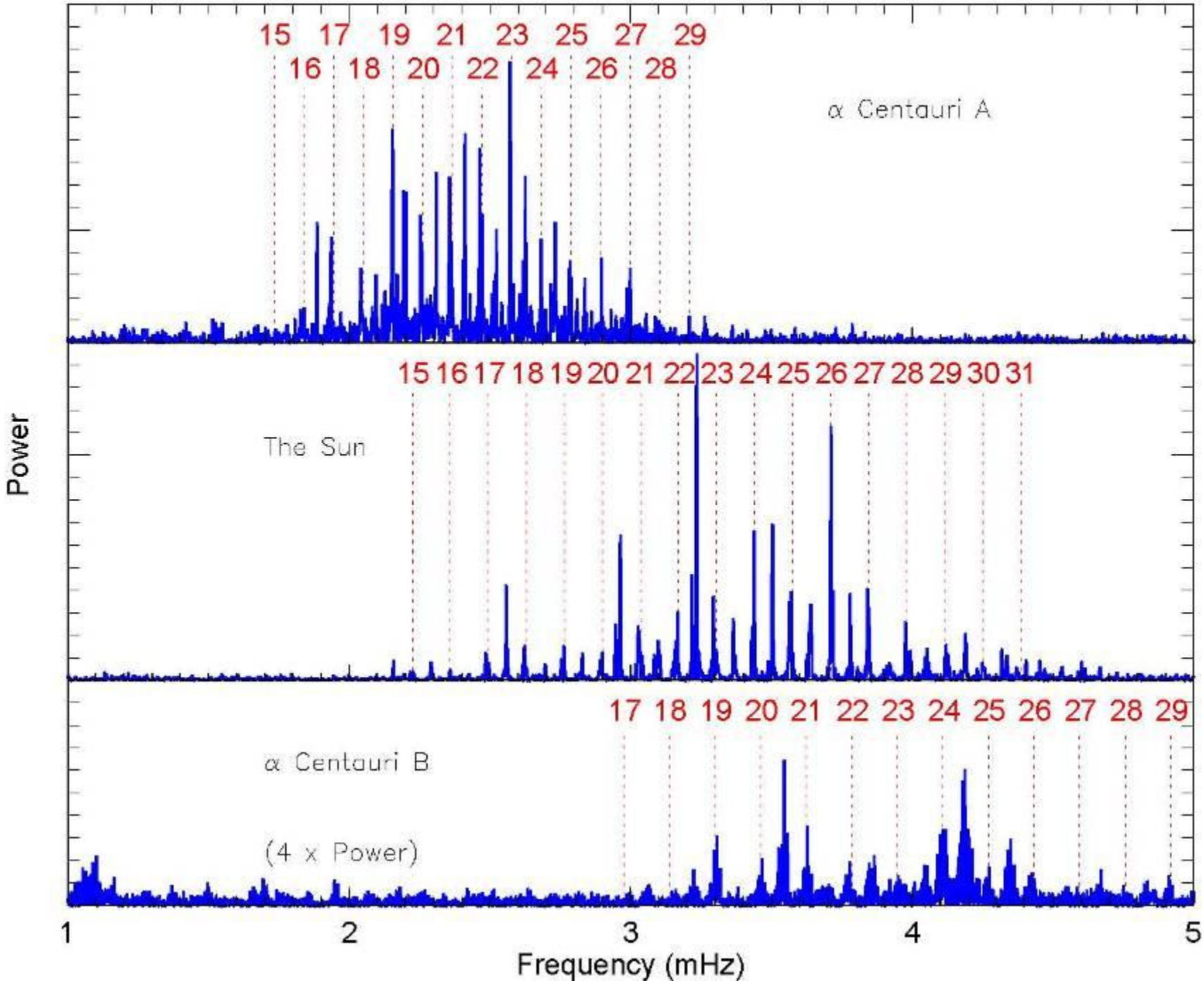
Frequencies of solar velocities:



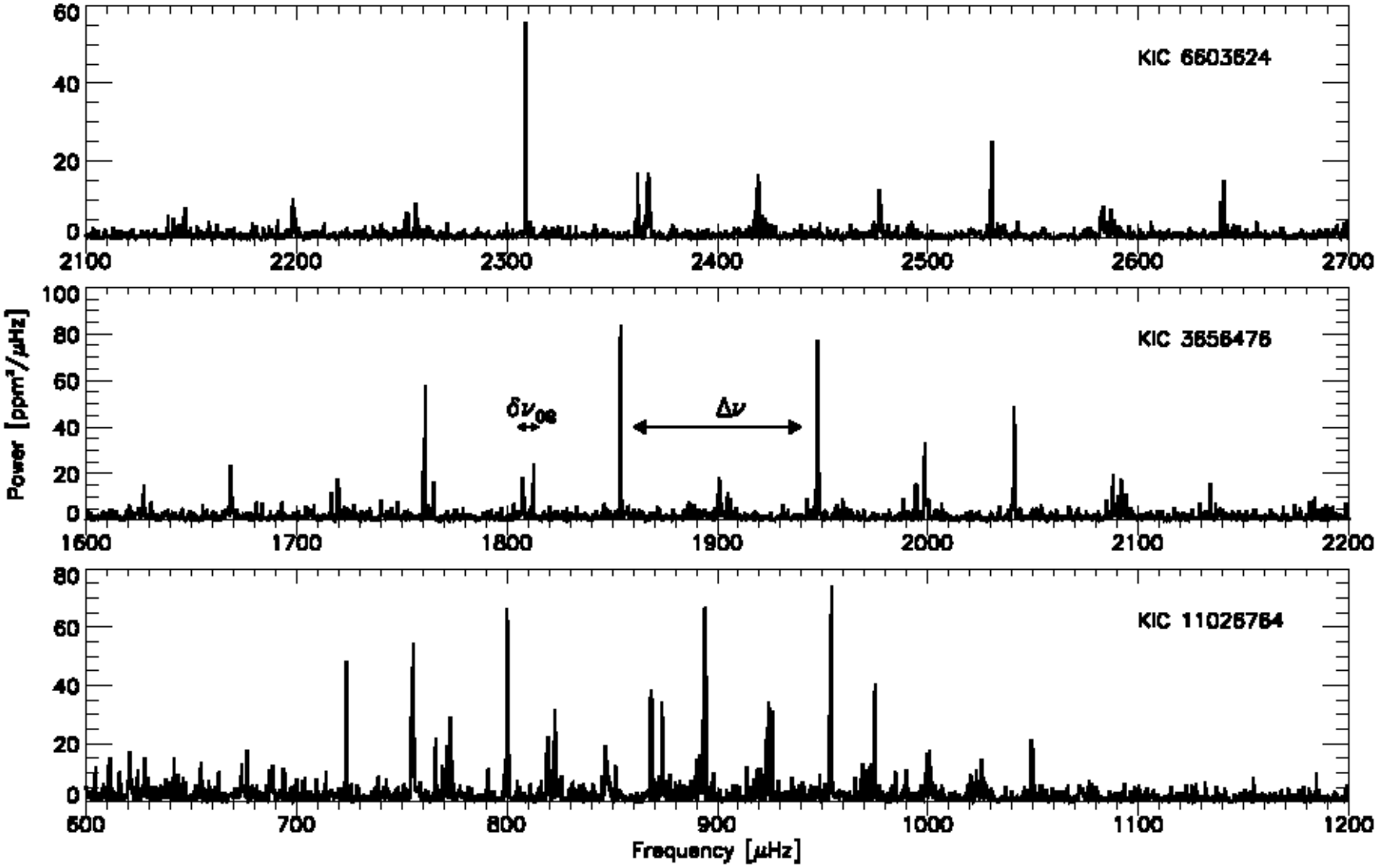
(Fourier power spectrum)

Oscillations in the Sun (sped up 300,000 times) 

We can test the laws of physics under extreme conditions


15 17 19 21 23 25 27 29
16 18 20 22 24 26 28
α Centauri A
15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
The Sun
17 18 19 20 21 22 23 24 25 26 27 28 29
α Centauri B
(4 x Power)
Power
1
2
3
4
5
Frequency (mHz)

Some oscillating stars with observed with Kepler



We can measure the ages of stars

Summary

- Oscillations measured in several nearby solar-like stars from the ground
- and now in hundreds of more distant stars with Kepler.
- we can measure sizes and ages of stars
- we can test theoretical understanding of gas under extreme conditions