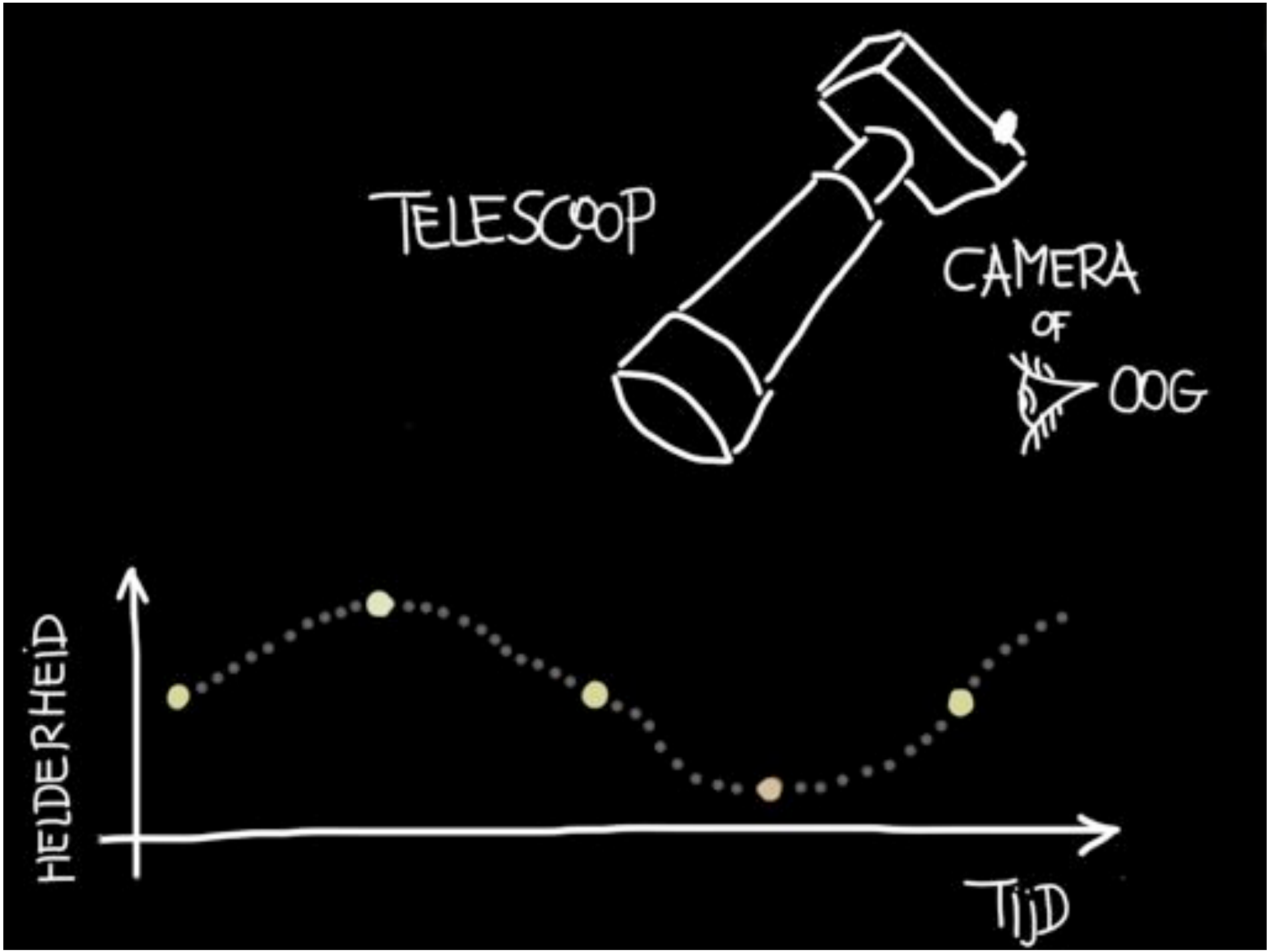
Sterrengeluiden… standaardkaarsen … spectroscopie!

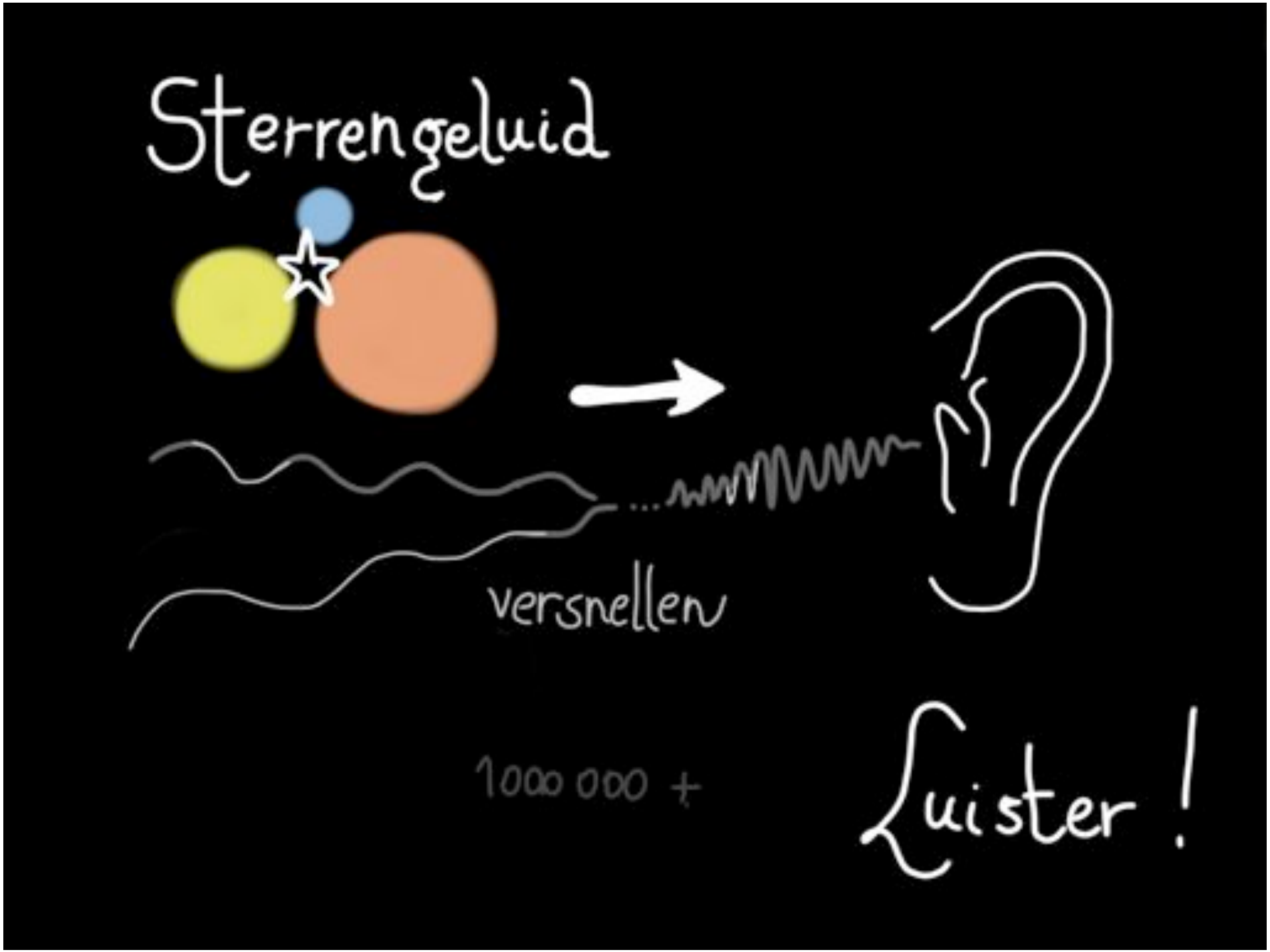
Katrien Kolenberg (UAntwerpen, KU Leuven)

Spectroscopiedag 24 november 2018, Sterrenwacht Tivoli, Oudenbosch NL

Sterren Zien Zingen


TELESCOOP
CAMERA
OF
OOG
HELDERHEID
TIJD


Luide Zon (ver !)
Luide Sterren (heeeel ver !)
Maan
Aarde
(niet op schaal)


Sterrengeluid
versnellen
1000 000 +
Luister !

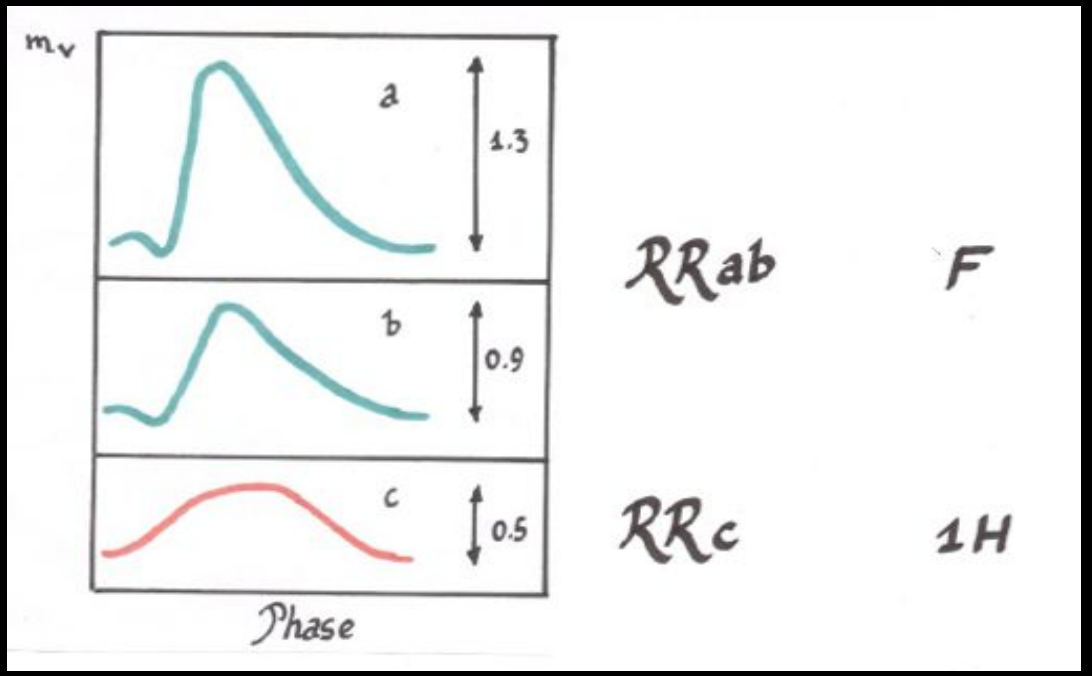

LIJKT MISSCHIEN HIEROP

RR Lyrae Stars: General Properties

RR Lyrae Stars: General Properties

- Standard Candles
- Witnesses of the Universe at Young Age
- "Pure Radial Pulsators"

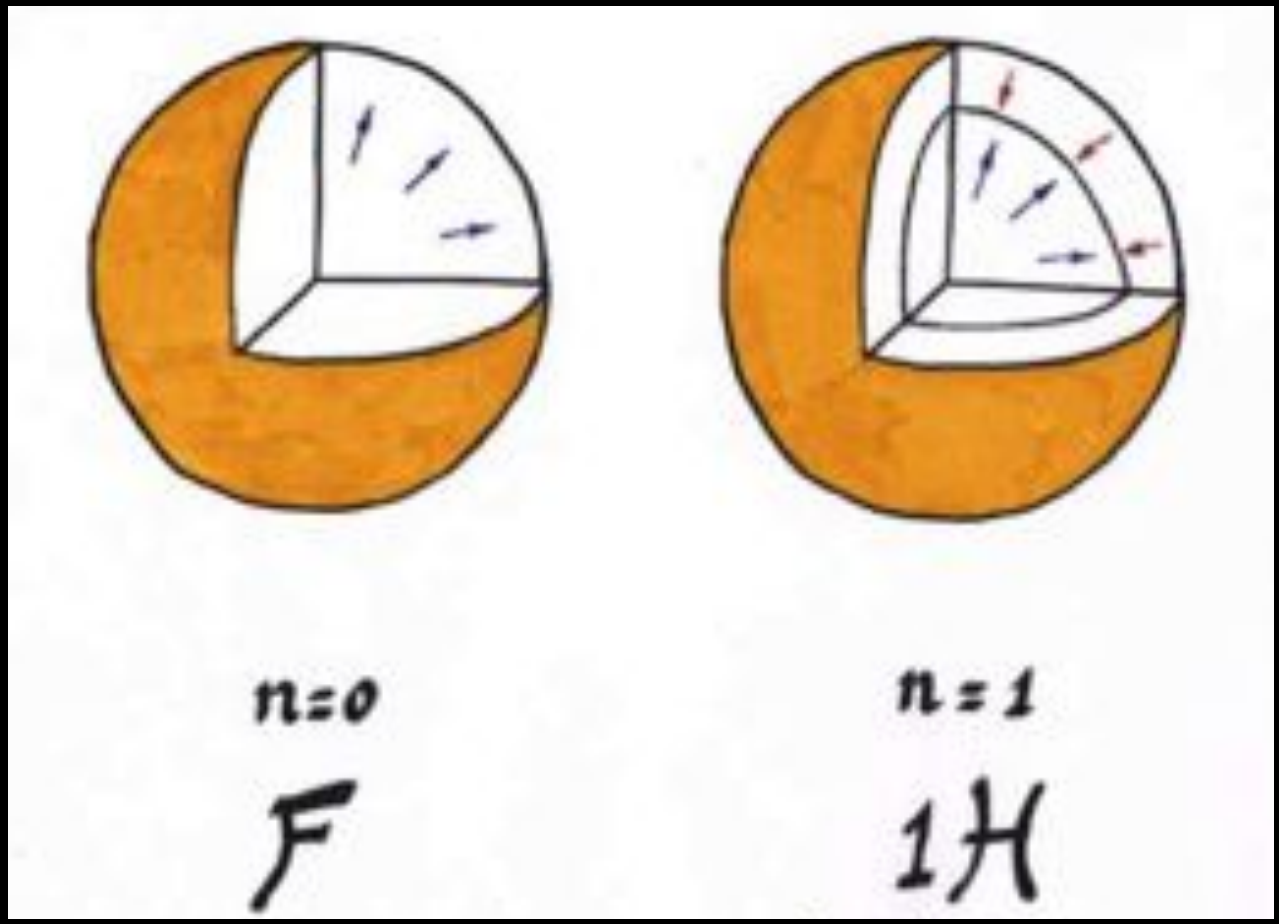
RR Lyrae Stars: General Properties



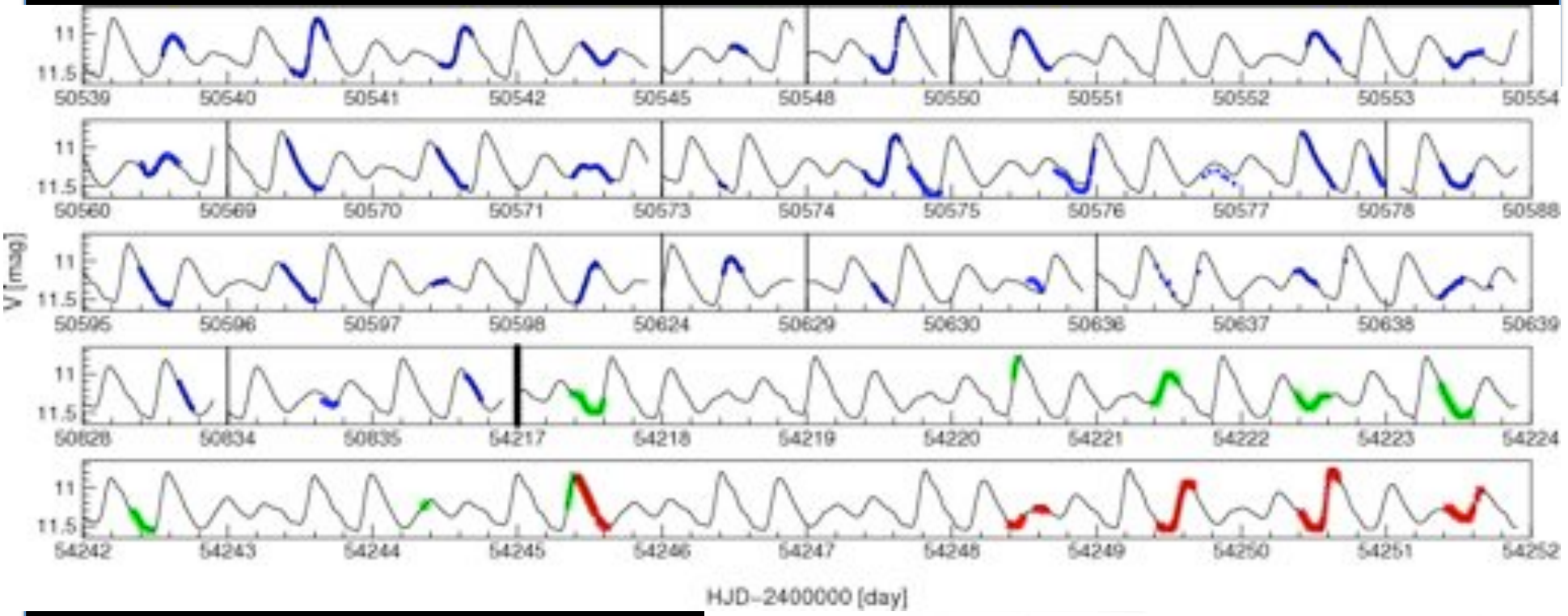
P = 0.2 - 1.1 d

Light variations of ~ 1 mag

Radial Pulsations

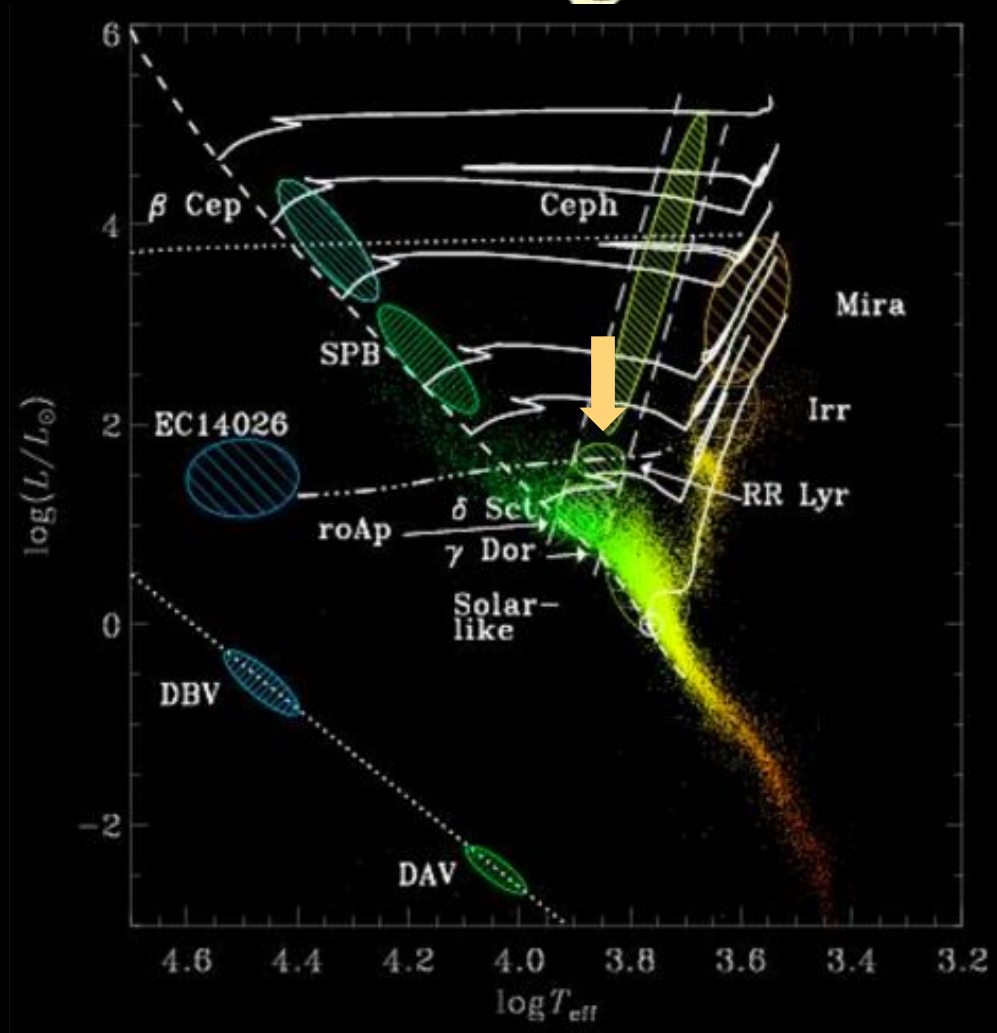


RR Lyrae Stars: General Properties



& RRd F+1H

RR Lyrae Stars: General Properties



UNIVERSITY OF CALIFORNIA PUBLICATIONS

ASTRONOMY

LICK OBSERVATORY BULLETIN

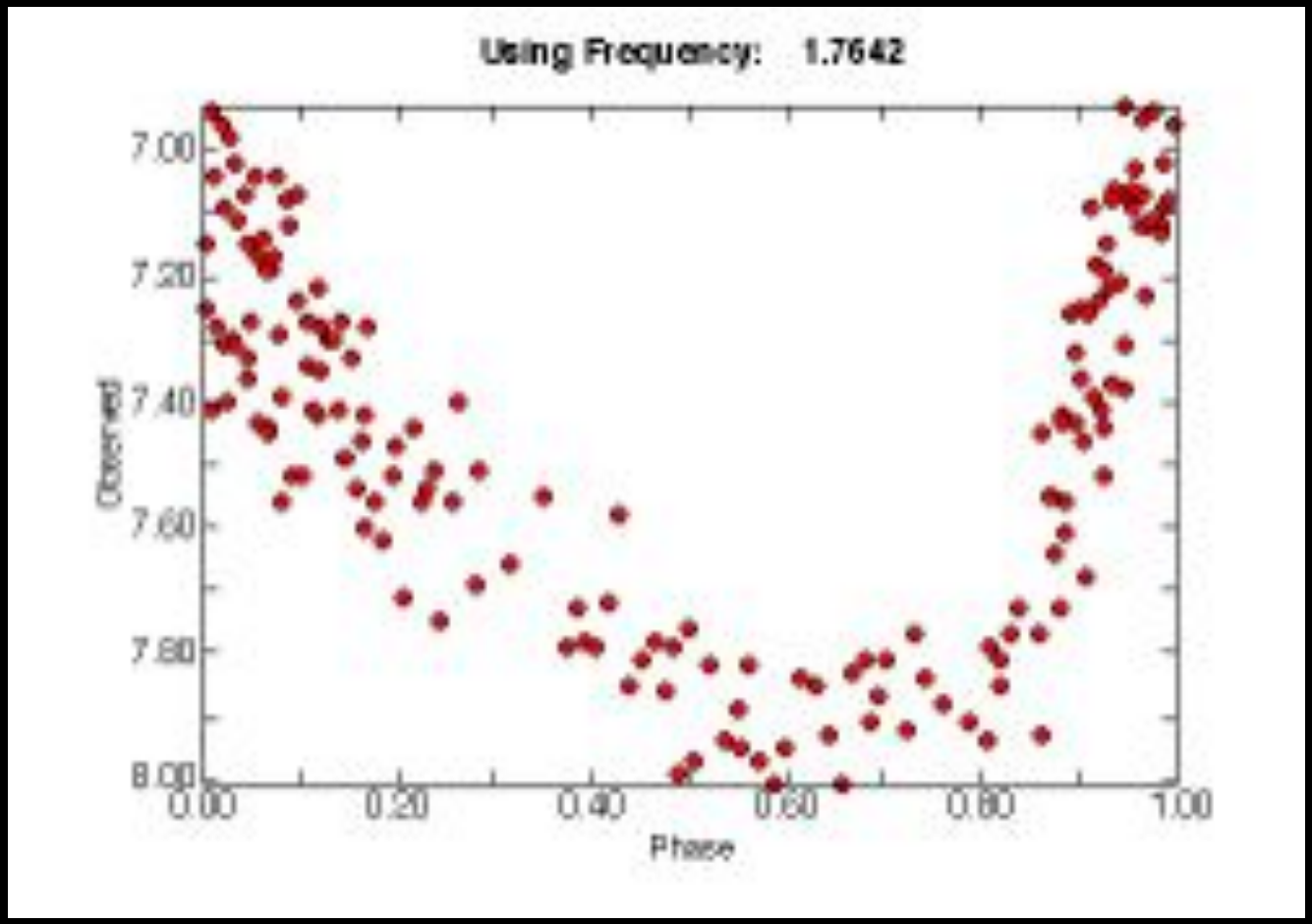
NUMBER 232

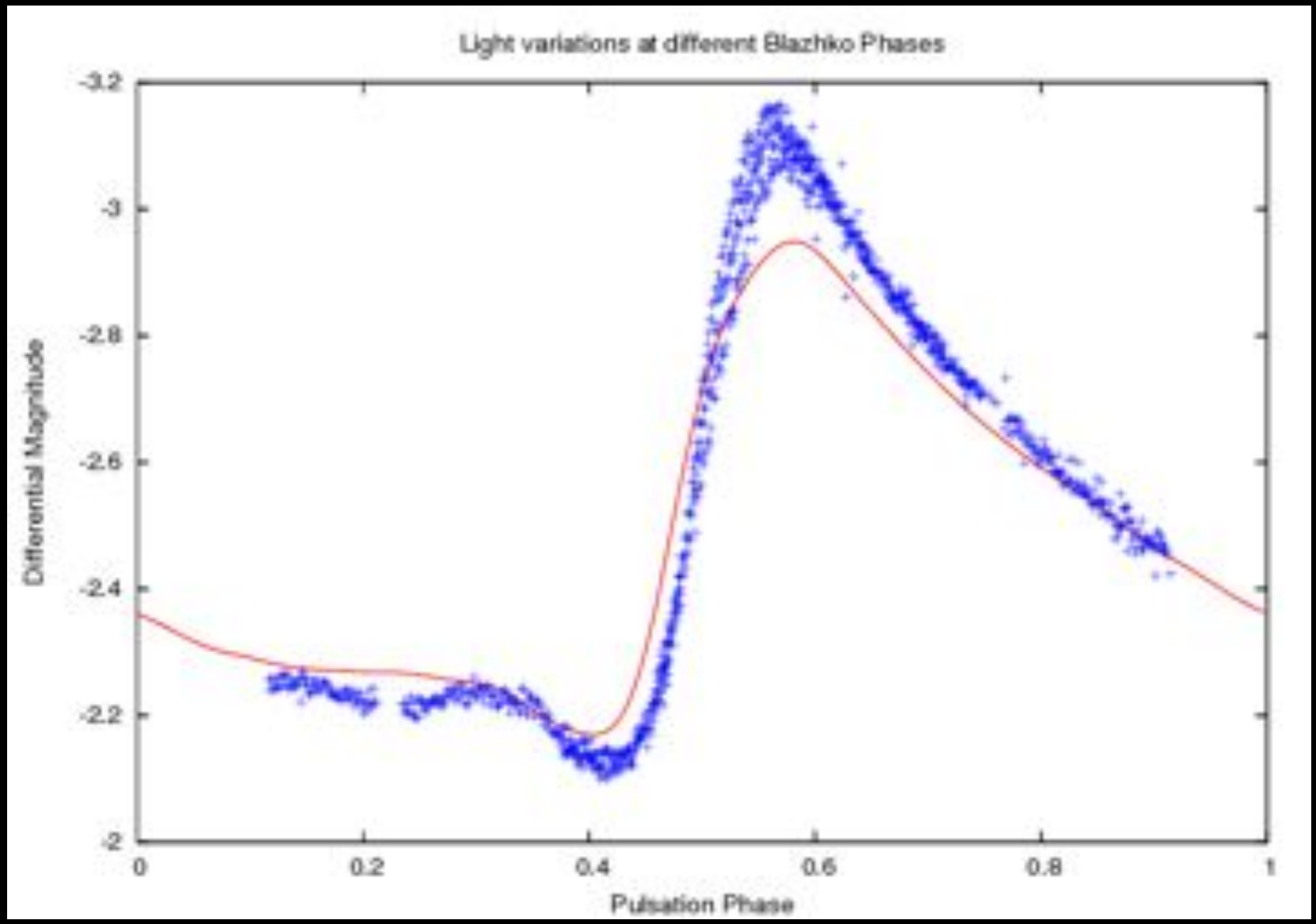
THE CLUSTER VARIABLE RR *LYRAE*[*]

The variability of RR *Lyrae* ($\alpha = 19^h\,22^m$; $\delta = +42°.6$) was discovered by Mrs. Fleming on a multiple-exposure photograph taken July 13, 1899.[1] From 1899 until the beginning of 1902 the star was observed by Wendell with the photometer attached to the East Equatorial of the Harvard College Observatory,[2] a total of 241 observations being secured. From these observations a period of 0.5668 day and a range in brightness of 0.85 magnitude were deduced. In the *Harvard Second Catalogue of Variable Stars*, RR *Lyrae* is assigned to Class IV, of the Harvard Classification, which includes all short-period variables whose light changes are not due to eclipses. But Class IV stars, although possessing similar characteristics of variation in general, fall into three groups according

In a letter to Director Campbell, Hertzsprung of Potsdam called attention to the fact that RR *Lyrae* is the brightest Cluster Variable so far known. Its light ranges between the seventh and eighth magnitudes, thus enabling it to be observed with a low-dispersion spectrograph attached to the 36-inch refractor. As a result of his own observations Hertzsprung found a period of 0.56682 day, and that a photographic maximum occurred at J. D. 2418939.448.

During the latter half of 1912, photometric observations of RR *Lyrae* were made at Mount Hamilton, and from them a new light curve was drawn. The observations upon which the curve is based, are as in TABLE I. With one exception, all the observations of August 20 and September 13 were made by Dr. S. D.


Using Frequency: 1.7642
7.00
7.20
7.40
7.60
7.80
8.00
Observed
0.00
0.20
0.40
0.60
0.80
1.00
Phase

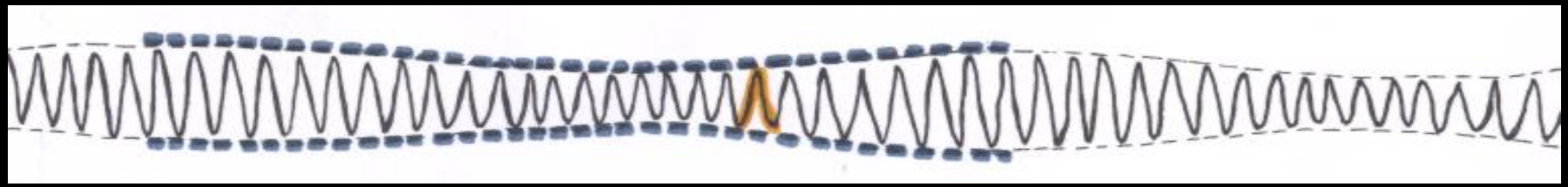


Pro-Am data (Kolenberg et al. 2006)

(Blazhko 1907)

The Blazhko Effect

Blazhko Period P_B



Radial Pulsation Period P_0

The Blazhko Effect

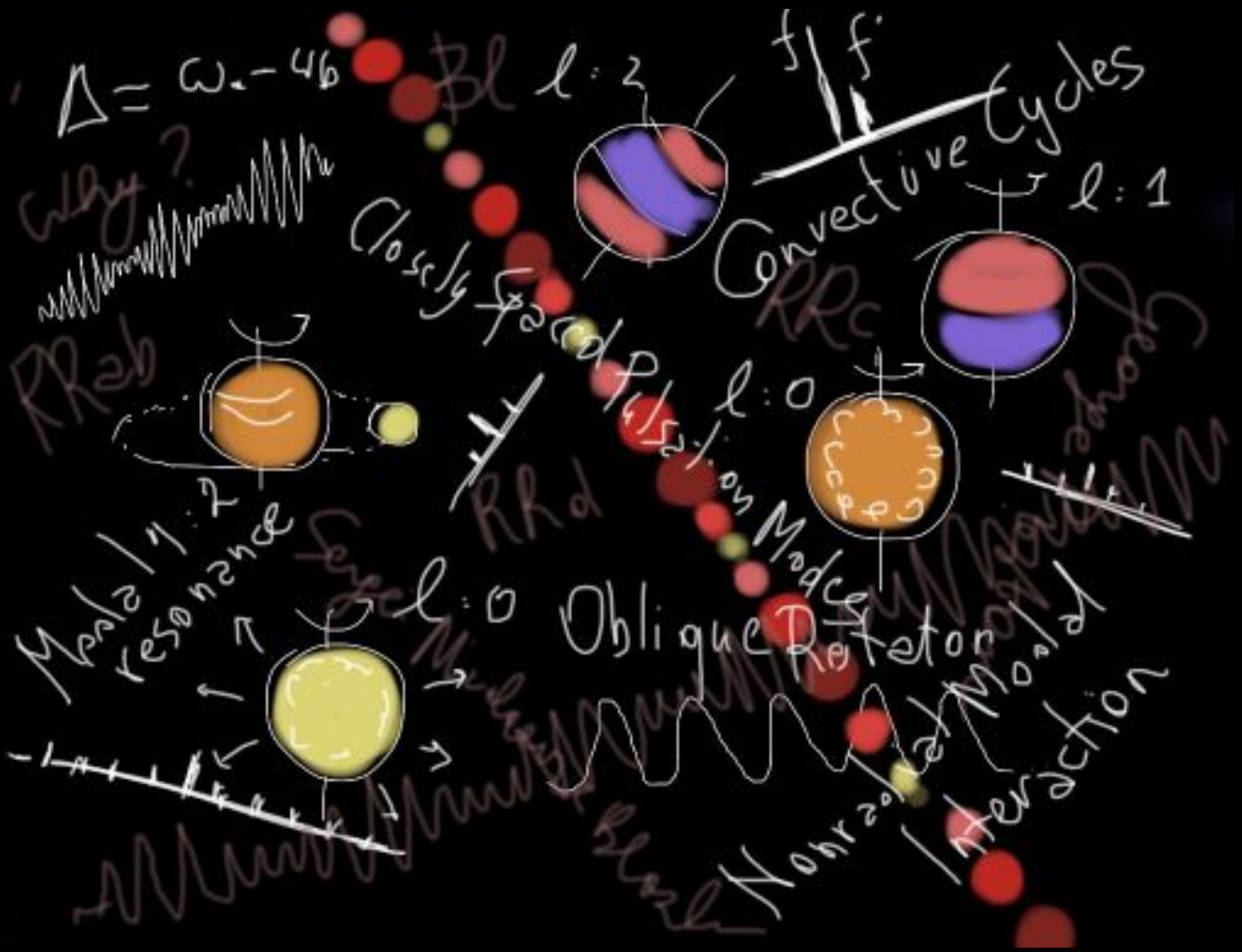
Not always regular

Period changes: “period noise”

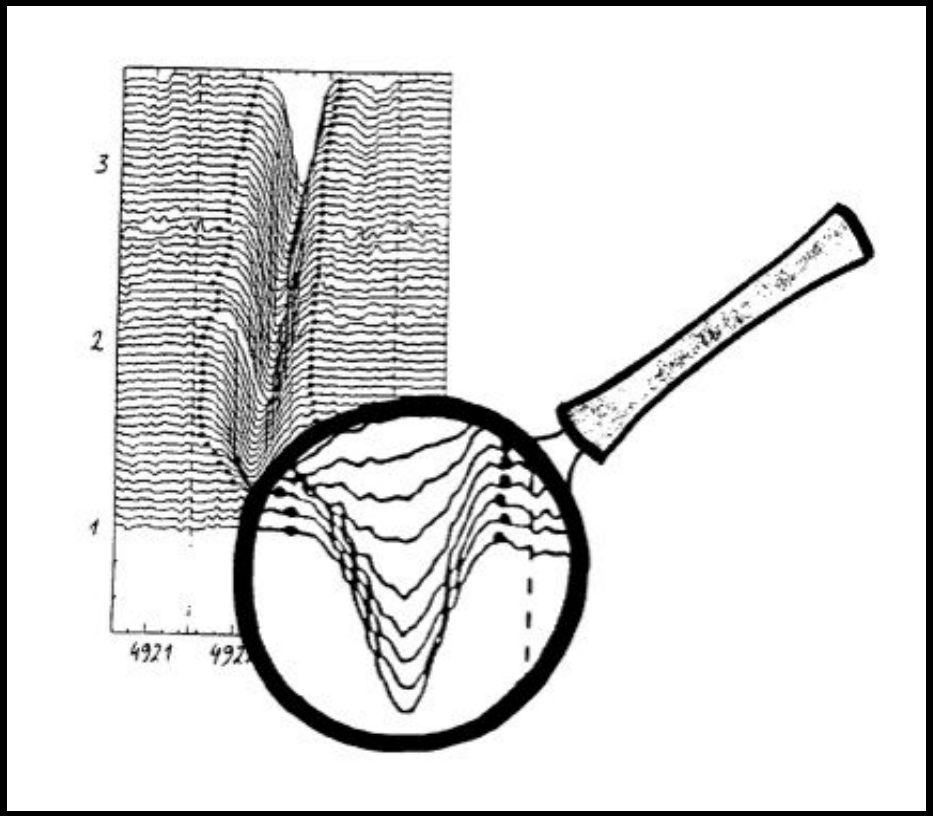
No exact repetition from one cycle to the next

Longer cycles (years)

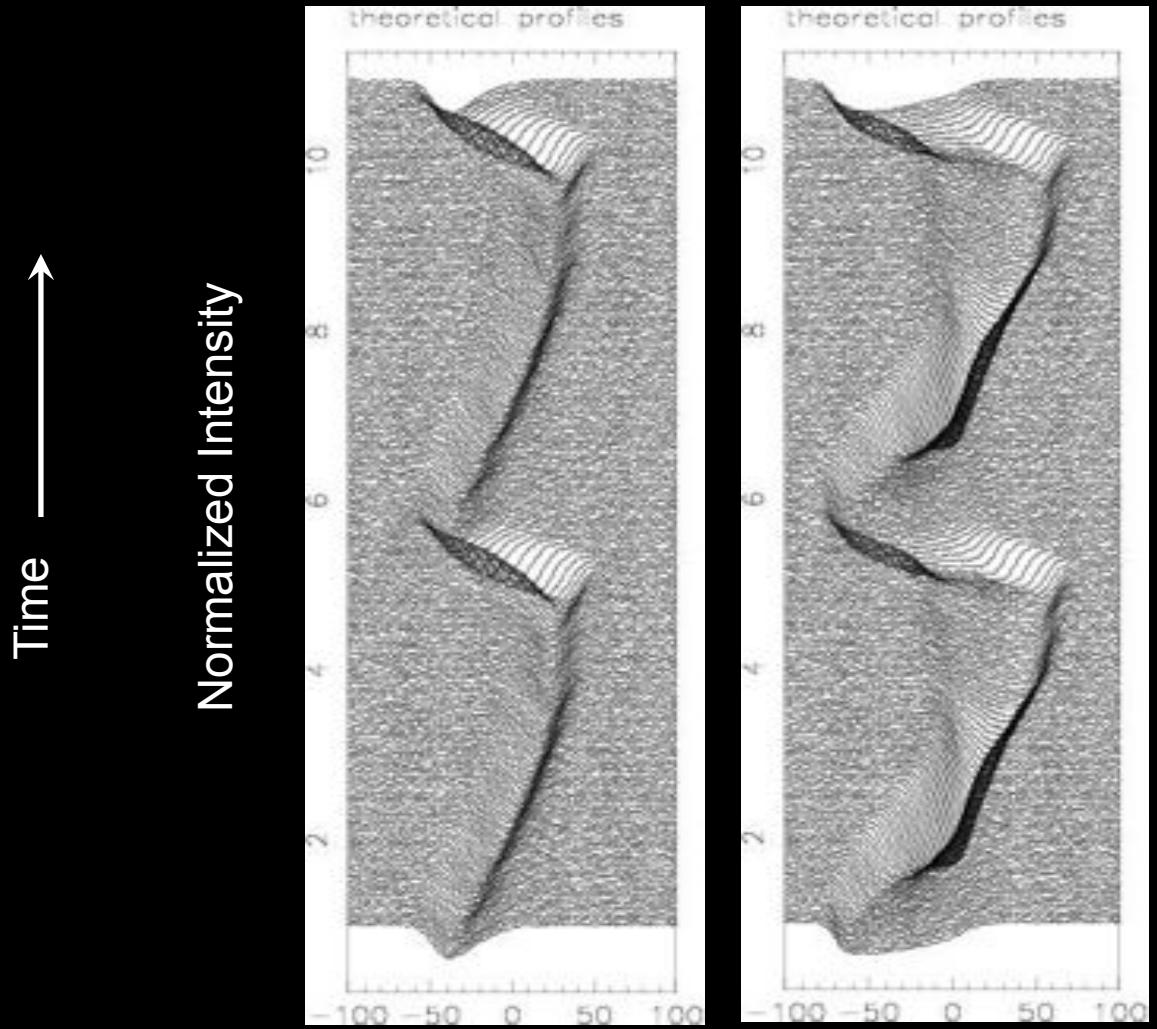
Explanations for the Blazhko Effect



Spectroscopic Study of the Blazhko effect



Influence of a nonradial mode upon the line profile variations



RR Lyrae Stars… in the past two decades

Large (and dedicated) surveys,
and space data:
many stars, new phenomena, new boost for astrophysics

RR Lyrae Community

Space data; Big Surveys; Dynamical Studies;
Period-Color-Luminosity relations;
The Blazhko Enigma;
Methods; Numerical Models;
Binarity; Pulsation and Evolution;
Tracing Galactic Structure

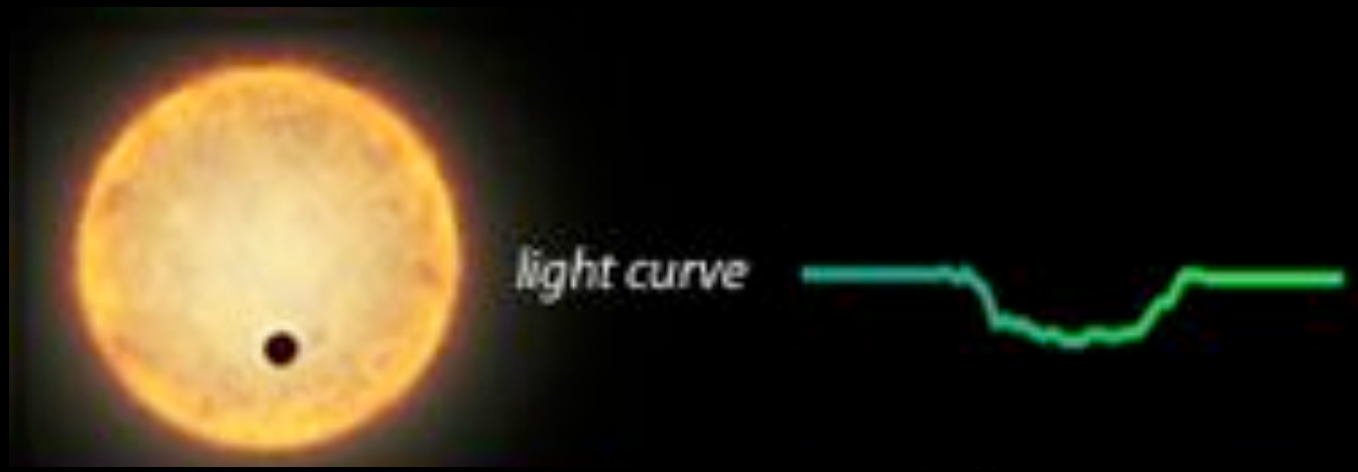
RRL2015, RRL2017, RRL2019

RRL2019: October 2019, New Mexico

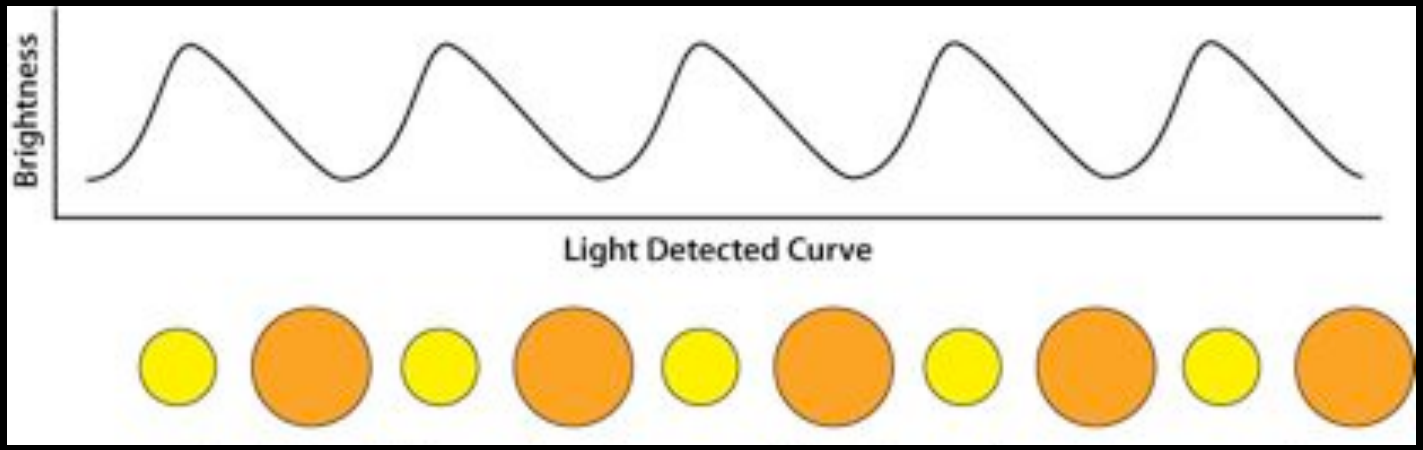

LOTS OF NEW FINDINGS
THANKS TO THE KEPLER MISSION
KEPLER & K2: 2009-2018

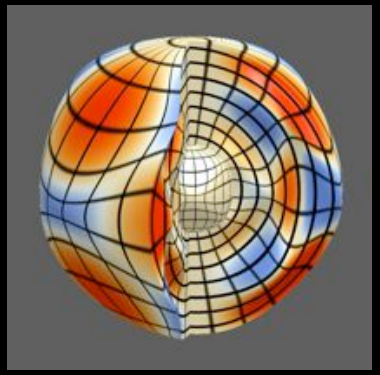
Kepler space mission – main goals

Finding Earth-like exoplanets around solar type stars in the habitable zone with the transit method

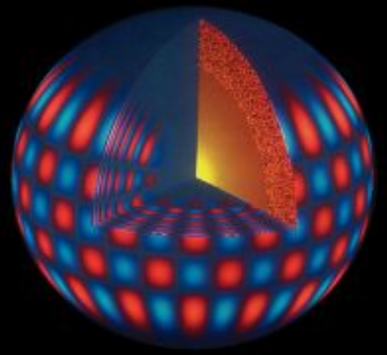


Kepler space mission – main goals

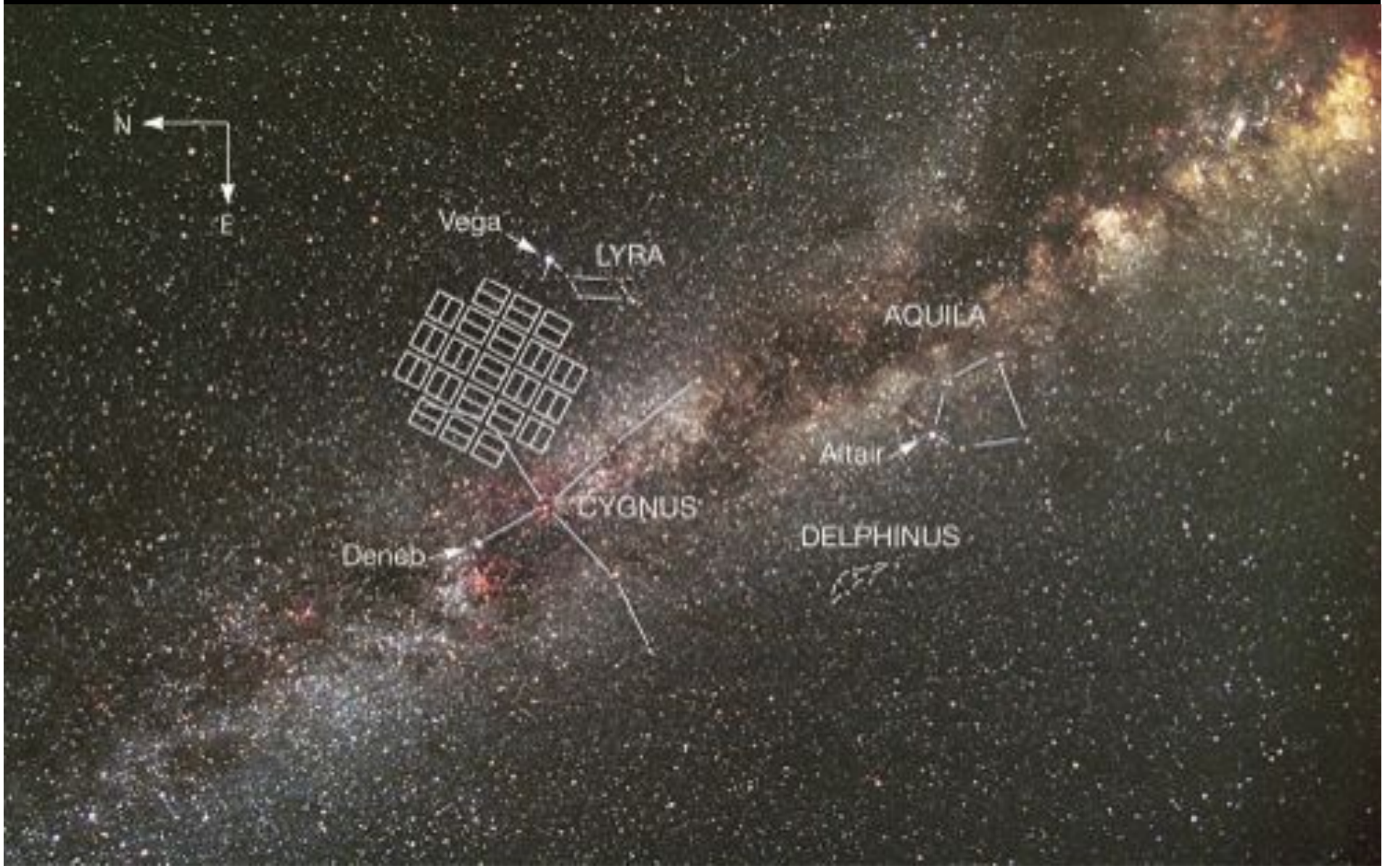




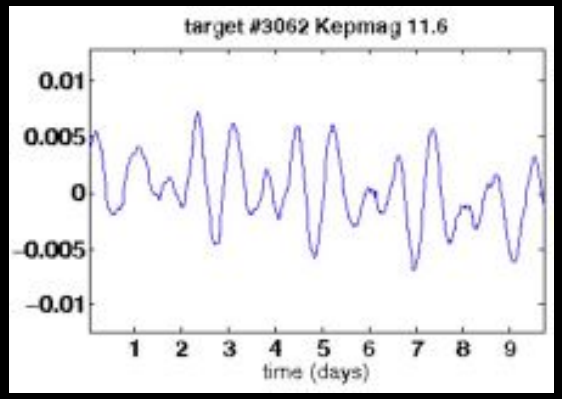
Stellar structure and evolution
via asteroseismology

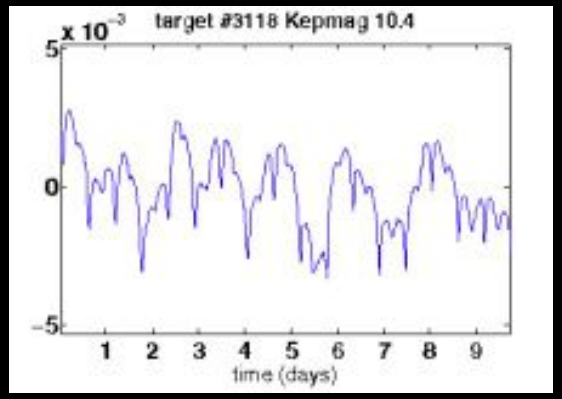


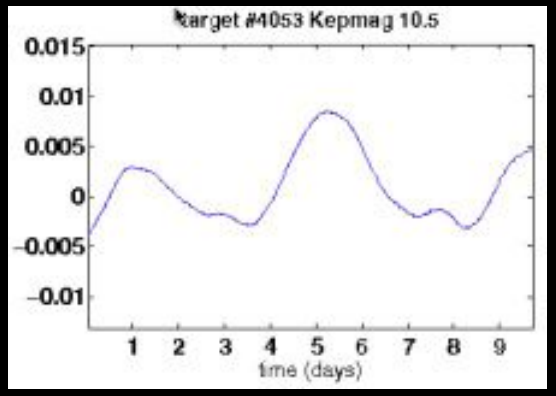
The Kepler field

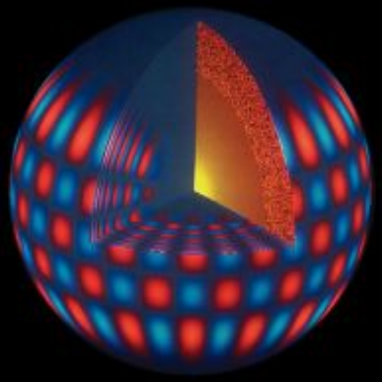


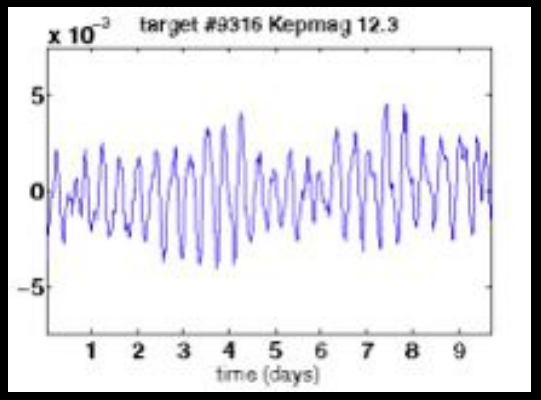
Asteroseismology with Kepler

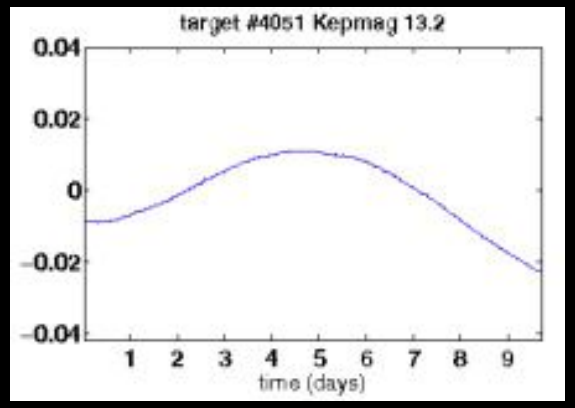


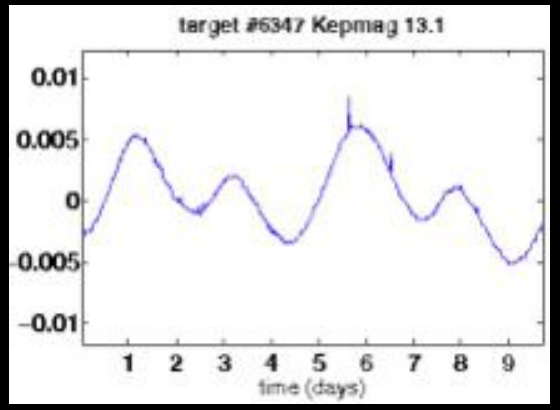


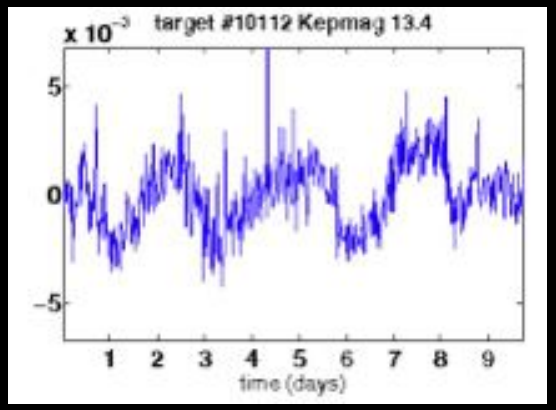




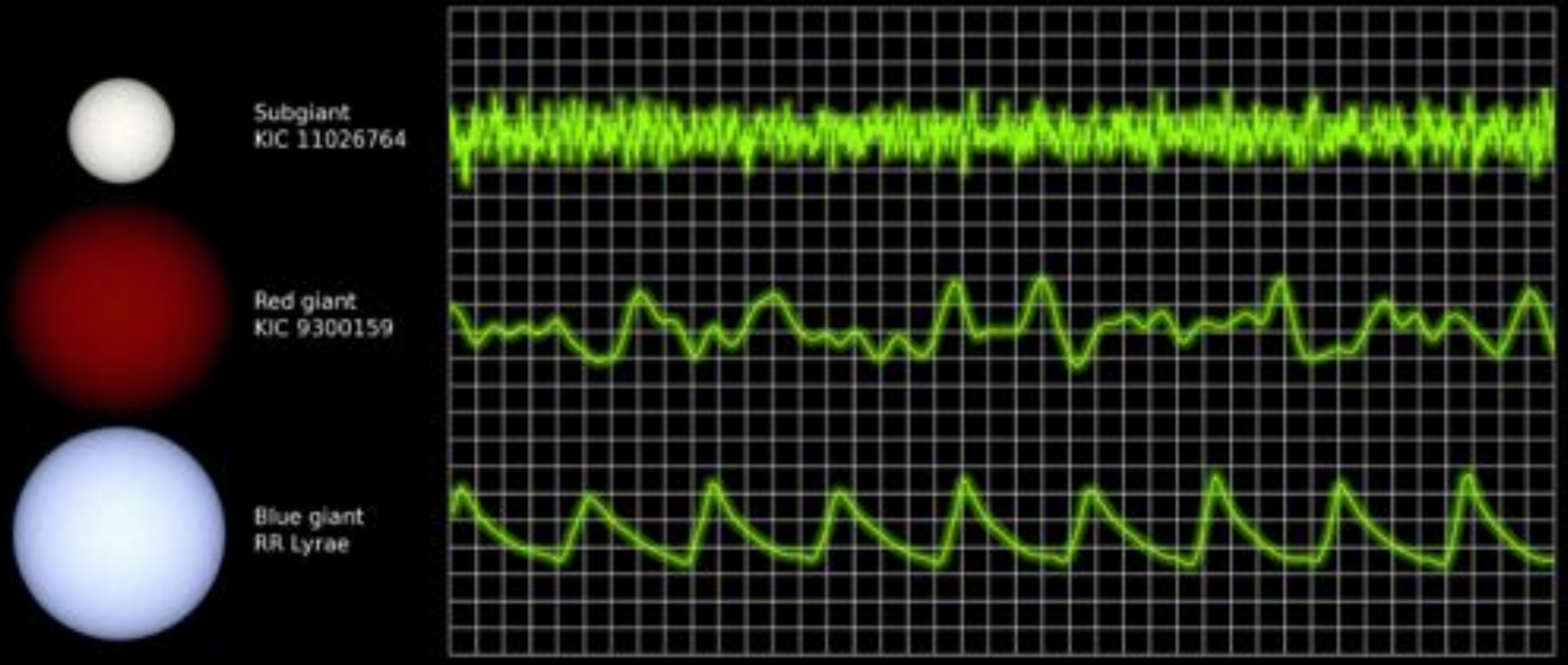




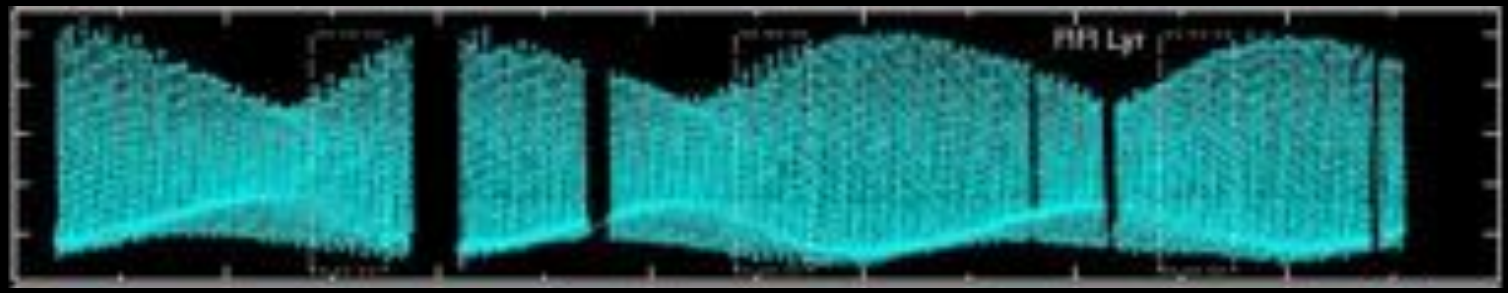




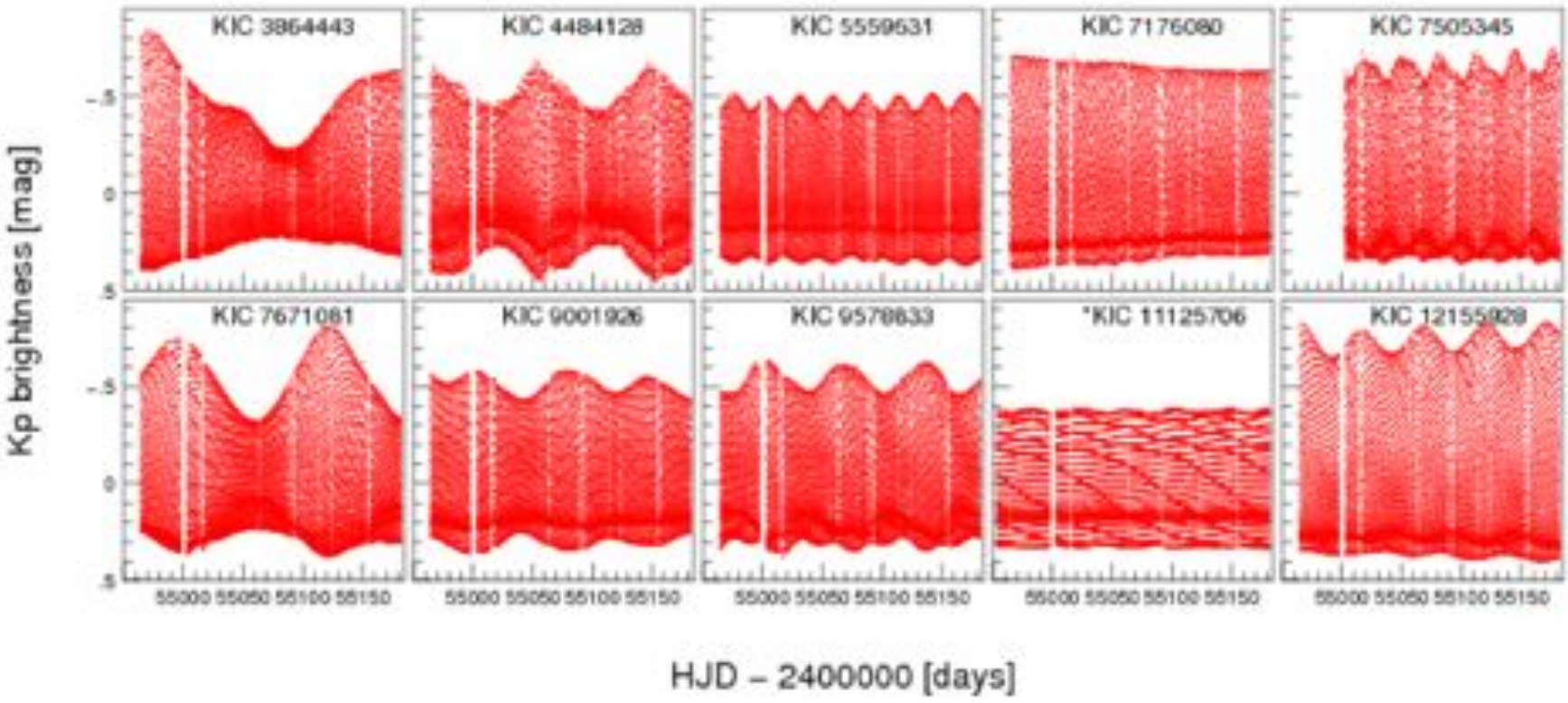
TAKING THE "PULSE" OF STARS



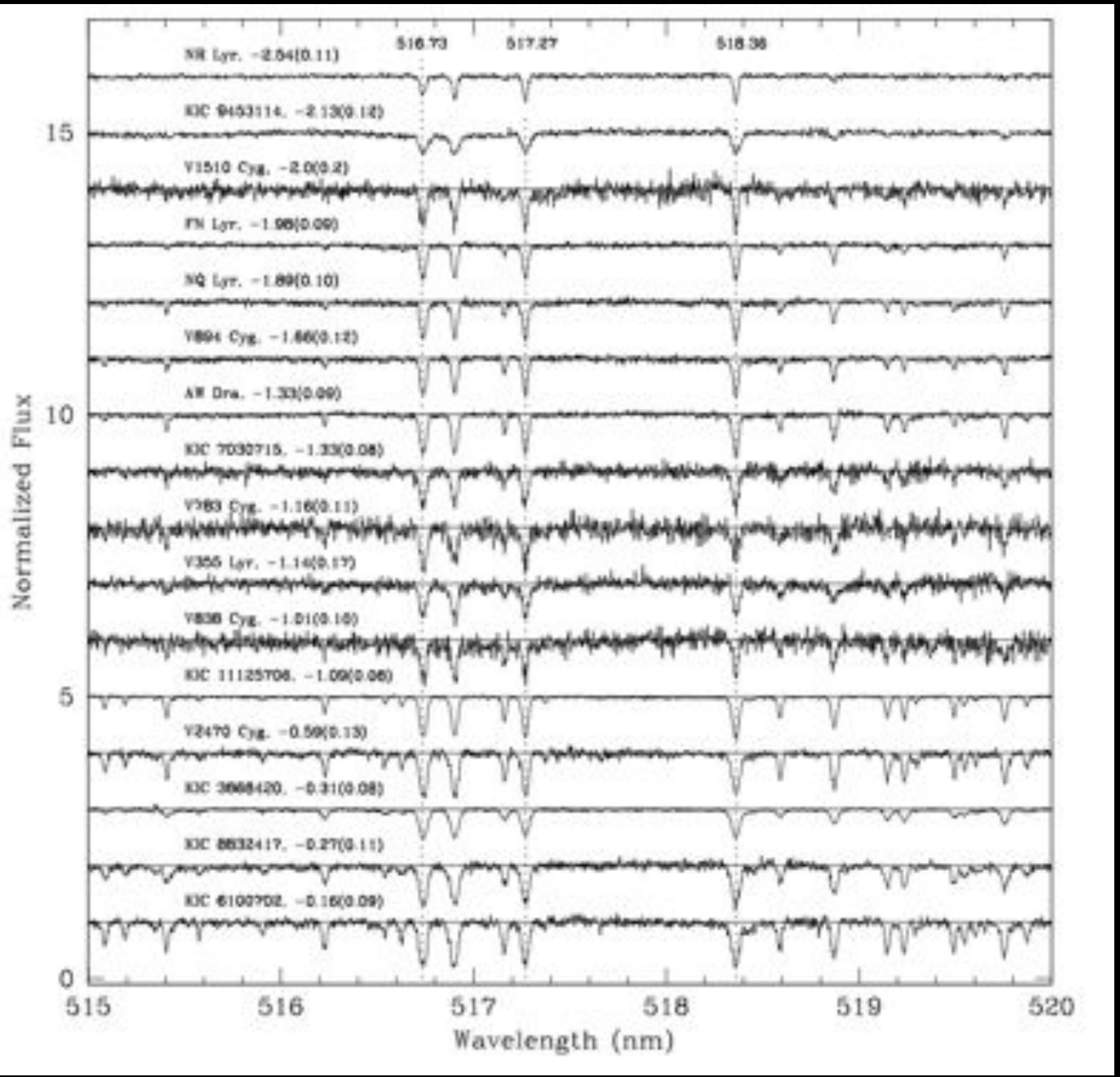
Kepler and the RR Lyrae Stars



Kepler's Blazhko Zoo



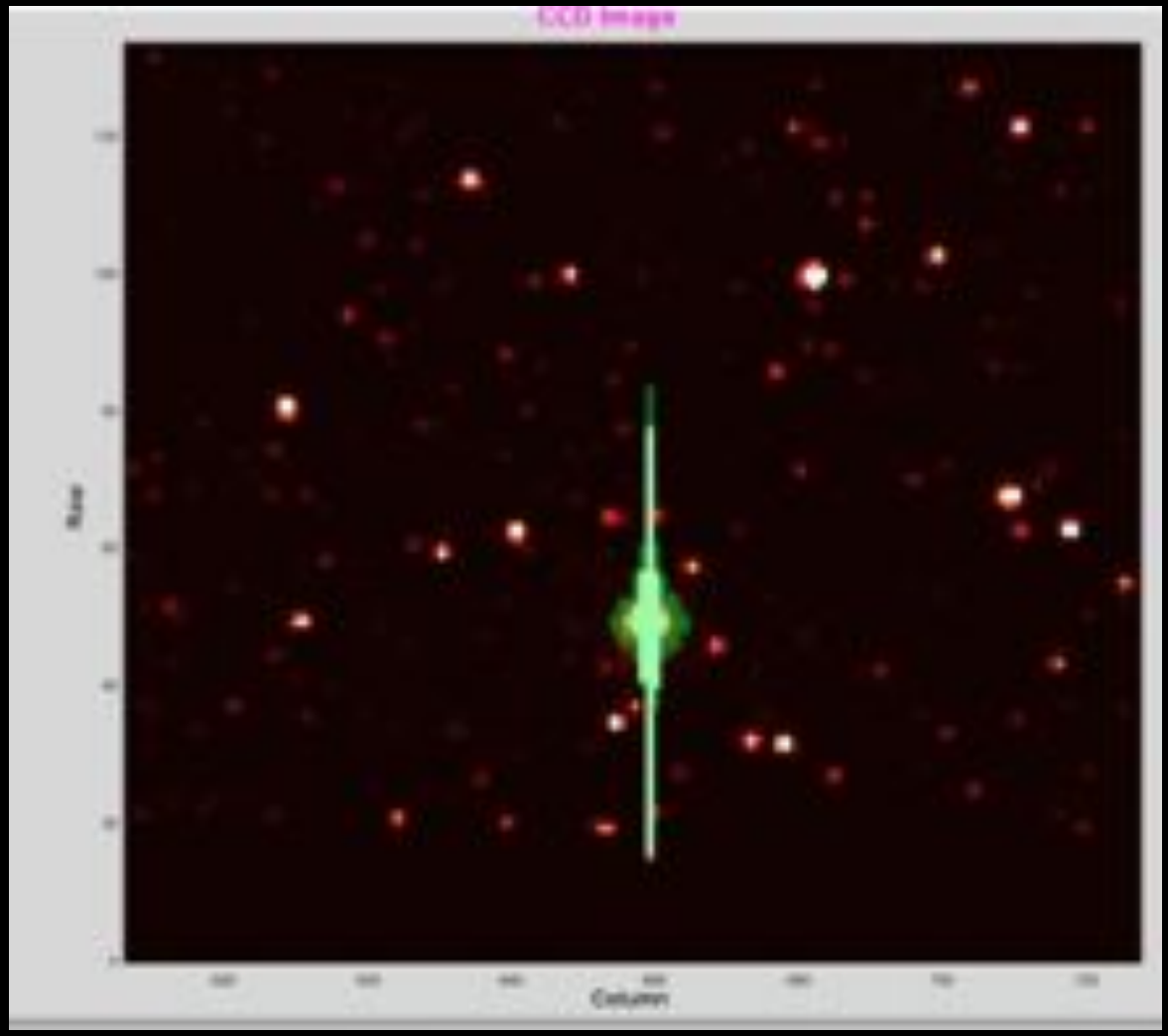
Benkö et al. 2010, MNRAS 409, 1585

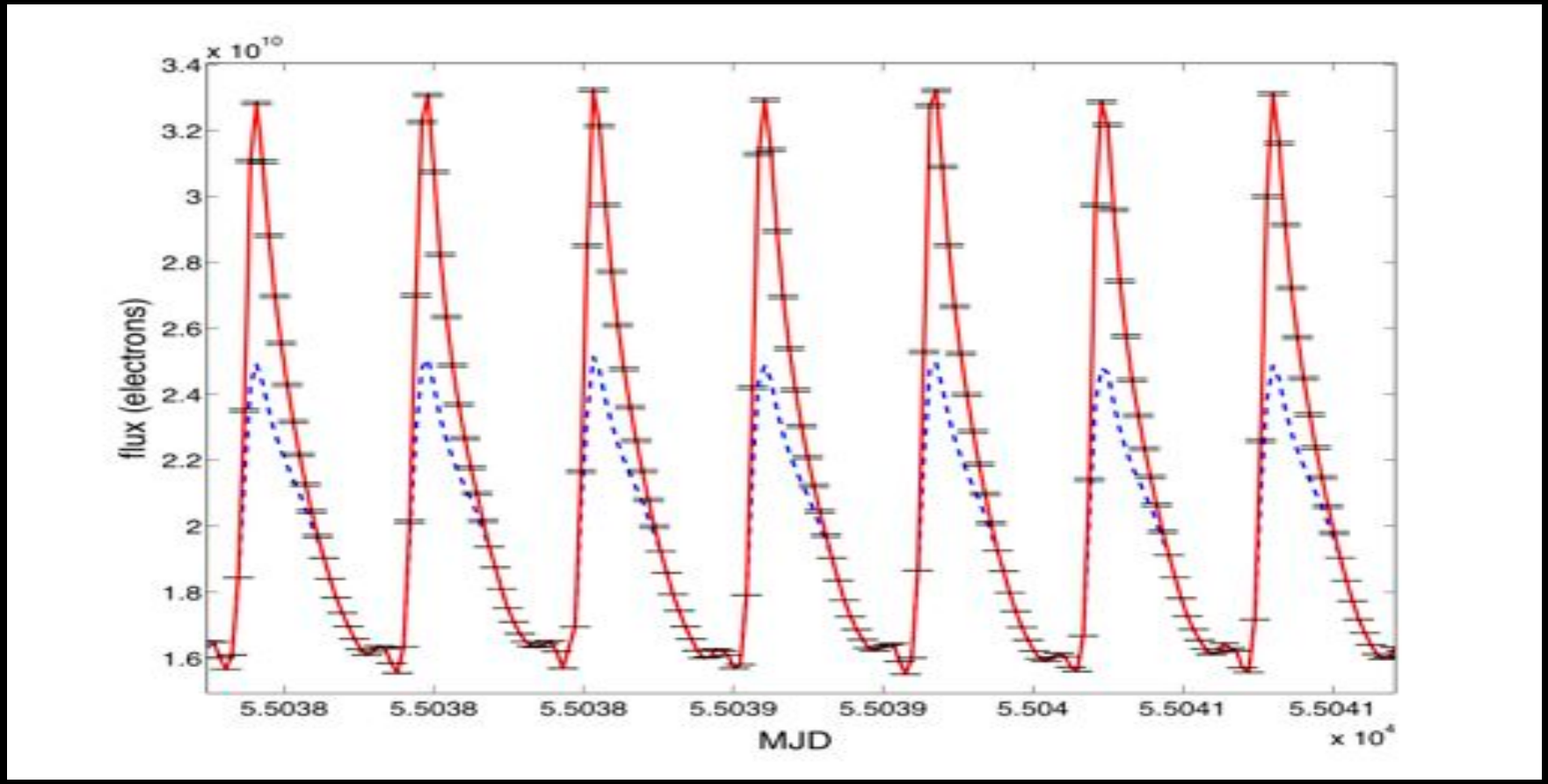


Nemec et al. 2013

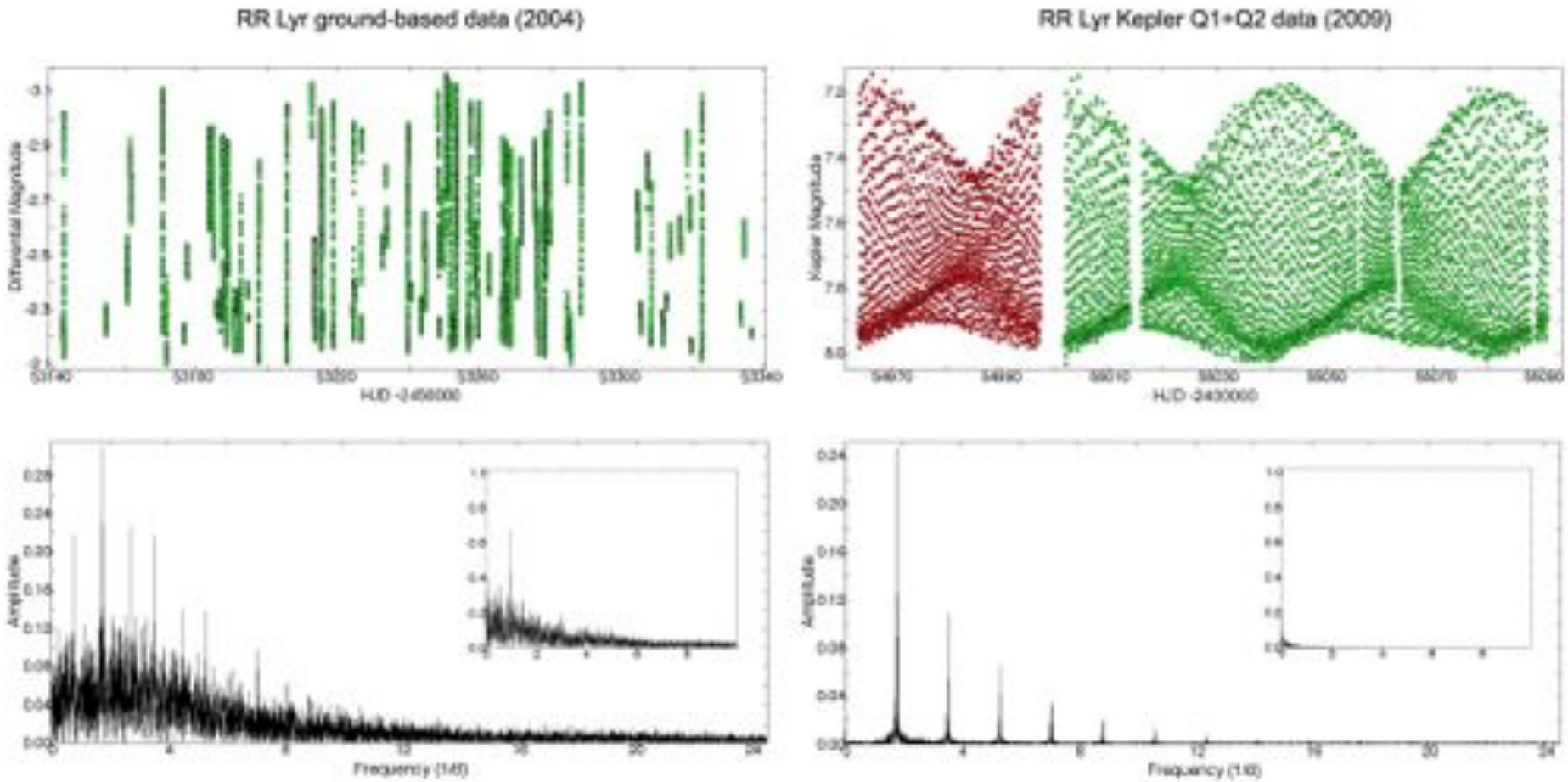
CFHT and Keck Spectra of all Kepler RRLyr stars

RR Lyr in the Kepler field (!)





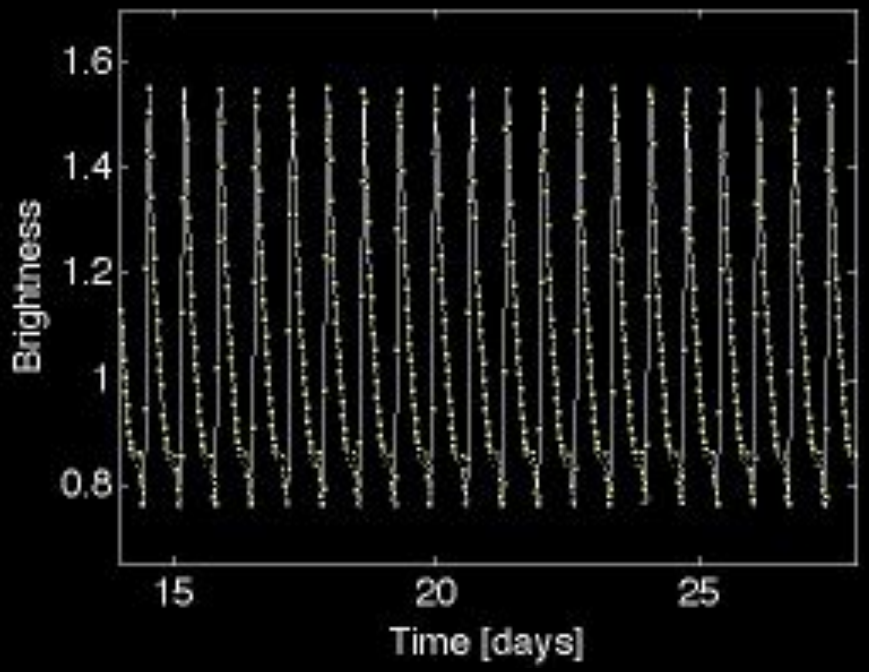
Custom apetrure by Steve Bryson (NASA Ames)

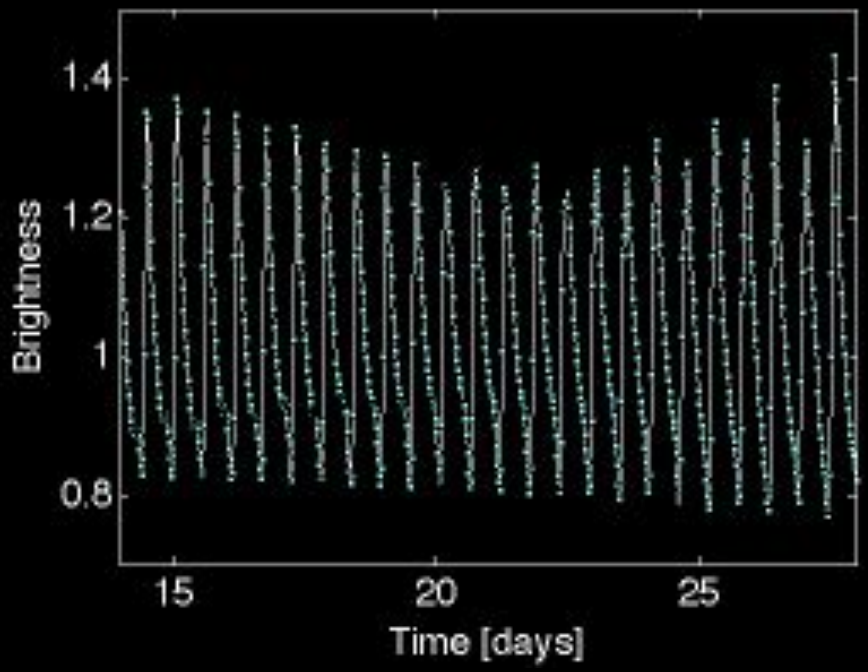


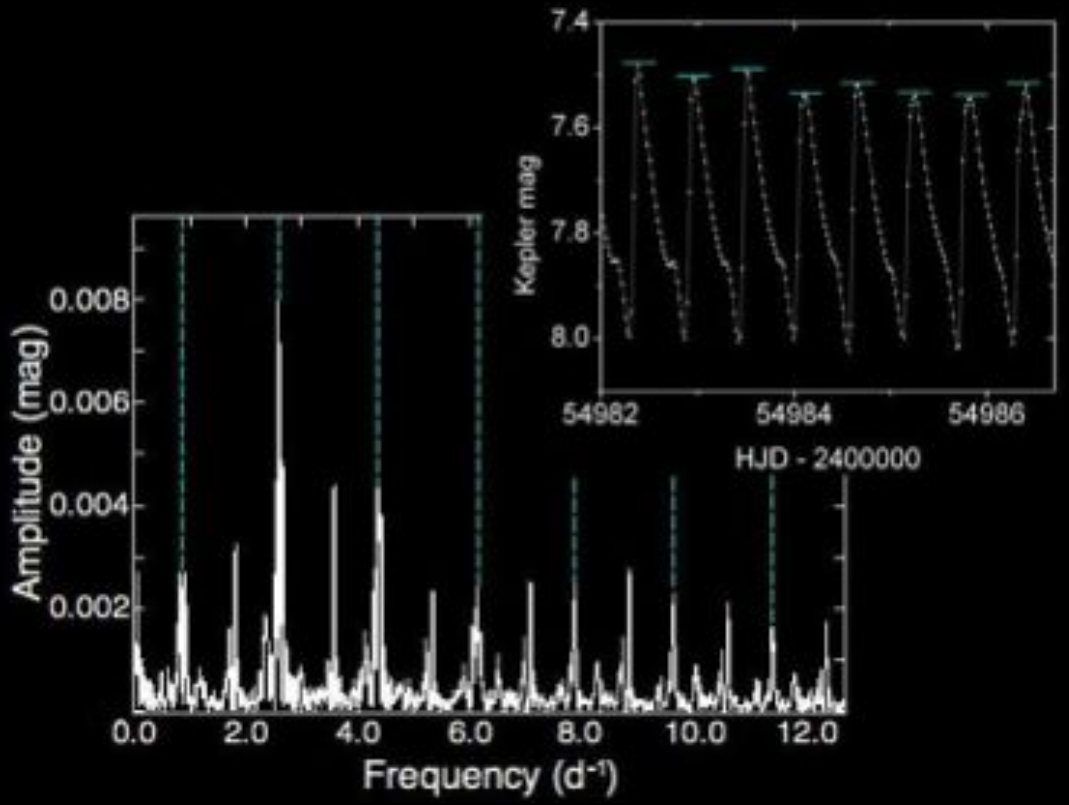
Kolenberg et al. 2006, A&A 459, 577

Kolenberg et al. 2011, MNRAS 411, 878

Why do some stars do it and others don‘t?







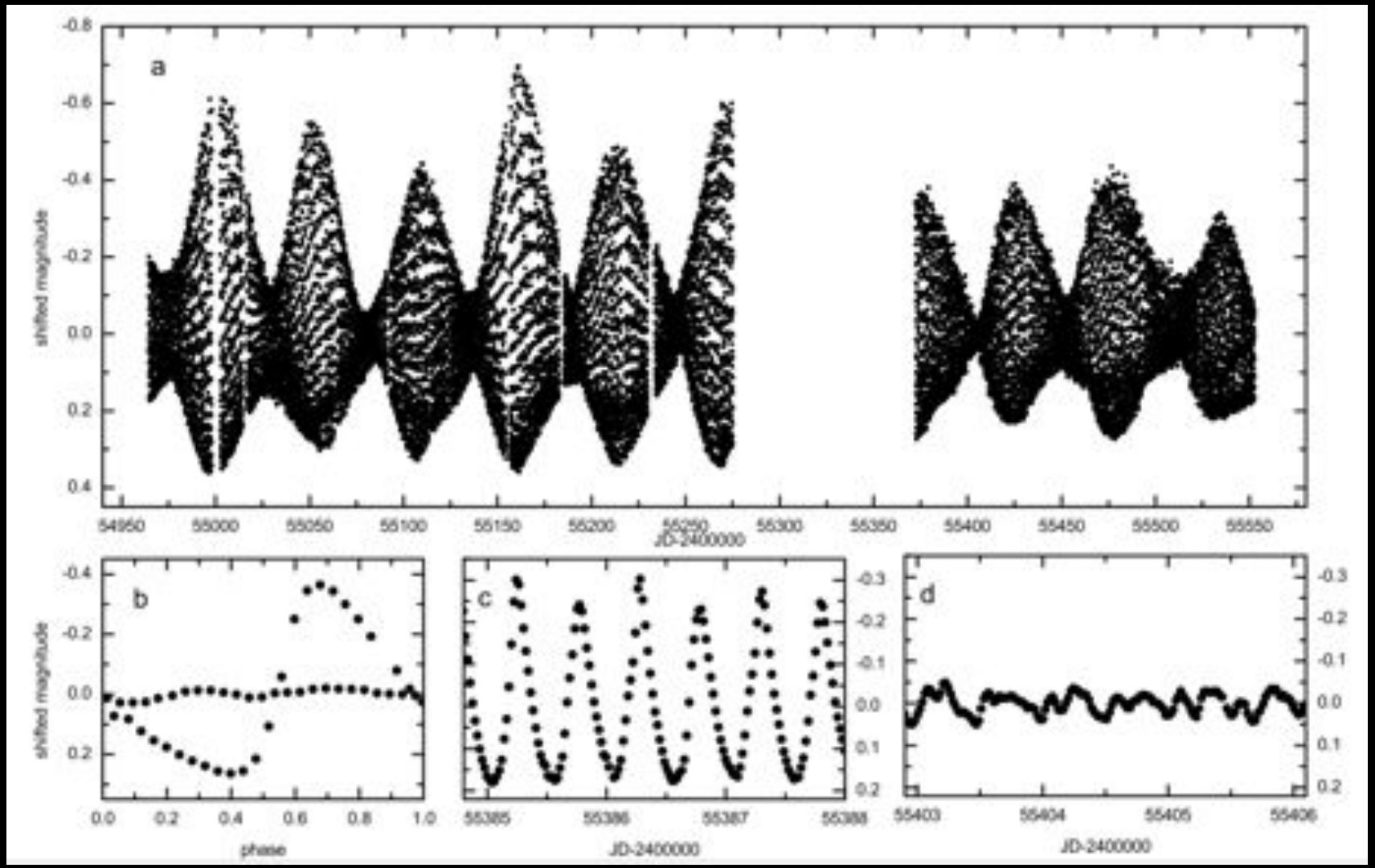
(1/2 f_O, 3/2 f_O, 5/2 $f_{O,}$…)

Kolenberg et al. 2010, ApJL 713, 198
Szabó et al. 2010, MNRAS, 409, 1244

Why was period doubling not seen before?

“terrestrial exclusion principle”

Crazy Star



Guggenberger et al., 2012

The complex case of V445 Lyr observed with Kepler: two Blazhko modulations, a non-radial mode, possible triple mode RR Lyrae pulsation, and more


GAIA MISSION

RR Lyrae Pro-Am collaborations

Dedicated ground-based observations for specific targets!

Looooong time base – slow evolution
Multicolor data supplement space mission data

Specific projects: photometry and spectroscopy

RR Lyrae Spectroscopy

- Abundance studies
- Radial Velocities
- Line profile variations

RR Lyr (prototype) – m_V = 7.1-8.1

RR Lyrae Spectroscopy

- Abundance studies
- Radial Velocities
- Line profile variations

TIME SERIES

RR Lyr (prototype) – m_V = 7.1-8.1

RR Lyrae Spectroscopy

- Abundance studies
- Radial Velocities *--- stellar/galactic dynamics, pulsation, binarity?*
- Line profile variations *--- stellar dynamics (& interior detail: pulsation, magnetism, comvection)*

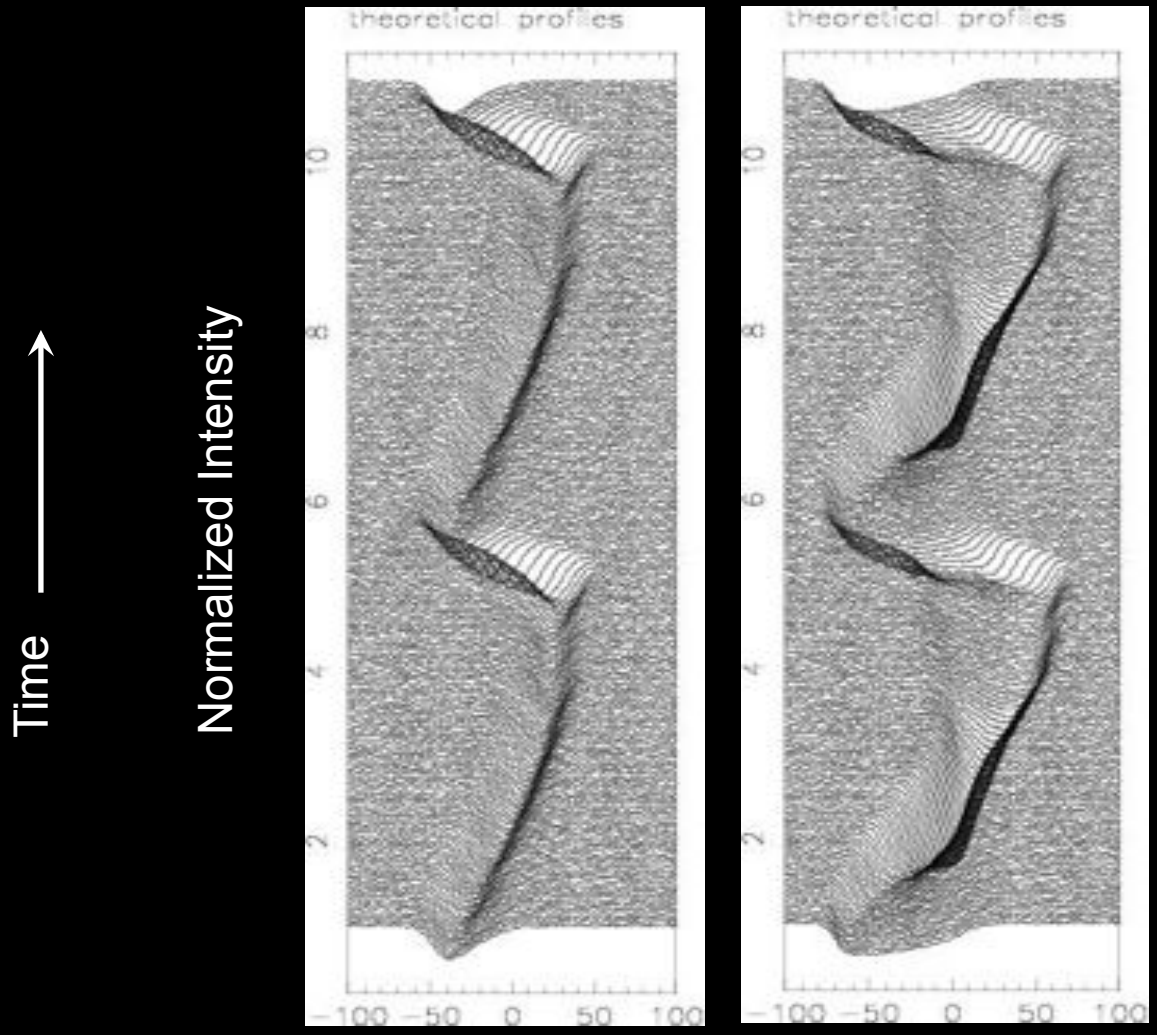
RR Lyr (prototype) – m_V = 7.1-8.1

RR Lyrae Spectroscopy

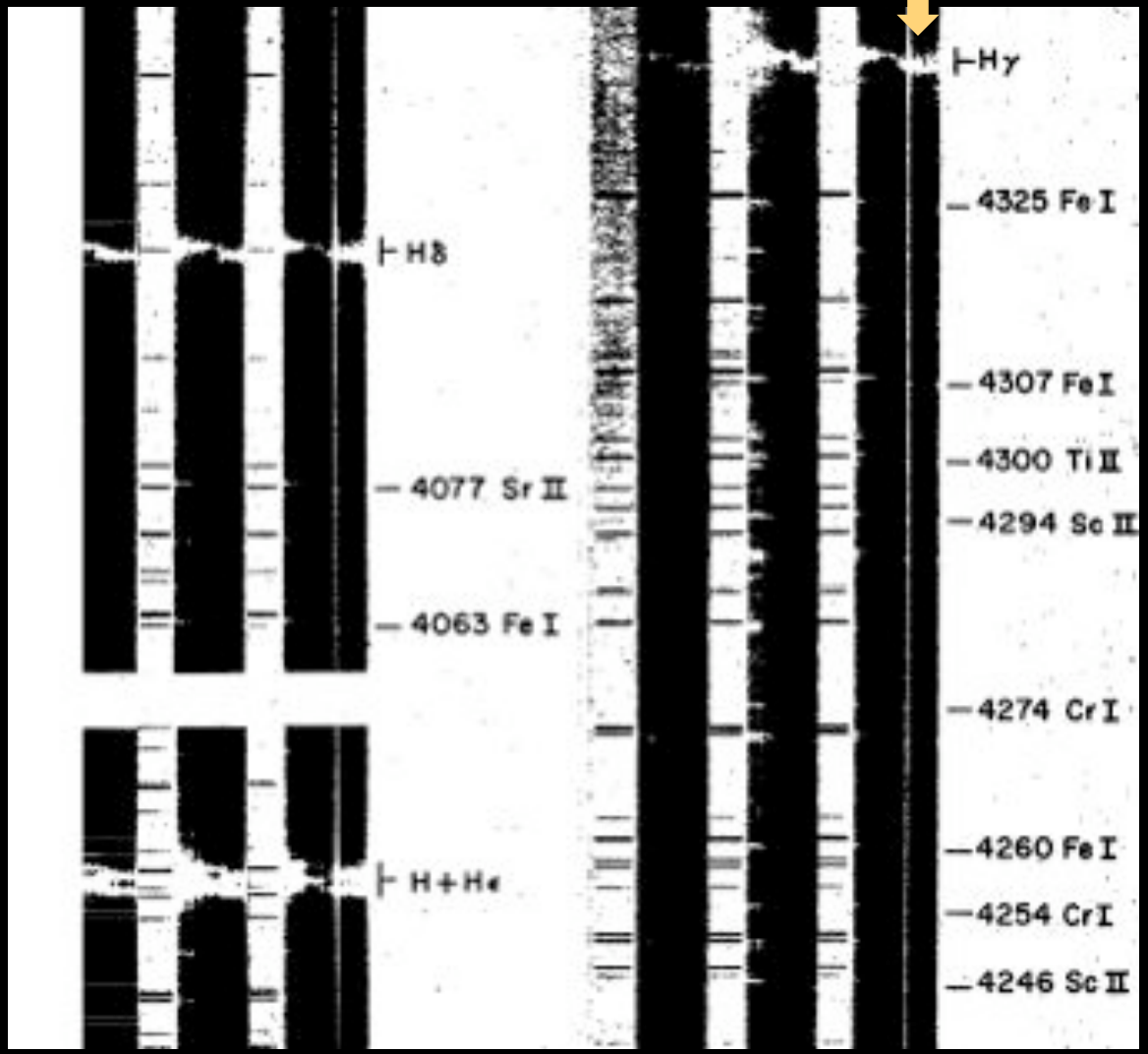
- Abundance studies: take a spectrum at the right moment
- Radial Velocities: time series, time resolution,
  combination of lines,
  mind the Van Hoof effect
- Line profile variations: minimum R > 30 000 and S/N > 100

RR Lyr (prototype) – m_V = 7.1-8.1

Influence of a nonradial mode upon the line profile variations



Spectroscopic Study of the Blazhko effect

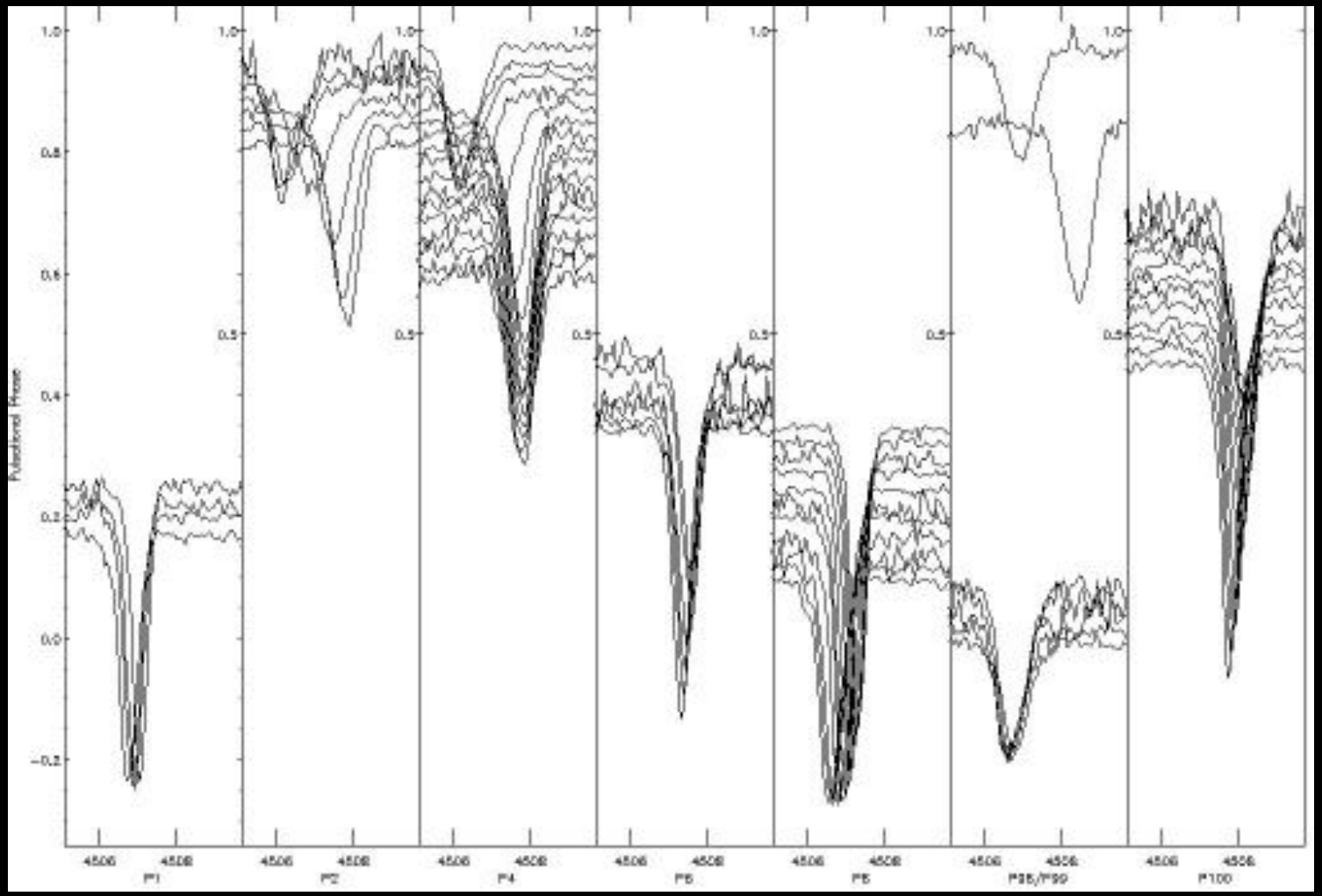


Preston, Smak & Paczynski (1965)

Level effect

No exact repetition

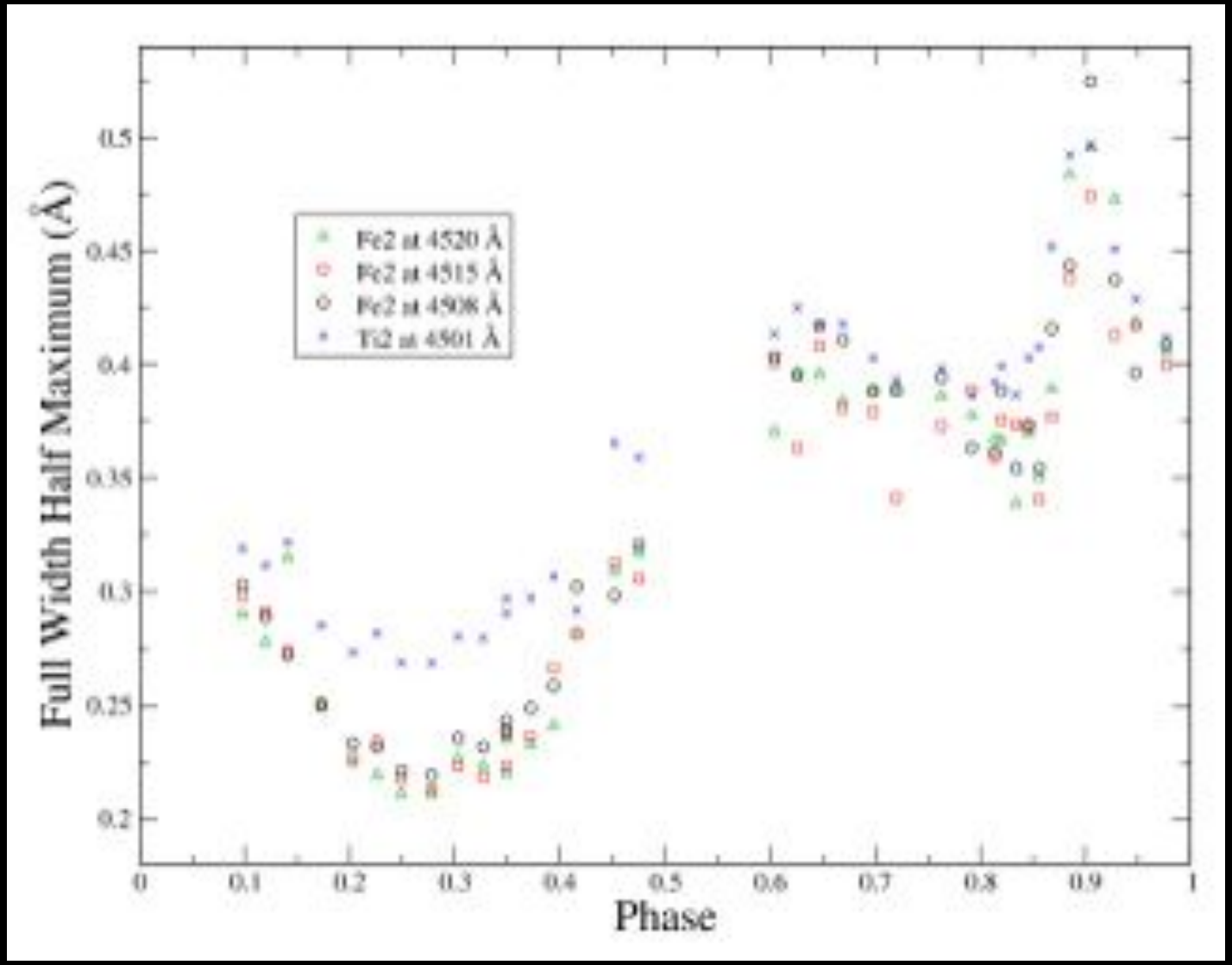
Spectra volgens pulsatiephase



----------one Blazhko phase---------- -----another one-----

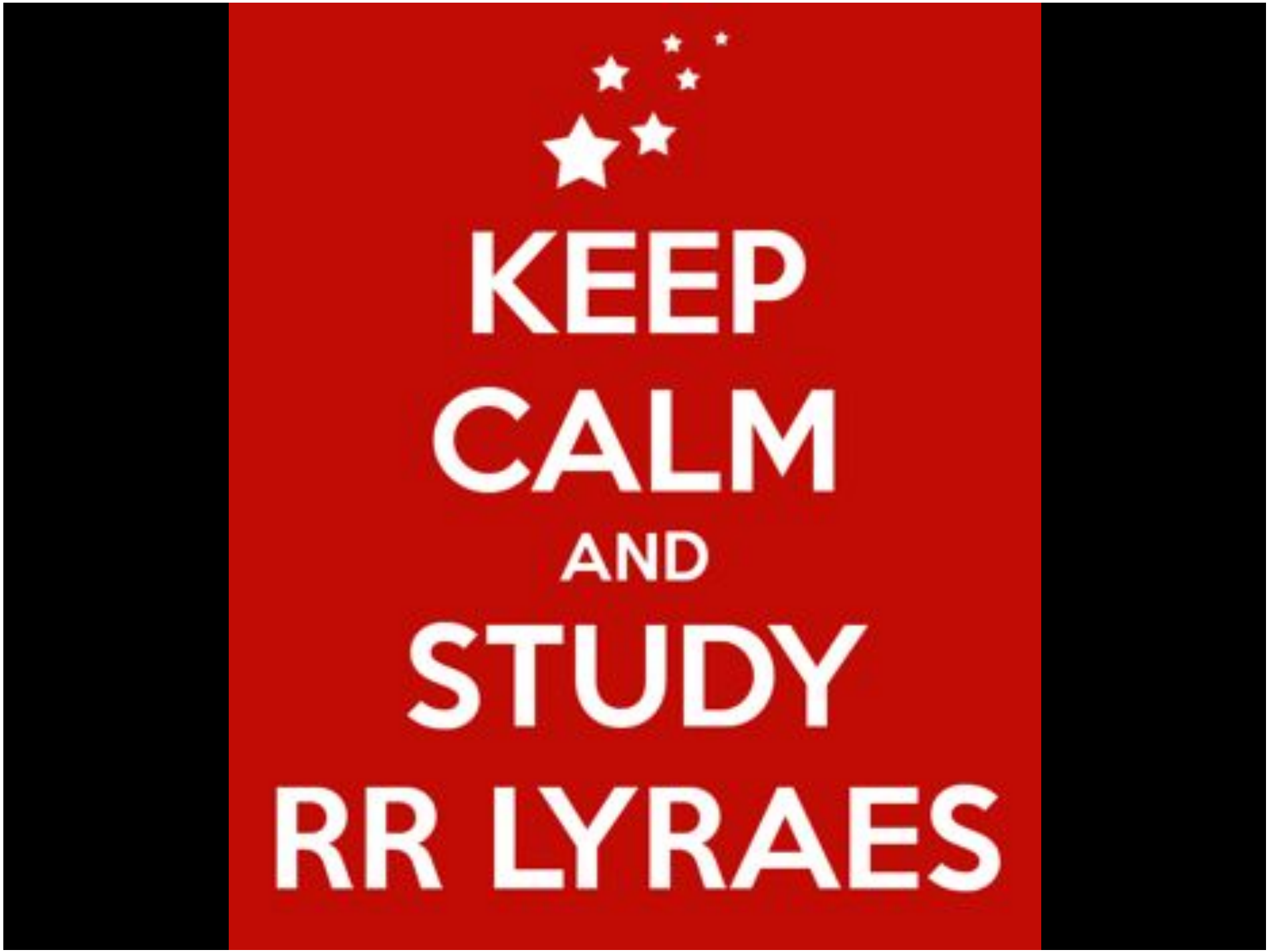
Spectroscopy of RR Lyr through the Blazhko cycle

Spectroscopic Study of RR Lyrae



Kolenberg et al. 2011

Kepler, K2, **TESS** – ground-based data


KEEP
CALM
AND
STUDY
RR LYRAES