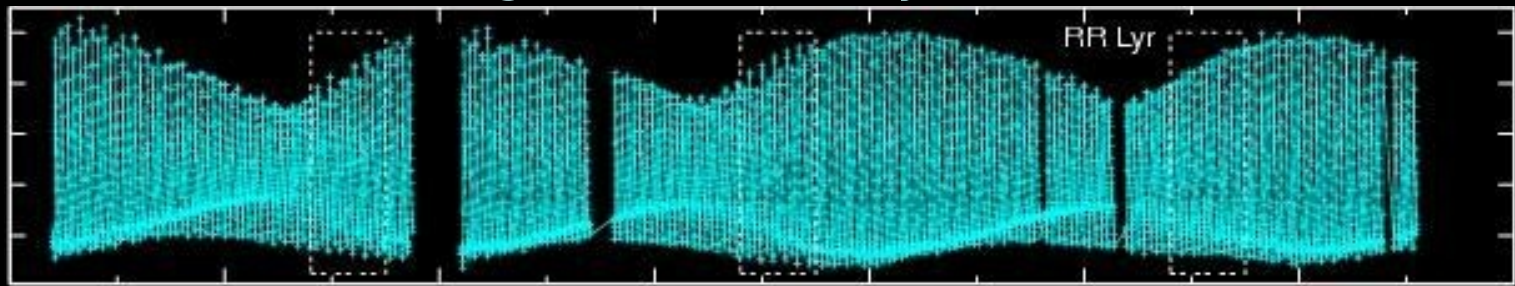


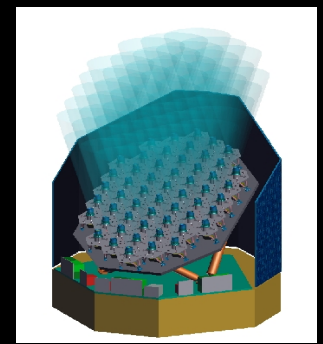
PLATO Science on RR Lyrae Stars

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K. Kolenberg + KASC WG7 +
KIK-group, <http://www.konkoly.hu/KIK/>

2013 July 31
Noordwijk, ESTEC
PLATO 2.0 Science Workshop



RR Lyrae variables

Radial pulsators

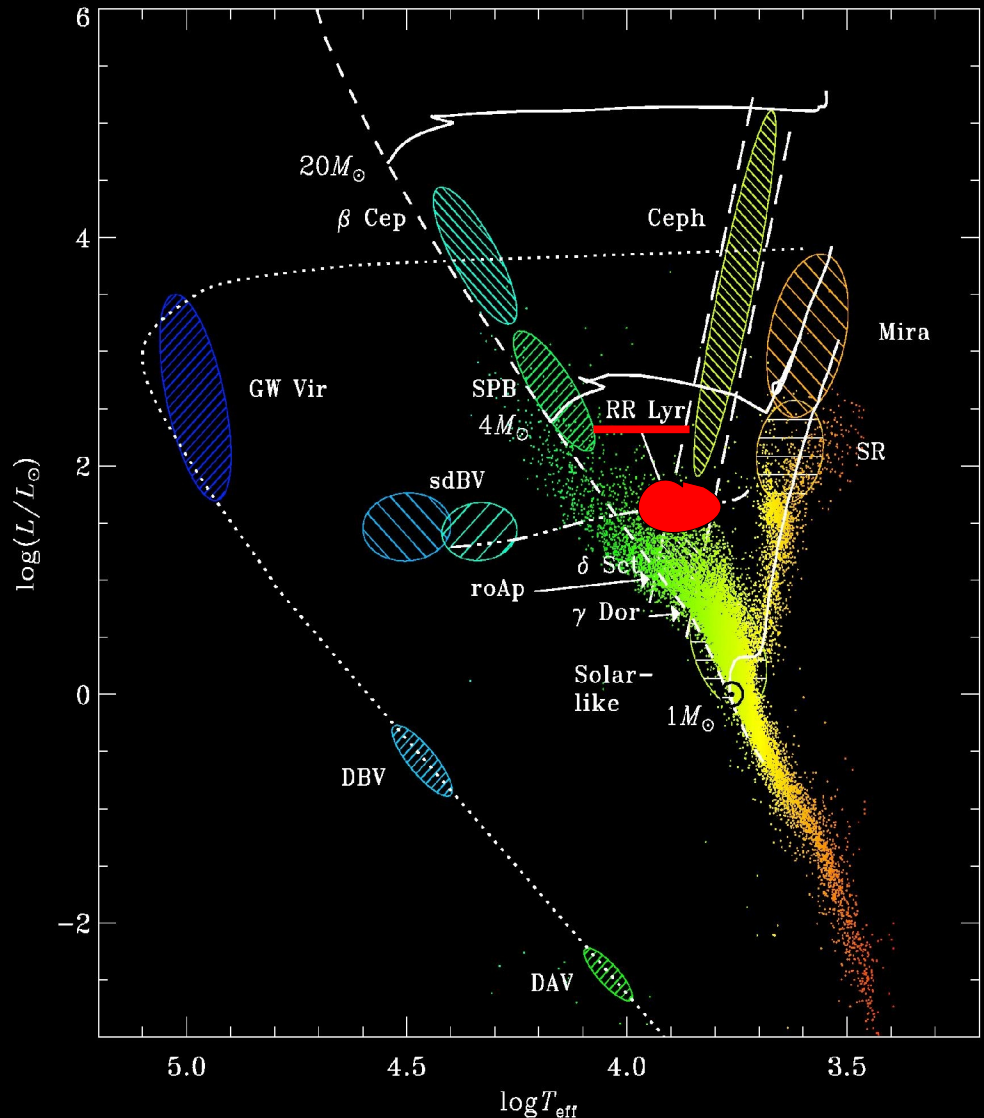
- RRab (fundamental mode)
- RRc (first overtone)
- RRd (double-mode)
- Kappa mechanism
- Period: 0.2 – 1.0 days
- Amplitude: 0.5-1.5 mag

Pop II. horizontal branch

- He-burning in the core
- GCs, halo, thick disk

Standard candles

Galactic structure tracers



Credit: Jørgen Christensen-Dalsgaard

RR Lyrae - unsolved problems

- Blazhko phenomenon

Amplitude and period modulation
century-old enigma (Blazhko 1907)

- long-period modulation
- very small modulation
- dis-/reappearance of the modulation
- multiple modulations
- irregularities

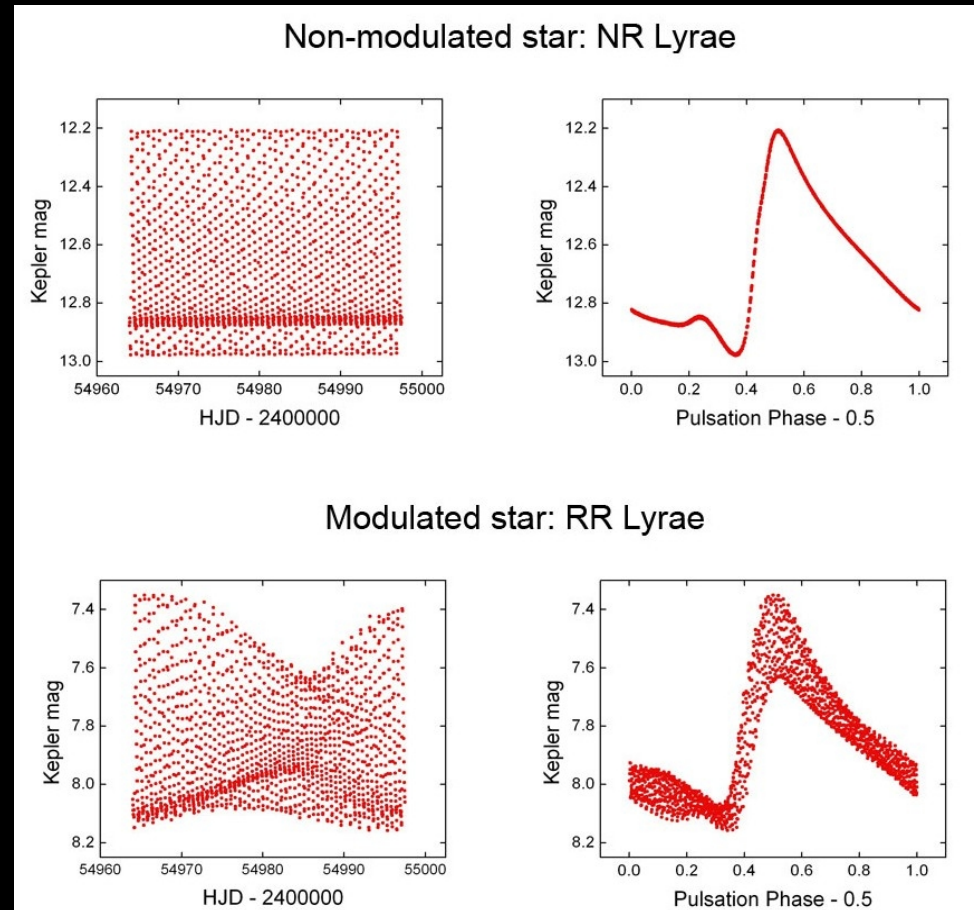
Need: long, uninterrupted monitoring

Presence of small amplitude radial and/or nonradial modes .
Do they play a role in the Blazhko-mechanism?

Need: precise photometry

- statistics, occurrence rate

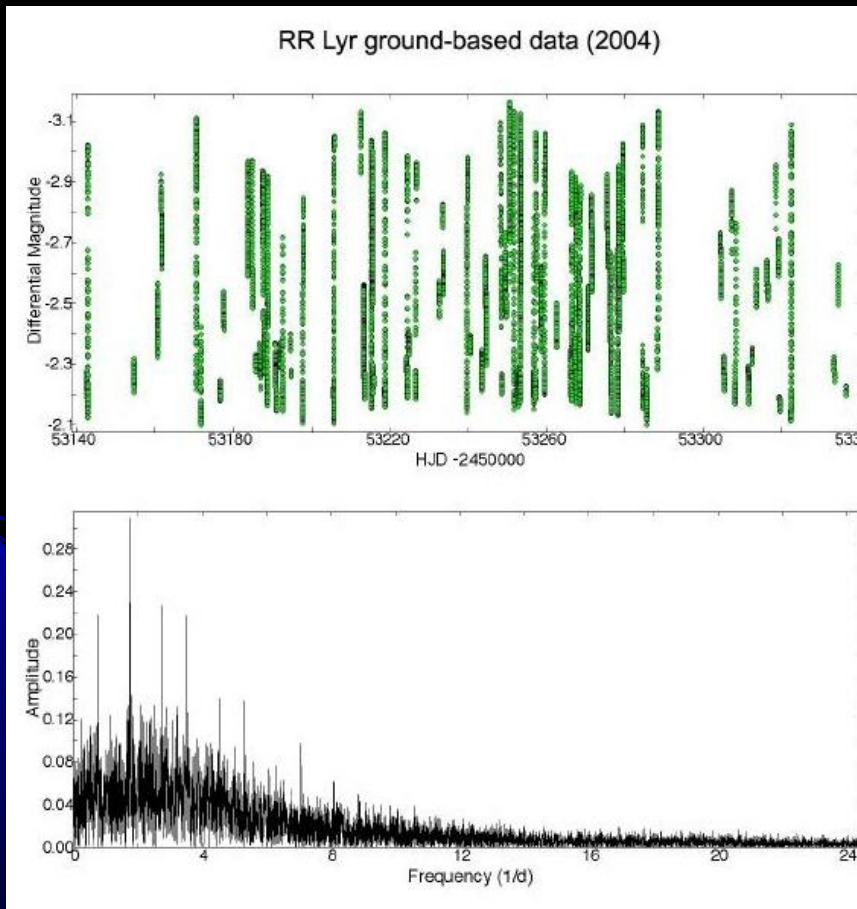
Need: many targets



Kepler Q1 data

Kepler: continuous monitoring

Kolenberg, Bryson, Szabó et al. MNRAS, 411, 1167, 2011

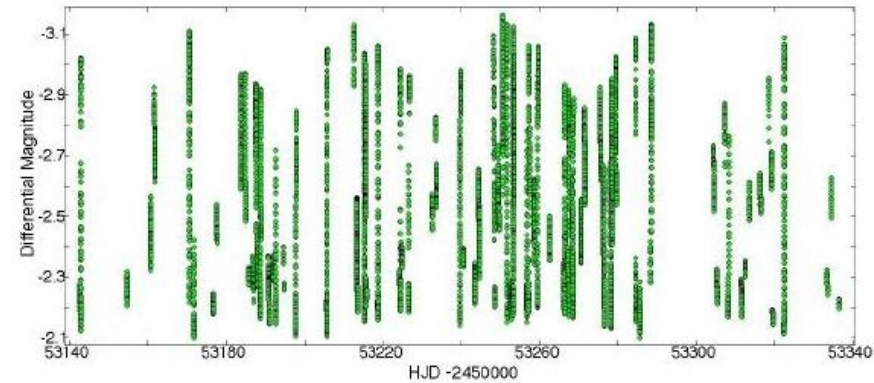


Ground-based multisite photometric campaign (6 observatories)

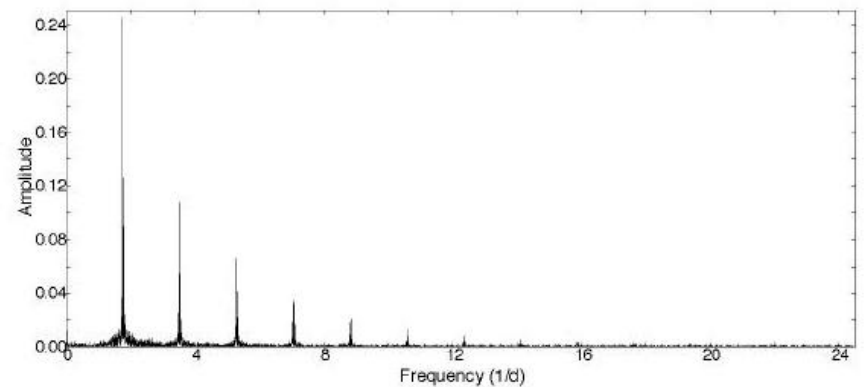
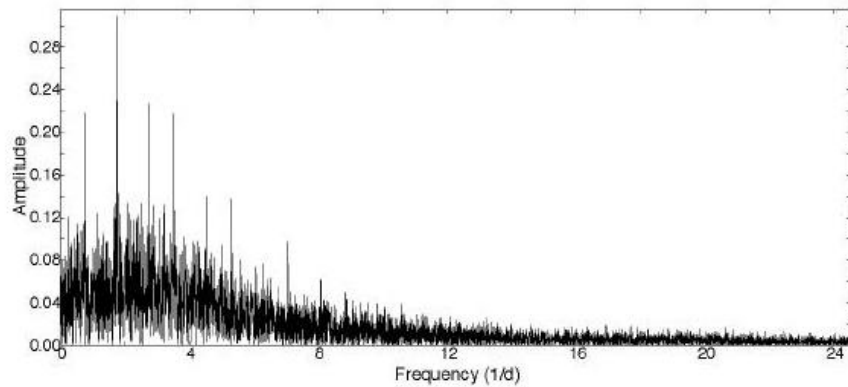
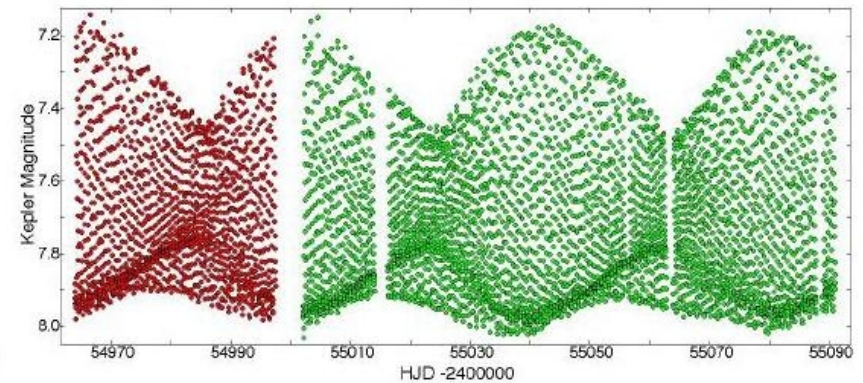
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RR Lyr ground-based data (2004)



RR Lyr Kepler Q1+Q2 data (2009)



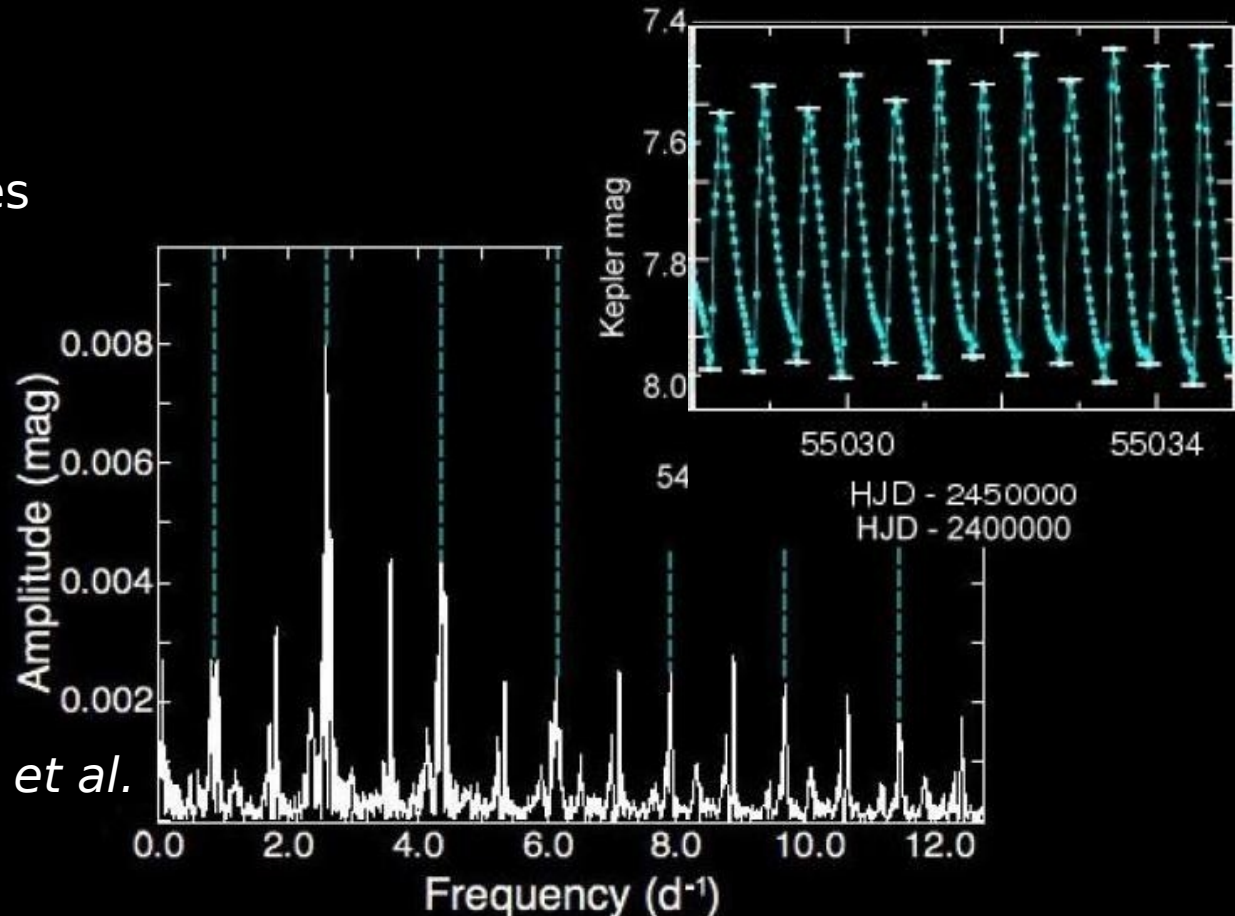
Ground-based multisite photometric campaign (6 observatories)

Kepler

An unexpected discovery: period doubling (PD) in RR Lyrae stars

Manifestation:

- alternating cycles
- half-integer frequencies ($1/2 f_0$, $3/2 f_0$, $5/2 f_0$...)



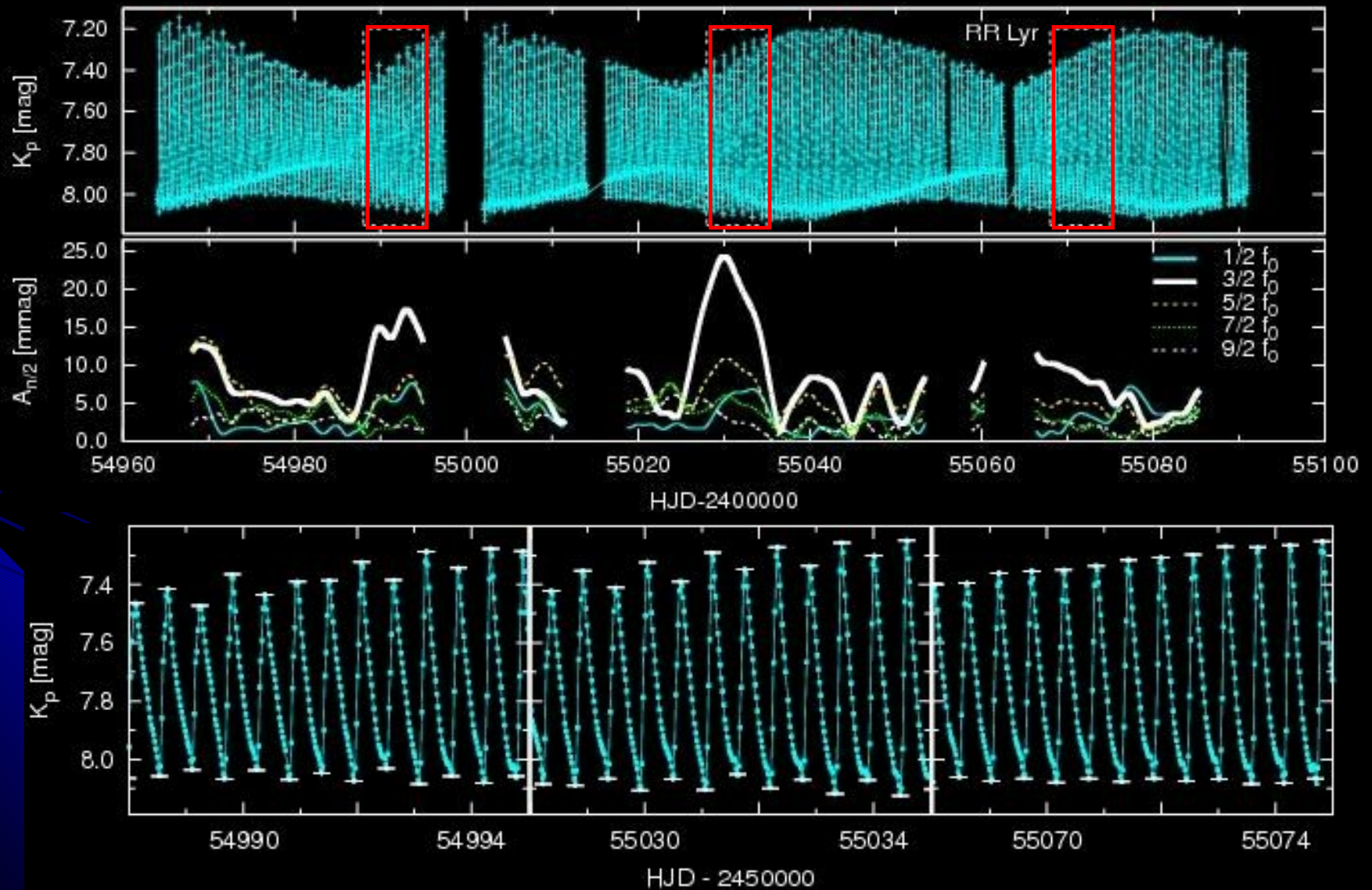
Kolenberg, Szabó, Kurtz, et al.
2010, *ApJL* 713, 198

Szabó, Kolláth, Molnár et al.
2010, *MNRAS* 409, 1244

RR Lyr Q1 Kolenberg et al. 2010

PD has never been observed in RR Lyr stars nor in RR Lyr models.

Period doubling in RR Lyr (Q1+Q2)



Period doubling

Period doubling:

- interesting nonlinear dynamical phenomenon
- Key to the Blazhko enigma:
 - period doubling is seen only in Blazhko stars
 - period doubling is seen in most of the Blazhko stars

Models and explanation

Hydrodynamic calculations proved that **the cause of the period doubling effect is a high order resonance (9:2) between the fundamental mode and the 9th radial overtone** (strange mode).

Szabó, R., Kolláth, Z., Molnár, L. et al.

2010, MNRAS 409, 1244

Kolláth, Z. Molnár, L., Szabó, R.

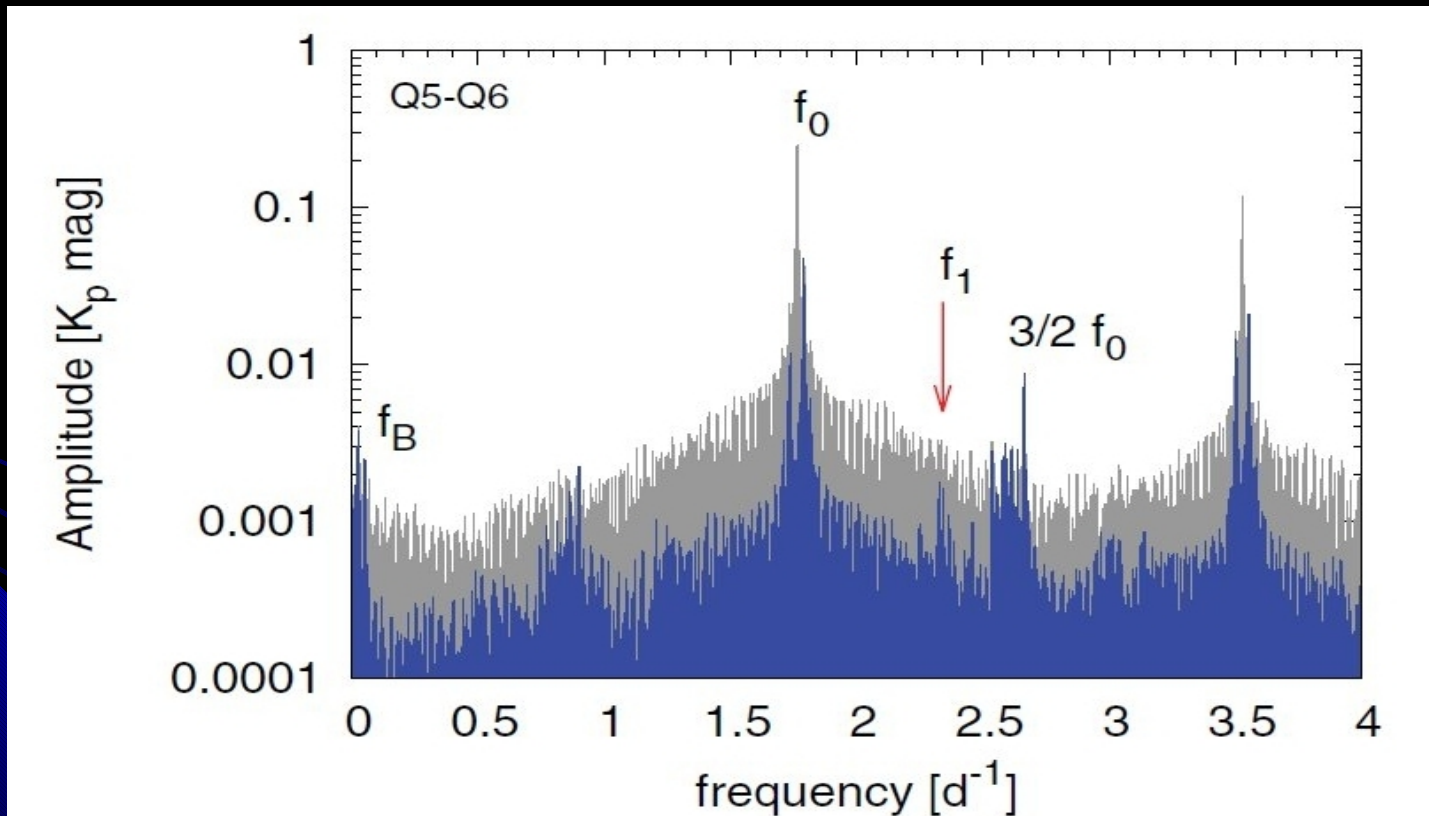
2011, MNRAS 414, 1111

Period doubling

PD led to the discovery of a plethora of other dynamical phenomena:

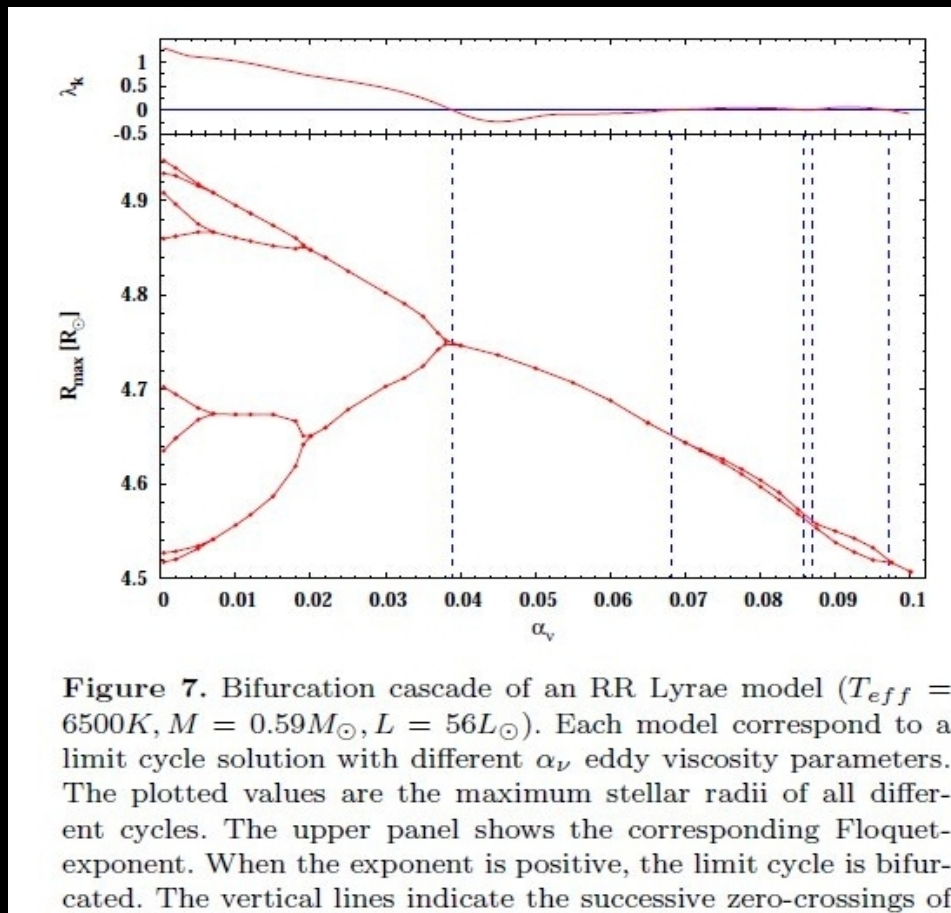
- **high order resonances** (9:2)
Szabó, Kolláth, Molnár et al. 2010, MNRAS 409, 1244
- presence of **high radial overtones** (strange modes)
Kolláth, Molnár, Szabó 2011, MNRAS, 414, 1111
- presence of other radial modes (**1st and 2nd overtones**)
in Blazhko stars
Molnár, Kolláth, Szabó et al. ApJL, 2012, 757, 13
- even low-dimensional **chaos**
Plachy, Molnár, Kolláth 2013, MNRAS in press, arXiv:1306.1526
- **new explanation of the Blazhko effect**
Buchler & Kolláth ApJ 2011, 731, 24

Excited first overtone, triple mode state, nonlinear asteroseismology



RR Lyrae the eponym, Kepler data
Molnár, Kolláth, Szabó et al. ApJL, 757, L13, 2012

Bifurcation cascades leading to chaos

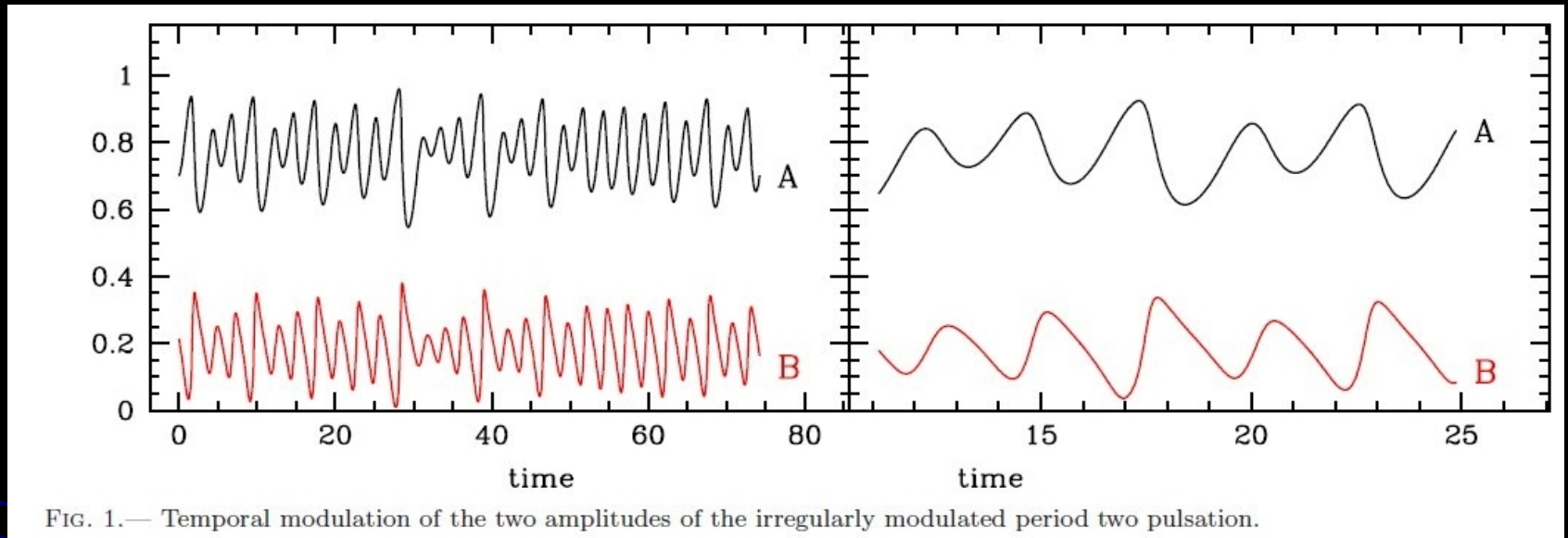


Bifurcation-cascade
(Feigenbaum)

This phenomenon
is a true bifurcation
in a dynamical
sense confirmed by
the cascade.

The cascade can
lead to chaos.

A new explanation for the Blazhko effect



Using amplitude equations it has been shown that irregular amplitude modulations naturally result from the nonlinear resonant mode coupling between the fundamental mode and the 9th overtone.

Buchler & Kolláth ApJL, 731, 24, 2011

Relevant parameters of sky surveys

- **Number of targets observed (sky coverage)**
 - **Limiting magnitude (dynamic range)**
 - **Passband(s)**
 - **Photometric precision**
 - **Duty cycle (temporal coverage)**
- **OGLE**
 - **CoRoT**
 - **Kepler**
 - **Gaia**
 - **LSST**
 - **TESS**
 - **PLATO**

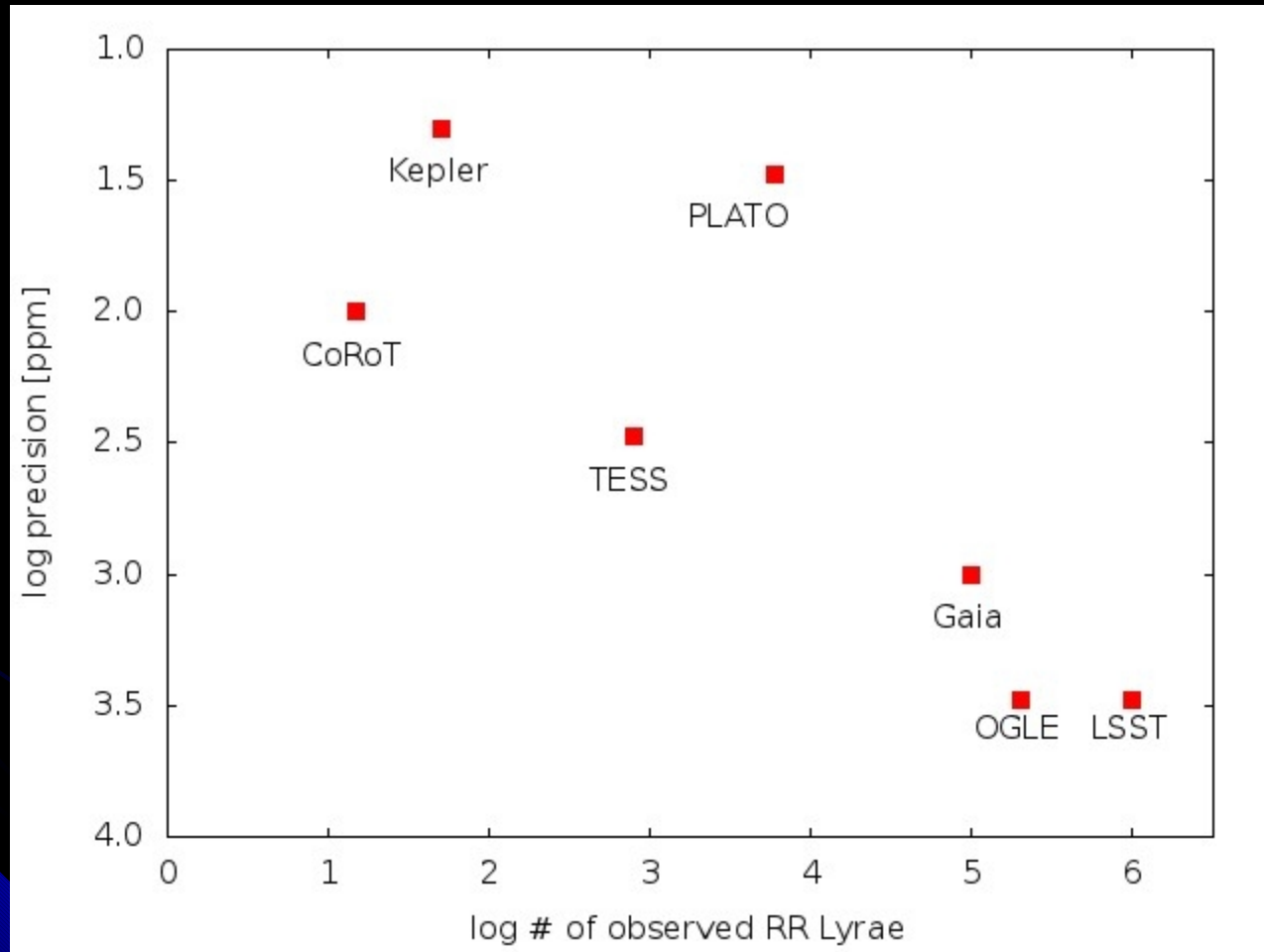
Exploring new territories of the parameter space usually (always?) leads to unexpected results!

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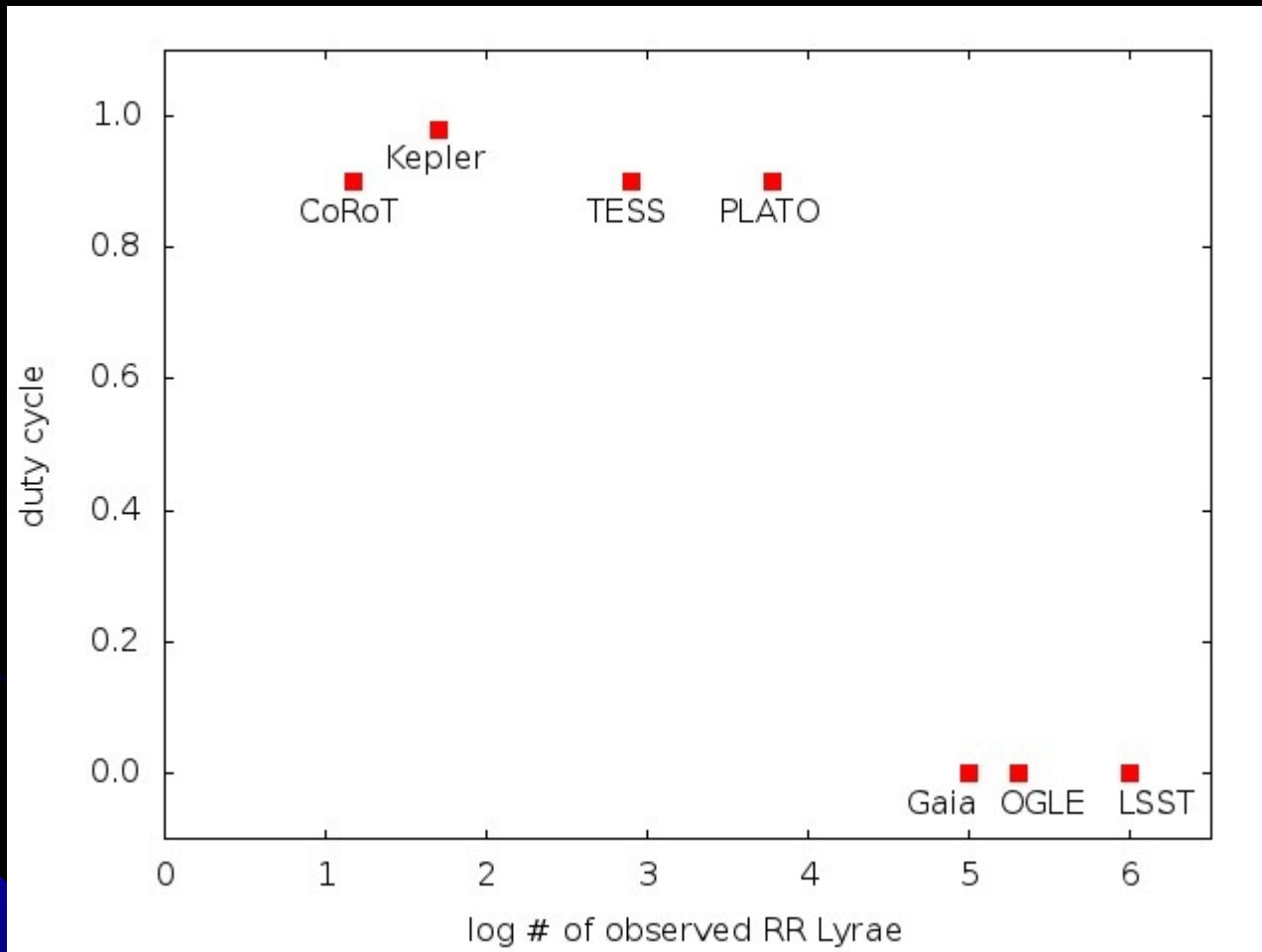
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PLATO prospects



PLATO will bridge the gap between the number of targets and precision.

PLATO prospects



PLATO will bridge the gap between the number of targets and duty cycle.

Thank you

