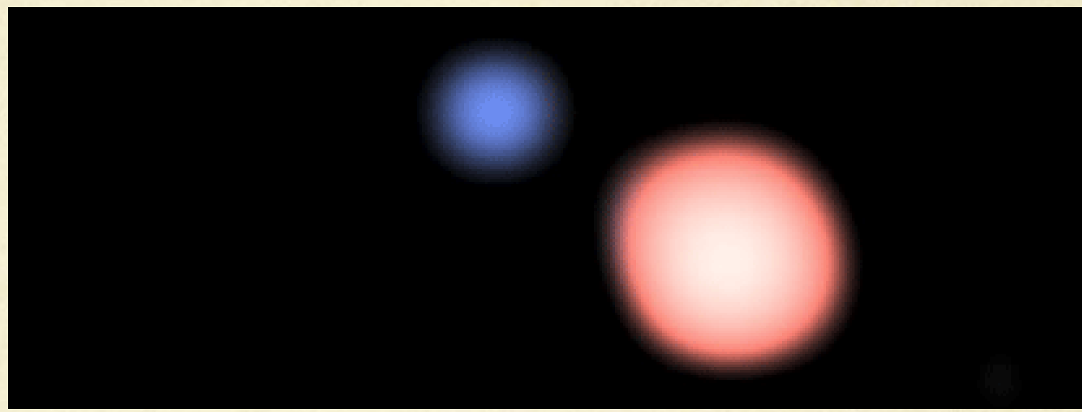
Calibrating Asteroseismology with Multiple-Star Systems



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PLATO mission conference - Sept 5th 2017

Context

- Solar-like stars: asteroseismology leads to global & internal properties
  - Scaling relations: comparison oscillations properties with the Sun's. Mass, radius ⇔ inference on age and distance
  - Massive use for Galactic archeology, exoplanetary properties, etc
- Classical pulsators (e.g., γ Dor, δ Sct, β Ceph, SPB, Be, roAp): asteroseismology is more complex than for solar-like stars
  - Difficulty in mode identification, rotational splitting, frequency combinations, mode selection, etc
  - Significant progresses lately (Bedding+15, Kurtz+15, Van Reeth+15)
- Important need for PLATO
  - Solar-like: scaling relations have never been thoroughly calibrated
  - Classical pulsators: workbenches to help deciphering oscillations
- Main focus on solar-like stars, but keeping in mind characterizing classical pulsators is very important too.

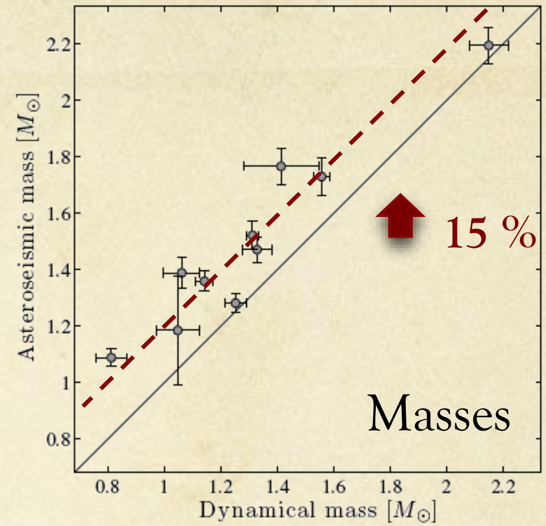
How to calibrate asteroseismology?

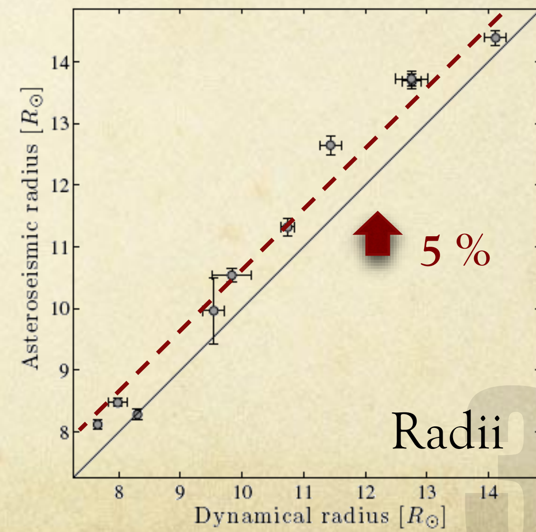
- Theoretical works
  - Most regard $\Delta\nu$ □ ρ (Stello+09; White+11; Miglio+13)
  - ν_{max} – g has less secure theoretical basis (Belkacem+11)
  - Need for independent M,R measurements of osc. stars

- Radii
  - Astrometry (GAIA): distance, extinction ⇔ radius
  - Interferometry: radius, provided LD, and bright enough
  - Accuracy within 5% (Huber+11,+12; Silva Aguirre+12; Baines+14)

- Masses: not many options
  - Binaries, triple systems (eclipse LC + RVs)
  - Gaulme+16: M overestimated by 15%, R by 5% for 10 red giants in EBs.
  - Brogaard et al (submitted): 3 RG/EB from Gaulme+16 sample. No significant overestimation provided $\Delta\nu$ modified

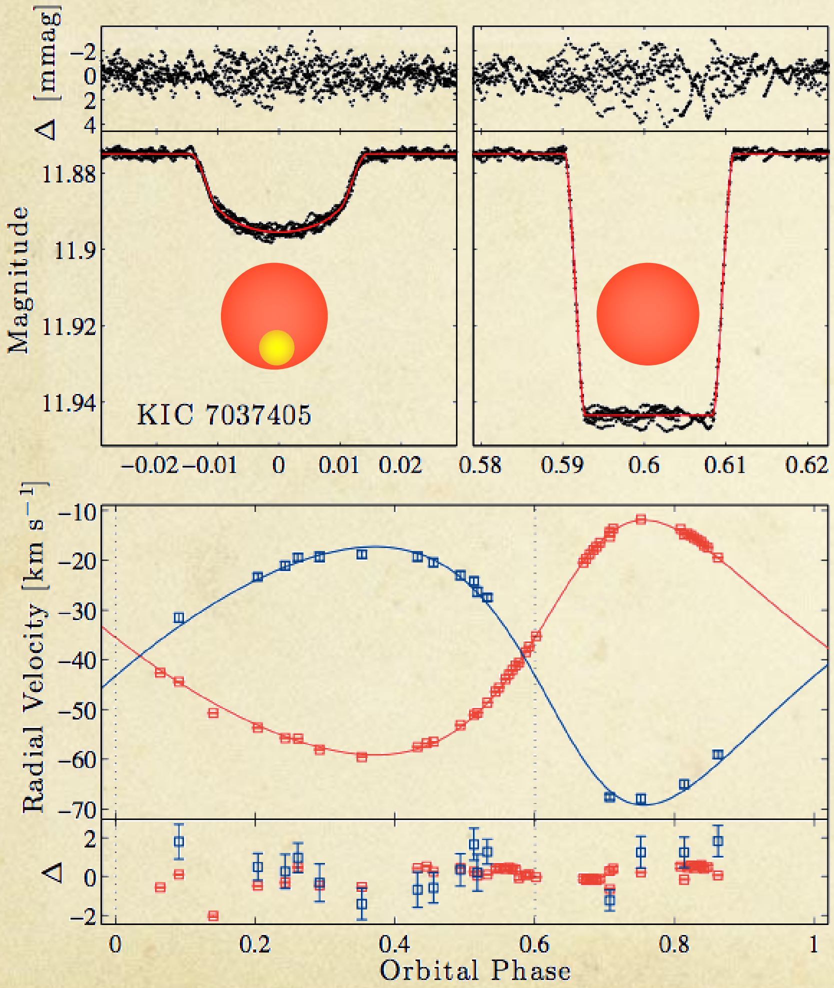
- Need a large sample
  - 50 solar-like from main sequence to red giant
  - 50 classical pulsators (g Dor, d Sct, hybrid)





[From Gaulme+16]

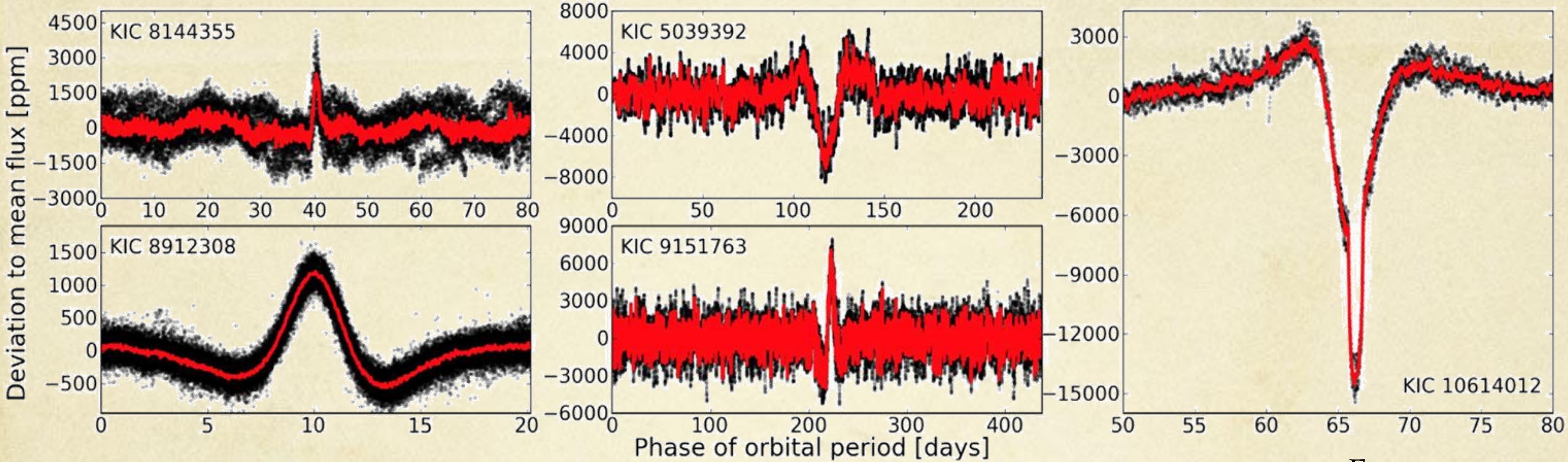
Eclipsing Binaries



From Gaulme+16

- ❑ Double-lined spectroscopic binaries (SB2)
- ❑ Eclipse photometry
  - ➢ R1/a, R2/a, T2/T1, e, *i*, limb darkening, P_{orb}, T_0,
- ❑ Radial velocities
  - ➢ M1 sin*i*, M2 sin*i*, P_{orb}, T_0, e, Ω
- ❑ Combined analysis: M1, M2, R2, R2

Eccentric binaries "heartbeat stars"

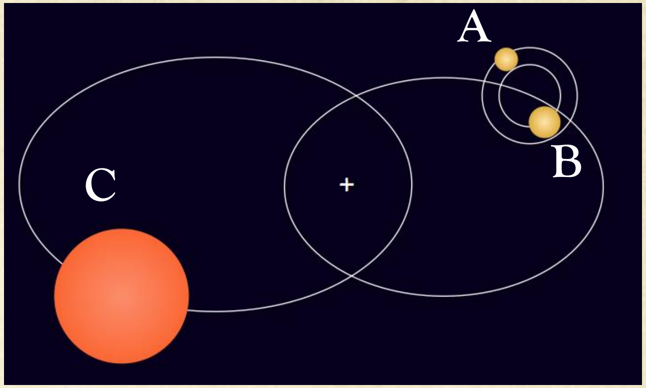


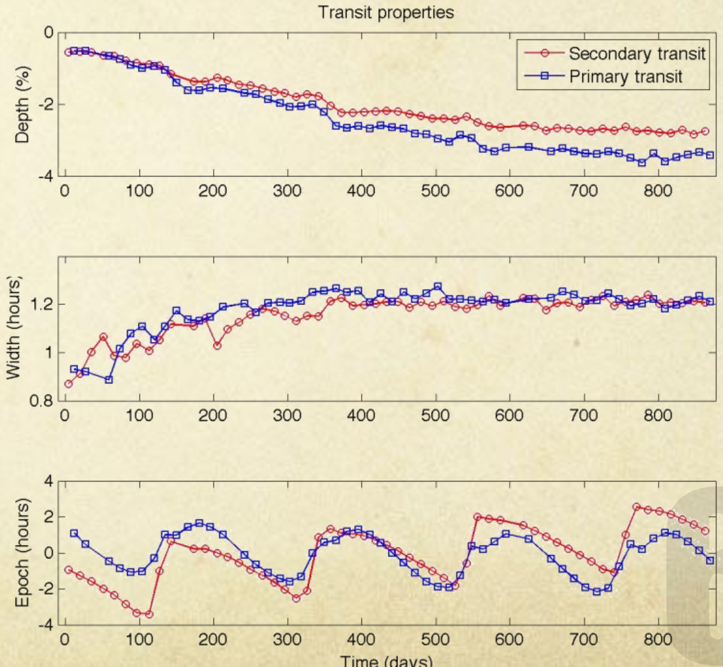
From Beck+14

- Highly eccentric binaries
  - Tidal distortion at periastron, tidal modes
  - LC modeling: inclination
  - Complementary RVs: if SB2 we can extract masses
- Are there many SB2s among heartbeat stars?
  - Likely not: small companion ⇔ long circularization & synchronization timescales (e.g., none in Beck+14)

Hierarchical triple systems

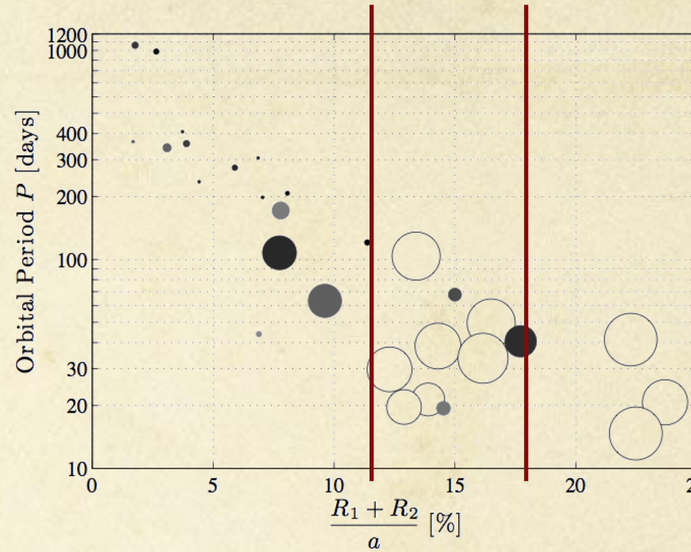
- Red giant + 2 main sequence
  - Eclipse timing variations
  - Light travel time + dynamical effects allow for estimating M_C and $M_{A,B}$
  - Rough estimate though (Borkovits+16)
- Complementary RVs
  - SB1 condition sufficient to measure Mc

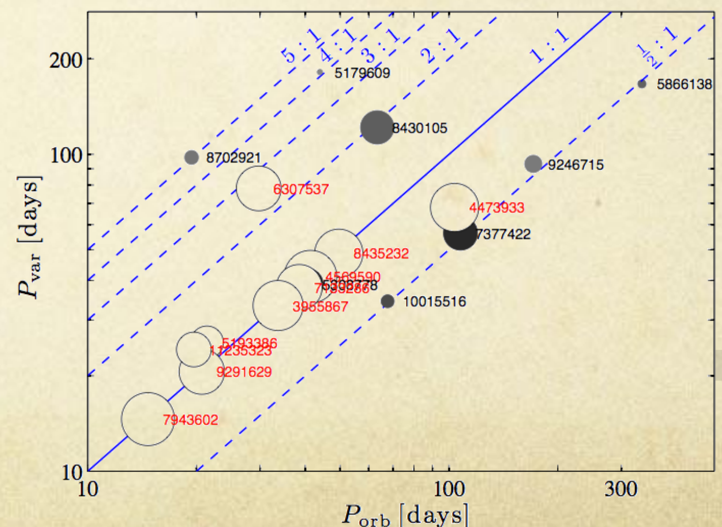




Oscillations suppression

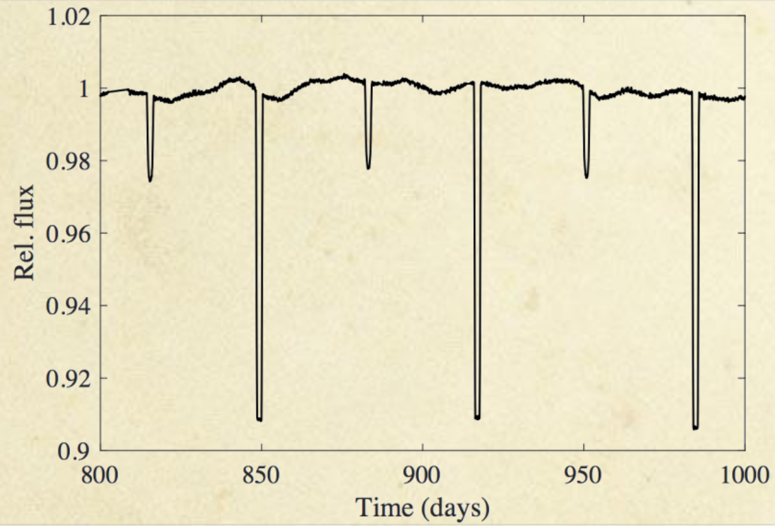
- Solar-like oscillators in EBs: only Kepler red giants
- Oscillations are suppressed when systems are too close (Gaulme+14)
  - [R1+R2]/a < 12 % always oscillations
  - [R1+R2]/a > 18 % no oscillations
  - Non-oscillating RGs: usually synchronized + circularized
- Triple system: no oscillations in Derekas+11 system
- Systems must not be too close

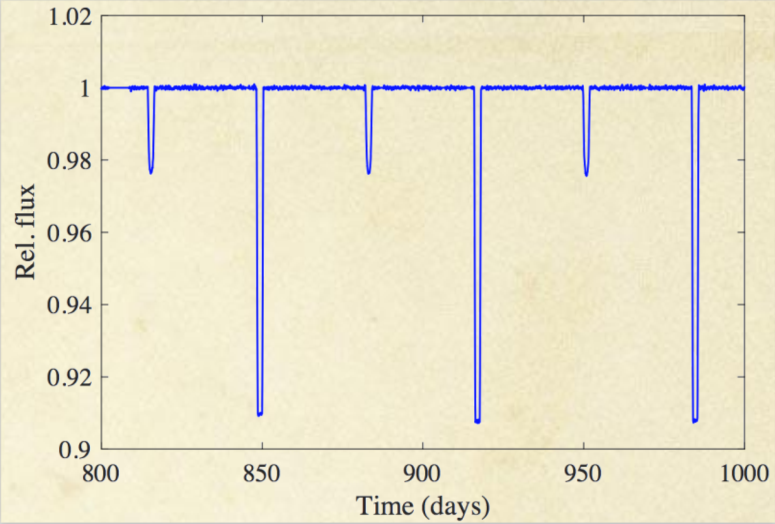


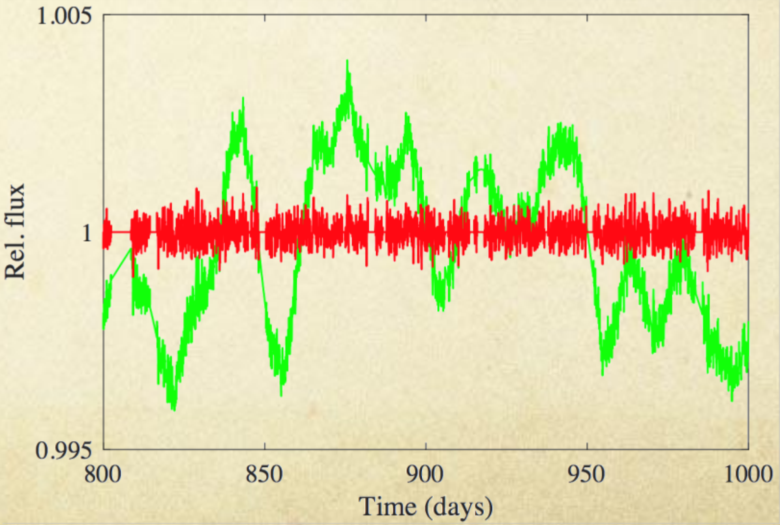


How to meet the goal

- Light curve processing
  - Eclipses
  - Rotation
  - Oscillations



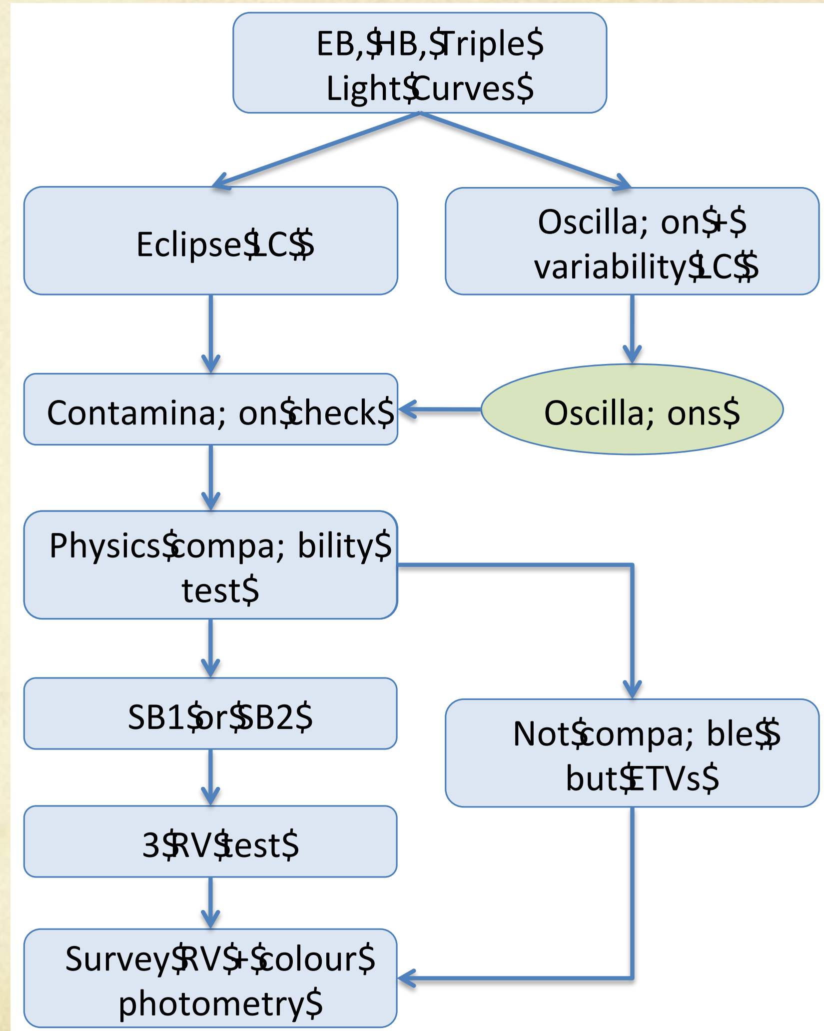




- Automatic procedure (Gaulme+13,+16)

How to meet the goal

- Target selection
  - Orbital period. E.g., for RGs, cannot be much less than 10 days
  - Target pixel files (contamination): comparison deepest eclipse and largest oscillation pixels
  - Kepler's third law: mass ratio
  - SB1 vs SB2 from 1 optical spectrum
  - RV variations



How to meet the goal

- Kepler and CoRoT: so far 24 solar-like and 25 classical pulsators for which masses can be determined

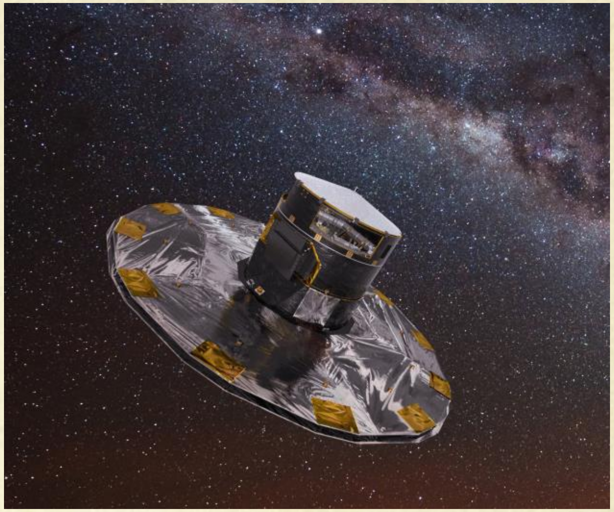
Osc type	System type	SB1/SB2	Osc.	#	#
Evolved Solar-like	EB: RG+MS	SB2	RG	17	24
	EB: RG+RG	SB2	1RG	2	
	HT: ETV (LTTE+dyn)	?	RG	5	
	EB: RG+MS	SB1	RG	15	59
	EB: RG+MS	SB2	None	18	
	HT: ETV	?	RG	6	
	HB: RG+MS	?	RG	20	
Classical	dEB: MS+MS	SB2	δ Sct and/or γ Dor	20	25
	SD: MS+MS	SB2		2	
	ELV: MS+MS	SB2		3	

From:
Gaulme+13,+14,+16; Beck+14,+15; Gaulme&Guzik+14, Coughlin+11, Garcia-Hernandez+15, Gaulme in prep.

- Existing databases: Kepler, K2, CoRoT
  - Few more EBs in Kepler among ≈3,000 EB catalog
  - K2: catalog of ≈700 EBs. Orbits limited to 90 days
  - CoRoT: 2,000 EBs + a few triple. Orbits limited to 180 days

How to meet the goal

- Main issue: so far, no solar-like oscillating main sequence and subgiant in EBs
- TESS: increase sample size; brighter magnitudes
- GAIA: expected to detect 250,000 EBs that are SB2
  - 40 RV measurements per star
  - Insufficient photometric precision
  - TESS targets
- PLATO
  - Workbench targets from GAIA EB catalog
  - Ground-based support: photometry, spectormetry (atm. param.)



Conclusions

- Calibrating asteroseismology of solar-like stars is fundamental for PLATO
- Reference classical pulsators will help deciphering their oscillation spectra
- Goal of at least 50 and 50 stars
- Red giants and classical pulsators: "easily" doable with current databases
- Main sequence & subgiants: GAIA, TESS. If not sufficient, prepare target characterization from ground for PLATO.
- Significant need of ground-based observations in the next 5-10 years: HR spectrometry, color photometry