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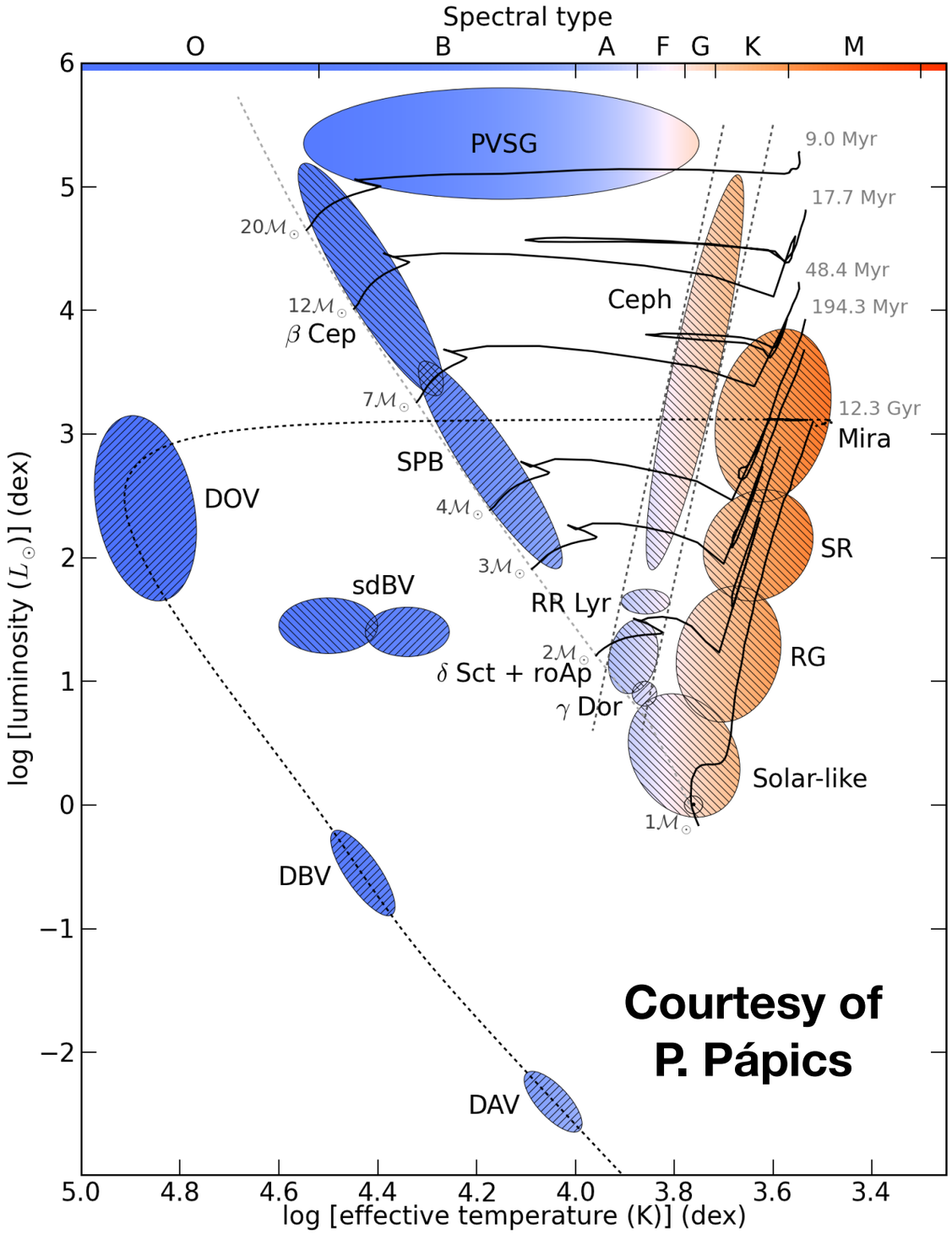
Asteroseismology of dwarfs and massive stars



Valentina Schmid: binaries
Péter Pápics: SPB stars
Conny Aerts: all the rest

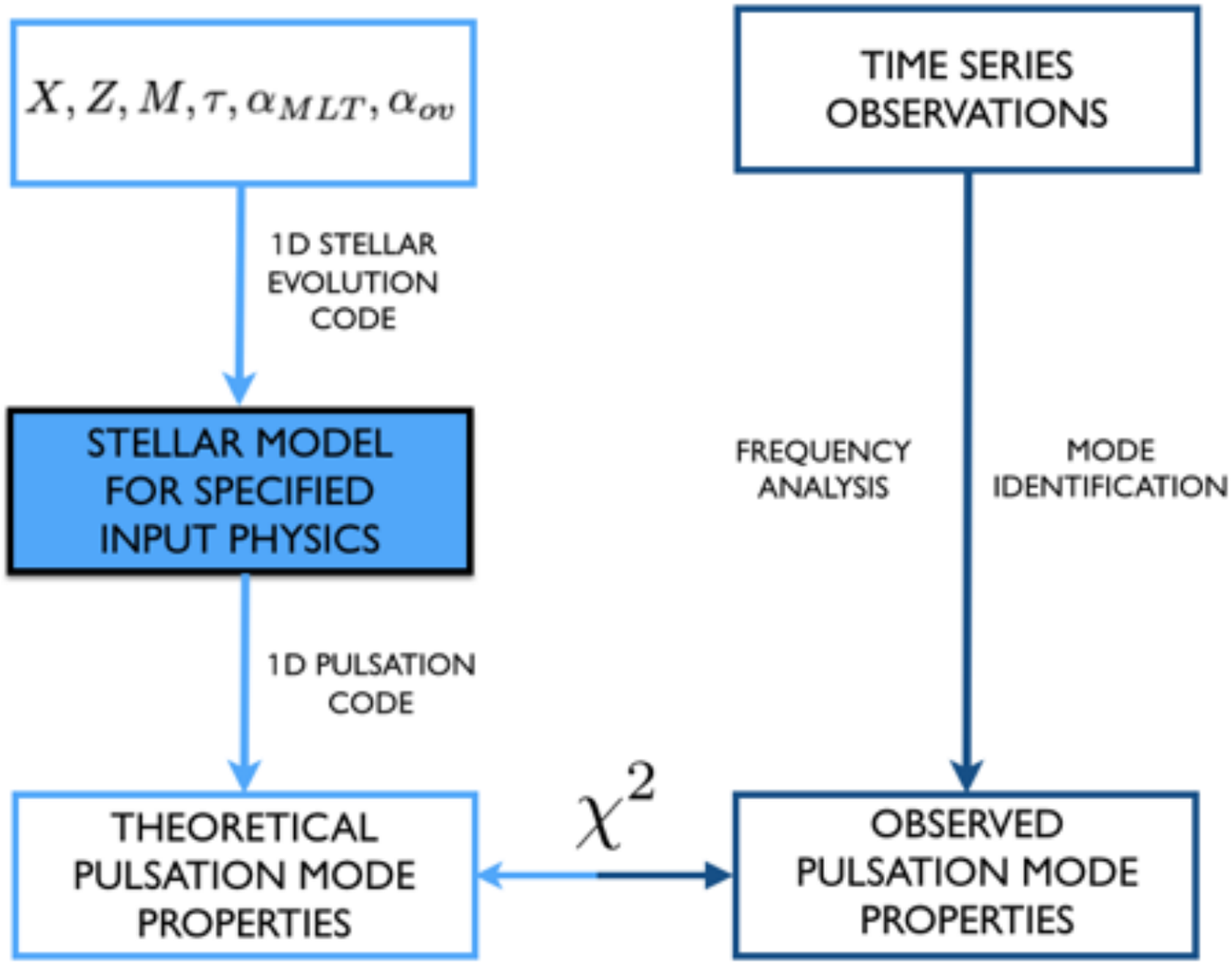
Highest mass: 24 M⊙ (CoRoT)
Lowest mass: 0.8 M⊙ (Kepler)

Solar-like pulsators: [0.8,2.0] M⊙
Heat-driven pulsators: >1.5 M⊙

Two global aims of asteroseismology

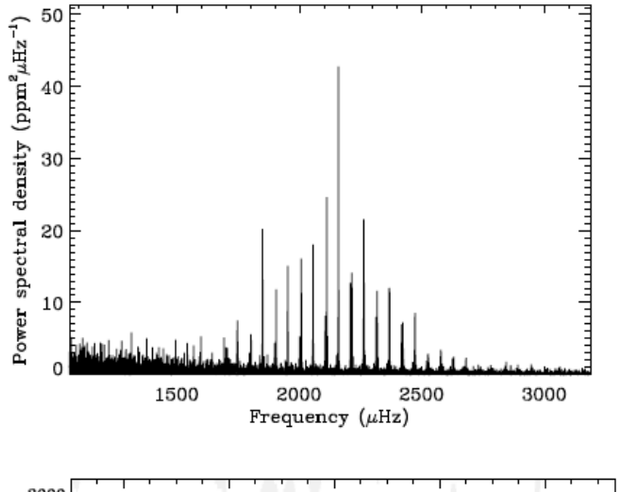
- Deliver **mass, radius, age** to **exoplanet, binary, cluster, galactic archeology … studies** **far better than classical observables** (photometric indices, spectroscopy, interferometry, polarimetry, …)

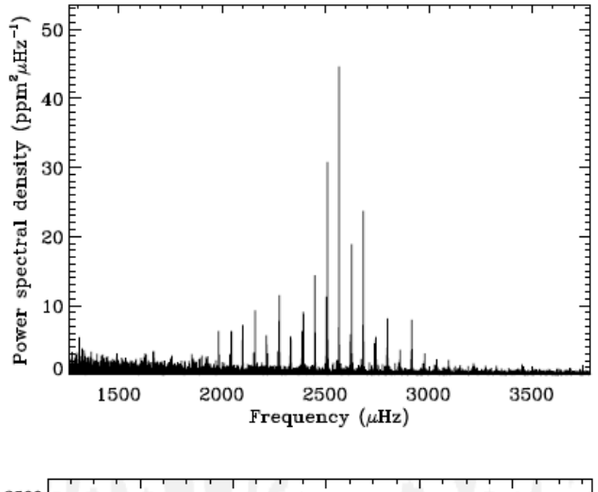
- Improve **stellar physics & stellar evolution** theory: **this talk**'s focus

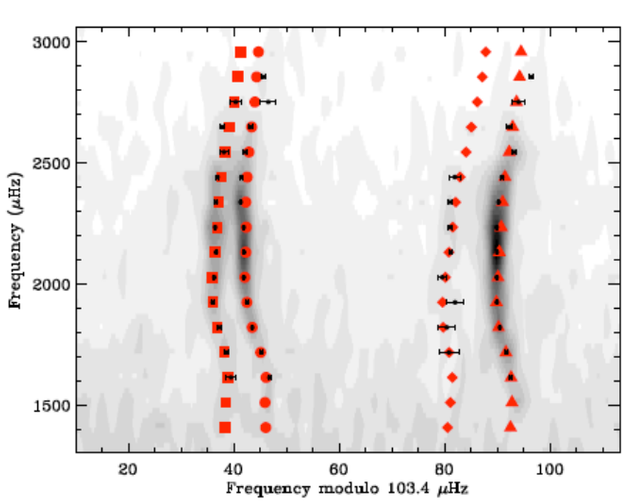


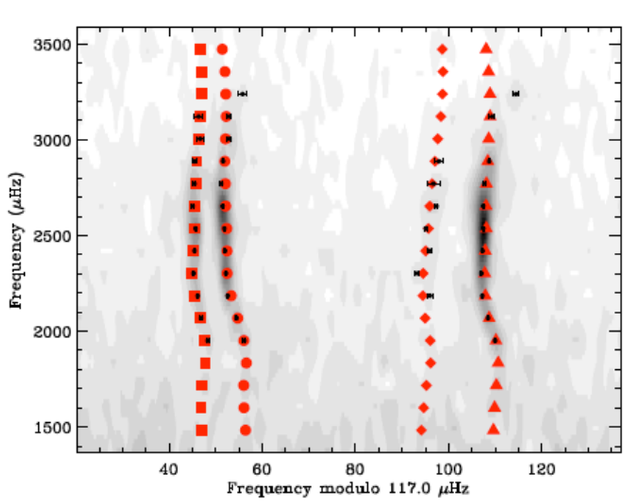
Solar-like p-mode pulsators

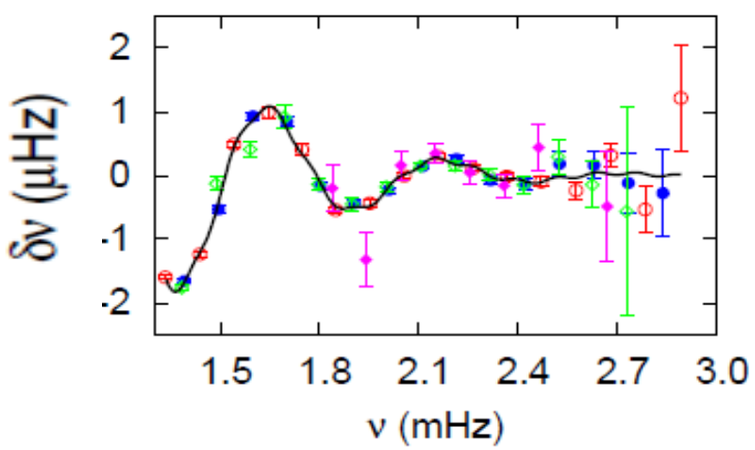
in-depth seismic probing à-la Helioseismology

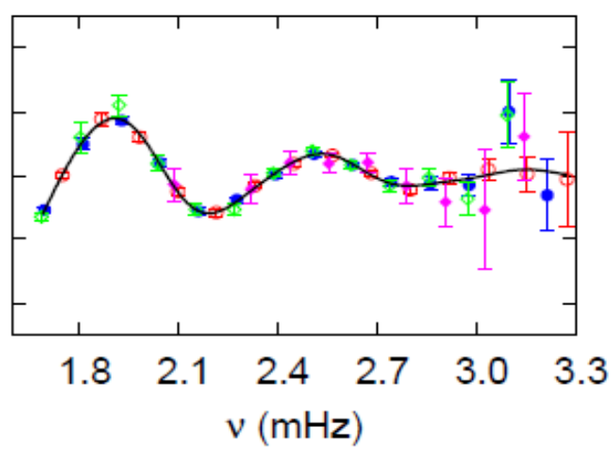












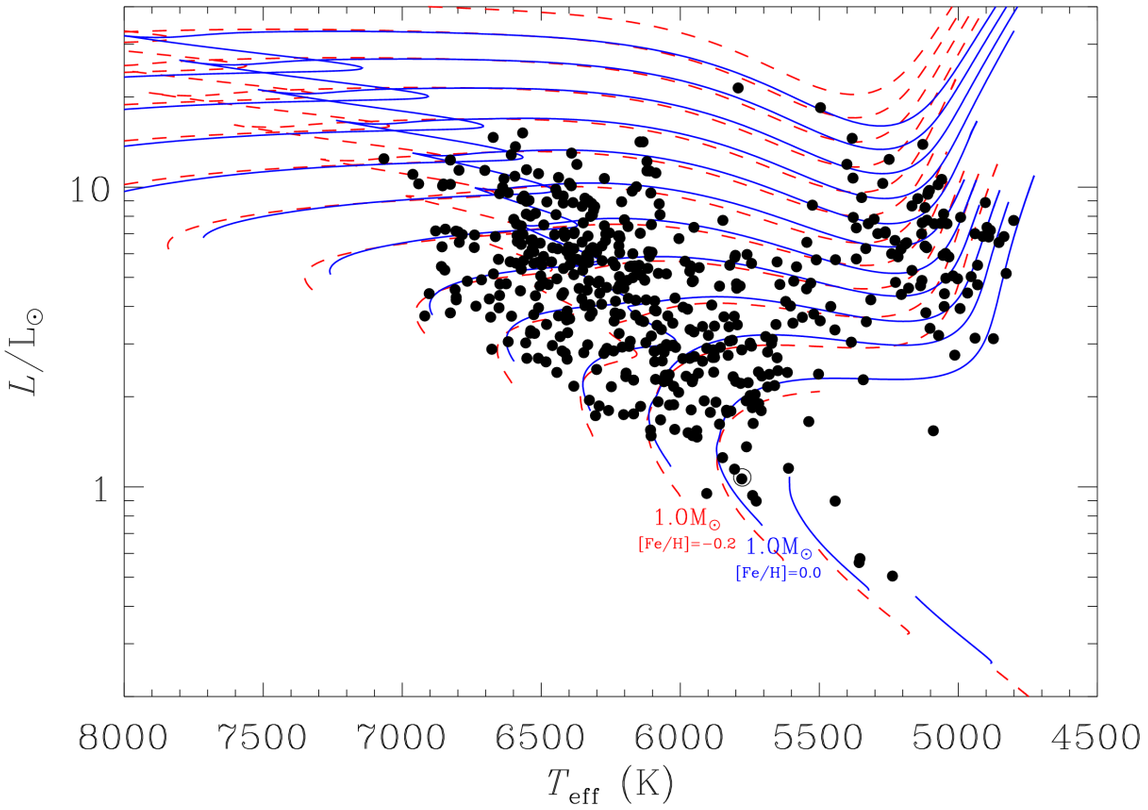
16 Cyg A&B, *Kepler*, Metcalfe et al. (2012)

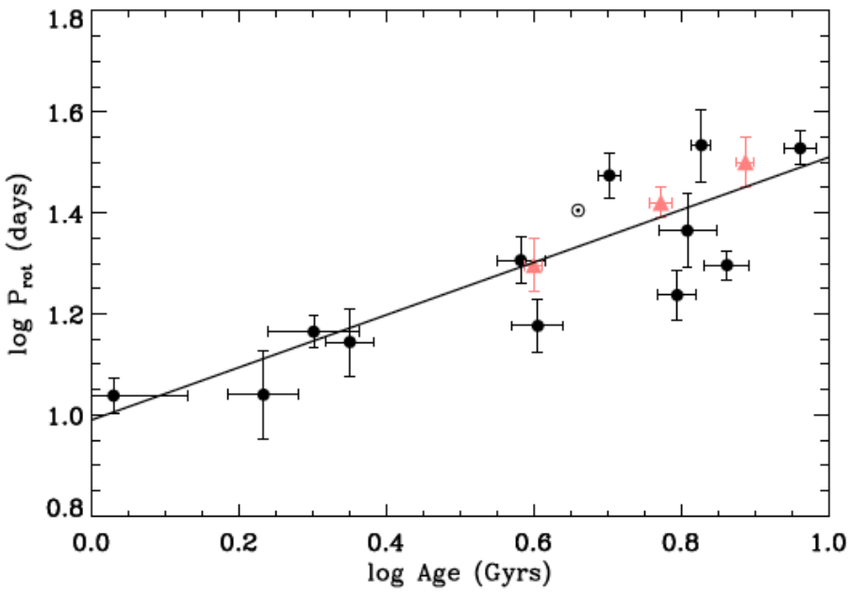
Seismic current Helium abundances of 0.24±0.01(2) for A(B) Verma et al. (2014)

Analysis of acoustic glitches (sharp features): gives depth of convective envelope & extent of He ionisation zone (Mazumdar et al. 2014)

“Easy cases”: solar-like p-mode pulsators

fulfill scaling relations with Sun as calibrator





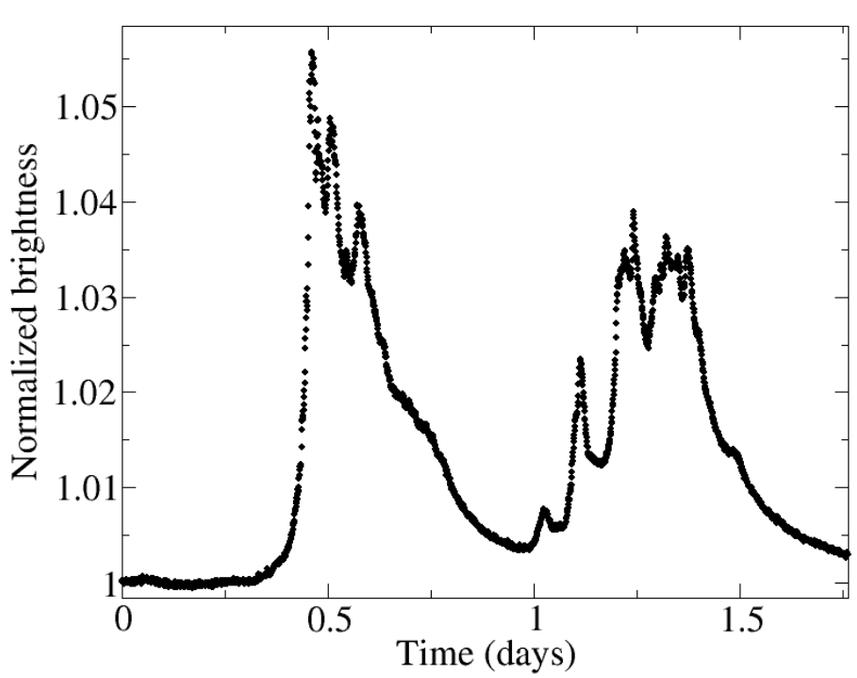
Ensemble asteroseismology + spectroscopy: M:3.7%, R:1.3%, age:12%, Chaplin et al. (2014)

When Gaia distance arrives, we get model-independent seismic mass & better age

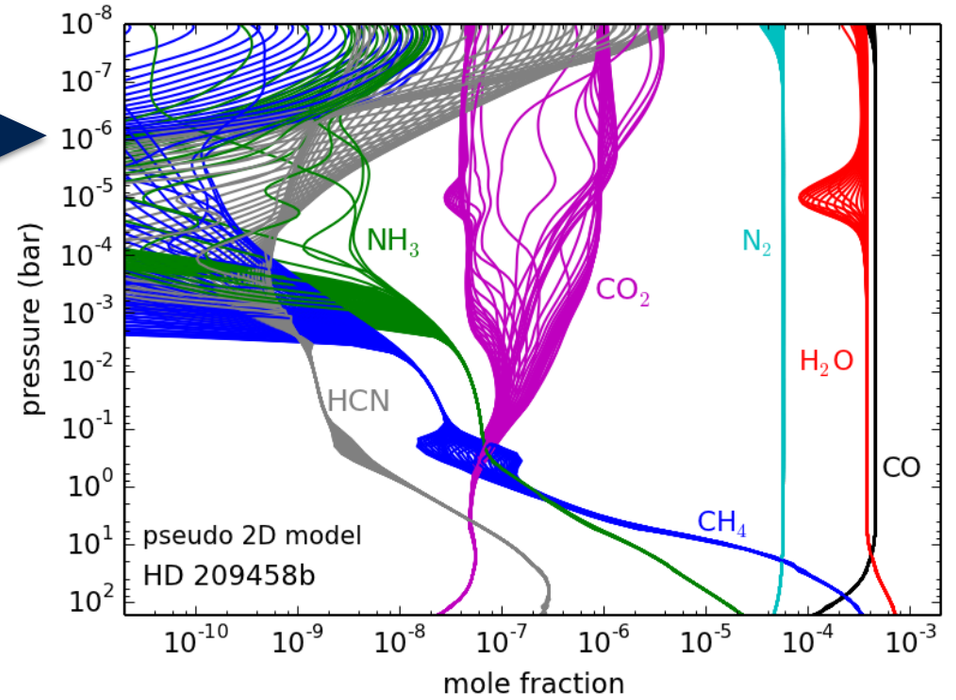
Age-P_{rot}(surf) relation from seismic modelling Metcalfe et al. (2014) García et al. (2015)

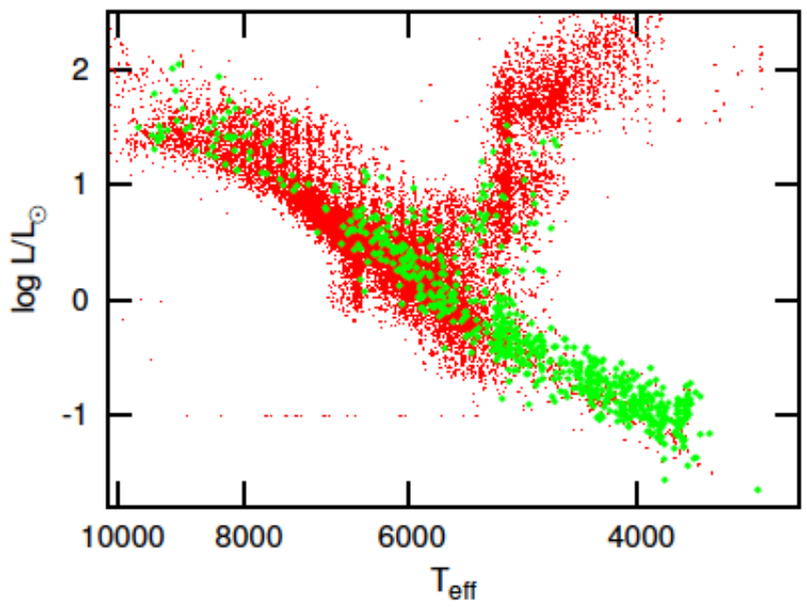
Suprising Stellar Flaring AF-type stars

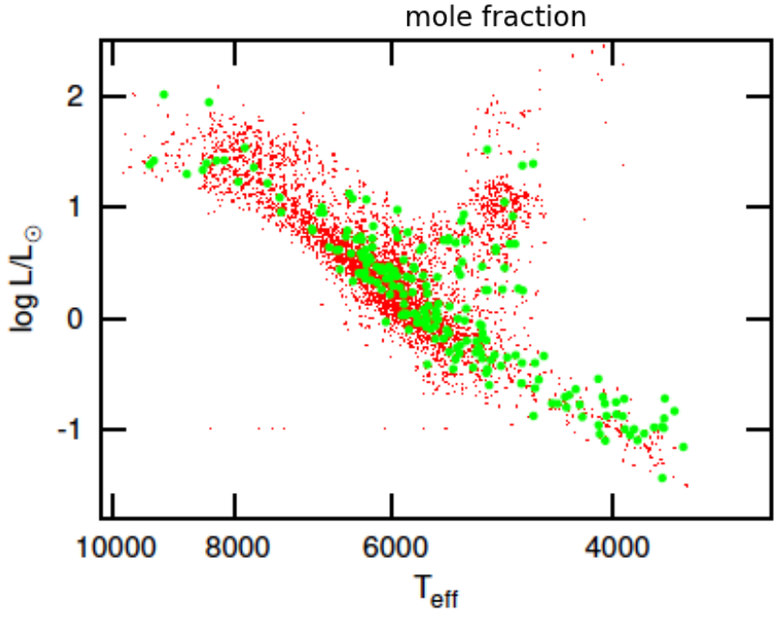
Impact on exoplanetary atmospheres?



?

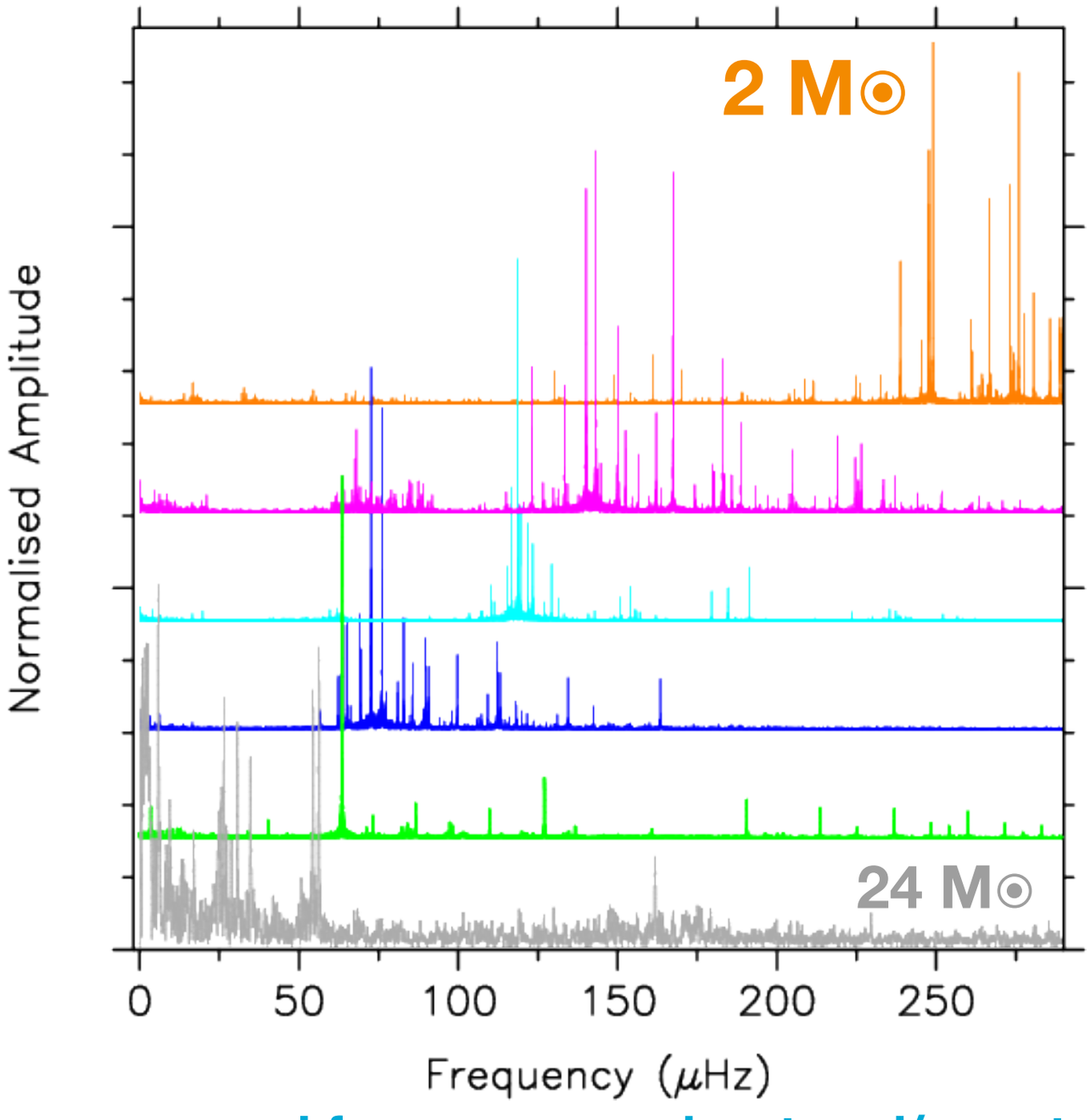




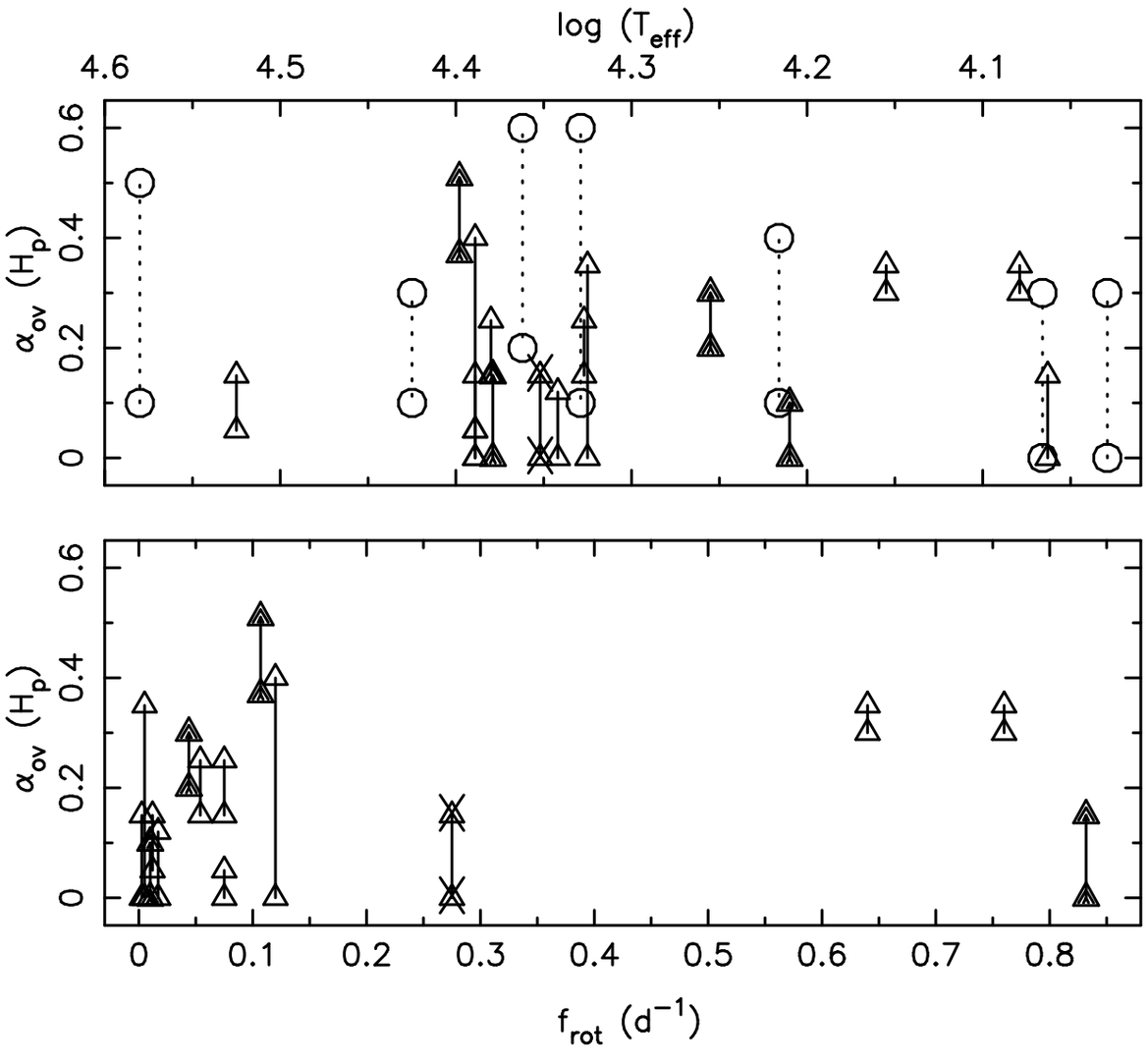


Balona (2015): Incidence of flares for AF-type stars much higher than thought so far from spectro-polarimetry (Donati & Landstreet 2009)

Heat-driven p&g modes in massive stars



Core overshoot in OB stars



need for core overshoot and/or extra mixing: 20% longer life (Aerts 2014)

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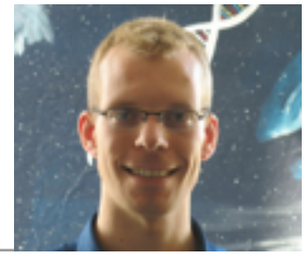
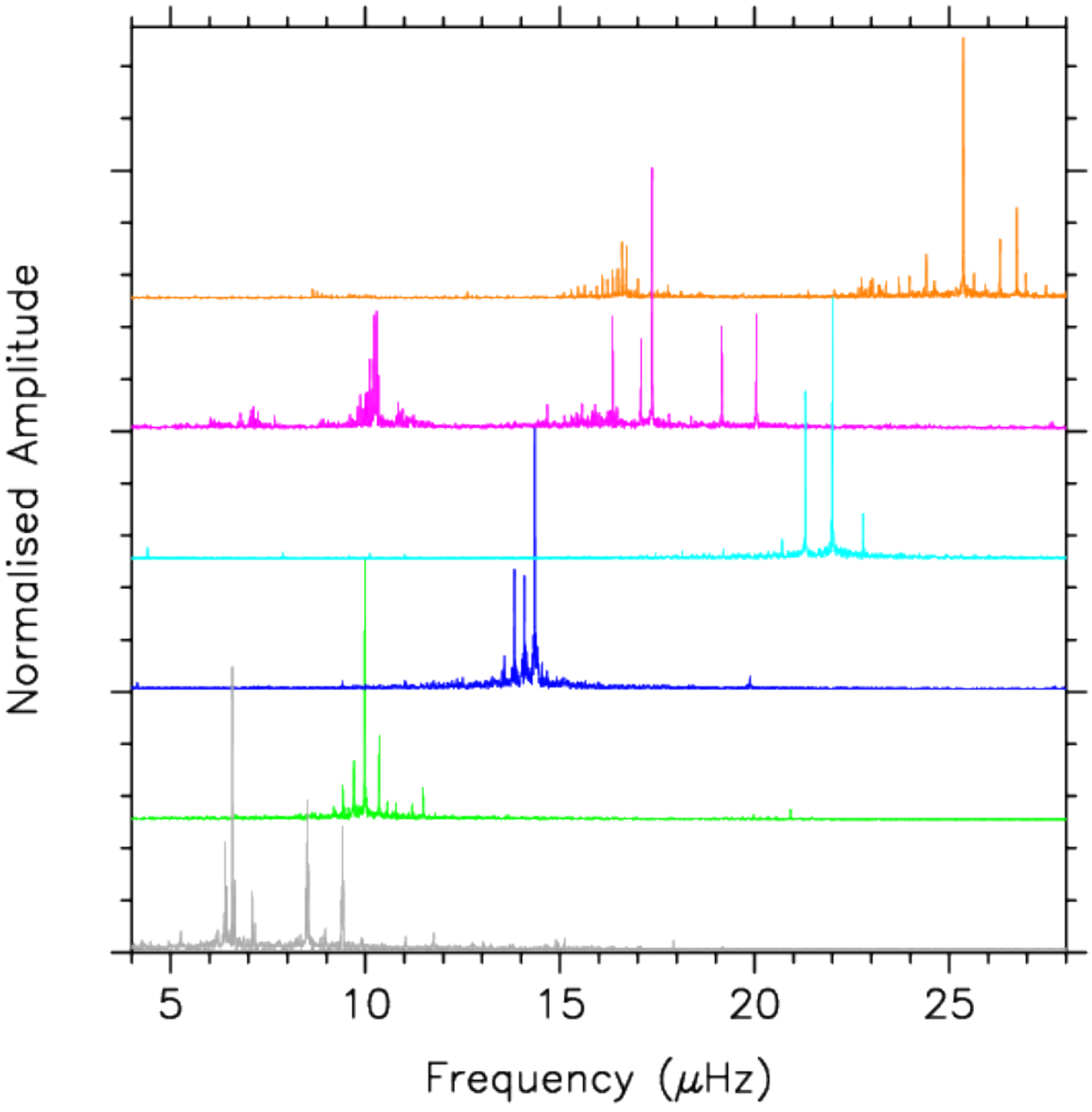
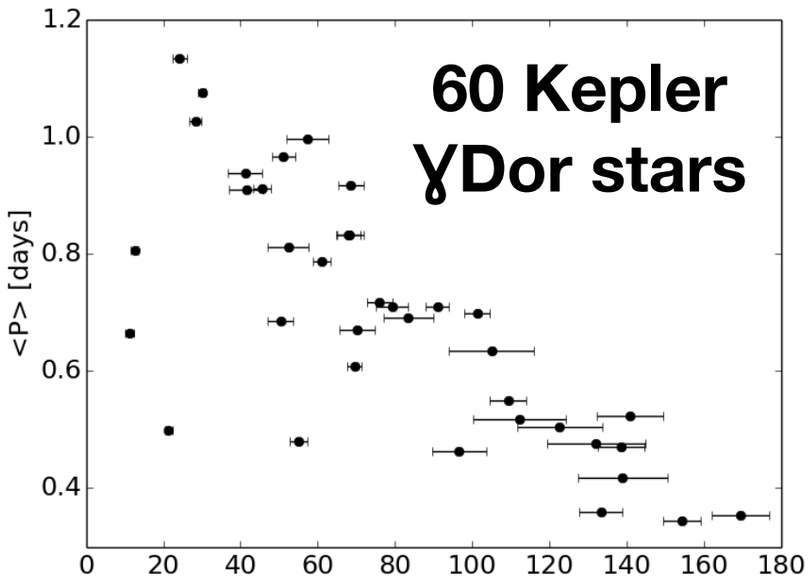
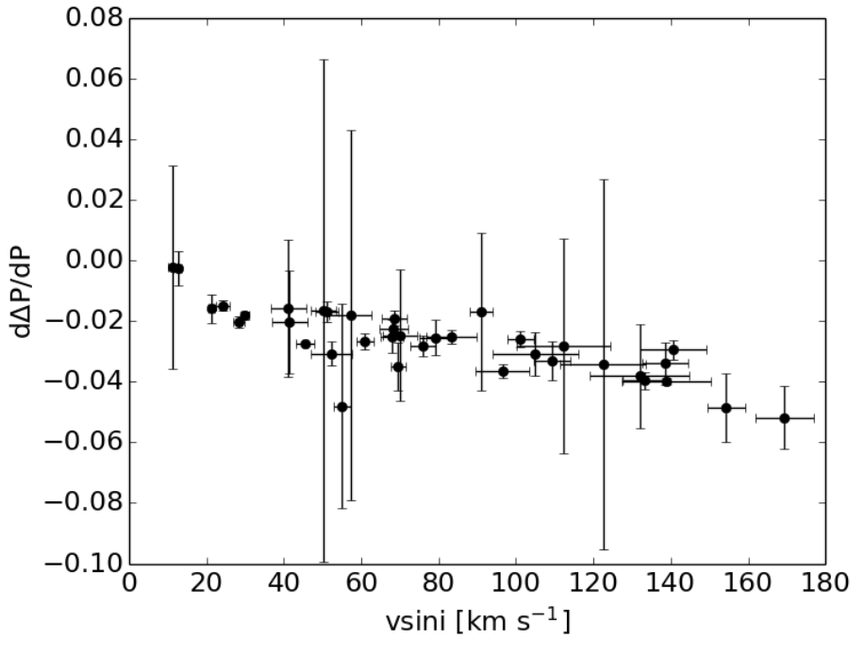


Gravity modes in B-type & F-type stars

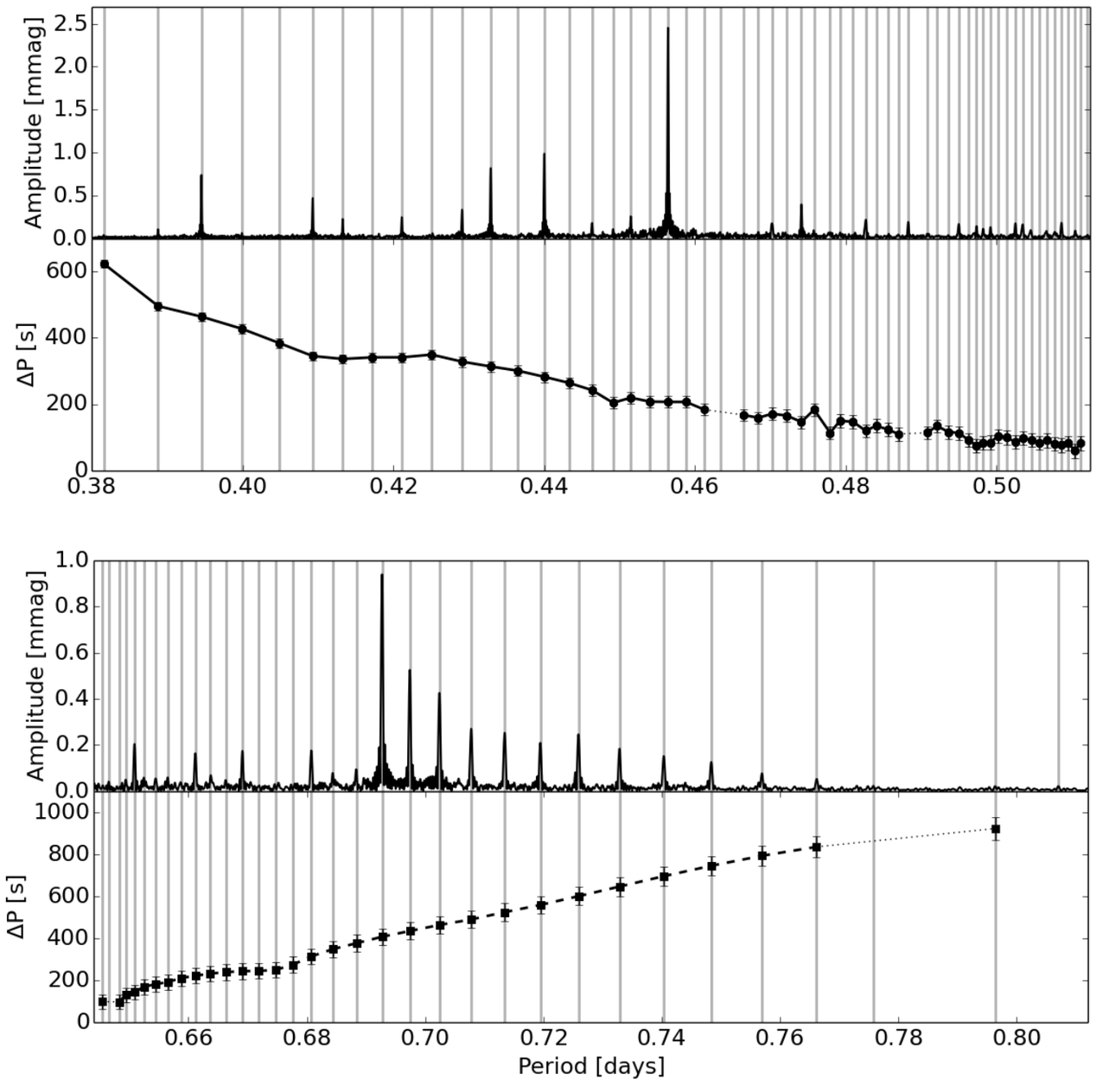


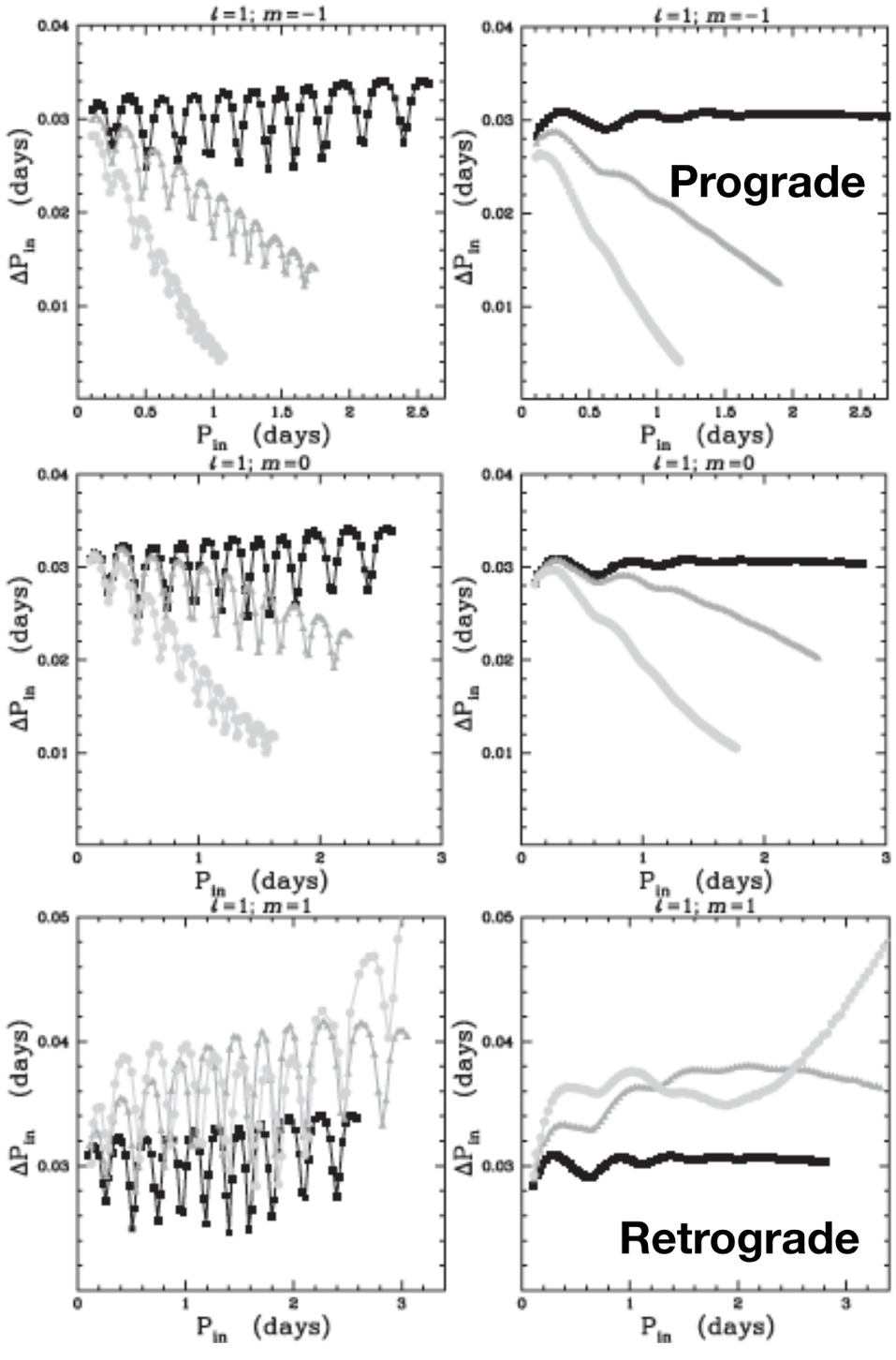




Tkachenko et al. (2013) Van Reeth et al. (2014 & coming soon…)

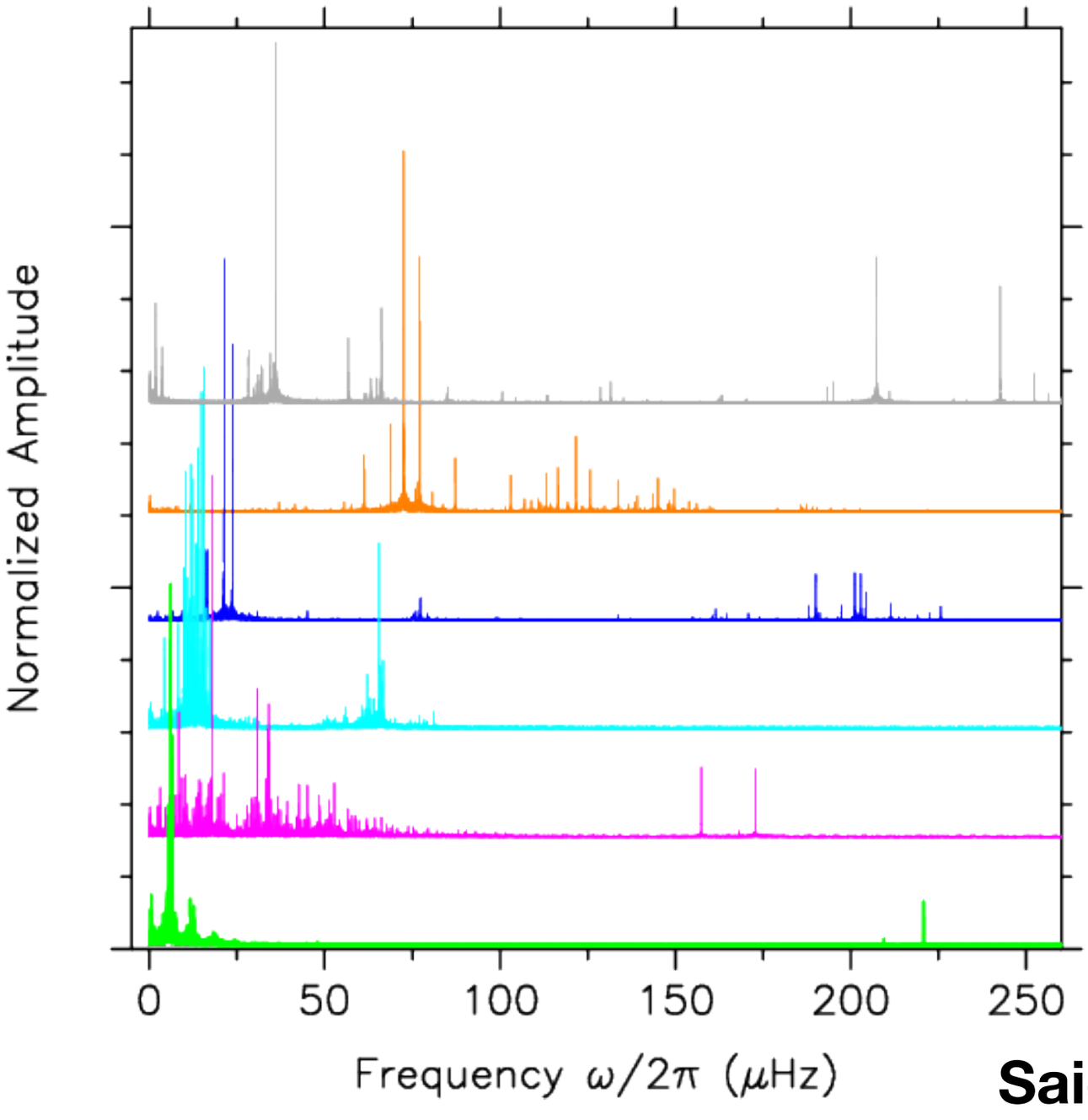
New way to derive mixing & Ω(r) in F stars

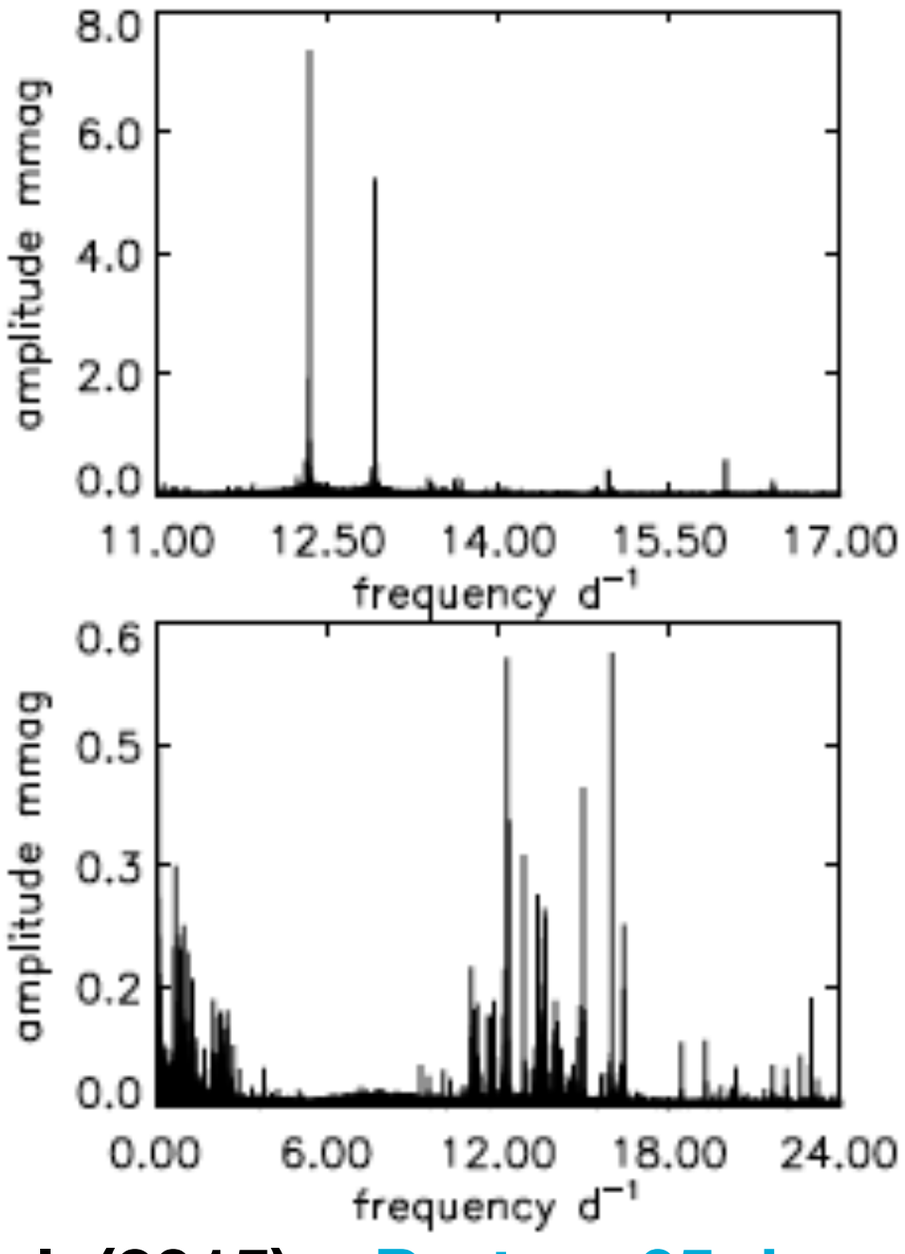




Bouabid et al. (2013) & Van Reeth et al. (soon)

Great asset: hybrid AF-type pulsators

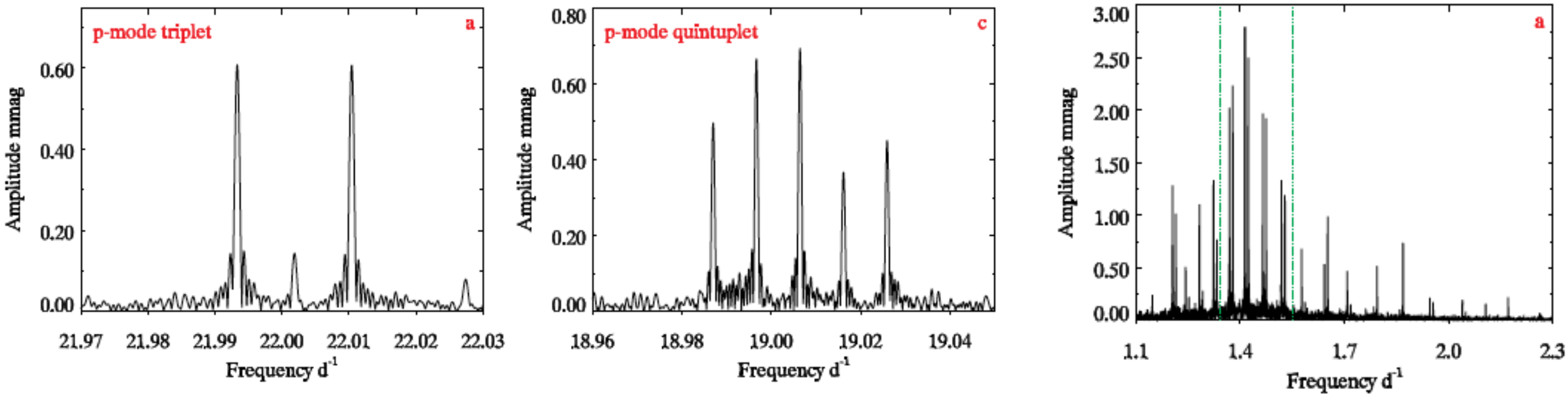


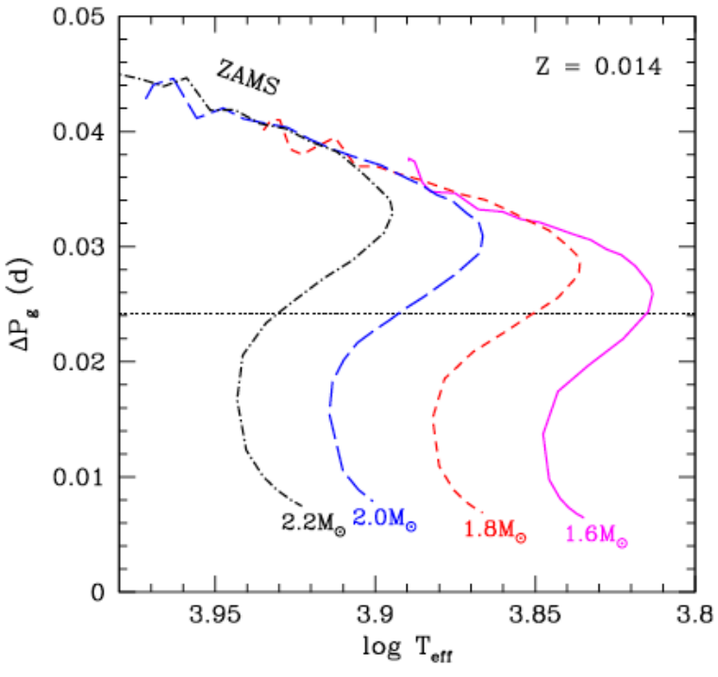


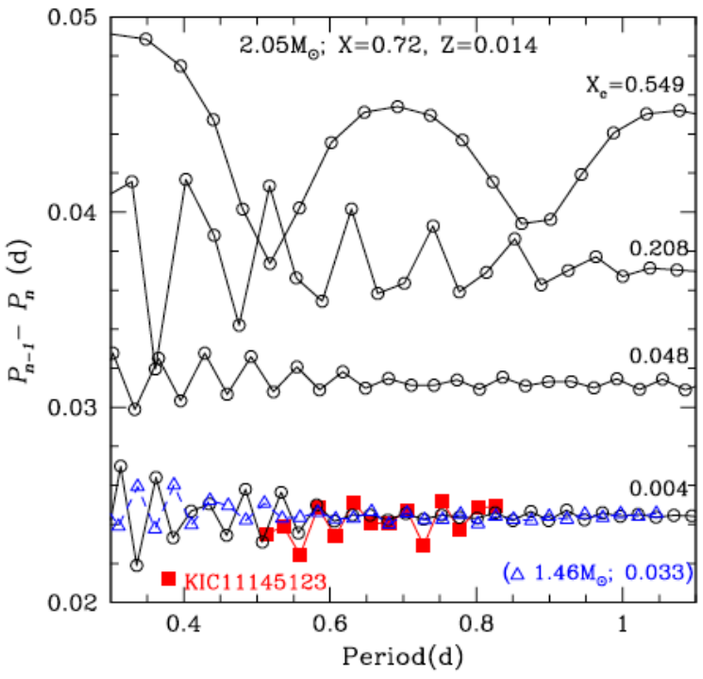
Saio et al. (2015): <Prot> ≃ 65 days,

slightly slower envelope-than-core rotation

Hybrid pulsators KIC 11145123 & KIC 9244992







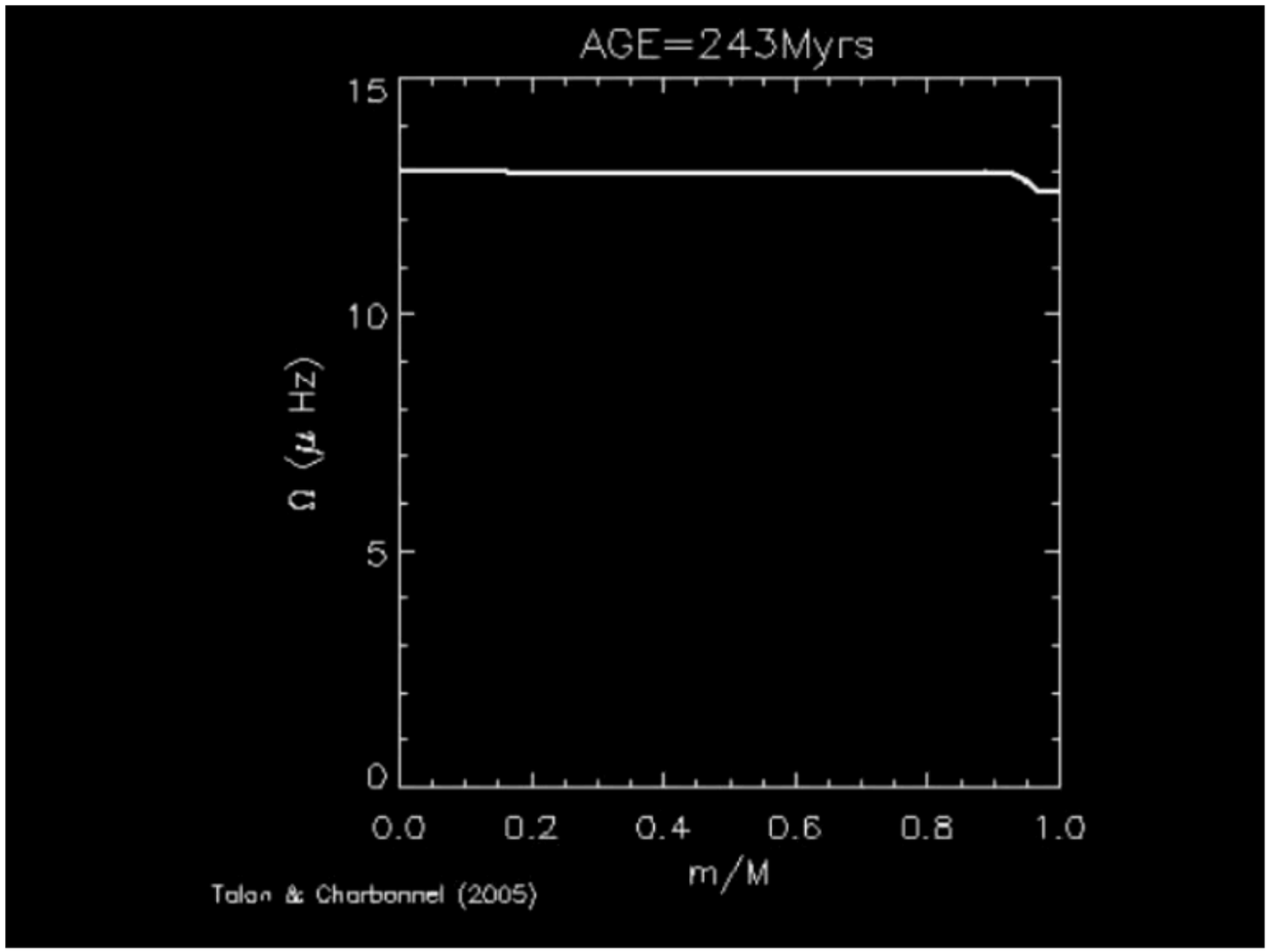
Kurtz et al. (2014): p- and g-mode triplets & quintuplets:

<Prot> ≃ 100 days, slightly faster envelope-than-core rotation

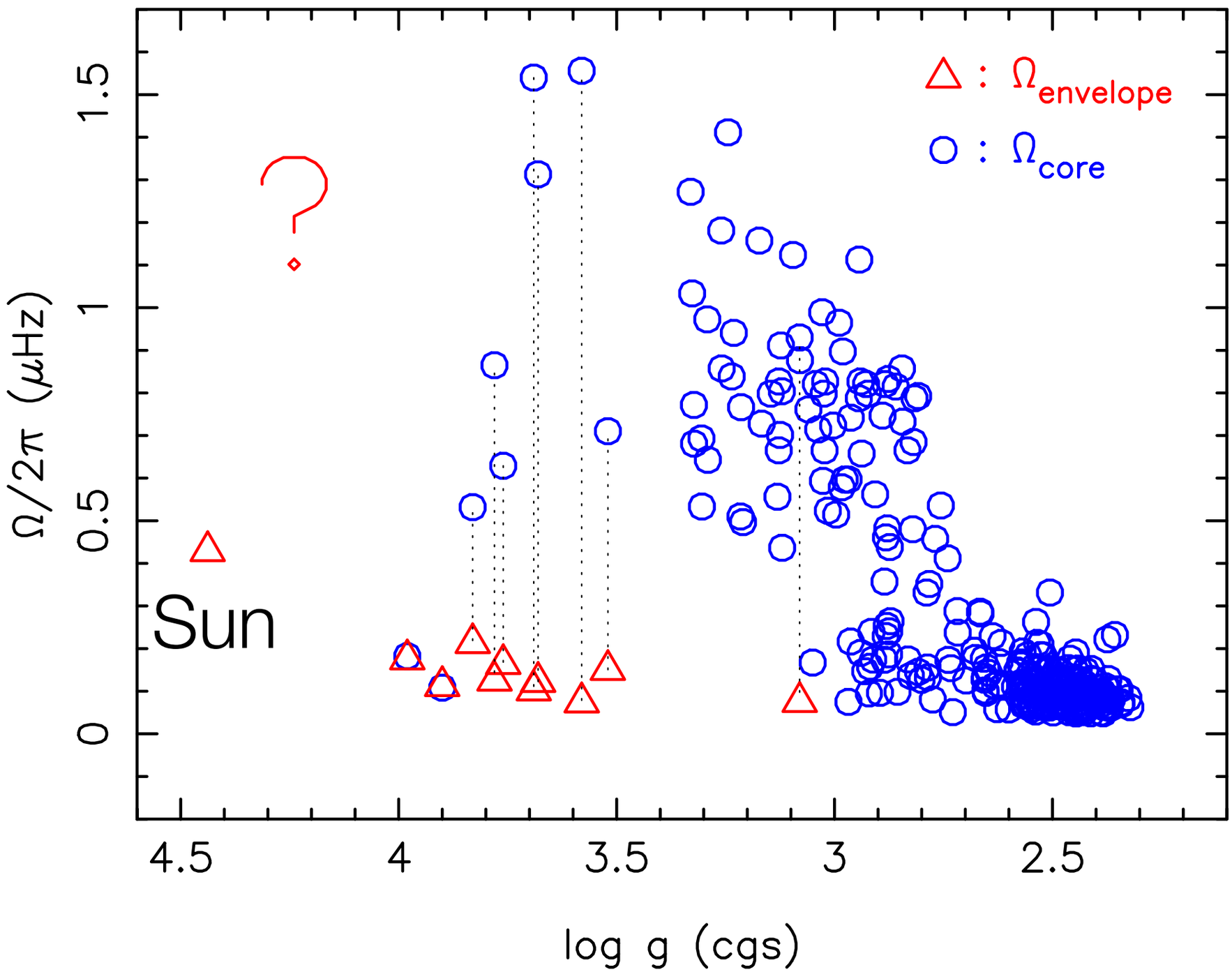
KIC 11145123 & KIC 9244992: IGW in action?

Physical mechanism must be efficient in AM transport inside the star + give opportunity to introduce faster-envelope and counter-envelope rotation: internal gravity waves

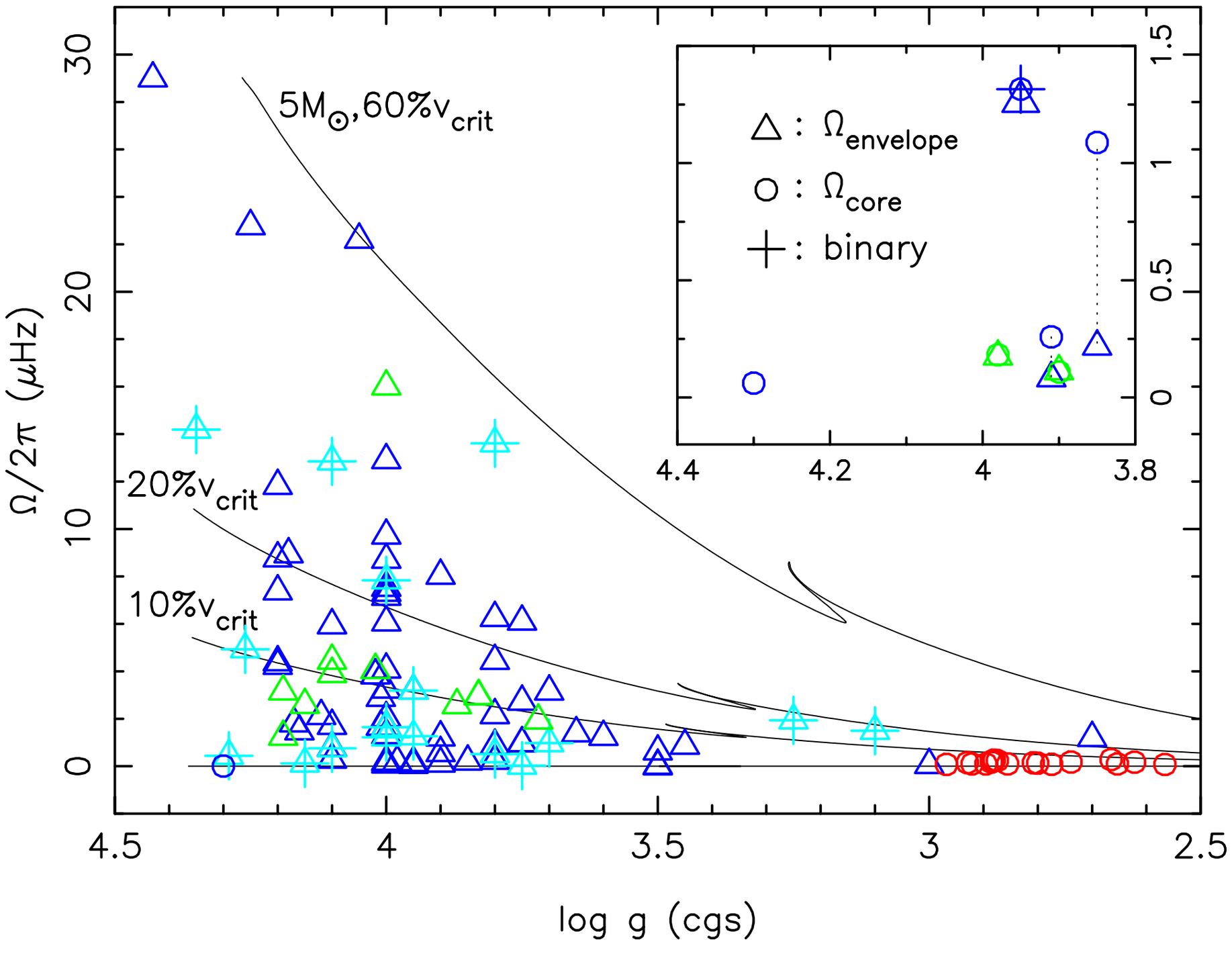
(Talon & Charbonnel 2005, Mathis et al. 2013, Rogers et al. 2013)



Internal rotation of unevolved dwarfs?



Internal rotation of massive stars?



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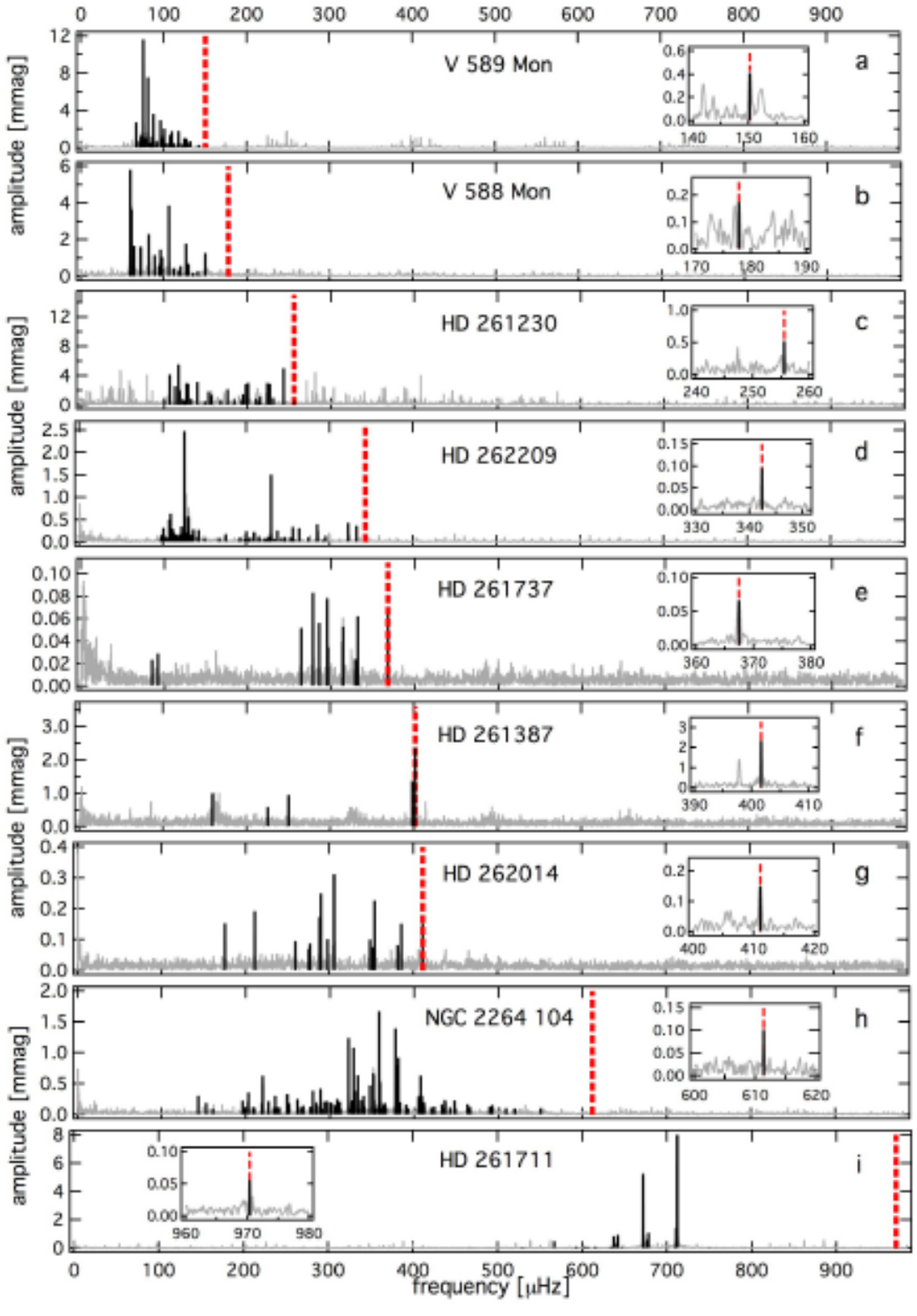
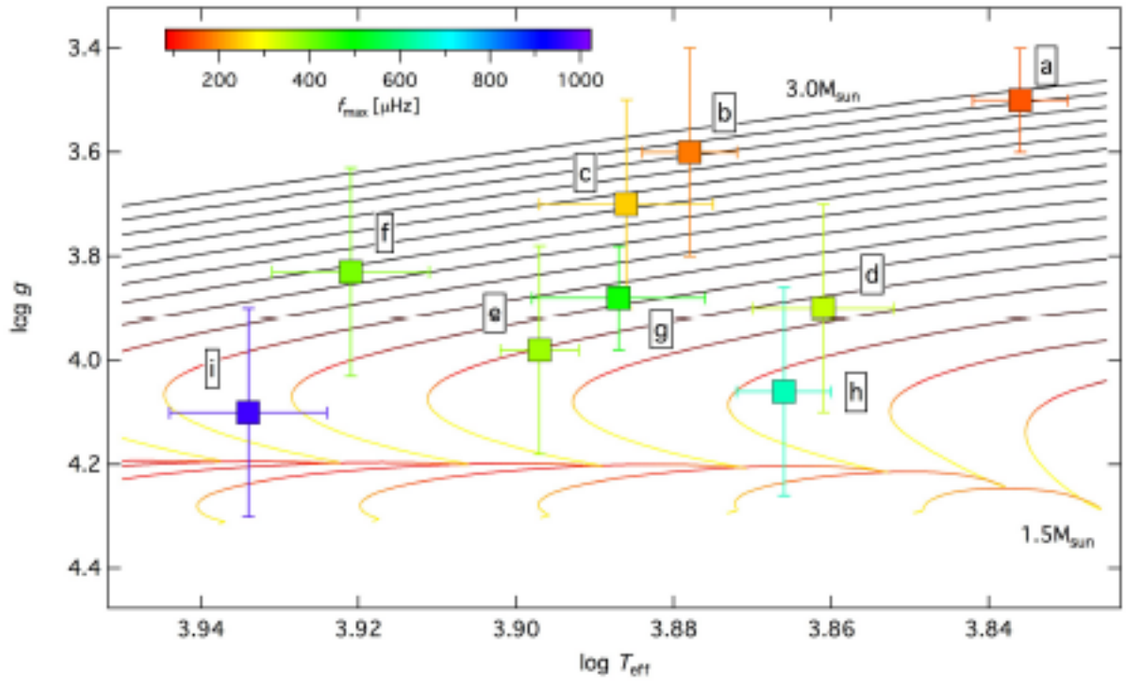
Asteroseismology of pre-MS stars

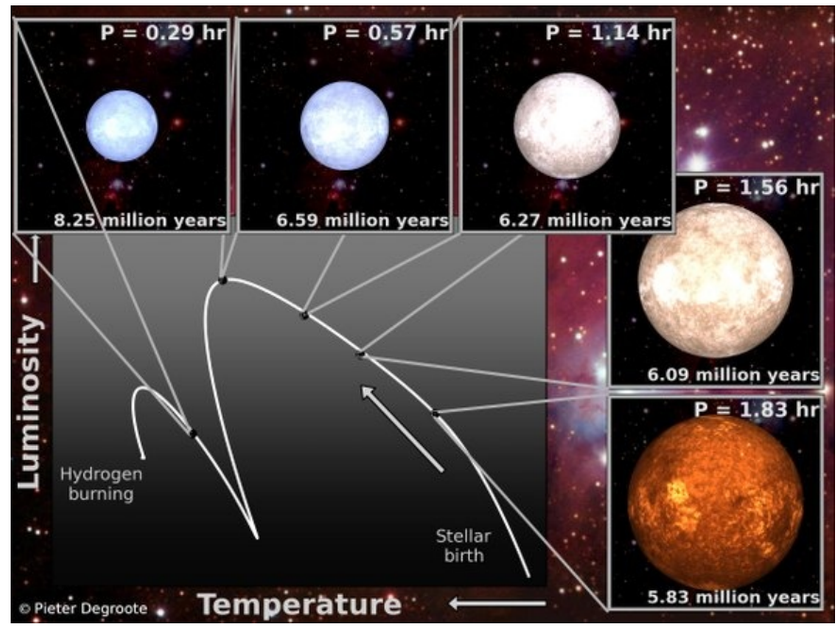




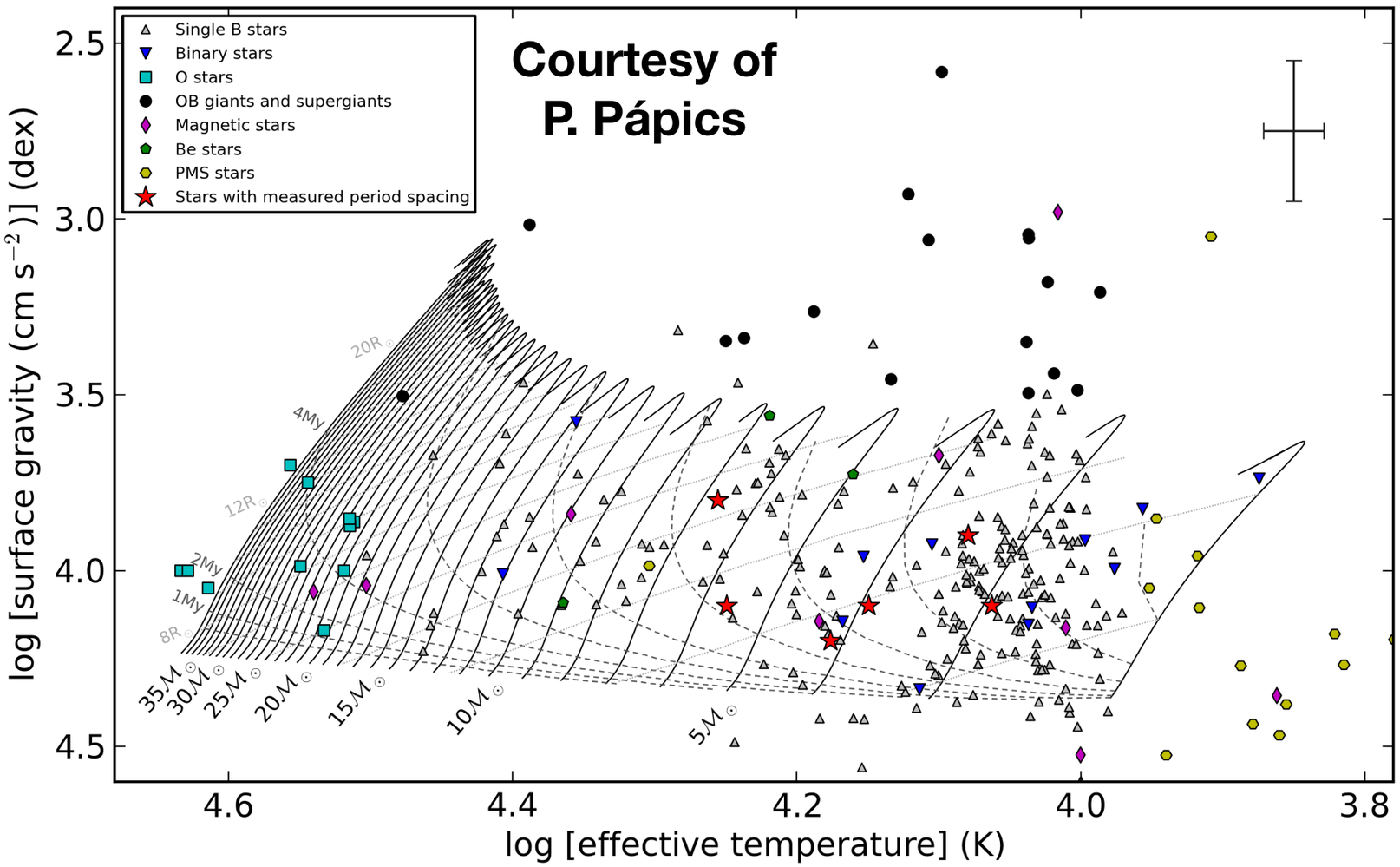
Seismic evidence for multiple epochs of star formation

Rotation is slower than assumed

Zwintz et al. (2014)



Asteroseismology: near future with K2



K2 (3 months monitoring/field) ecliptic mission:

MASSIVE consortium focuses on under-represented targets

Sub-class	PI	Prio 1	Prio 2	Prio 3	Sub-class	PI	Prio 1	Prio 2	Prio 3
Be stars	Neiner	34	0	0	O stars	Aerts	14	0	0
magnetic stars	Briquet	35	0	0	single B stars	Pápics	66	307	636
pre-MS stars	Zwintz	24	0	0	binary OB stars	Tkachenko	51	5	0
OB supergiants	Moravveji	82	31	0					

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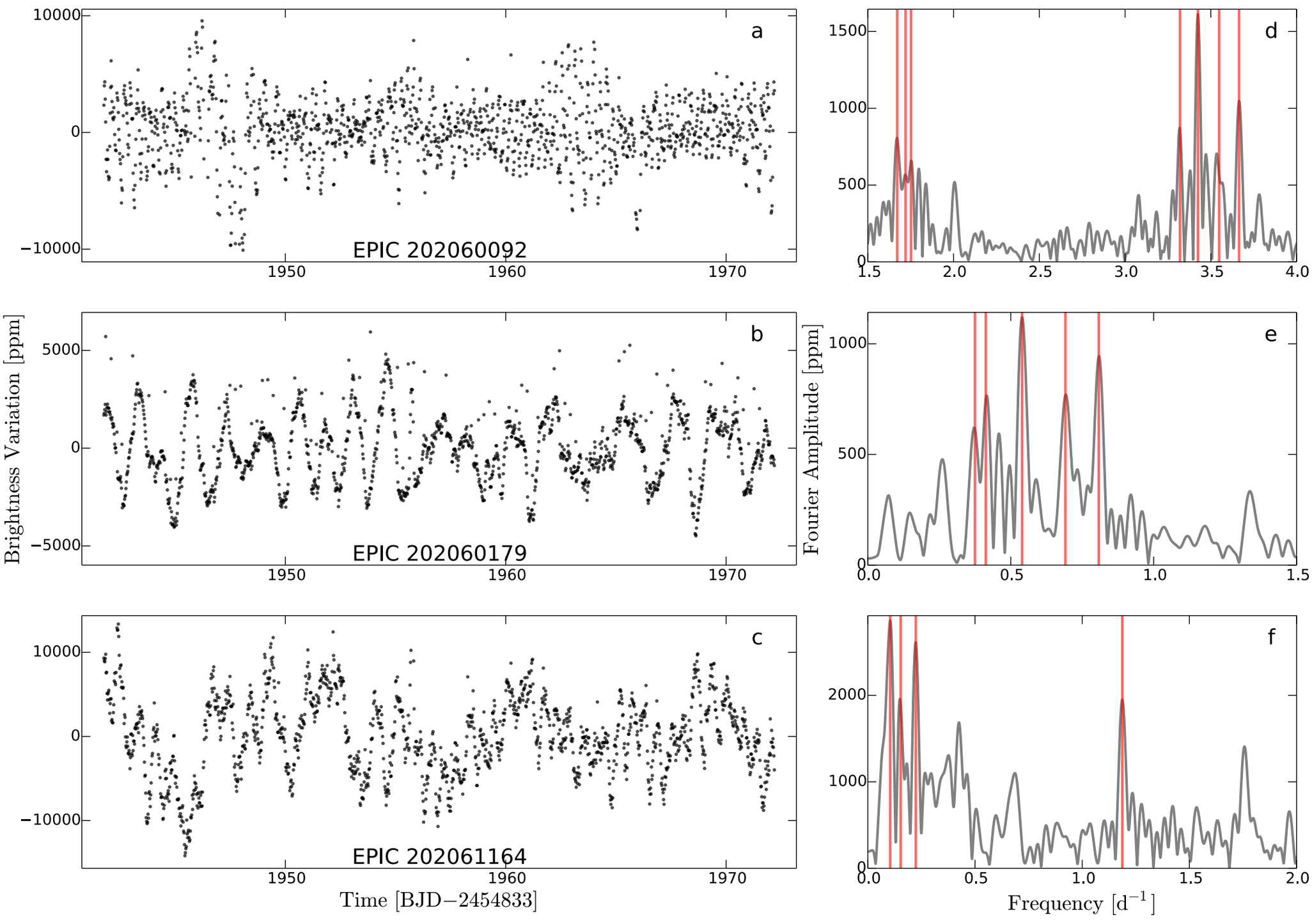
K2's first view on O-type pulsations



Asteroseismology: mid-term future

Add Gaia distance (mid-2016 to 2020) or interferometric radius to seismic modelling to eliminate one dimension in parameter space

VLT at Paranal

ESO PR Photo 41a/99 (8 December 1999)

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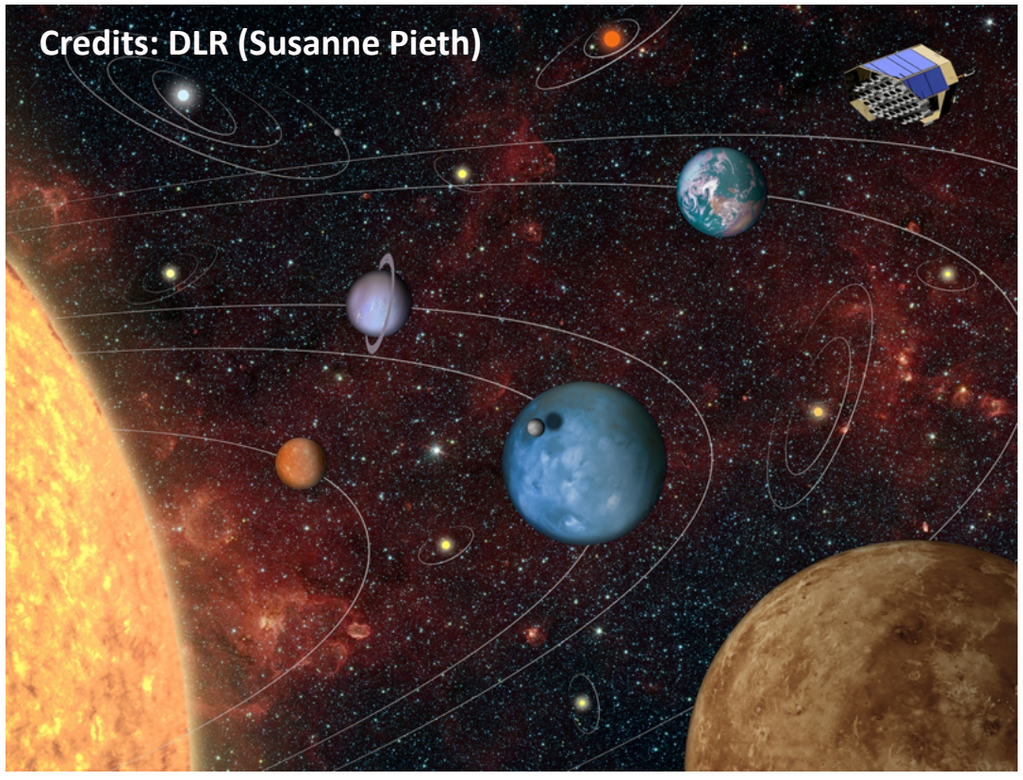
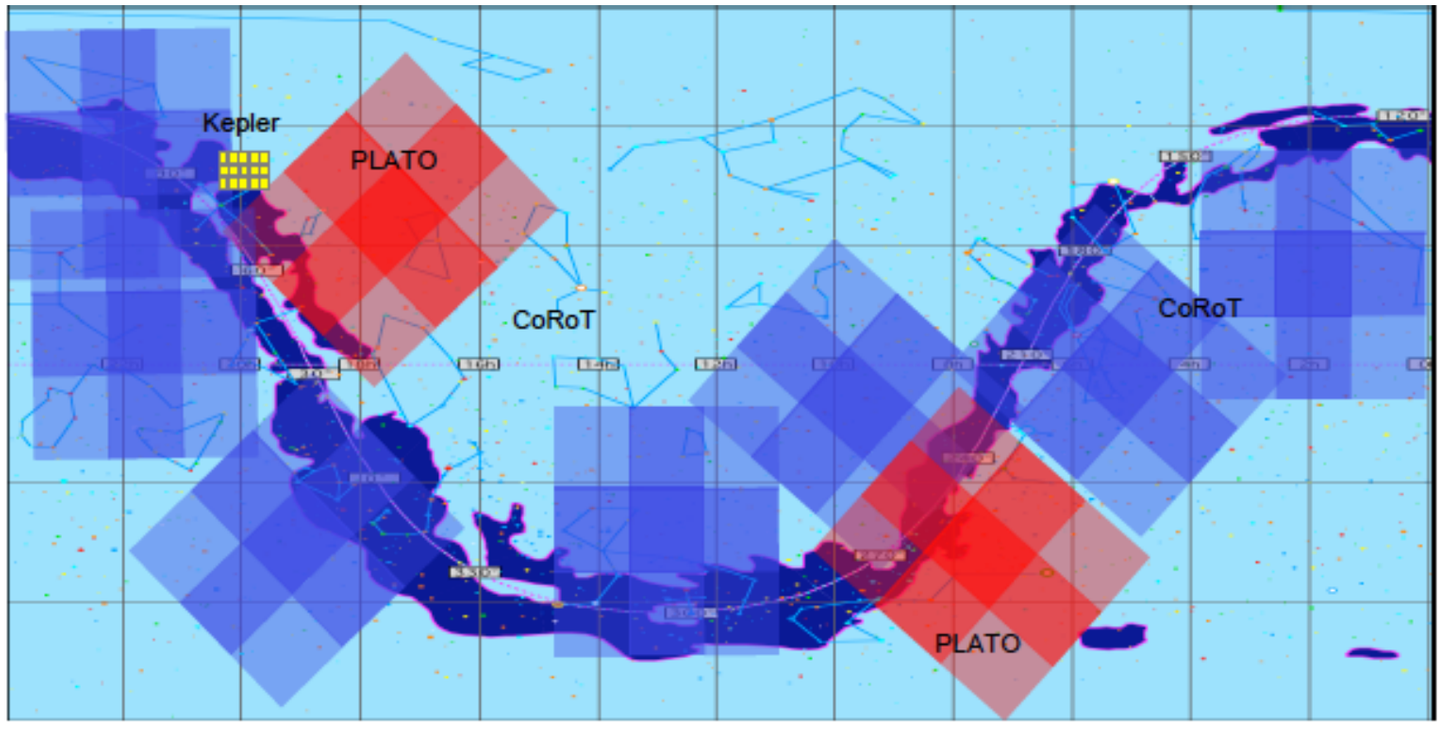
Asteroseismology: farther future

Beyond 2024:
PLATO main mission & its Complementary Science Programme, step-and-stare phase with targets of choice
I welcome suggestions from this community:
https://fys.kuleuven.be/ster/Projects/plato-cs/





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30 ECTS

Education in asteroseismology

SpaceInn.eu

Science@Leuven
Masters Scholarships

sc.kuleuven.be

erasmus

“Now is (still!) a good time to become an asteroseismologist…”

because the best is yet to come for stellar physics…

Some Open Questions in Stellar Physics

- How do stars rotate at birth?
  Does it matter for their future evolution?
- How does interior rotation change with evolution?
- What are the physical mechanisms of core-envelope coupling during core H burning?
- Asteroseismology of OBA supergiants with mass loss?
- How does AM loss/redistribution affect star-planet interactions?
- How does stellar activity/variability interact with exoplanetary atmospheres?
- **To Galaxy evolution researchers: upgrade your input from stellar evolution to seismically calibrated versions!…**