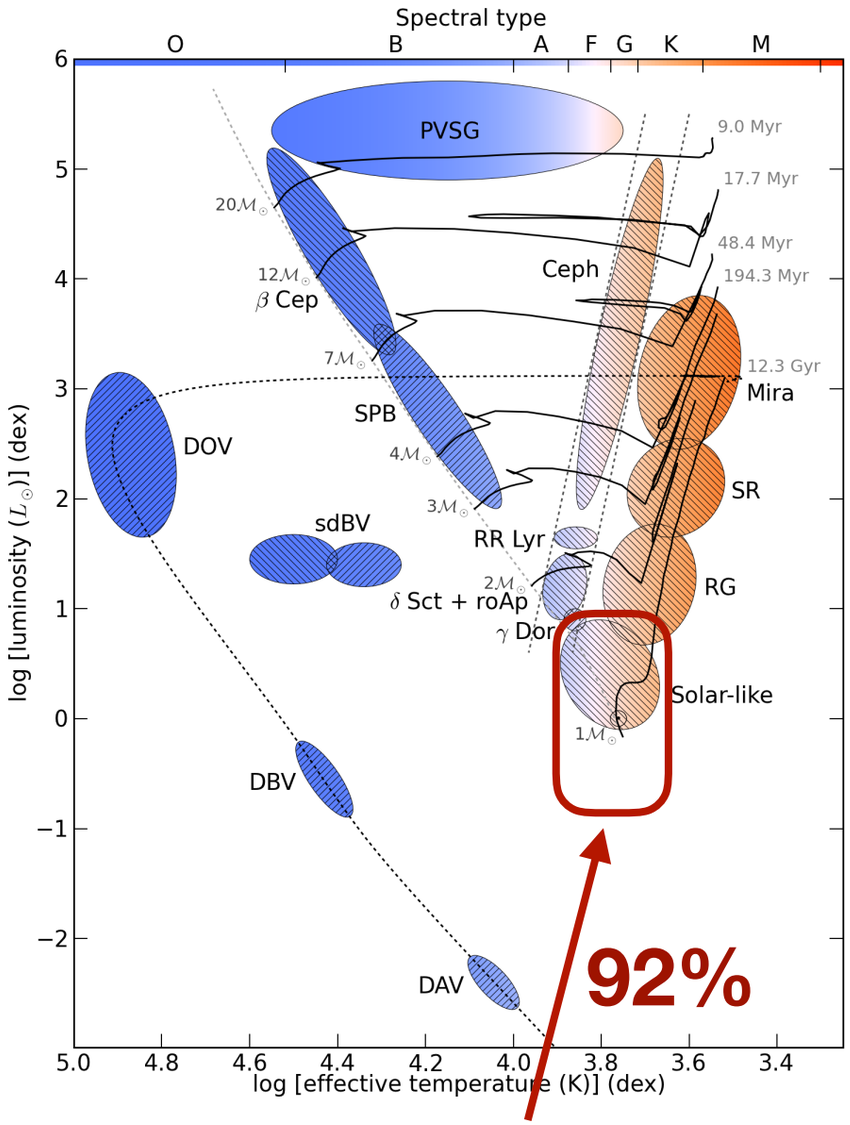
Better Stellar Models, Better Exoplanets…

Towards an optimal set of calibration stars for PLATO
(Core Science!, i.e. 92% of data rate….)

Ana Heras, Marie-Jo Goupil & Conny Aerts, on behalf of PSWT

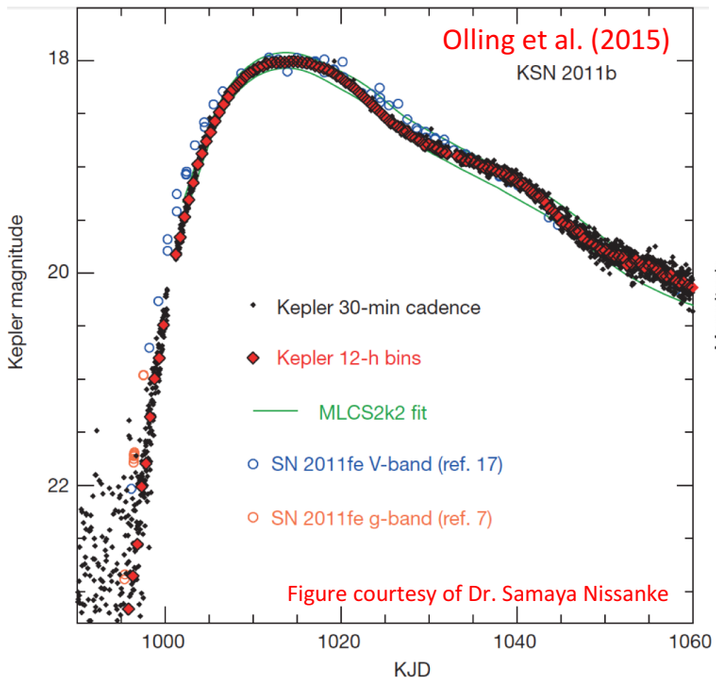
PLATO Core vs Complementary Science (GO)

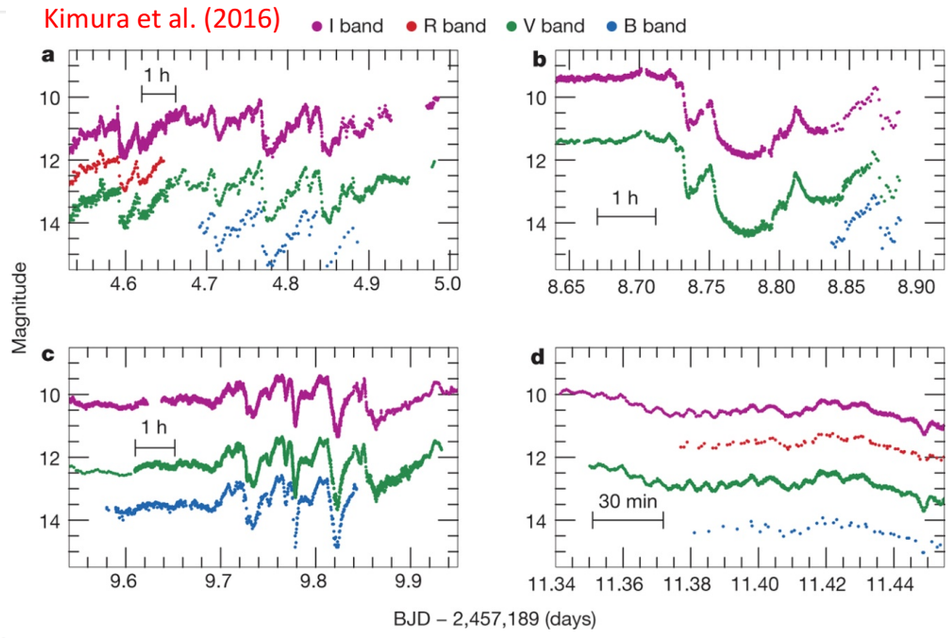
Stellar Science → **Extragalactic Science** → **Transient phenomena**



Core Science

Asteroseismology of exoplanet host stars (later than F5)





Extragalactic Science

- **SNe explosions** in distant galaxies: progenitor shock-breakout physics
- **Monitoring cores of AGNs** to understand SMBH accretion & variability

Transient Universe

- **Mapping and understanding of accretion physics near YSOs**
- **White dwarfs, black holes, and neutron stars:** monitoring in fast cadence asap after transient

PLATO Complementary Science

From the instrument/SMP viewpoint…

Towards an optimal set of calibration stars for PLATO: boundary conditions & freedom

Ana Heras, Marie-Jo Goupil & Conny Aerts, on behalf of PSWT

Slide courtesy of Ana Heras

PLATO Calibration targets (i)

Calibration targets are defined as those objects **required** in addition to science targets to:

- Derive calibration parameters of the S/C and payload
- Evaluate the instrument and scientific performances
- Monitor de system behaviour
- Derive the scientific products that will be delivered to the community according to the SMP

Slide courtesy of Ana Heras

PLATO Calibration targets (ii)

- In ESA observatories, the typical amount of observing time dedicated to calibration is 5-15% of the total, depending on the complexity of the observatory and the time it has been in operations
- In PLATO, the calibration target allocation will be decided by the Science Working Team, considering:
  - the science TM volume
  - the on-board processing capabilities

  } After these parameters are well known following the associated units PDRs

  - the observation duration for each calibration target
  - the trade-off between their need and the observation of core-science targets

Slide courtesy of Ana Heras

PLATO Calibration targets (iii)

- The SMP does not address specifically the calibration targets, but they are assumed to be part of the mission operations
- Calibration target data are not proprietary, they become public as soon as they are validated
  - The exception is for calibration targets also included in approved guest observer programmes: The guest observer's programme proprietary time as defined in the SMP applies

Slide courtesy of Ana Heras

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Which type of stars? How many are needed for PLATO's core science?
Note: not all stars offer us (suitable) oscillations…

Kepler/TESS-ting of stellar models

Some important poorly (un-)calibrated physical ingredients:
(see also talks by Josefina Montalbán & Sébastien Deheuvels)

- interior rotation & **angular momentum transport**?
- interior & surface magnetic fields, surface effects?
- interior convective/radiative interface layers?
- near-core **mixing** & convective core mass & radius?
- atomic diffusion, including radiative levitation?
- tidal forces/waves and their evolutionary effects?
- …

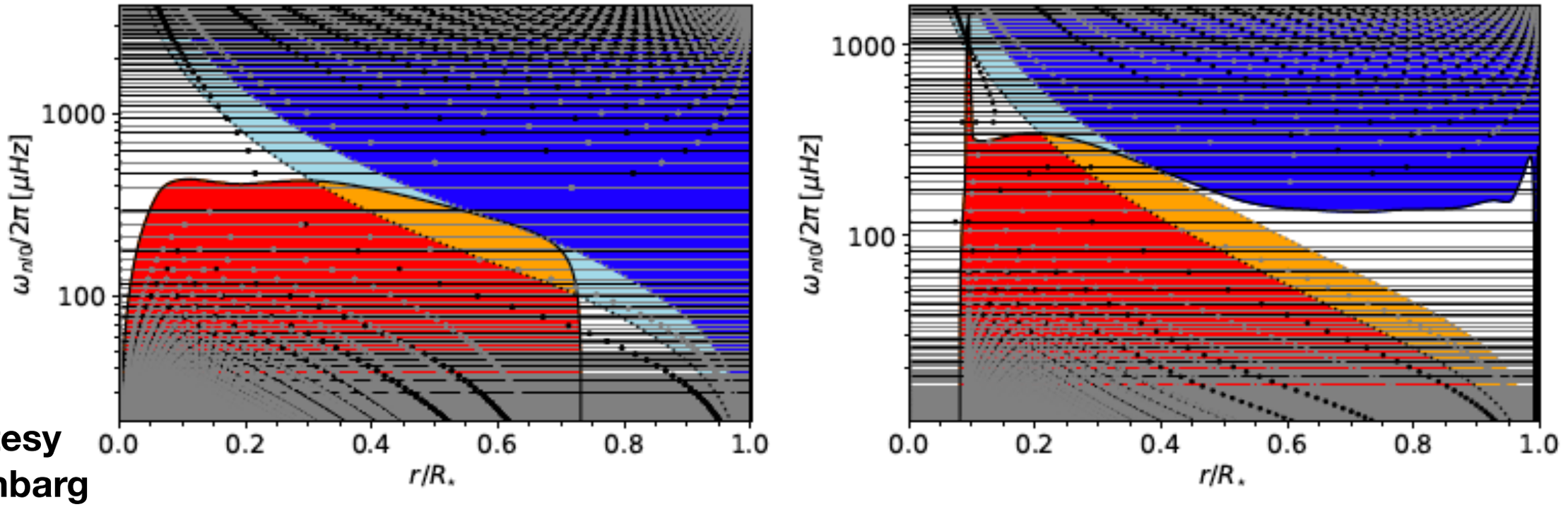
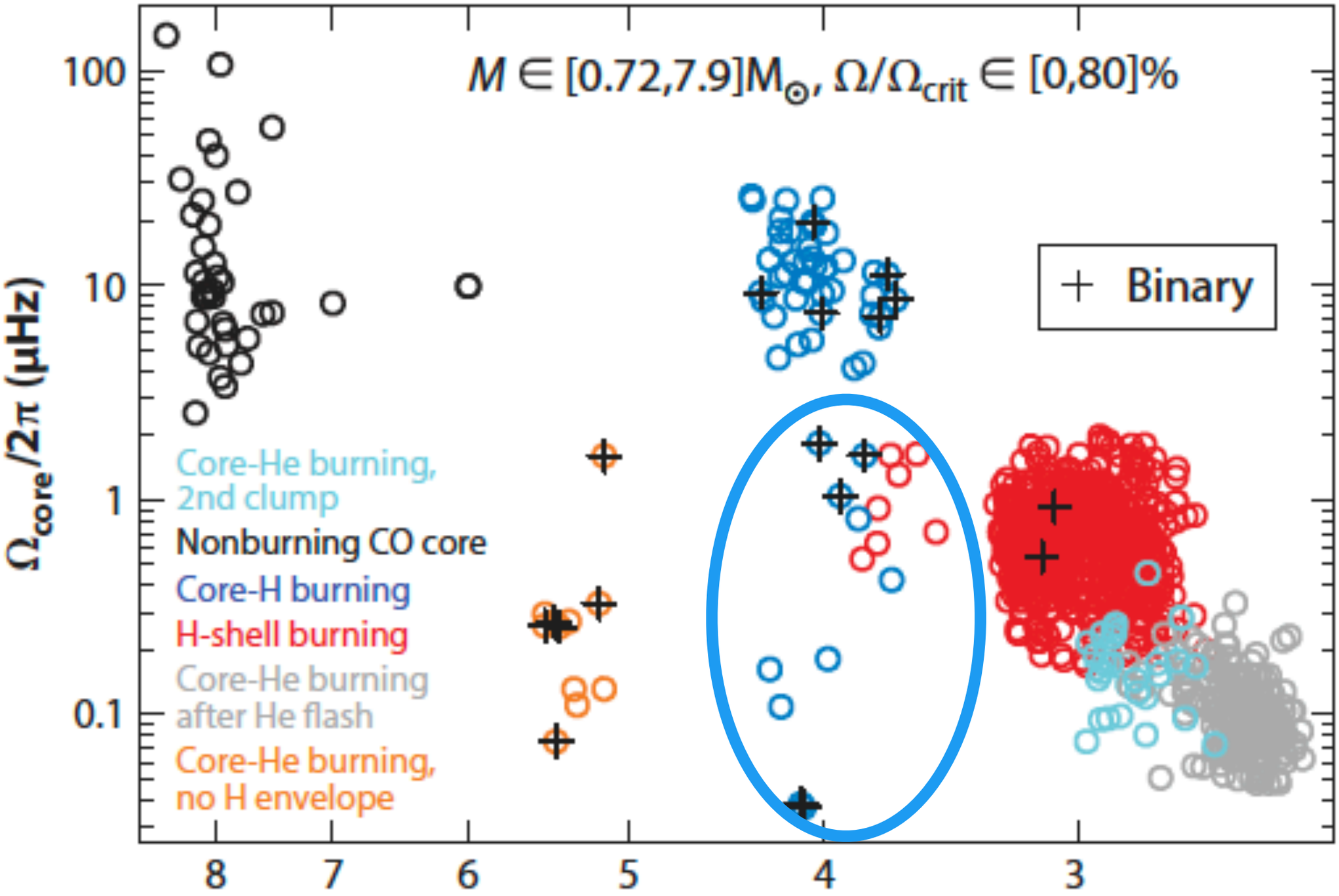


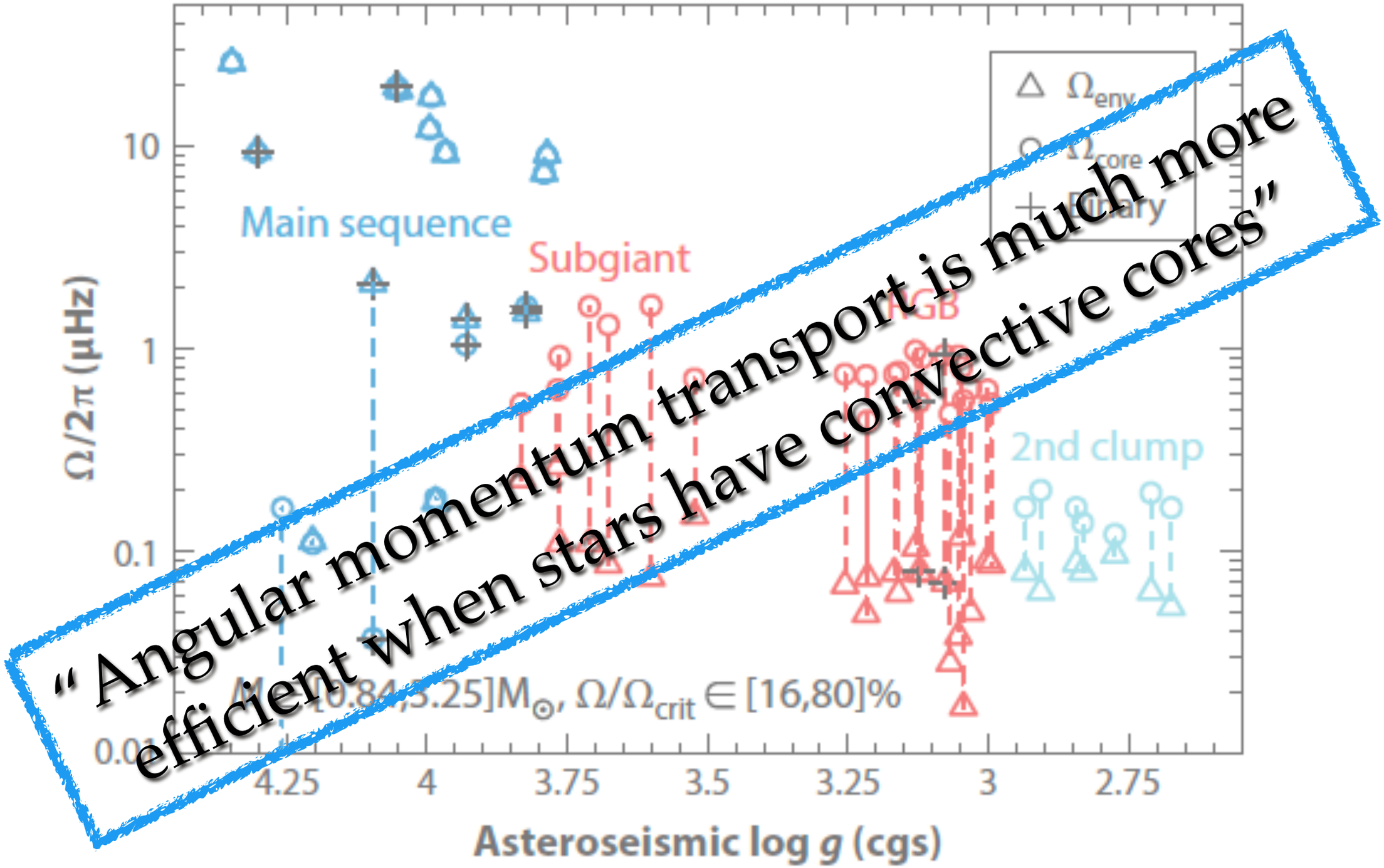
Figure Courtesy of Joey Mombarg

Kepler: core rotation from g/mixed modes (+2yr)



Deheuvels et al. (2014)
Aerts et al. (2019, ARAA)

Kepler: interior/surface rotation

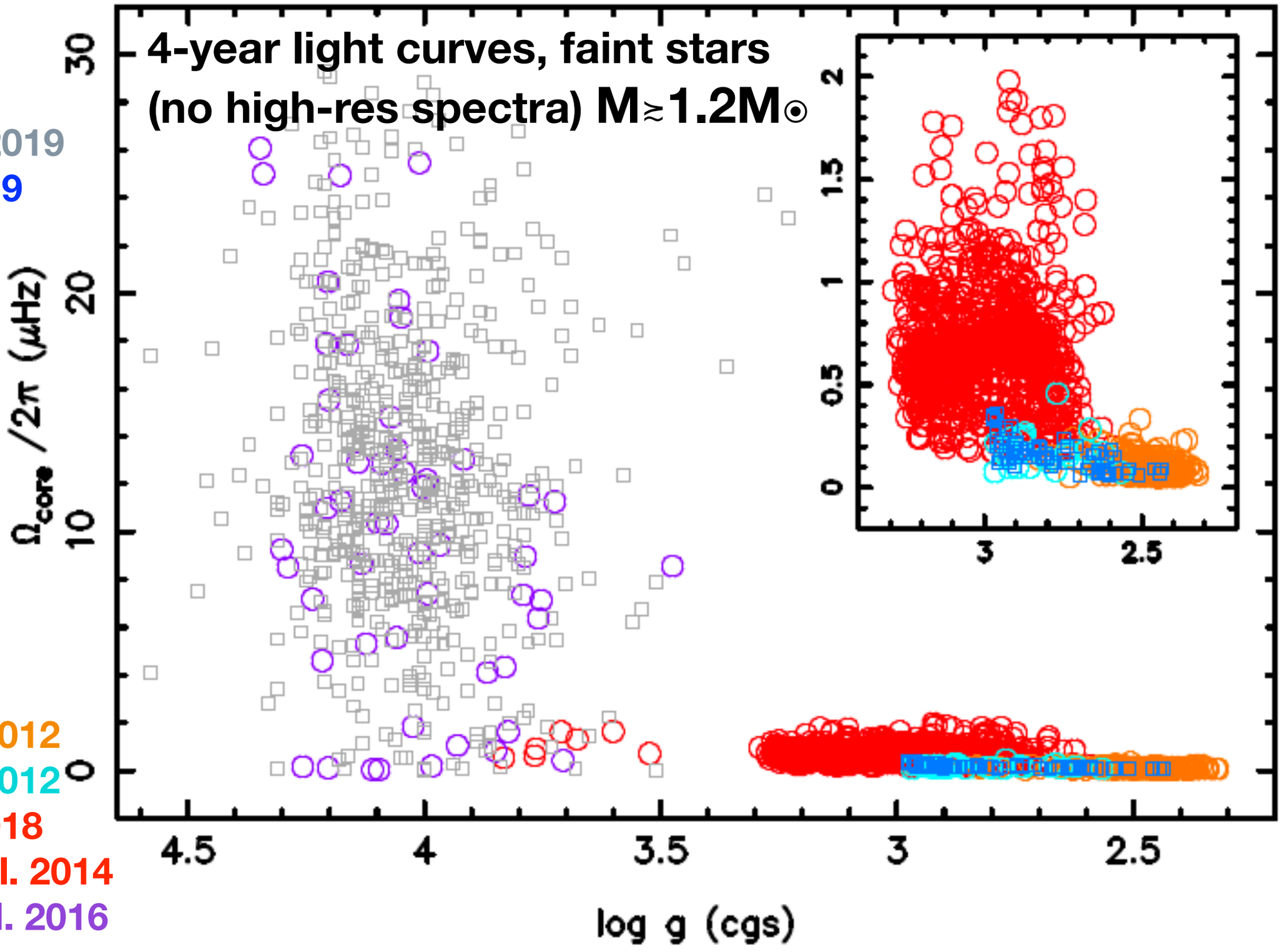


"Angular momentum transport is much more efficient when stars have convective cores"

Aerts et al., 2019, ARAA

Kepler: interior rotation, updated

Gang Li et al. 2019
Tayar et al. 2019



Mosser et al. 2012
Mosser et al. 2012
Gehan et al. 2018
Deheuvels et al. 2014
Van Reeth et al. 2016

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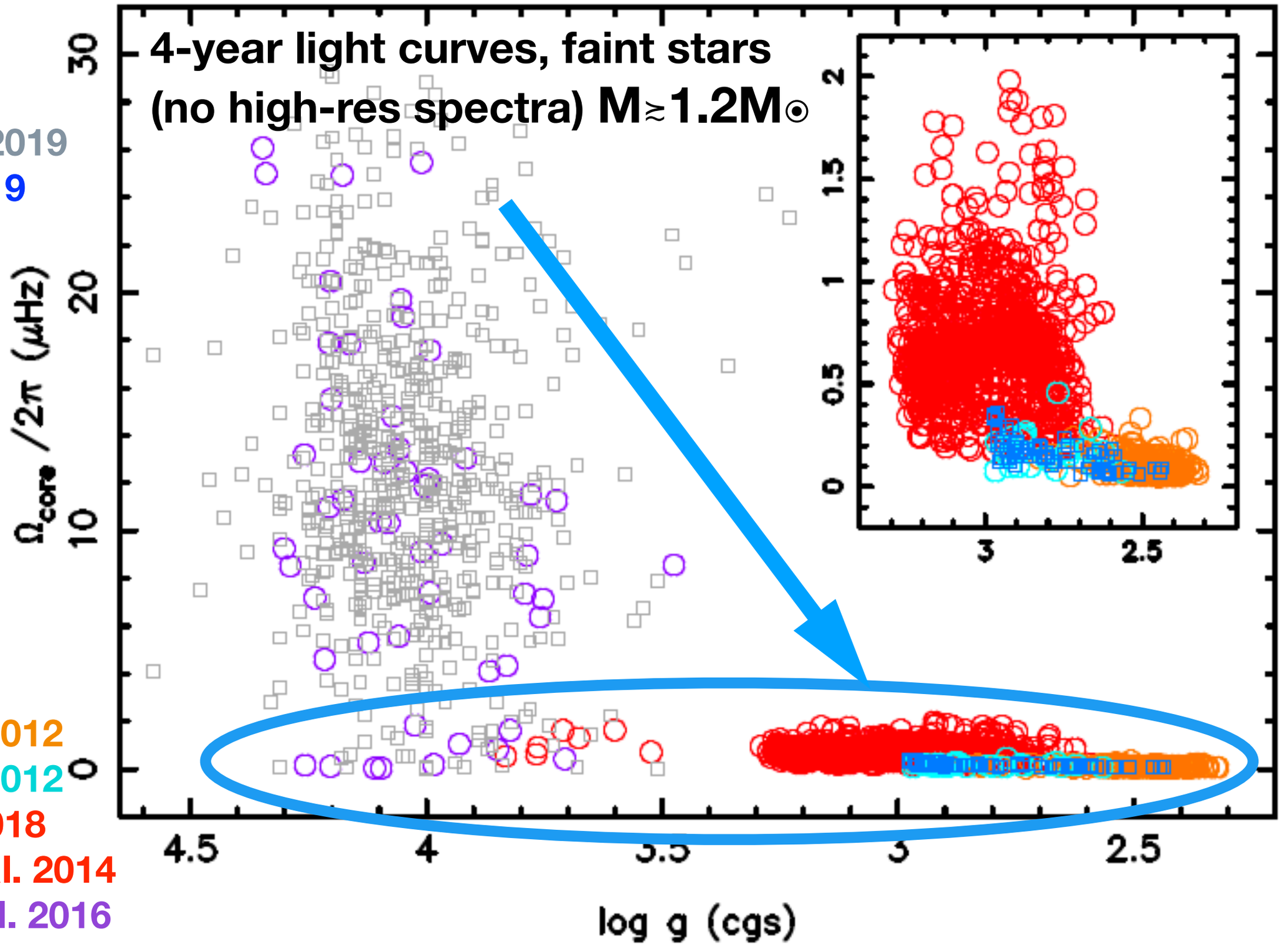

Mosser et al. 2012
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Micro-/macroscopic mixing: age!

$$\frac{\partial X_i}{\partial t} = \frac{3}{8\pi\rho r^2}\frac{\partial \mathcal{L}_{\rm IGW}}{\partial r} + \mathcal{R}_i - \frac{1}{\rho r^2}\frac{\partial}{\partial r}\left(\rho r^2 X_i w_i\right)$$
$$+ \frac{1}{\rho r^2}\frac{\partial}{\partial r}\left[\left(D_{\rm conv} + D_{\rm ov} + D_{\rm shear} + D_{\rm eff}\right)\rho r^2 \frac{\partial X_i}{\partial r}\right]$$

(e.g., Zahn 1992; Charbonnel & Talon 2005; Maeder 2009; Palacios 2013; Deal et al. 2019)

Optimal benchmark stars & oscillation modes to calibrate this?…

"We must also stress that there is no reason à priori to use the solar calibrated values for stars more massive than the Sun."
(Deal et al. 2019)

Micro-/macroscopic mixing: age!

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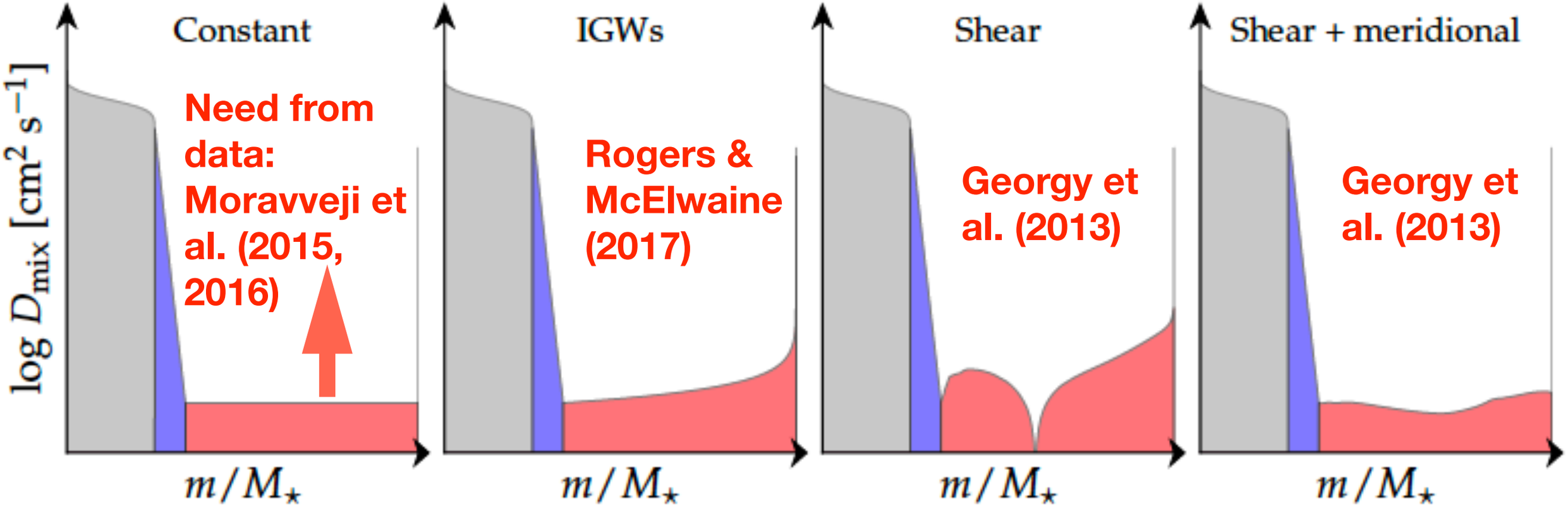

for M ≳1.3M⊙

Figure Courtesy of May Gade Pedersen (KU Leuven)

Current Benchmark Work in WP120

Using selected benchmark targets, to calibrate stellar models from **model-independent stellar parameters**, e.g.,

(see previous talks at this meeting…)

- *Eclipsing binaries* (Pierre: give your trash bin to PLATO-CS)
- Stars with interferometric radii (calibrators, limb darkening…)
- Luminosity from Gaia (but tricky in offsets; cf. talk Maria)
- (Open) *clusters* possible as calibration targets - should try…
- "Well-known" stars/pulsators with ***accurate*** *mass/age* to assess challenging aspects of physics (rotation, mixing, magnetism, etc.), e.g., solar analogues, TESS(-CVZ) stars,…
- etc. **Others/Additions from you!**

Dedicated classes of & specific calibration stars should be identified in 1st long pointing of PLATO FoV: 2 years prior to launch

Needs for various science cases

PLATO calibration plan = **PSWT task**, is subject to +5D optimisation problem
possibly with (anti-)correlations between stellar & exo science :-)

- must treat all core science topics, incl. $M \lesssim 0.8\ M_\odot$
- telemetry/datarate (5 to 15% taken away from core science)
- needed duration of photometry (e.g., year(s) for core rotation)
- need/preference for imagettes versus onboard LC
- calibration stars are part of core science: which ones need to be included in ground-based follow-up?…
- …

Will be checked & needs to be approved by ESA Advisory Structure (SMP)