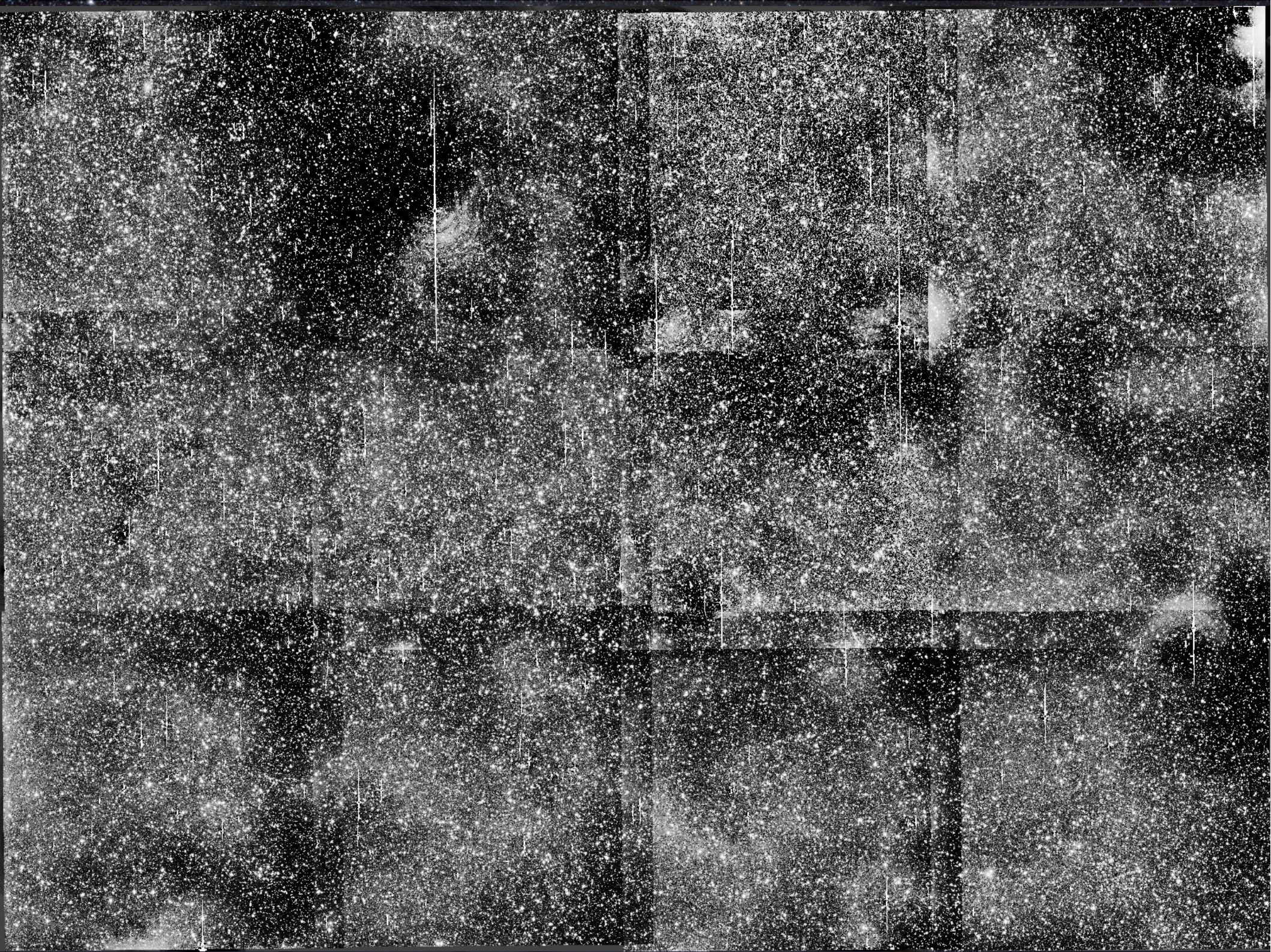
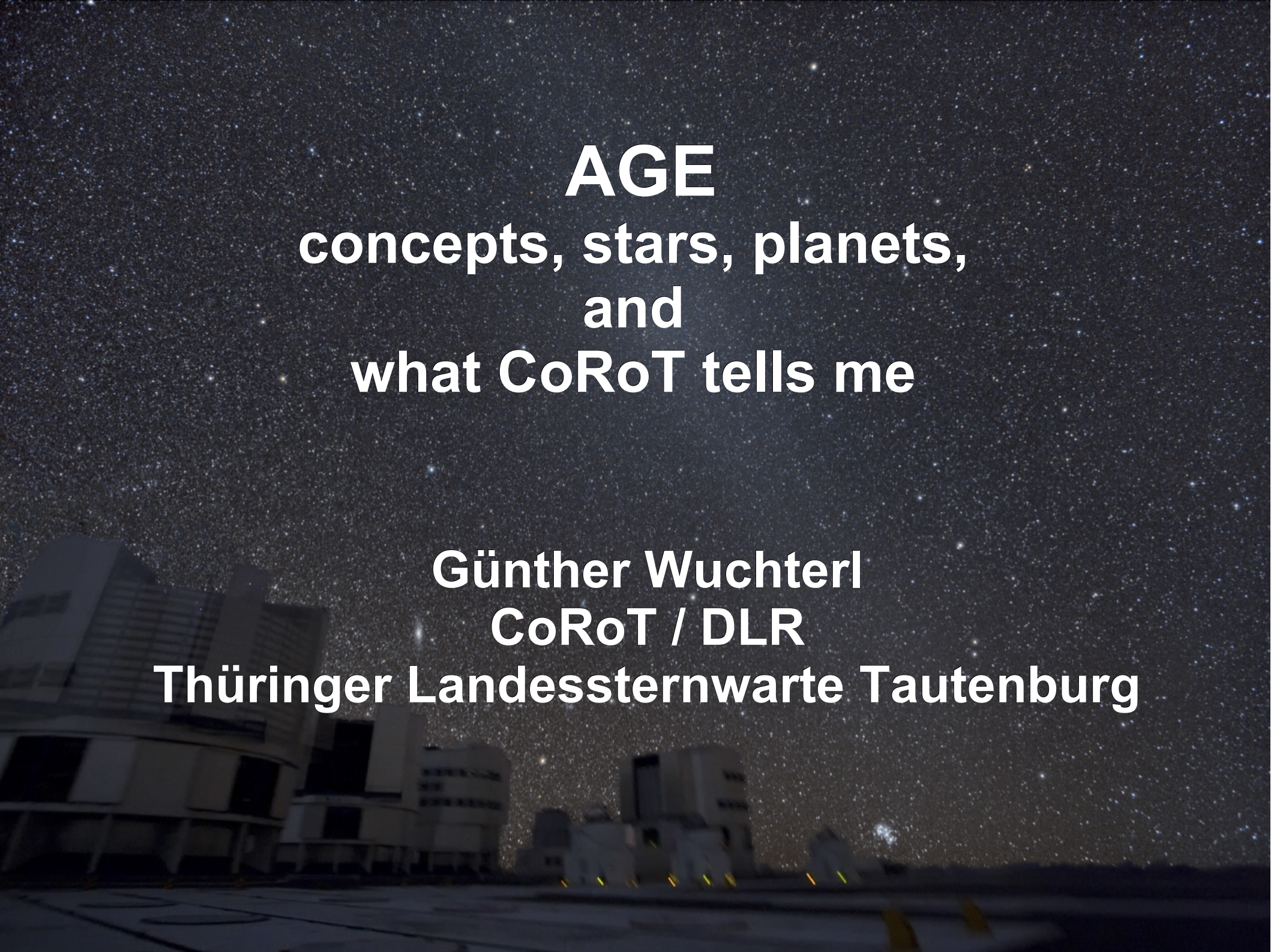
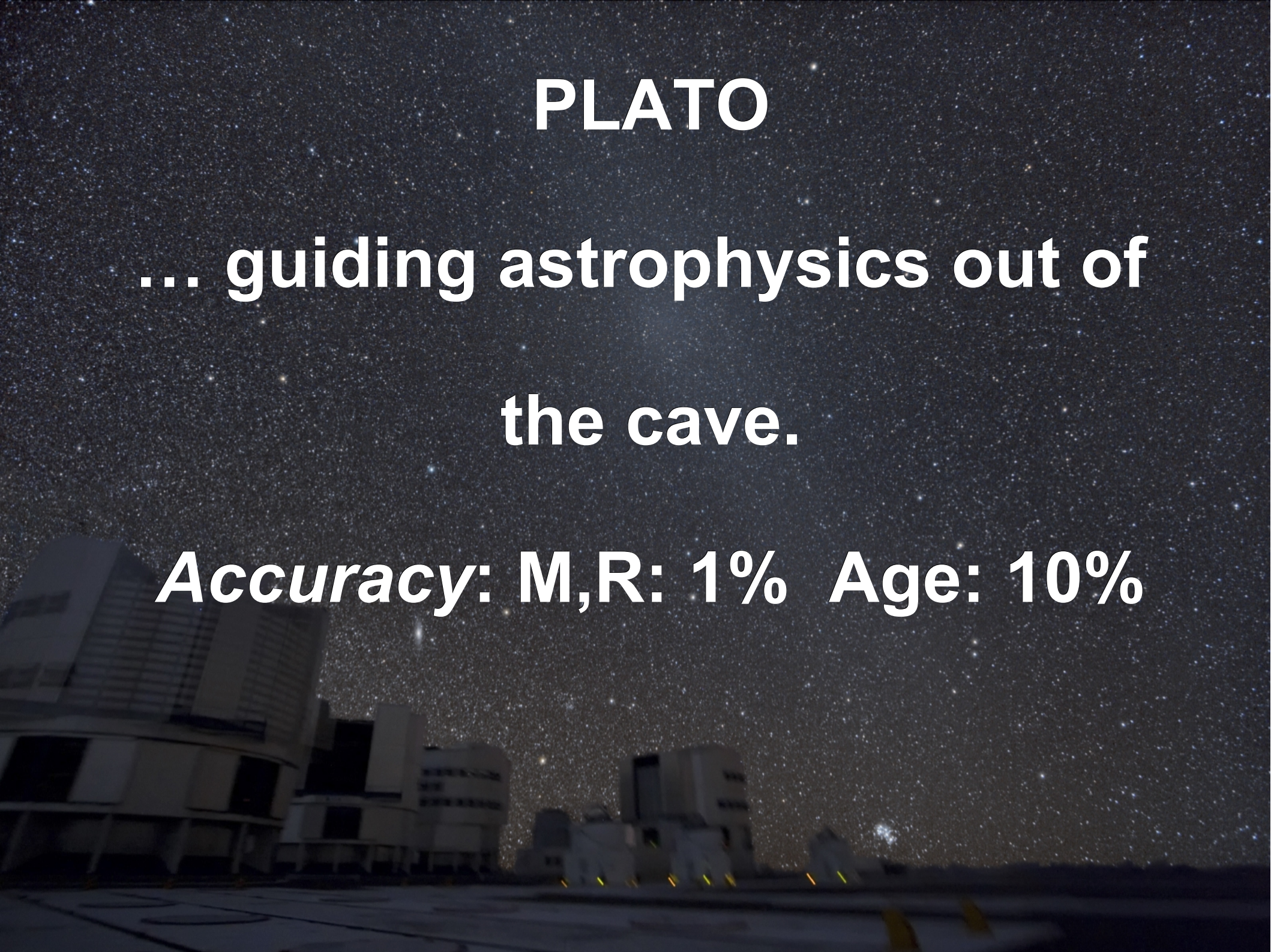




AGE
concepts, stars, planets, and what CoRoT tells me

Günther Wuchterl
CoRoT / DLR
Thüringer Landessternwarte Tautenburg


PLATO
… guiding astrophysics out of
the cave.
Accuracy: M,R: 1% Age: 10%

View of the cave 1605

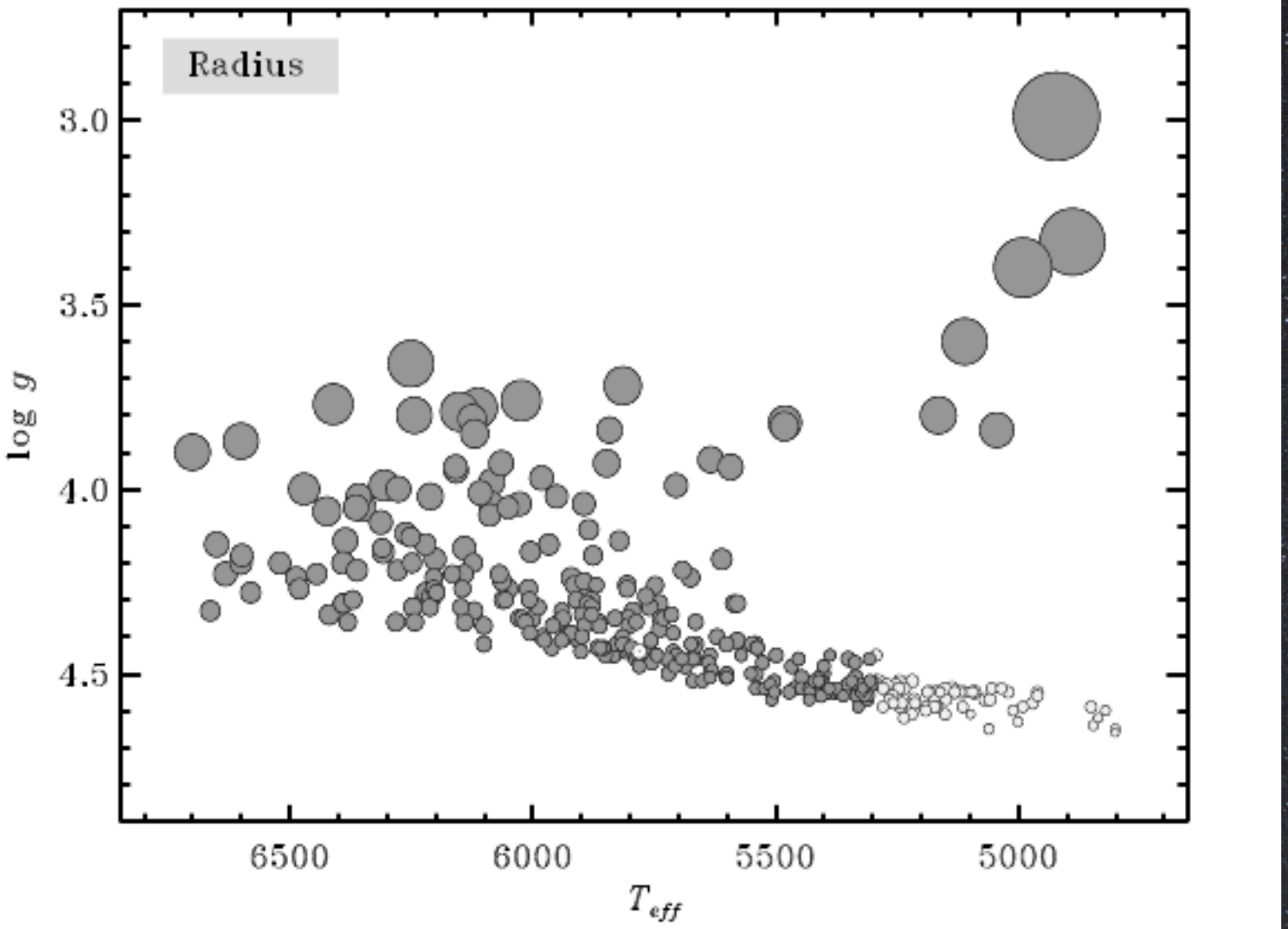
View of the cave Feb 2011

- The light: 115 planet host
- The shadows: 122 transiting planets
- The sound: p-modes l=0,1,2 for 5+ hosts
- The wall
  - Measurement of stellar parameters
  - Quantitative origin an early evolution of stars and planets
  - Convection

Accuracy now

Spectro-scopic Stellar Radii

F,G,K <25 pc



Fuhrmann 2011, MNRAS

Accuracy – spectro vs. interferometry

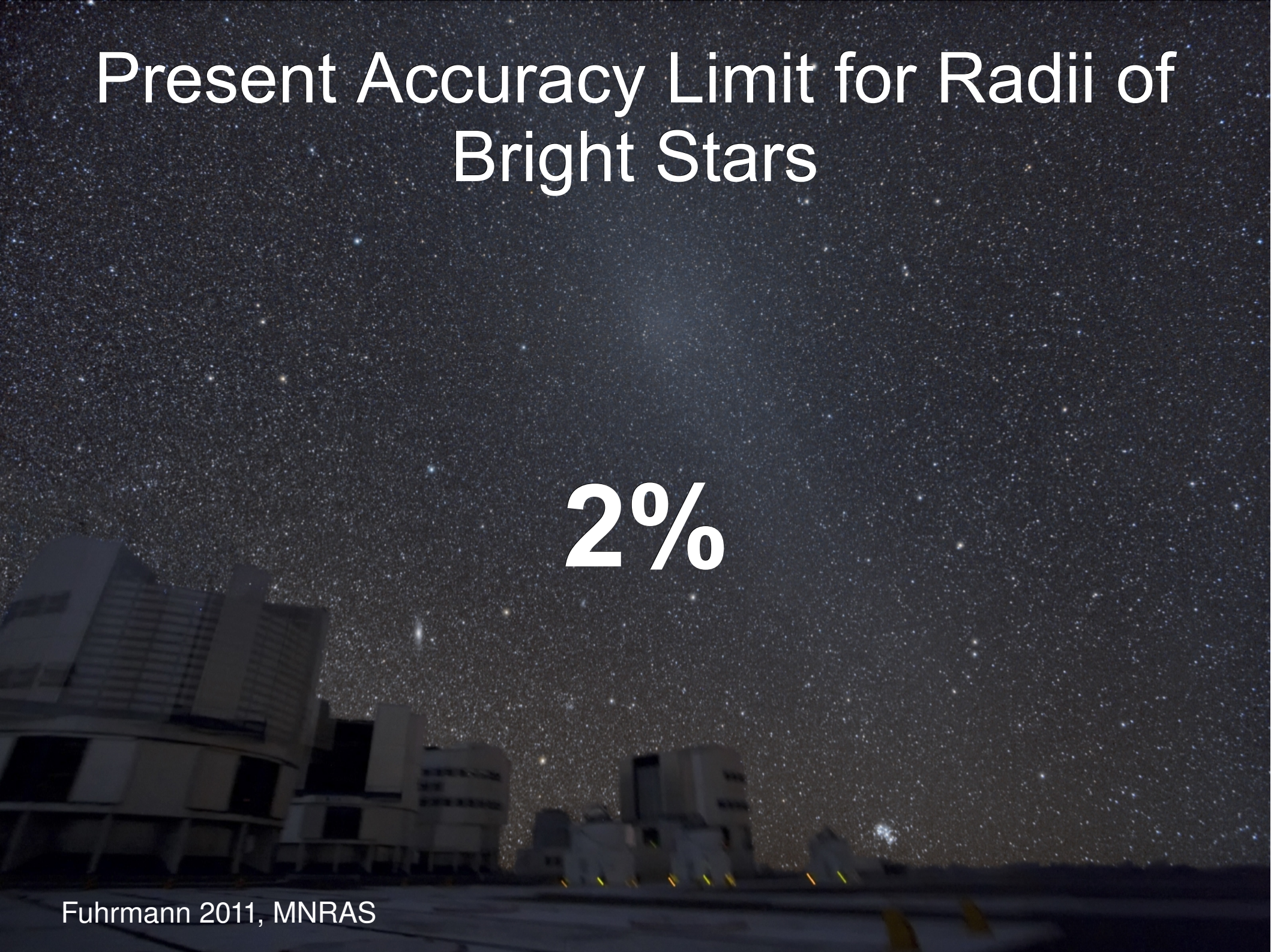
Table 2. Stellar radii from Balmer line effective temperatures versus interferometry. The homogeneously derived spectroscopic data have 1σ uncertainties at the 2 per cent level; the precision stellar radii from interferometry reach even down to 0.5 per cent. The stars in this table are arranged from dwarfs, turnoff stars, and subgiants, to the bottom of the red giant branch. The differences in the stellar radii, while generally small, are tentatively related to this sequence. Note that both sets of data refer here to the revised van Leeuwen (2007) Hipparcos parallaxes.

Object	HR	HD	T_{eff} (K)	$\log g$ (cgs)	$R_{Balmer\ lines}$ ($R_\odot$)	$R_{Interferometry}$ ($R_\odot$)	Ref.	Diff. (per cent)
ϵ Eri	1084	22049	5054	4.54	0.763 ± 0.015 (±1.99%)	0.735 ± 0.005 (±0.68%)	1	+3.81
σ Dra	7462	185144	5265	4.57	0.786 ± 0.015 (±1.94%)	0.776 ± 0.007 (±0.96%)	2	+1.29
τ Cet	509	10700	5373	4.54	0.816 ± 0.016 (±1.91%)	0.791 ± 0.004 (±0.51%)	1	+3.16
μ Cas A	321	6582	5387	4.45	0.779 ± 0.017 (±2.13%)	0.790 ± 0.009 (±1.12%)	2	–1.39
Procyon	2943	61421	6470	4.00	2.118 ± 0.038 (±1.78%)	2.058 ± 0.022 (±1.07%)	3	+2.92
						2.059 ± 0.022 (±1.07%)	4	+2.87
η Boo Aa	5235	121370	6023	3.76	2.761 ± 0.061 (±2.20%)	2.781 ± 0.050 (±1.81%)	3	–0.72
						2.696 ± 0.054 (±2.00%)	5	+2.41
						2.683 ± 0.042 (±1.57%)	6	+2.91
β Vir	4540	102870	6085	4.04	1.687 ± 0.031 (±1.84%)	1.704 ± 0.022 (±1.26%)	7	–1.00
μ Her Aa	6623	161797	5592	3.94	1.706 ± 0.030 (±1.73%)	1.746 ± 0.035 (±2.00%)	3	–2.29
δ Eri	1136	23249	5044	3.84	2.339 ± 0.047 (±2.00%)	2.328 ± 0.028 (±1.20%)	5	+0.47
η Cep	7957	198149	4990	3.40	3.986 ± 0.080 (±2.01%)	4.066 ± 0.062 (±1.52%)	8	–1.97
η Ser	6869	168723	4921	2.99	5.822 ± 0.120 (±2.05%)	5.871 ± 0.028 (±0.48%)	9	–0.83

Notes: (1) Di Folco et al. (2007); (2) Boyajian et al. (2008); (3) Mozurkewich et al. (2003); (4) Kervella et al. (2004); (5) Thévenin et al. (2005); (6) van Belle, Ciardi & Boden (2007); (7) North et al. (2009); (8) Nordgren et al. (1999); (9) Mérand et al. (2010)

Fuhrmann 2011, MNRAS, Baines et al. (2008, 2009), van Belle & von Braun (2009)

Present Accuracy Limit for Radii of Bright Stars



2%

Fuhrmann 2011, MNRAS

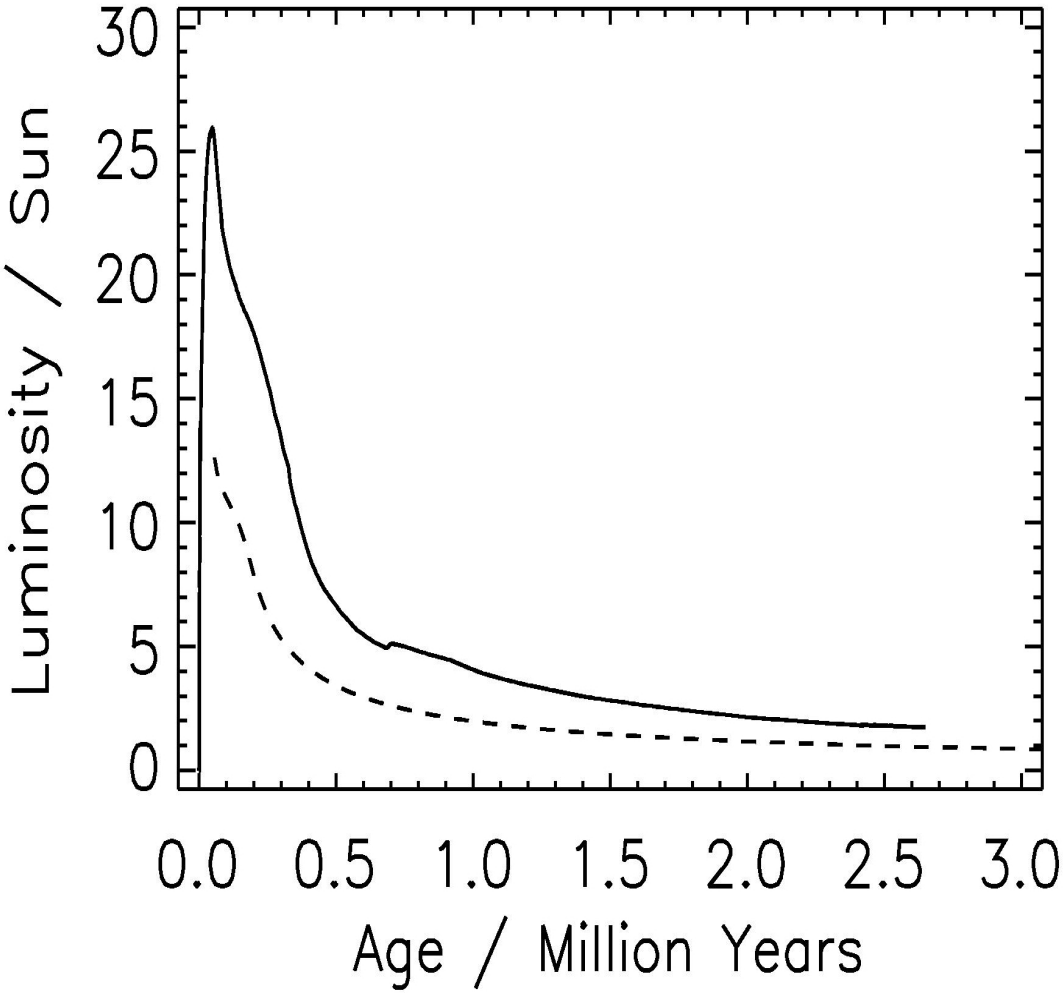
Chronology I: Age

- No sit, watch and count in stellar evolution
- Age is not a direct empirical quantity
- A parameter in a theory
- Needs
  - epoch (zero – point)
  - clock
- Clock: well constraint, controlled and understood physical process
- **: Clock=mature theory in the PLATO context**

Chronology II: On Clocks and Clouds

- Cloud collapse to PMS
- Age zero: formation of the photosphere

- Contraction-clock
- Radiative YSO
- PMS: 10% at UMa age
- Memory?



Wuchterl and Tscharnuter 2003

Chronology III: The Convection Trilemma

- The clock – stellar interior: $\Lambda/H_P = 1.5 – 2.0$
- The temperature – atmosphere: $\Lambda/H_P = 0.5$
  - Seismo density needs T_{eff} or T(r) for sound-speed to get the mean stellar density
- The planet radius – ingress with limb-darkening $\Lambda/H_P = ?$

Present heuristics: freeze convection to 1958 MLT, Christensen Dalsgaard et al. 2009

Mach about Plato

15. Es liesse sich leicht durch analoge Beispiele aus andern Gebieten der Physik darthun, dass die Menschen überhaupt die Neigung haben, ihre selbstgeschaffenen abstrakten Begriffe zu hypostasiren, ihnen Realität ausserhalb des Bewusstseins zuzuschreiben. Platon hat von dieser Neigung in seiner Ideenlehre nur einen etwas freien Gebrauch gemacht. Selbst Forscher wie Newton waren, ihren Grundsätzen zum Trotz, nicht immer vorsichtig genug. Es verlohnt sich also wohl der Mühe, zu untersuchen, vorauf dieser Vorgang in diesem besonderen Falle beruhen mag. Wir gehen bei unsern Beobachtungen von der

It would be easy to demonstrate from other areas of physics that humans generally tend to To ascribe material existence to their self-created abstract concepts, to ascribe to them a reality outside the consciousness. Plato just used this tendency rather freely in his theory of ideas. Even scientists like Newton where, in spite of the principles, not cautious enough.

Mach, Wärmelehre, p.551, Leipzig 1900

What CoRoT tells me - I

Theory:

- systems to be expected (Lissauer 1995, pre Peg, Funk et al. 2009)
- 2/3 Neptunes, 1/3 Jupiters (Wuchterl et al. 2006, pre CoRoT; Broeg 200);

Observations:

- RV for planet mass: 2 measurements at extremes → CoRoT-7: 110 meas. to disentangle system
- Kepler: no RV-mass for half the multis (… "America waives the rules") - rem. Neptune

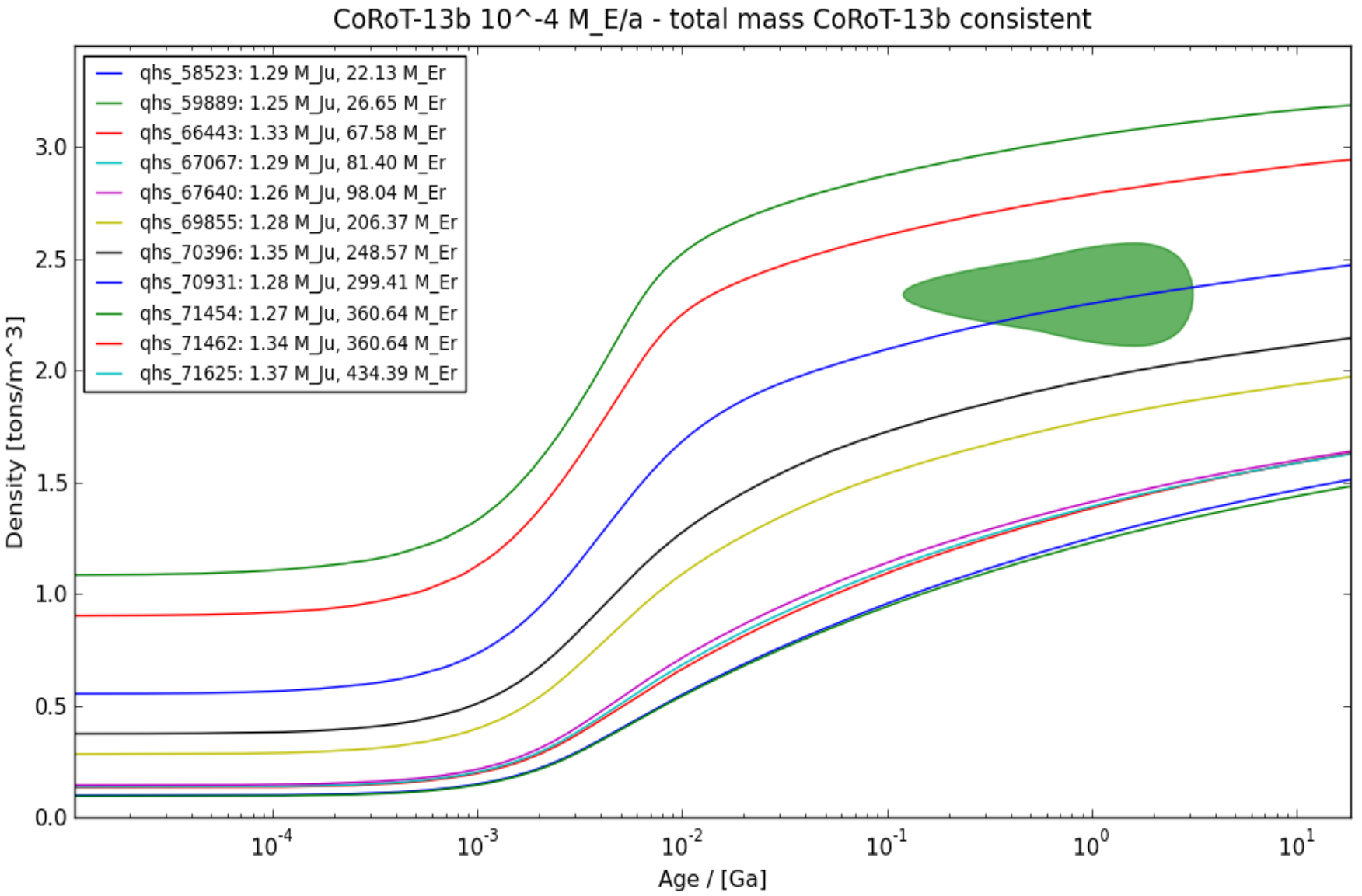
What CoRoT tells me - II

- : make correctable theory tools accessible to data analysis design and procedures as well as observation-planning.

  e.g. consistent limb darkening, stellar atmospheres, planet radii and ages for your favourite flavour of convection.


One planet analysis one physics

CoRoT-13b: density and theory



MACH - the PLATO clockmaker

- Theoretical mission support with age accuracy management
- Consistent theory for
  - stellar and planet formation and evolution
  - seismological and planet-transit analysis

- Motto: try another convection this morning
- determine limb darkening for transit-planet-radii

with same convection theory used for seismo stellar structure and stellar atmos for T_{eff}

Remember Socrates' remark:

"As for the man who tried to free them and lead them upward, if they could somehow lay their hands on him and kill him, they would do so."

Conclusion

- Inter community theoretical mission support needed to unify tools in seismo and exoplanets and to control the better than 10% age accuracy.
- Break the de-facto freezing of convection to 1958 MLT in all theory domains.
- Bridge the gap between data analysis and theoretical progress.
- Build a toolbox for PLATO-astrophysics.


Plato.astronomy2009.at