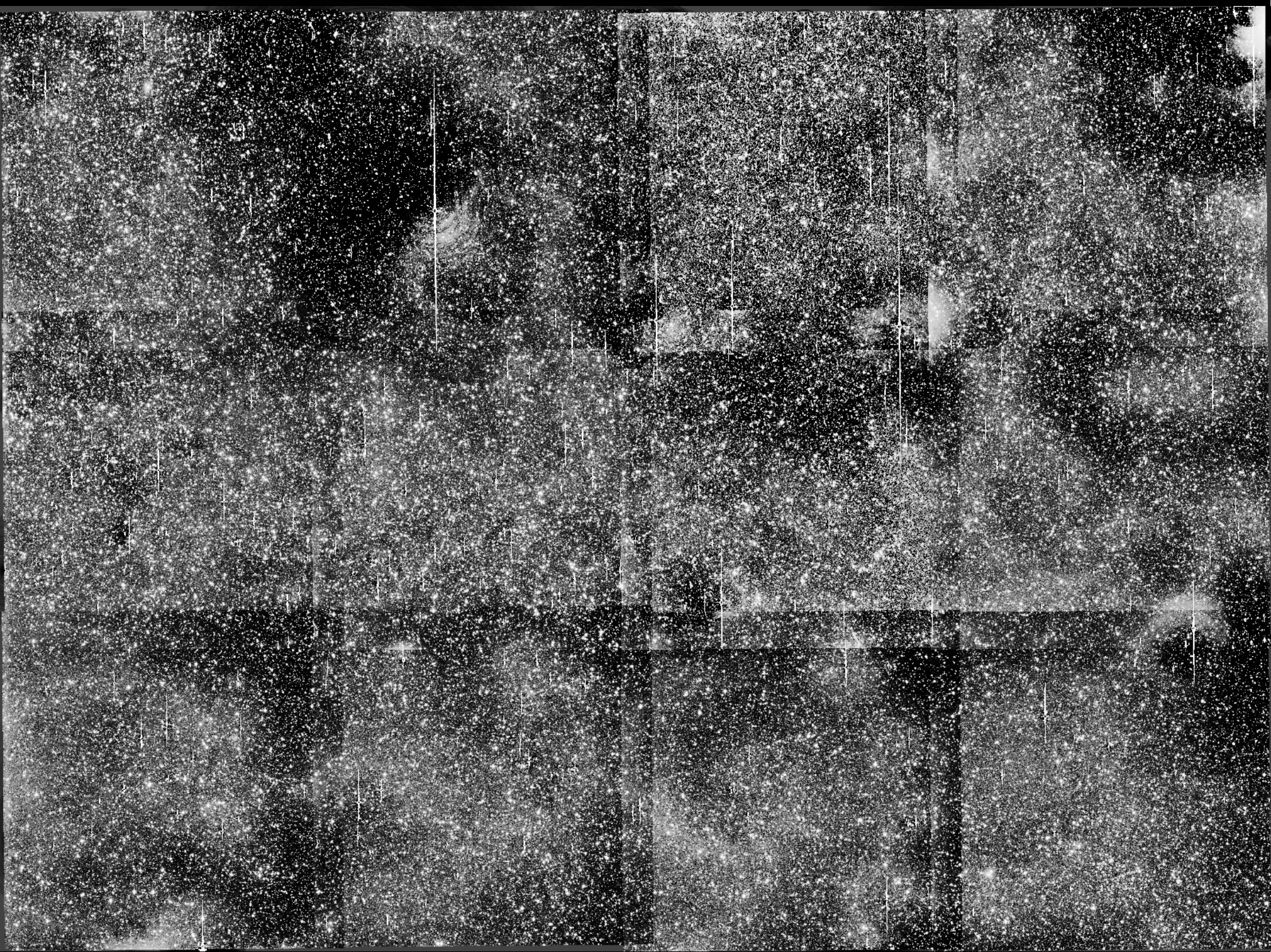
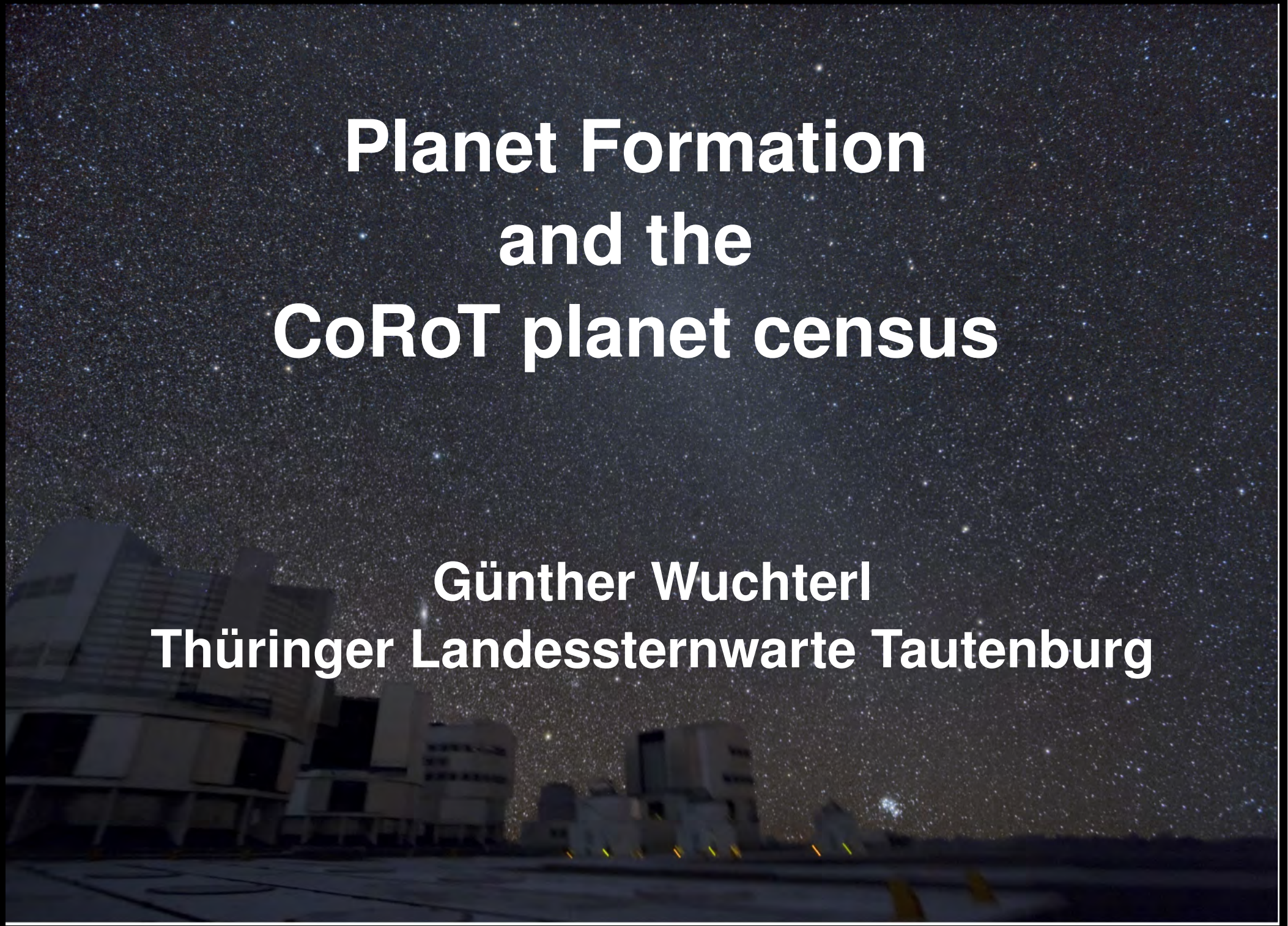


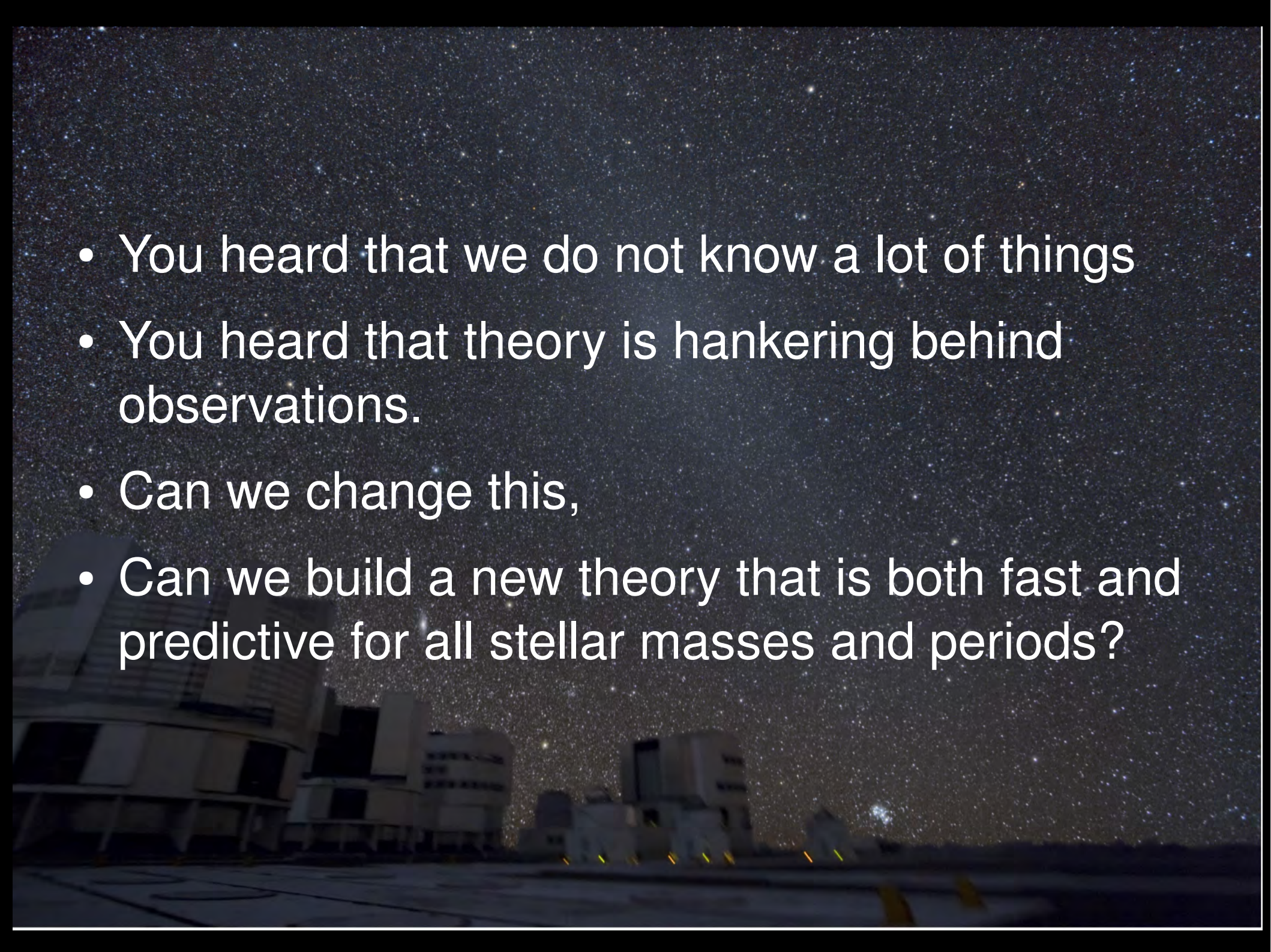


Planet Formation and the CoRoT planet census

Günther Wuchterl
Thüringer Landessternwarte Tautenburg

Making good planets is hard!

- Understand star formation
- Understand nebula formation
- Understand planetesimal formation



- You heard that we do not know a lot of things
- You heard that theory is hankering behind observations.
- Can we change this,
- Can we build a new theory that is both fast and predictive for all stellar masses and periods?


General Theory of Planet Formation

Assumptions and Principles

- Diversity of nebulae: study planet formation in any gravitationally stable nebula for all stellar masses,
- Strong planetesimal hypothesis: there are always enough planetesimals,
- Study cores of all masses including zero - Do not separate into nucleated instability or disk instability;

Calculate and Count

- Choose host star and orbital period
- Planetary equilibria with all core masses
- Hydrostatic equilibrium (P vs. core and gas)
- Thermal equilibrium (L vs. planetesimal accr.)
- Mechanically (pressure) and thermally (radiation into equilibrium temperatur nebula) connected to the nebula

How to understand this?

- Think of planet formation as analogy to the van der Waals gas with gravity as the long-range force,
- Take planets as analogy to the liquid phase in coexistence with the nebula as gas,
- Look at
  - Pečnik and Pečnik+W for the isothermal case
  - Broeg and Broeg+W for realistic planets
  - Wuchterl et al. For the CoRoT-stellar-mixture

Results

Planetary equilibria in stable nebulae

Radiative/Convective gas-spheres; SCVH + Ferguson

Stars: spectral types A,G,K,M; 0.4 to 2 $M_{\odot}$

Periods: 1 to 64 days.

Mark 1: Dec 2005

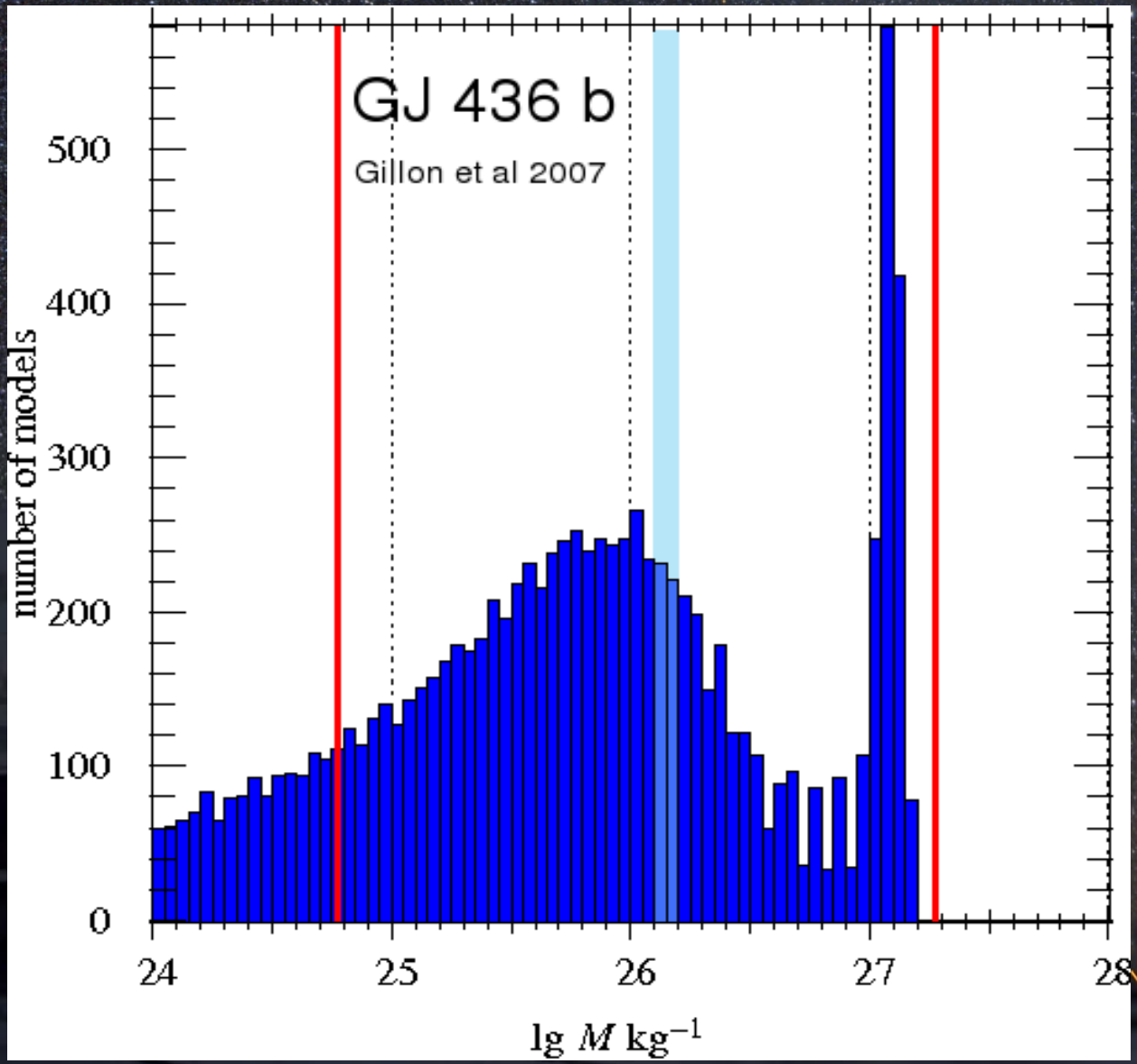
Mark 2: Sept 2007

Mark 3: June 2008

At Chris Broegs webpage

http://www.space.unibe.ch/~broeg/

GJ 436 b – the first Hot Neptune



Planetary masses

Blue: CoRoT Mark 1 theoretical mass spectrum for 0.4 M_{Sun} and 4 d period (Mark 1.1 Broeg '06);
Red: Earth and Jupiter;
Light-blue: GJ 436b.

Theoretical planet populations for CoRoT – Two Steps

1. *Formation* at *short* periods ("launch prediction": planetary IMFs for CoRoT stellar masses and CoRoT planet periods,
2. *Evolution* for these initial populations: radii and epoch of observation radius distributions;

1: 2006 Dec. 26th: CoRoT Launch Prediction: Planetary Masses from Formation Theory

Wuchterl et al.; 2006+n, Lammer et al. 2006+n

Dec. 26th: **astro-ph/0701003 ;astro-ph/0701565**

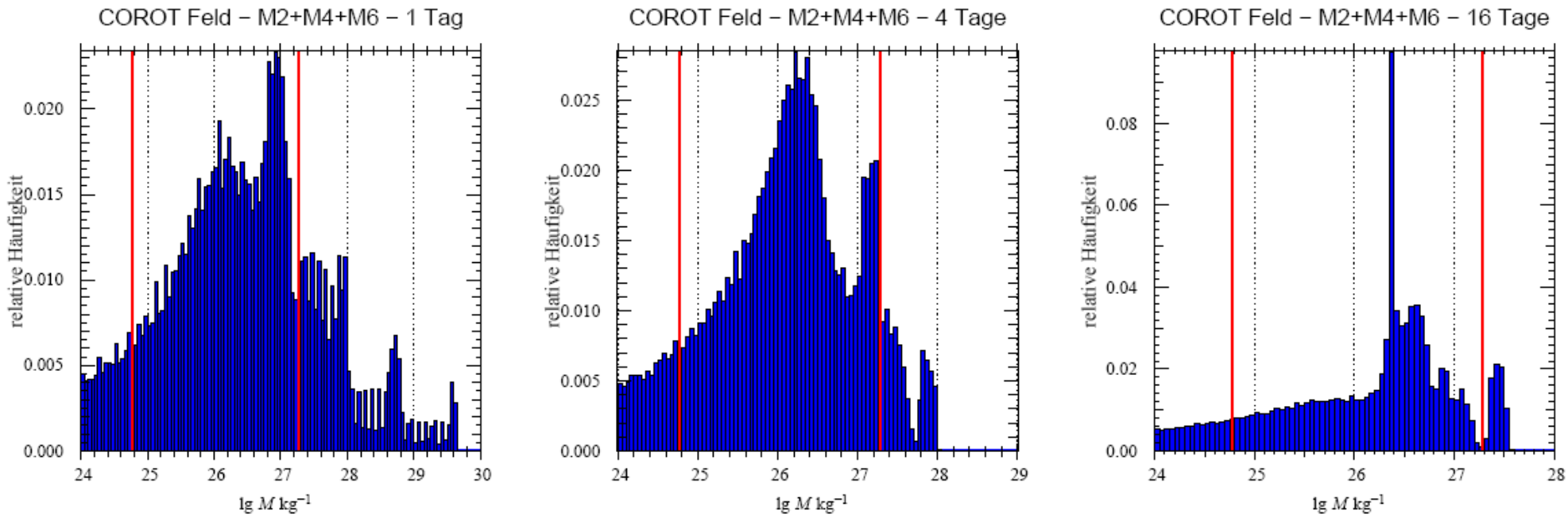
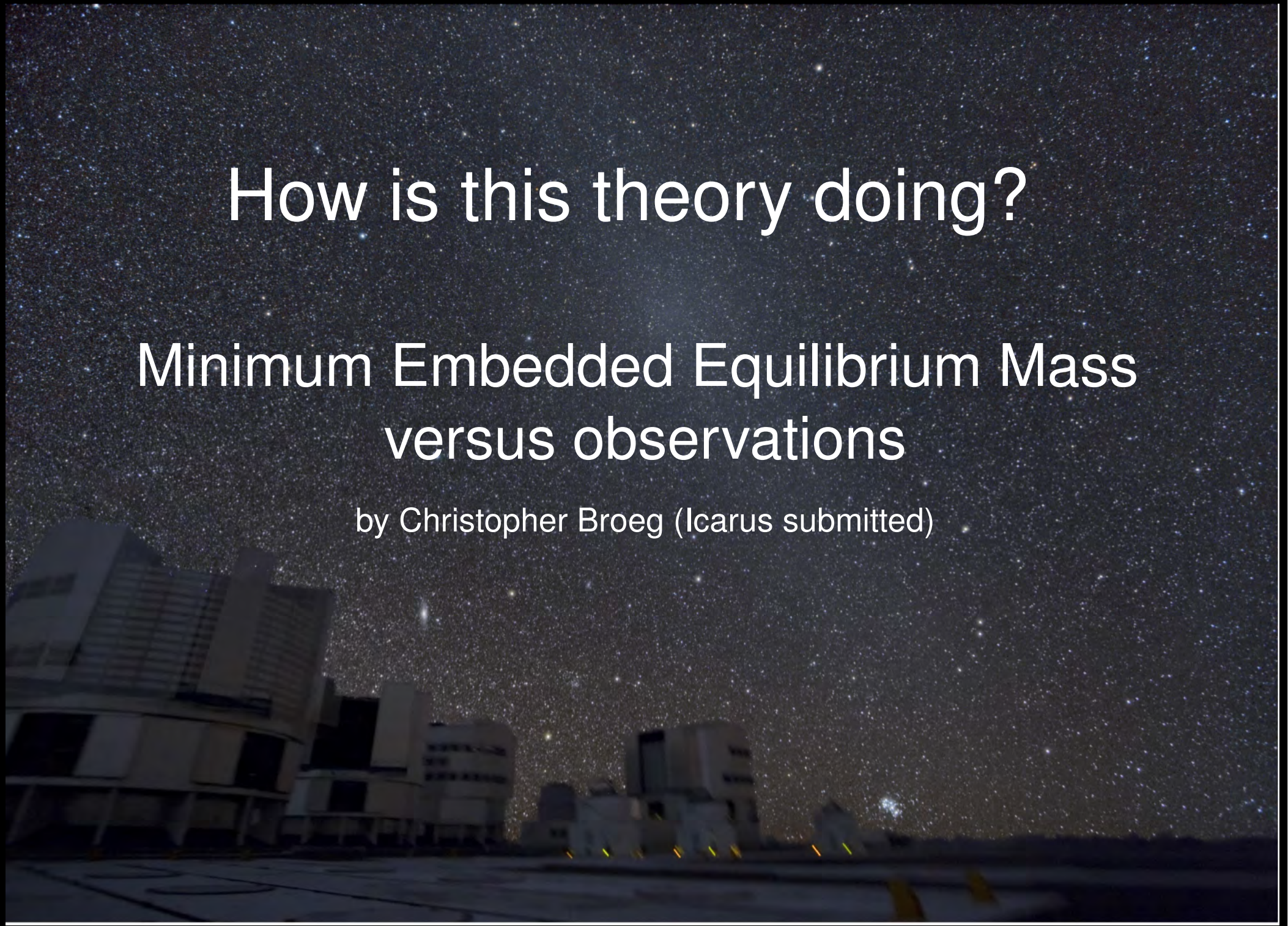


Fig. 1. Theoretical planetary initial mass functions calculated from planet formation theory for a typical CoRoT-field. Results are shown for planetary orbital periods of 1, 4, and 16 days, from left to right. The relative frequency is plotted as function of lg mass in kg. Vertical red lines mark the Earth and Jupiter masses. ~ 10^6 planetary models in total. Structures of width < 0.3 dex have to be taken with care, because of undersampling in spectral type due to the unexpected richness of the mass-spectra. ('M2+M4+M6' designates planetary core-accretion and is not related to the stellar population).



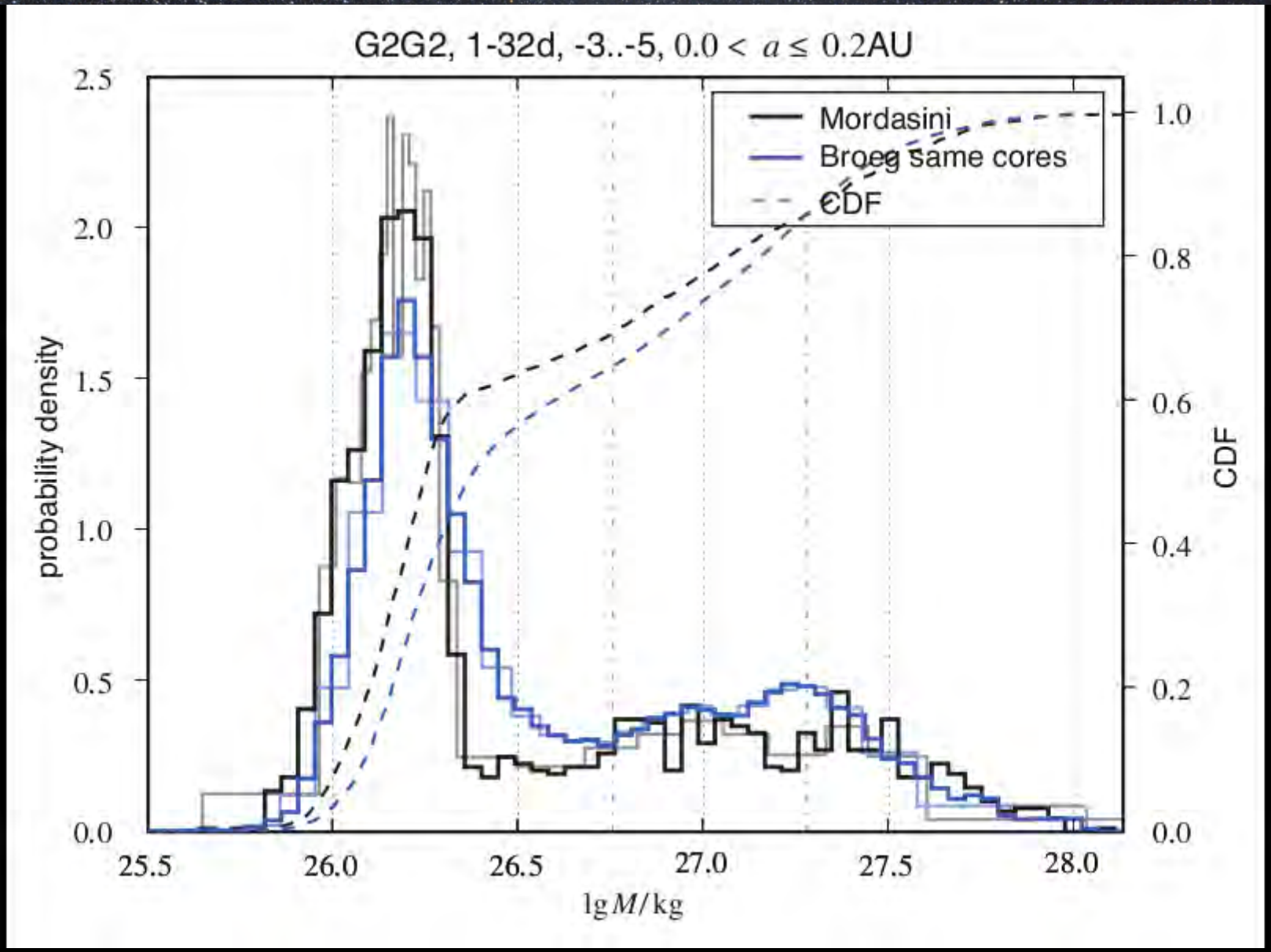
How is this theory doing?

Minimum Embedded Equilibrium Mass versus observations

by Christopher Broeg (Icarus submitted)

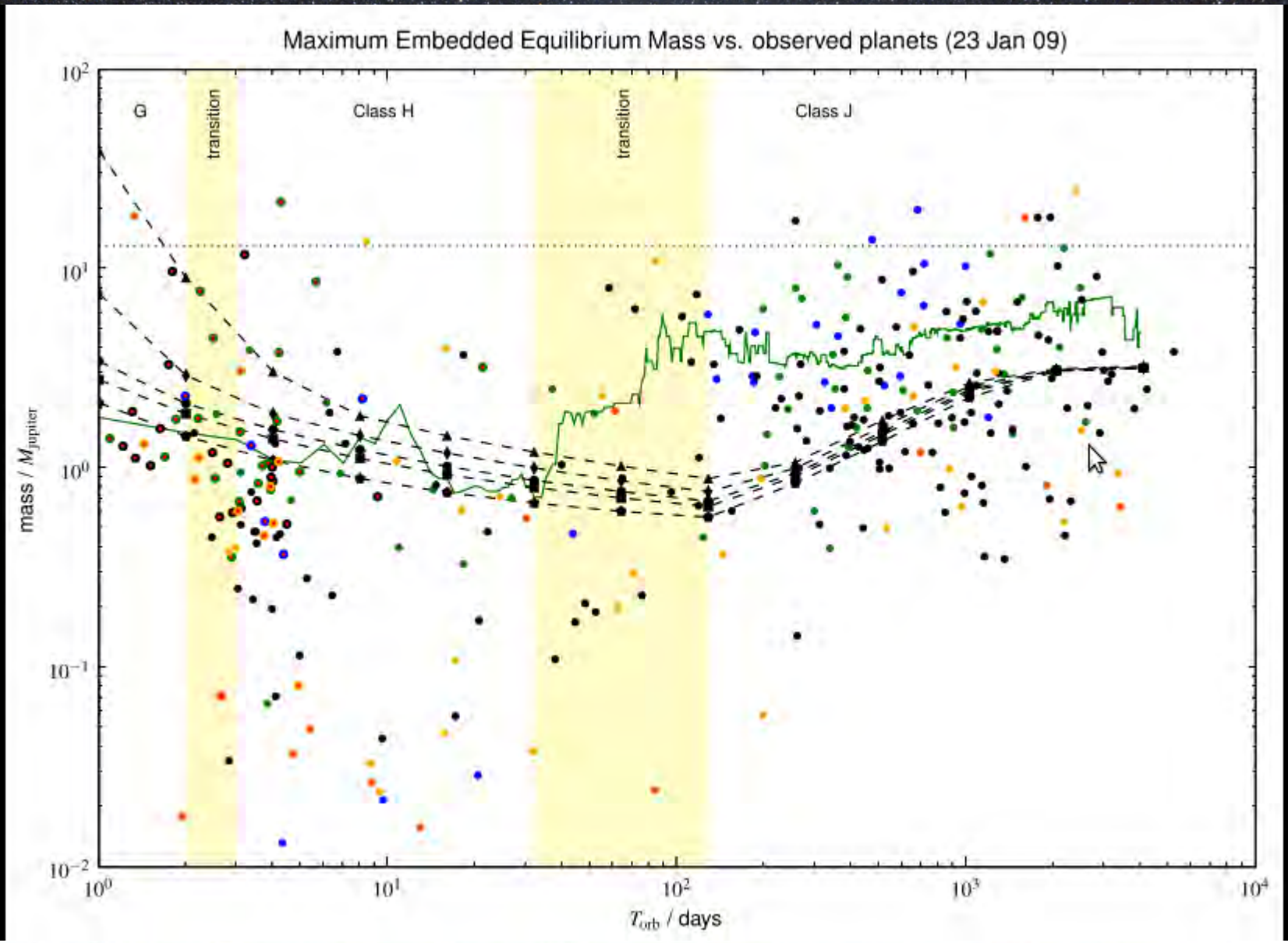
Is this queer? Comparison to conventional theory

See Poster by Broeg

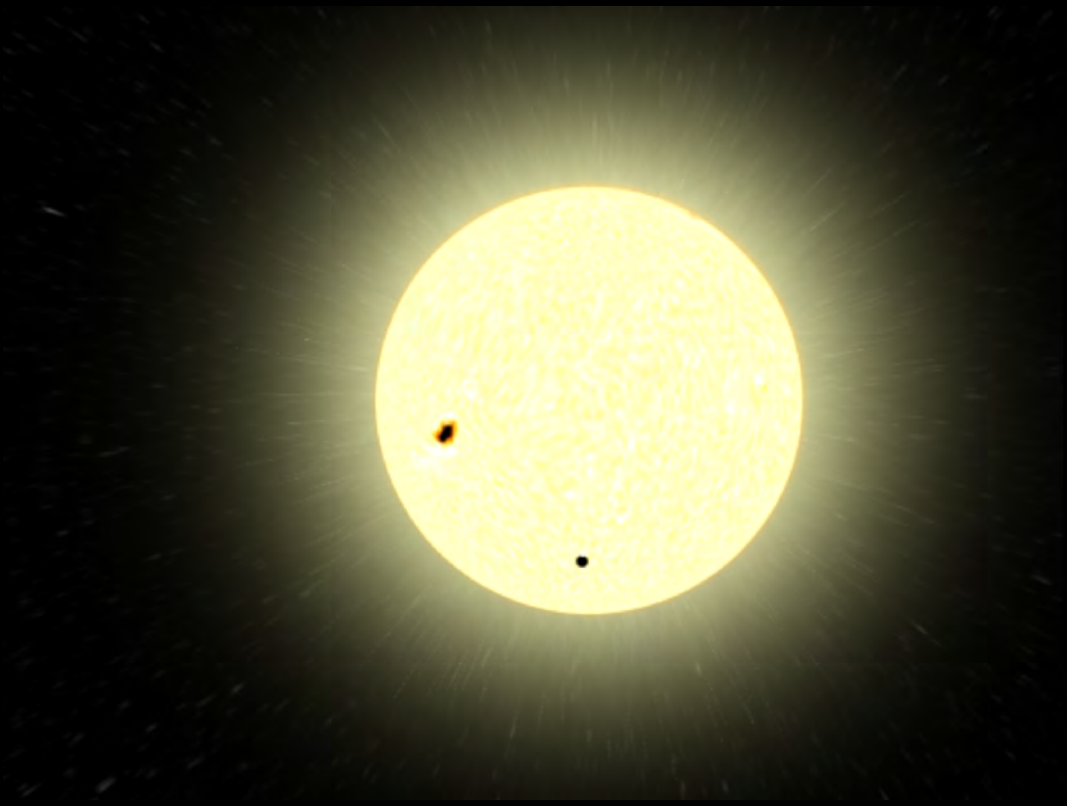


What about observations?

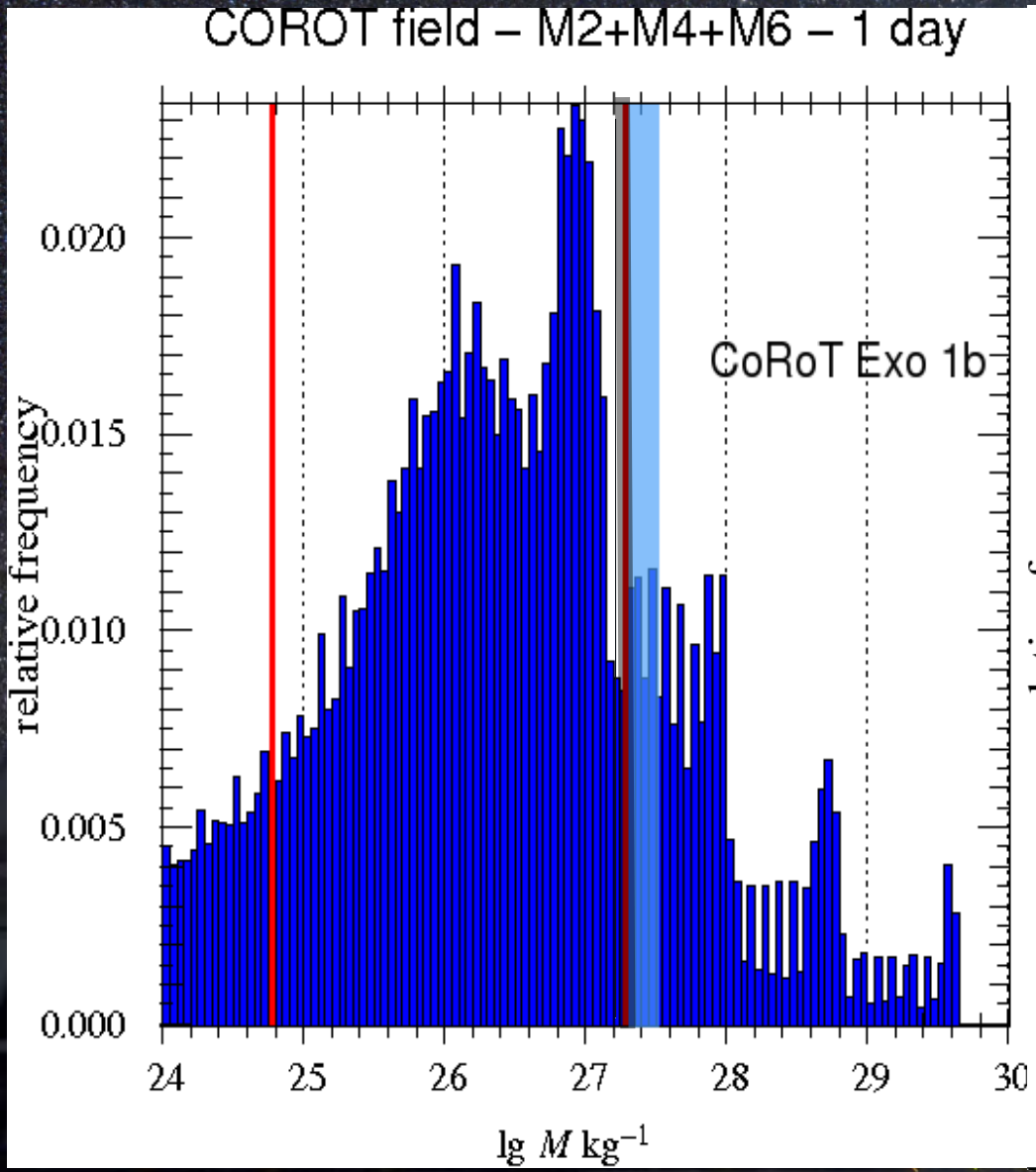
See Poster by Broeg

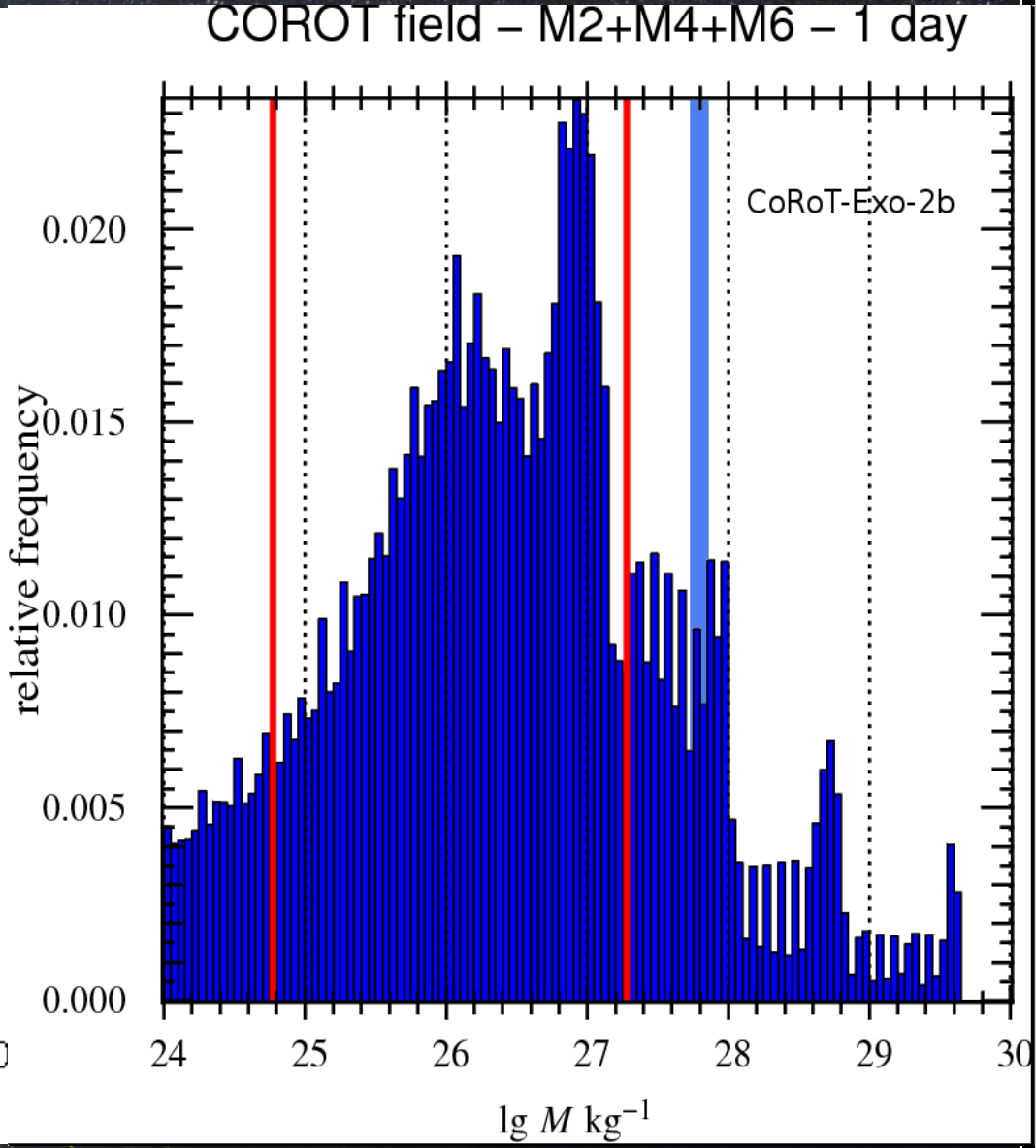



The CoRoT Seven



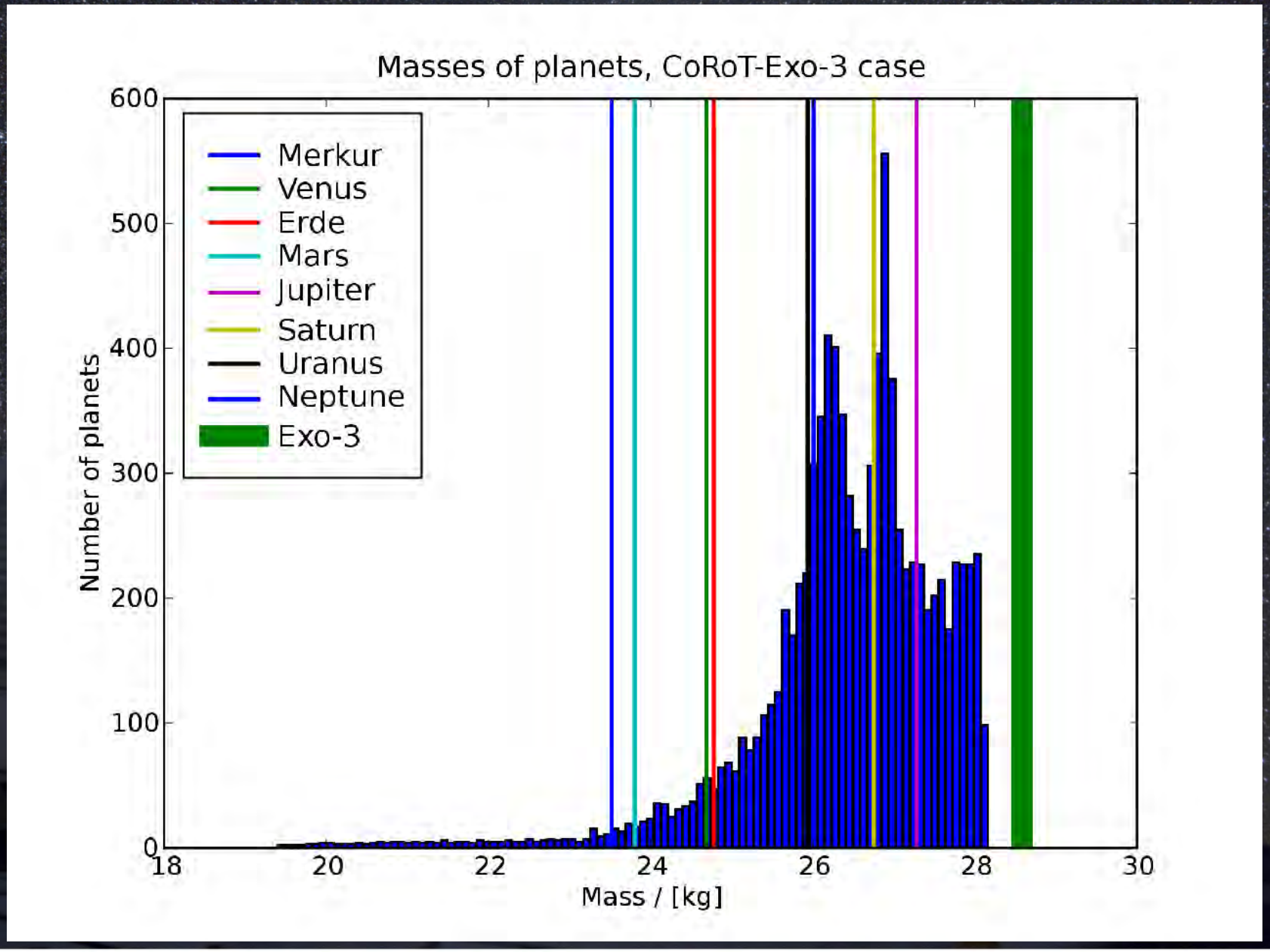
CoRoT-Exo-1b, -Exo-2b



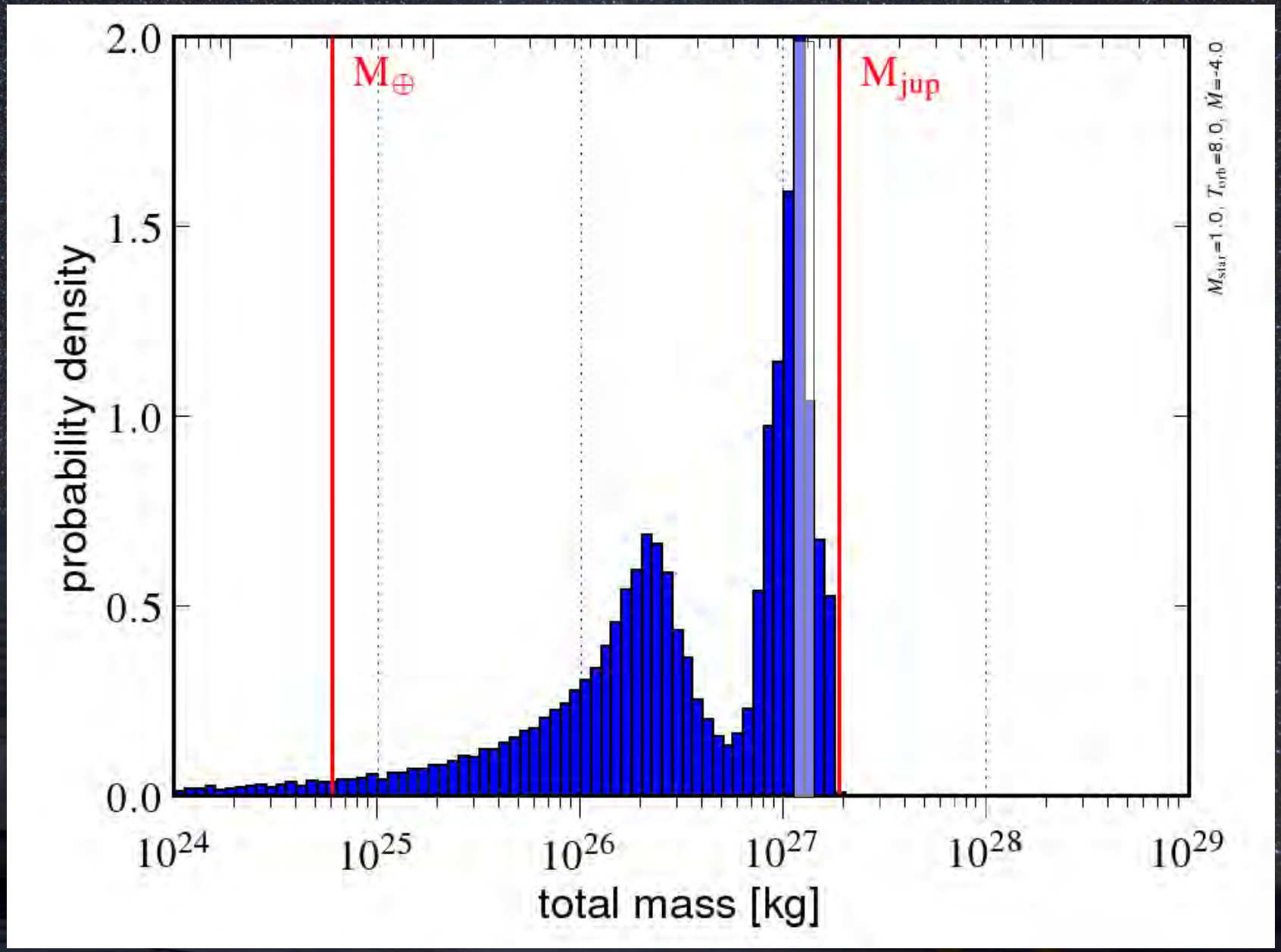


Theoretical predictions: Broeg 2006, 2007, Wuchterl et al. at CoRoT-launch, astro-ph/0701003

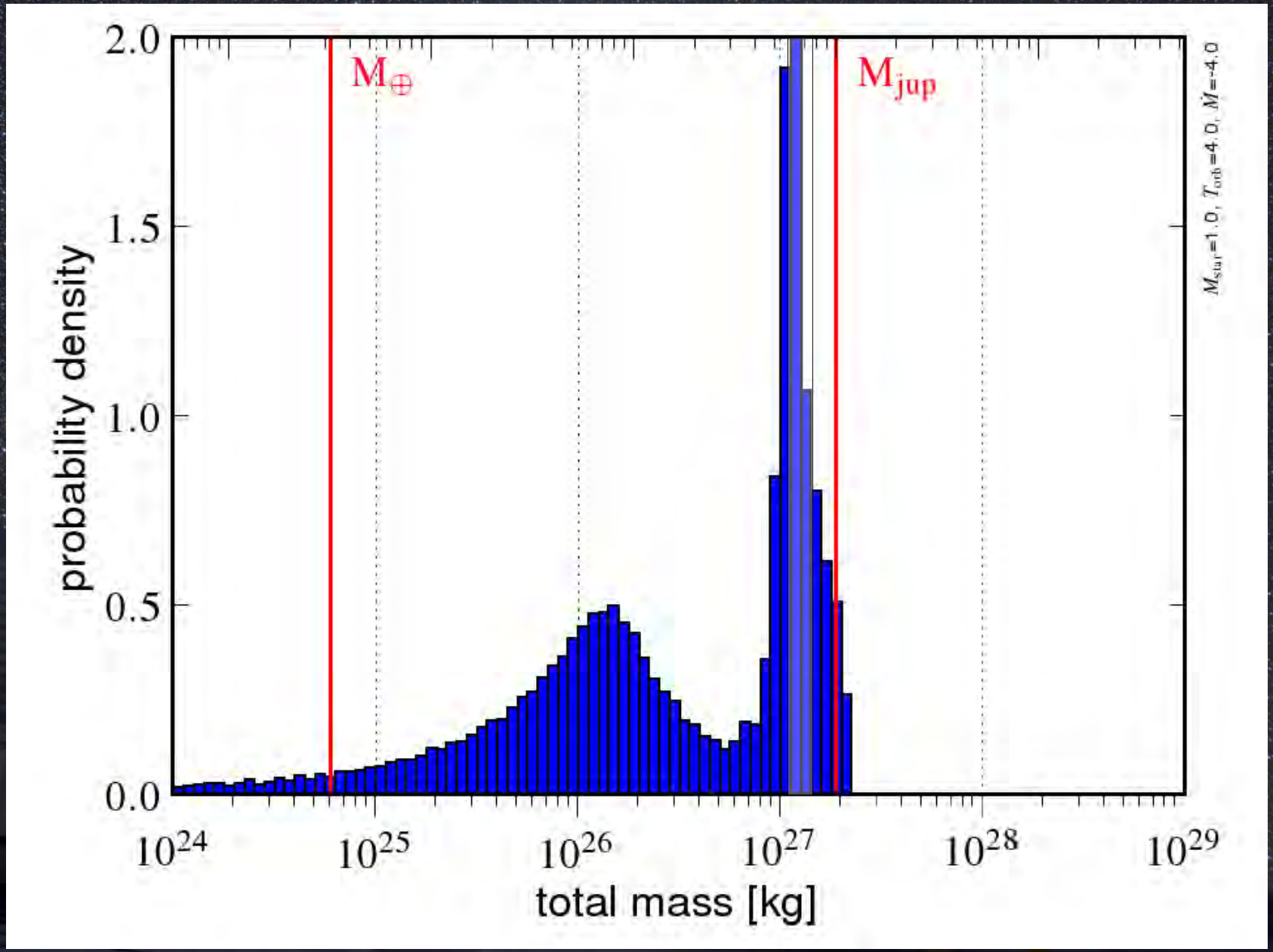
Planets at 1d/1M$_\odot$ vs CoRoT-Exo-3b



CoRoT-Exo-4b and theory for Exo-4



CoRoT-Exo-5b and theory for Exo-5

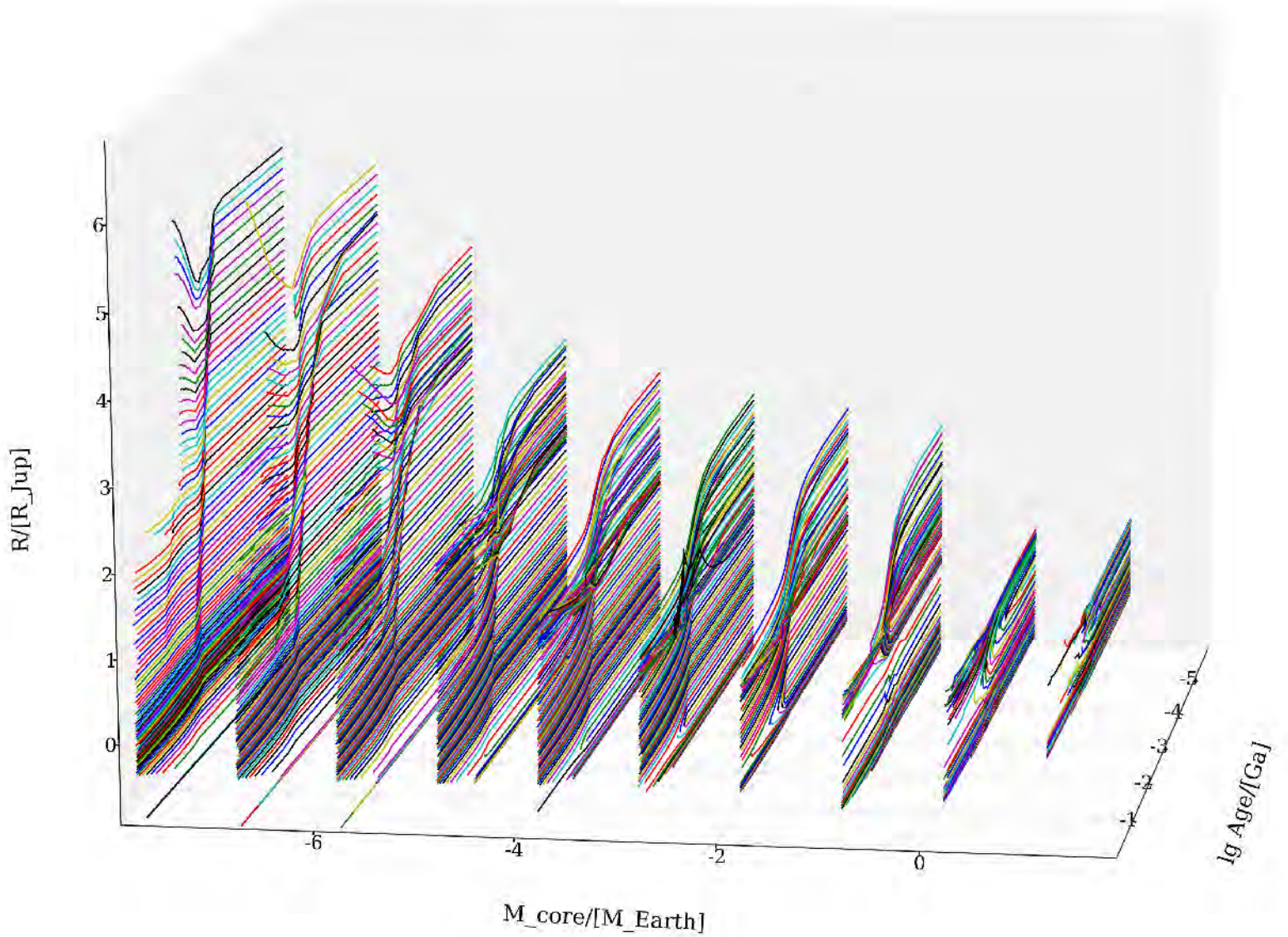


2: Evolution and Age
From initial to present radii

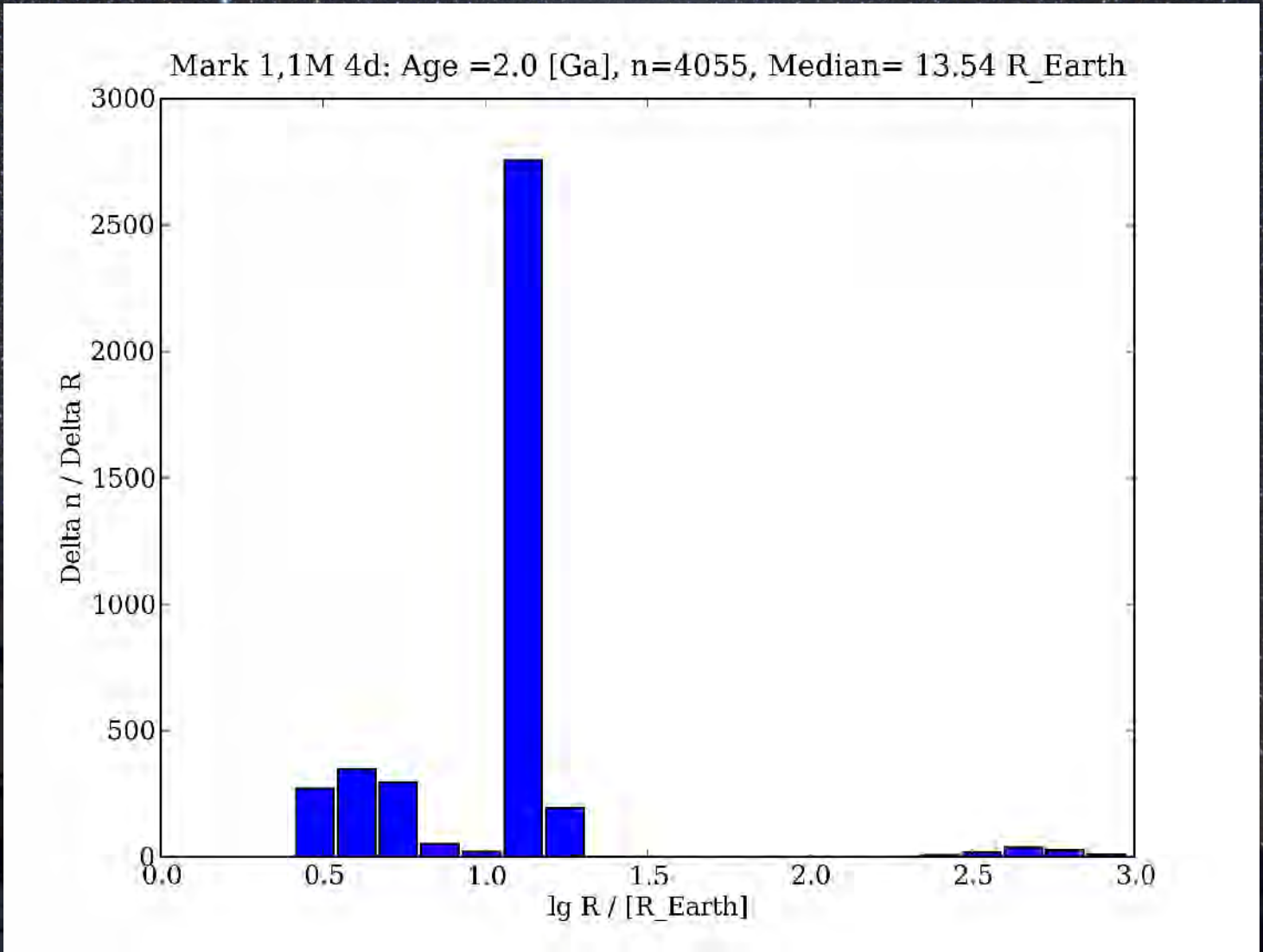
Initial masses and interior structure for the “IMF”-ensemble of planets

Evolution of planetary populations:
switch-off planetesimal accretion
nebula decompression (if any)

Radius versus time for population



Evolution with constant mass => radius function: M_Sun, 4 d, 2 Ga



Conclusion

- General Theory is faster than observation,
- ... is predictive for the entire discovery space, stellar masses 0.4 to 2 , 1 to 50 day online,
- CoRoT-planets at or near peaks in the mass spectra,
- Distribution of radii bimodal as masses,
- Transit searches need to “jump” from Jupiters to Neptunes with not much in between.

CoRoT-Exo-7b - goodies

http://corot.TLS-Tautenburg.de/Exo-7b

Src01 mosaic, Alfred Jensch 2m TLS Tautenburg, Bringfried Stecklum