Stellar inputs to exoplanet search and characterisation

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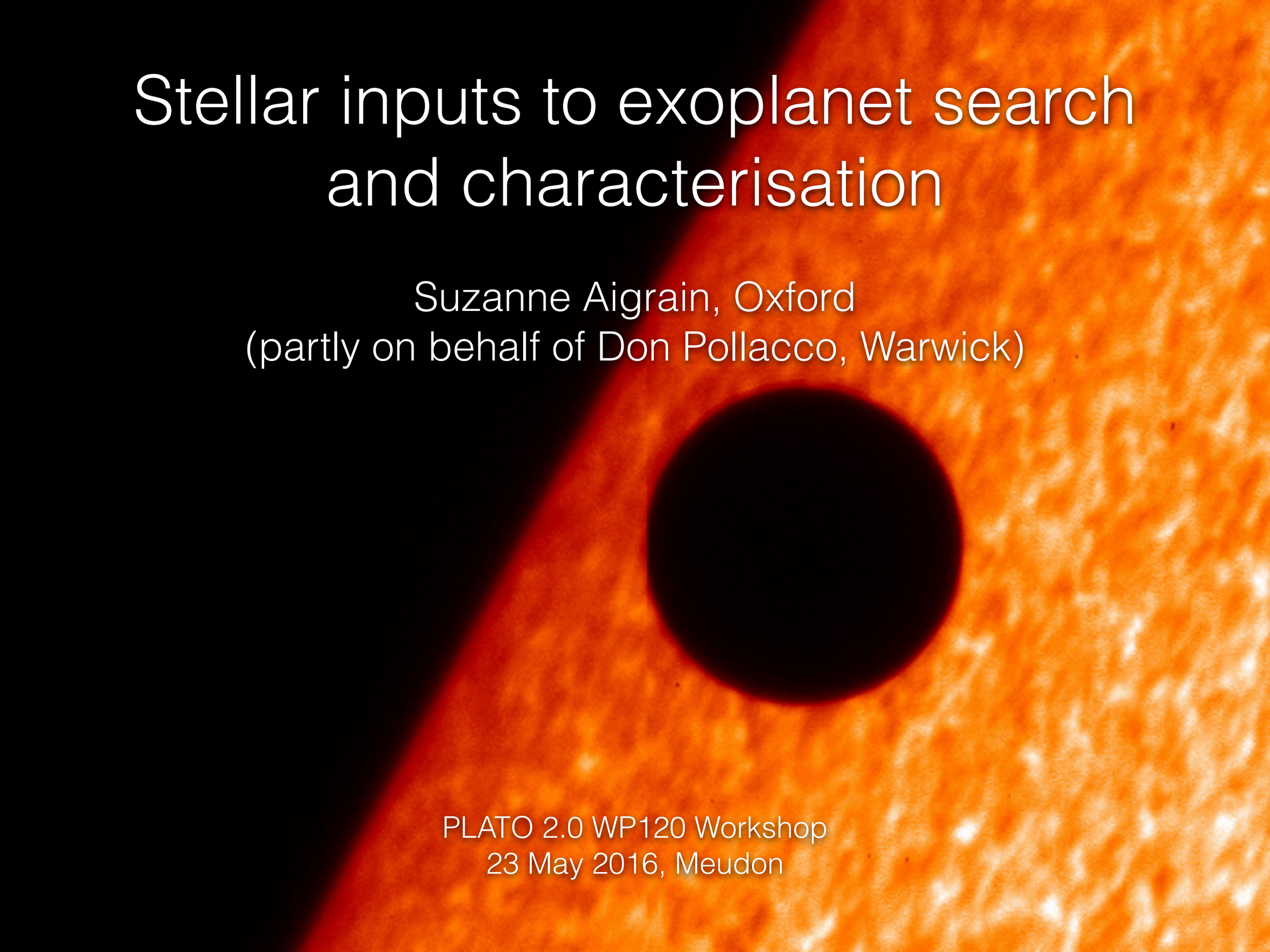
(partly on behalf of Don Pollacco, Warwick)



PLATO 2.0 WP120 Workshop
23 May 2016, Meudon

Why the star matters to us…

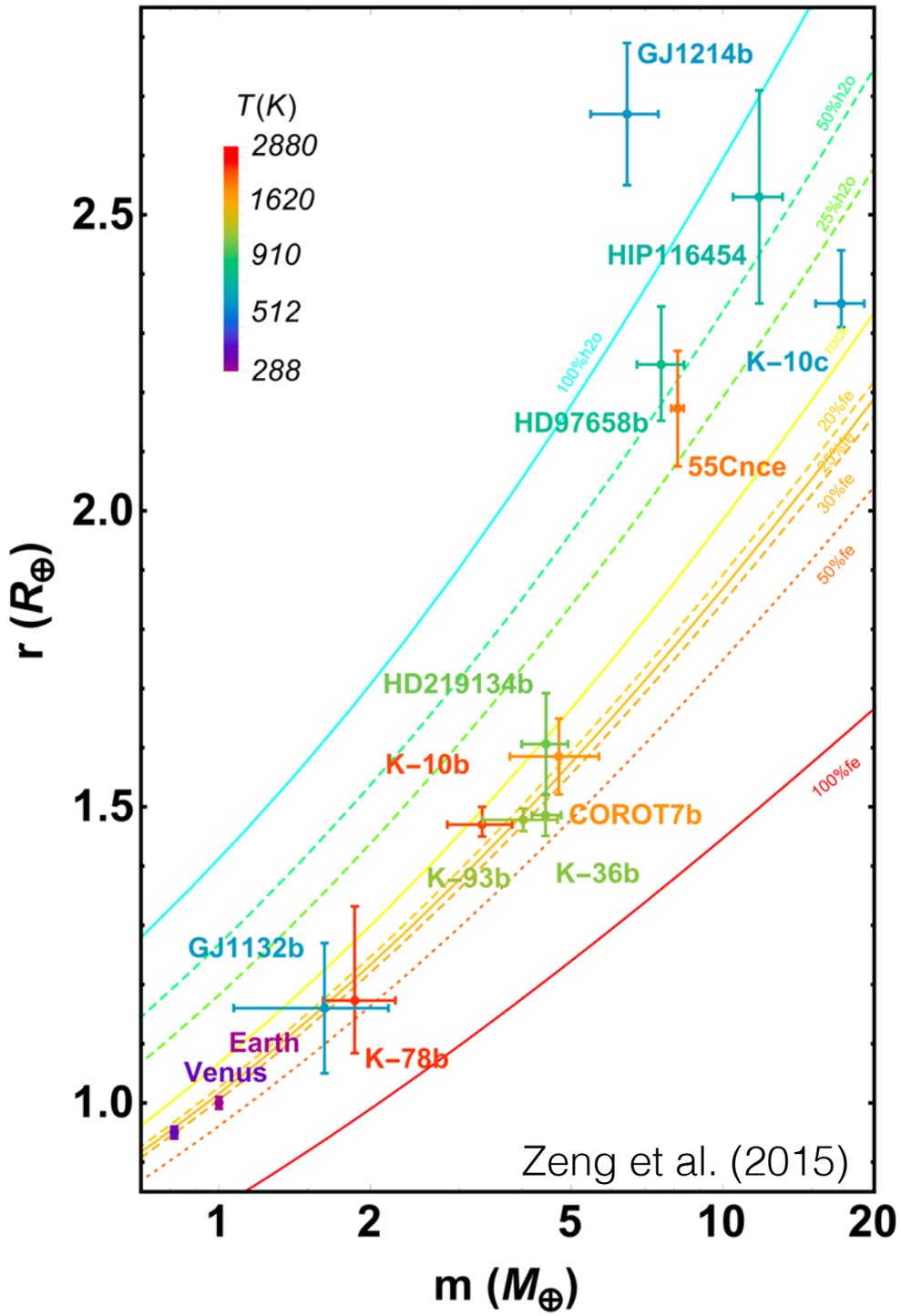
- Stellar variability limits transit detectability
- Planet parameters measured relative to stellar parameters
- Stellar activity hinder RV mass measurement

Basic requirements: stellar radius and mass

- Transit gives $R_p/R_\star$, RVs give $M_p/M_\star$

- Errors on $M_\star$ & $R_\star$ often dominate errors on R_p & M_p

- Need to know $M_\star$ & $R_\star$ to a few %.



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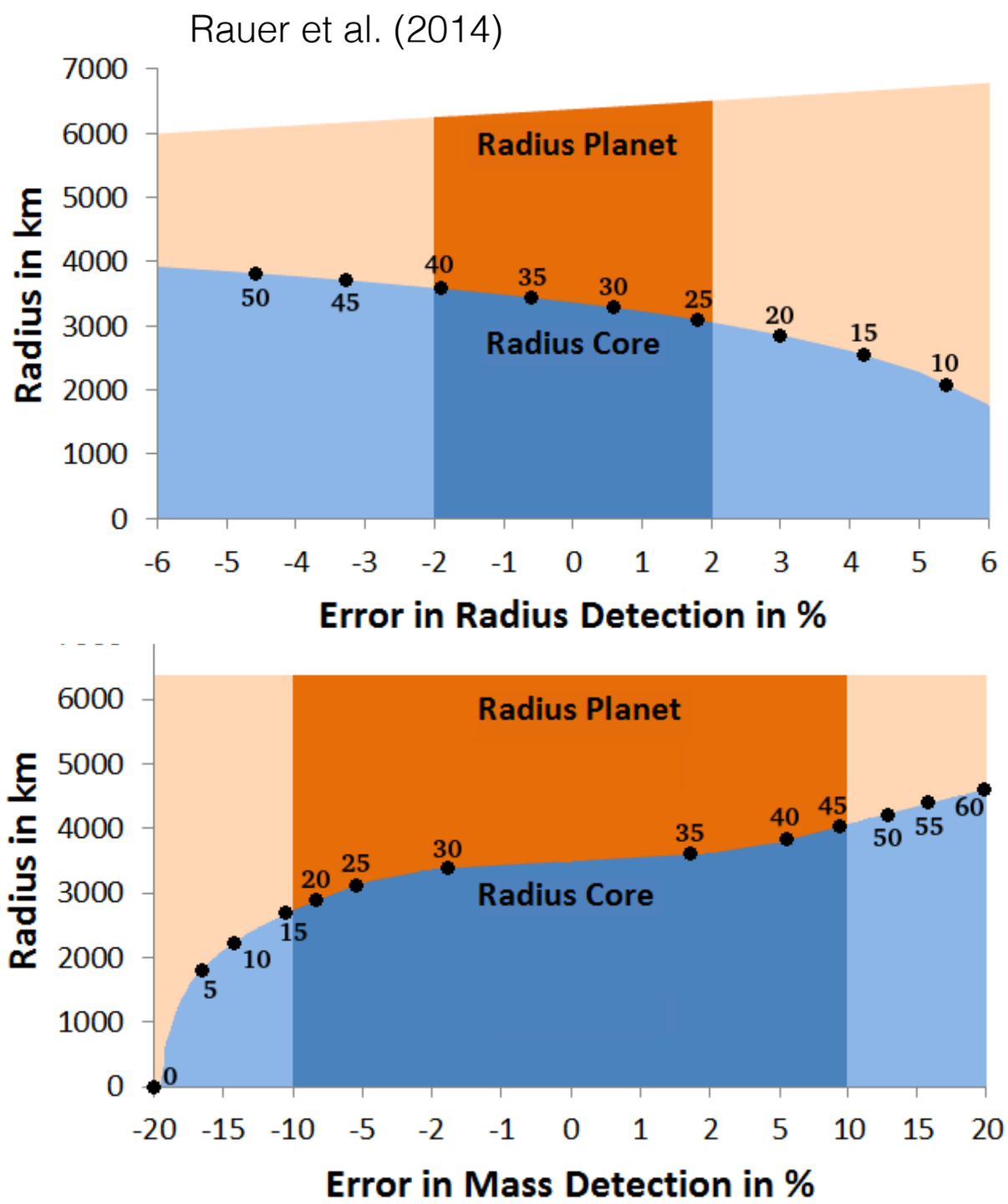
Rauer et al. (2014)

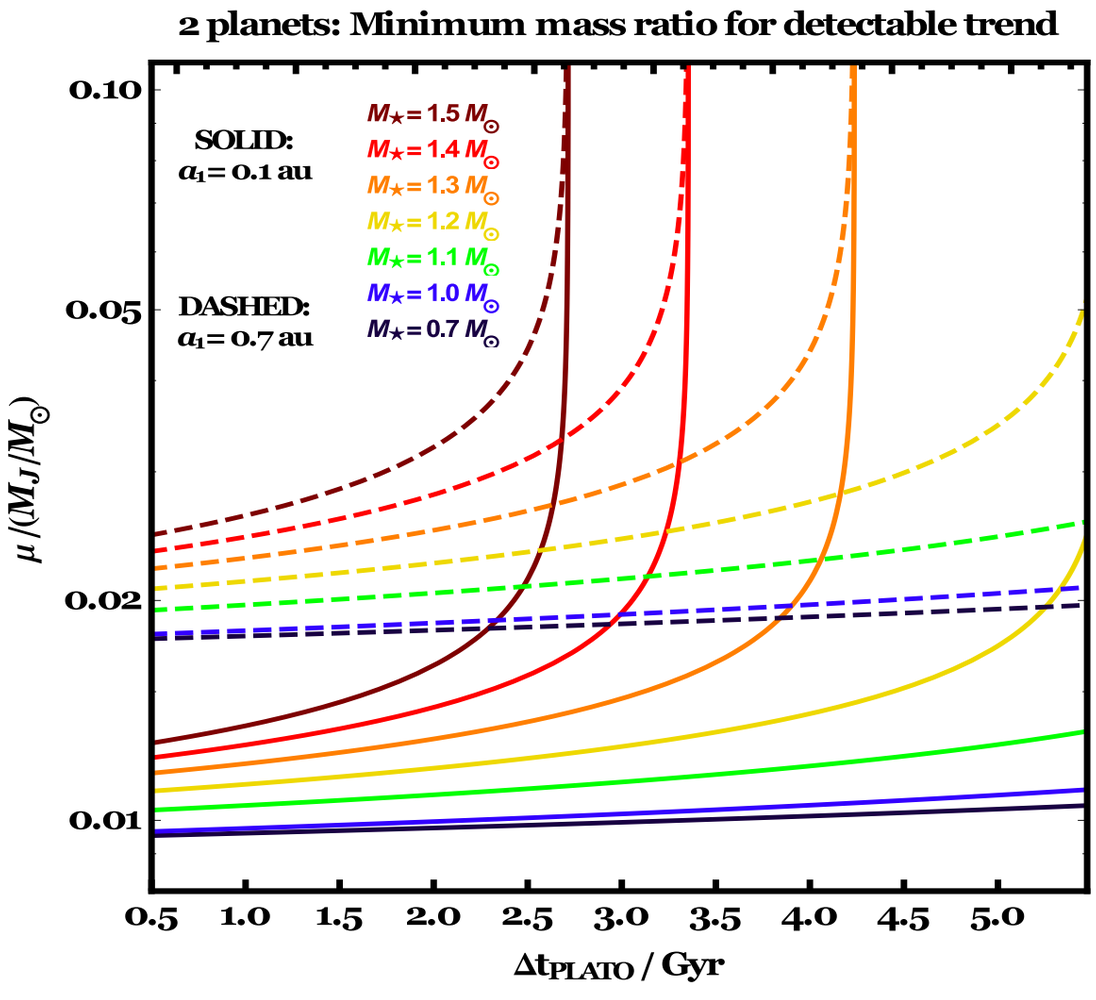


Basic requirements: stellar age

- We want to investigate the dynamical and thermodynamical evolution history of the planetary systems we detect

- E.g.: planet incidence expected to decrease with increasing age for tightly packed systems of multiple planets, can PLATO detect it? (Veras et al. 2015)

- Need to know stellar age $t_\star$ to ~10 %.



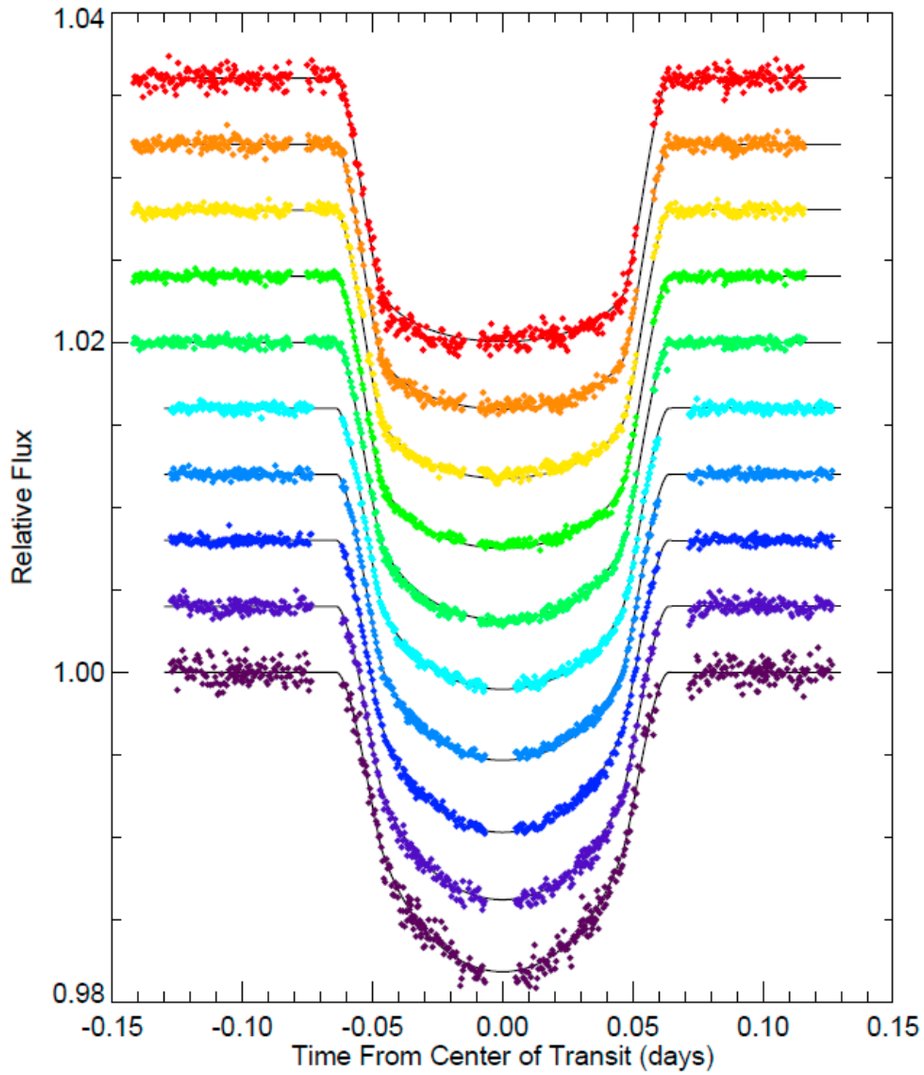
Veras et al. (2015)

Stellar density and limb-darkening

- Transit fit involves $a/R_\star$ (related to $\rho_\star$ via Kepler's 3rd law) and limb-darkening model

- Asteroseismology: direct, model-independent constraint on $\rho_\star$

- Not sure if stellar pipeline will provide any info on limb-darkening?



Knuston et al. (2007)

Which properties affect accuracy of stellar parameters?

- How does the accuracy of $\rho_\star$, $M_\star$, $R_\star$, $t_\star$ depend on factors such as T_{eff}, activity level, rotation rate?

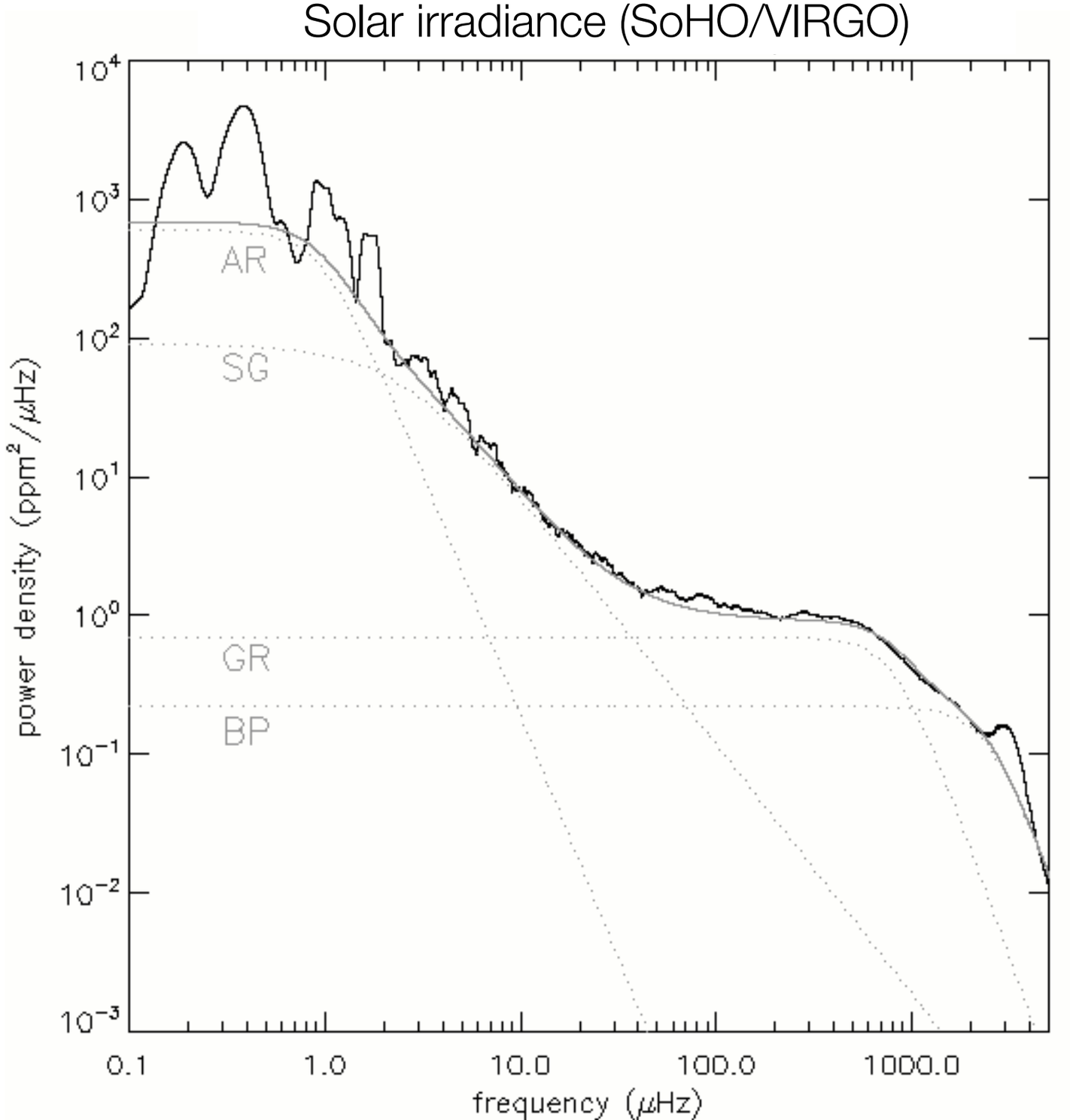
- Prioritise targets to observe (input catalog) and later candidates to follow-up where precise stellar parameters can be expected?

Impact of activity on planet detection

- Transits are typically a lot shorter than the dominant timescales for activity

- Activity and granulation do matter for shallow, long-duration (long-period transits)

- Activity is THE main issue for RV follow-up



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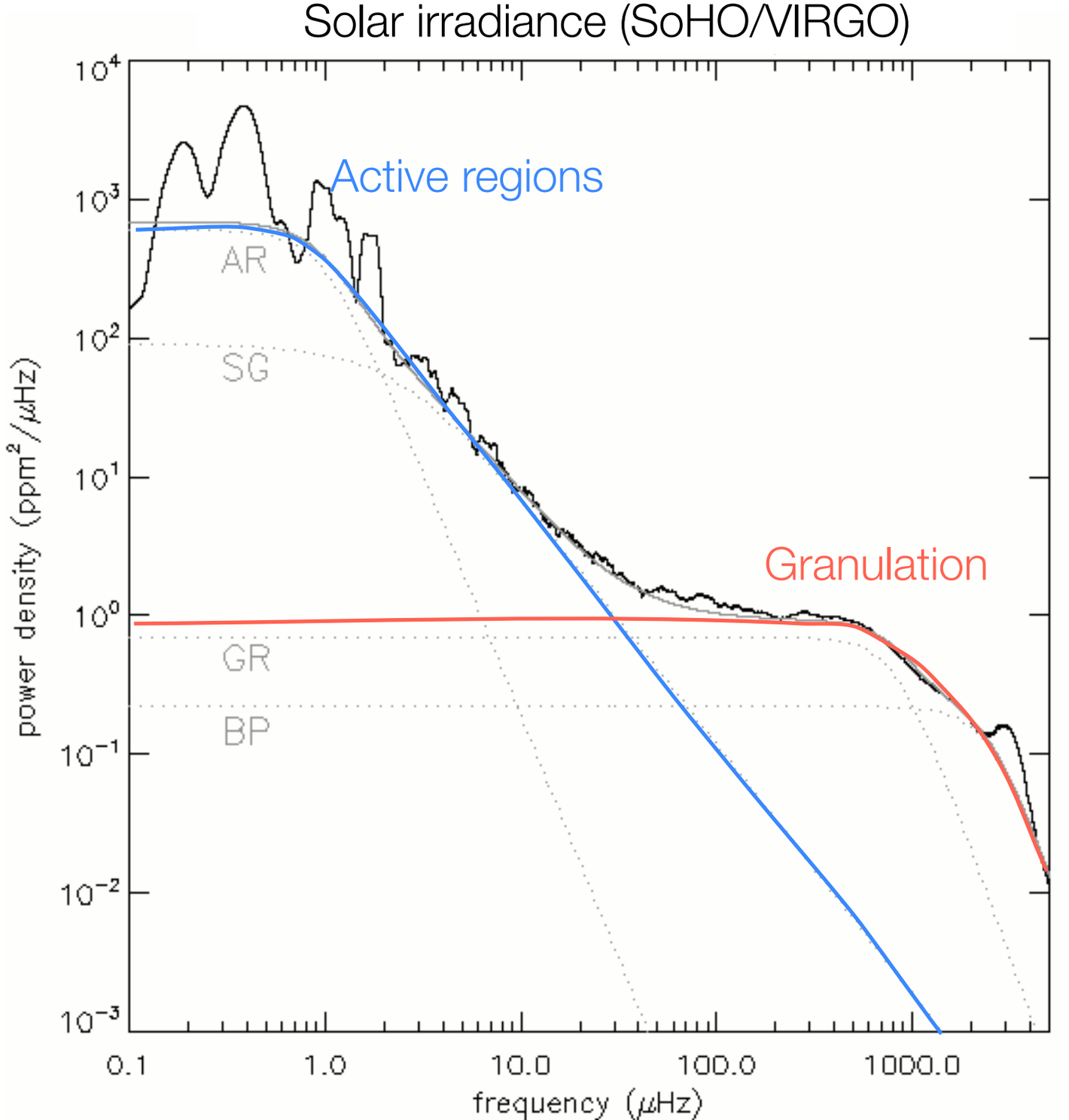

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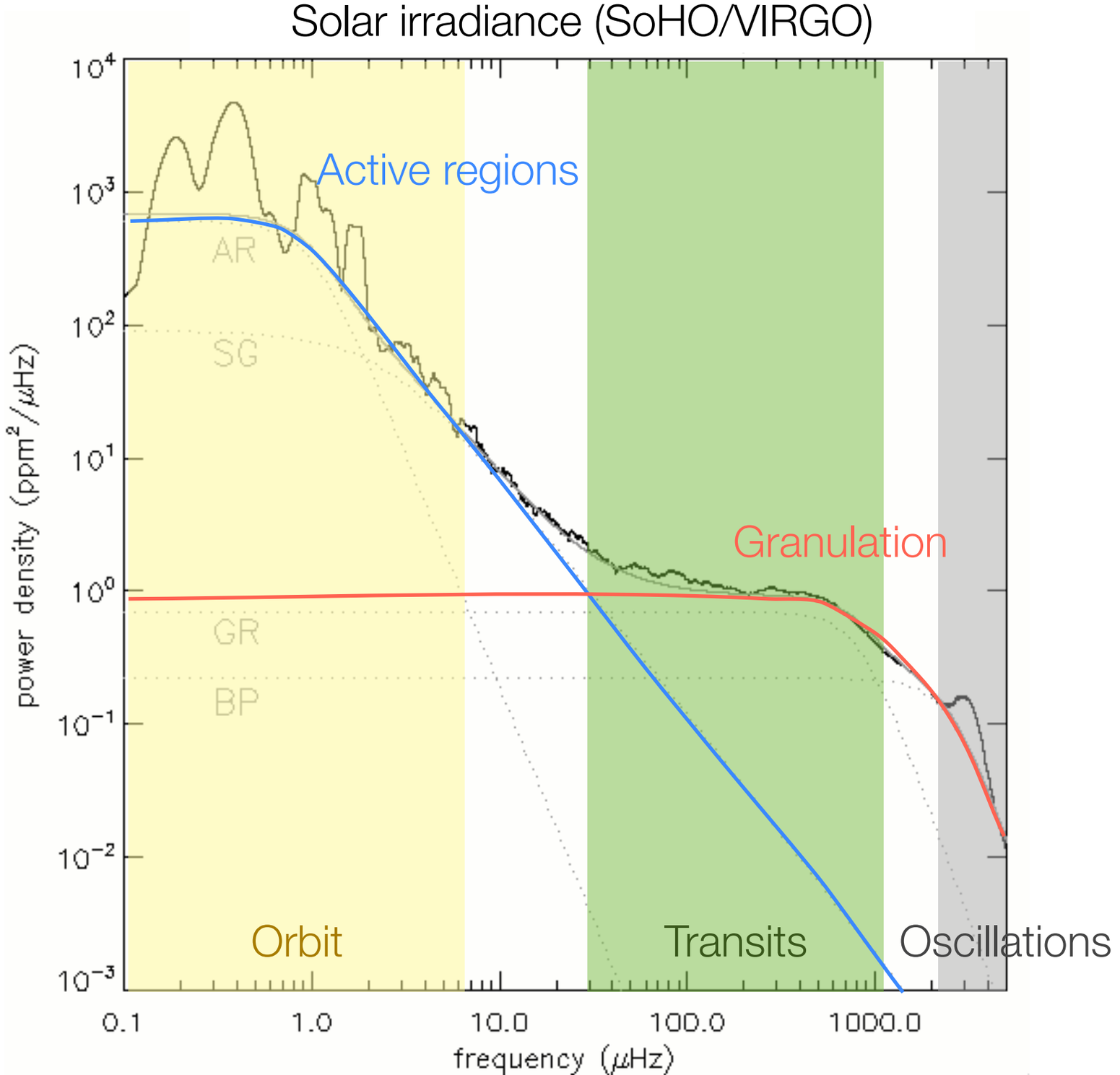
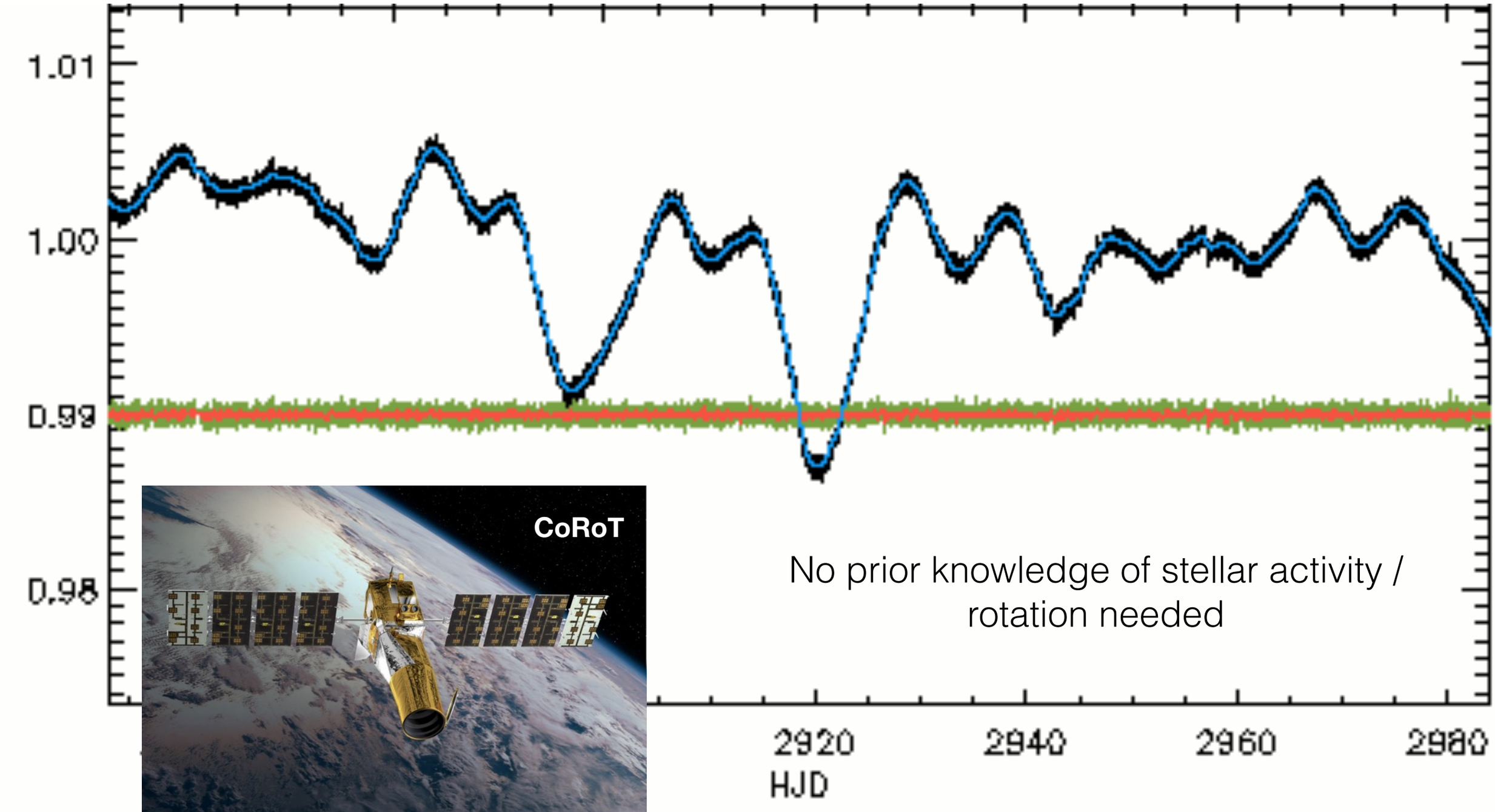


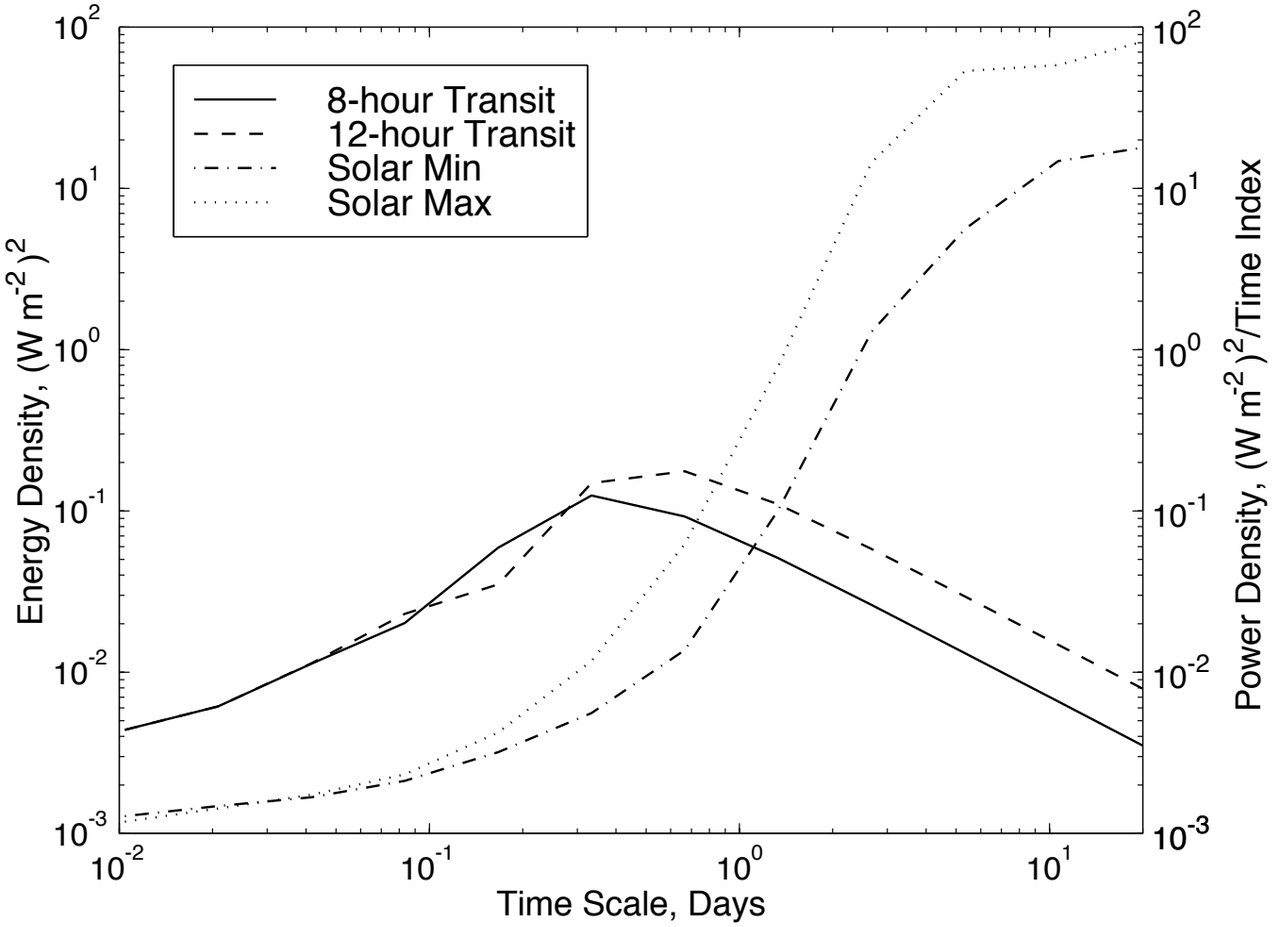
Detecting transits in the presence of activity - I

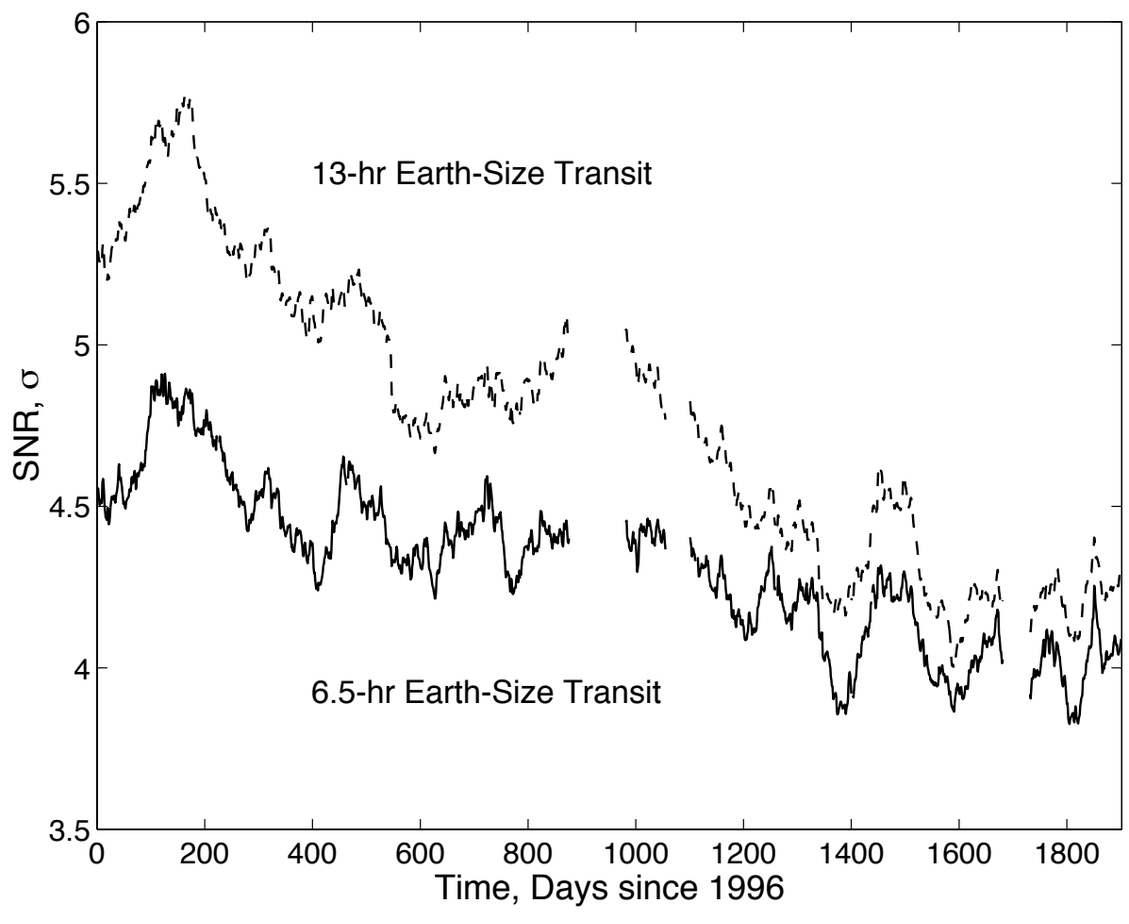


No prior knowledge of stellar activity / rotation needed

Detecting transits in the presence of activity - II

Jenkins (2002)





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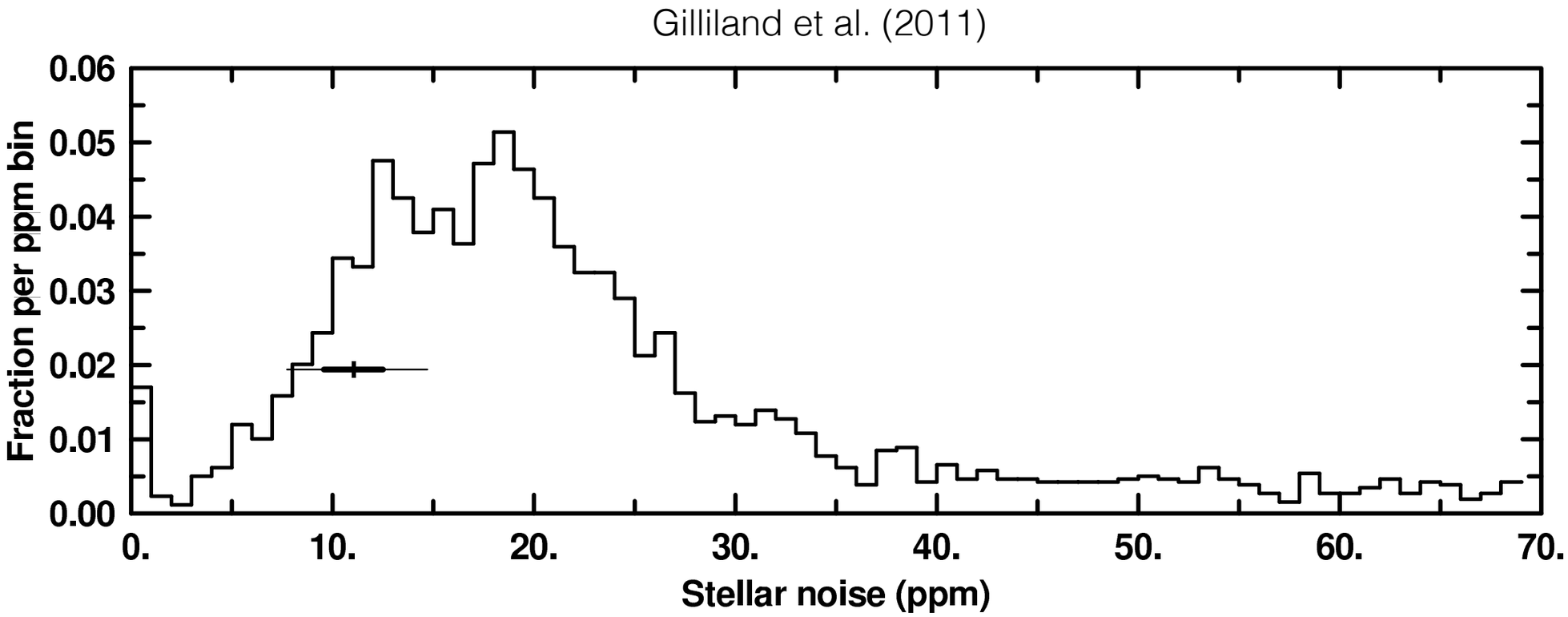
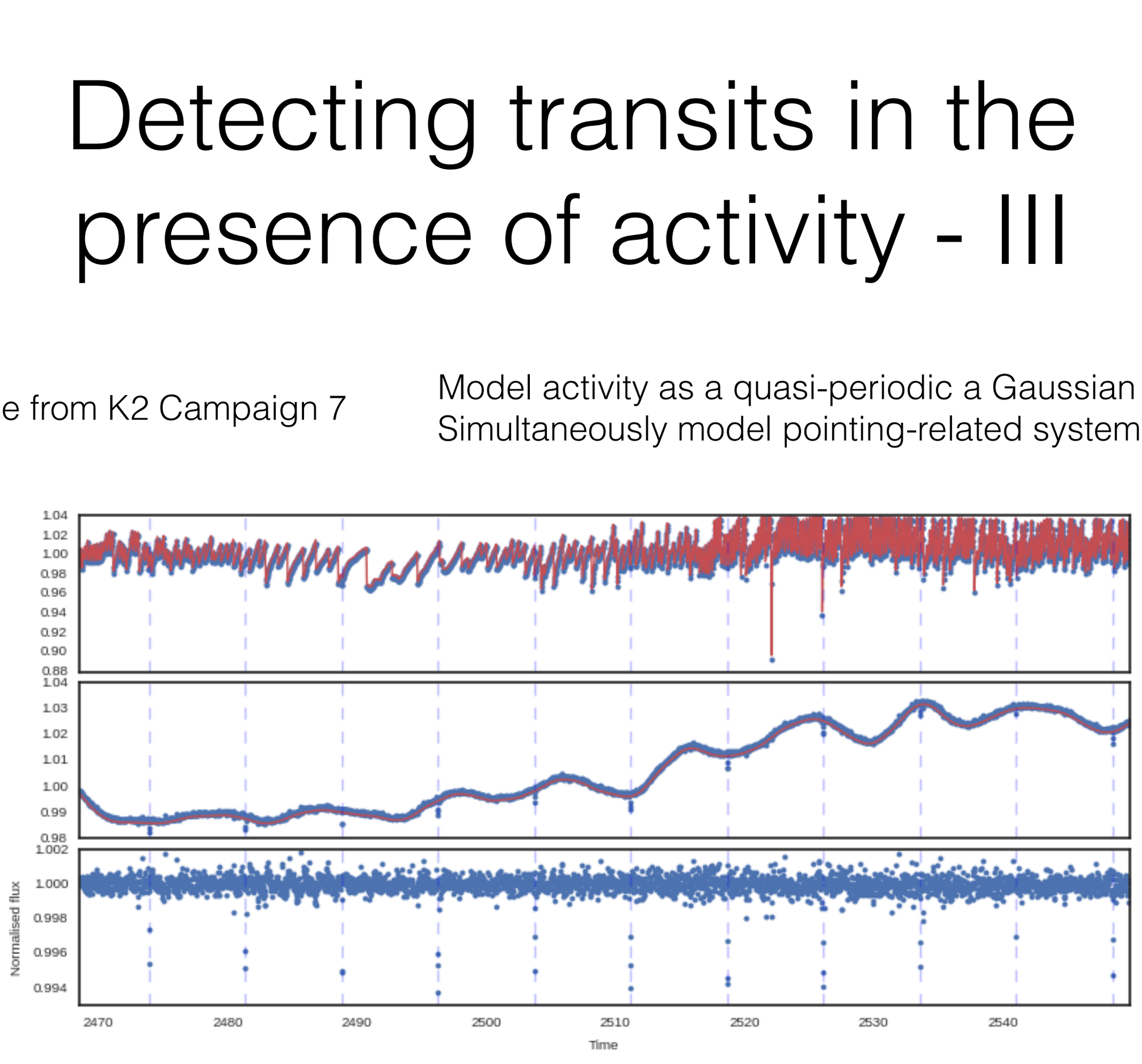


Detecting transits in the presence of activity - III

Example from K2 Campaign 7

Model activity as a quasi-periodic a Gaussian process.
Simultaneously model pointing-related systematics

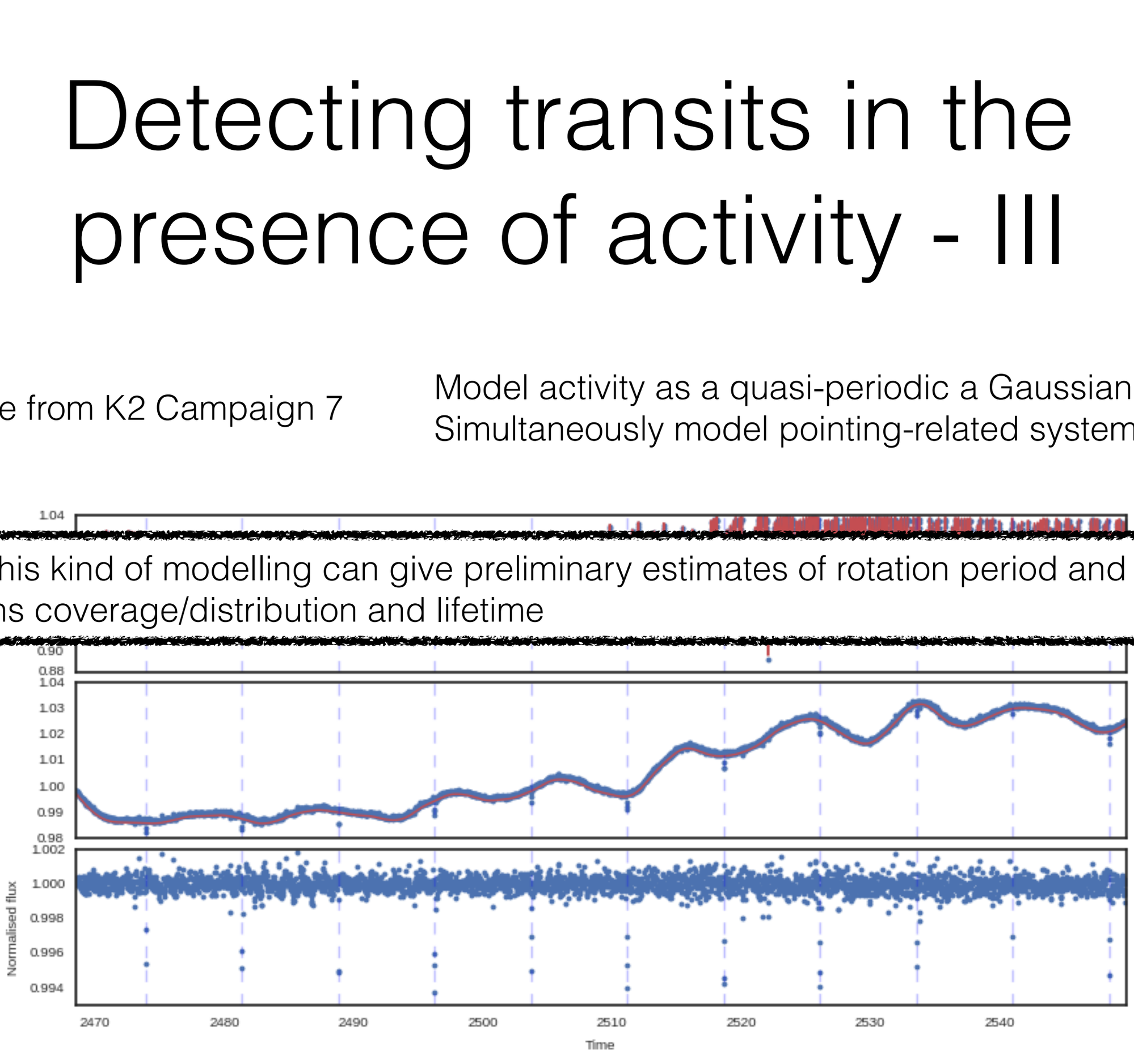


Detecting transits in the presence of activity - III

Example from K2 Campaign 7

Model activity as a quasi-periodic a Gaussian process.
Simultaneously model pointing-related systematics

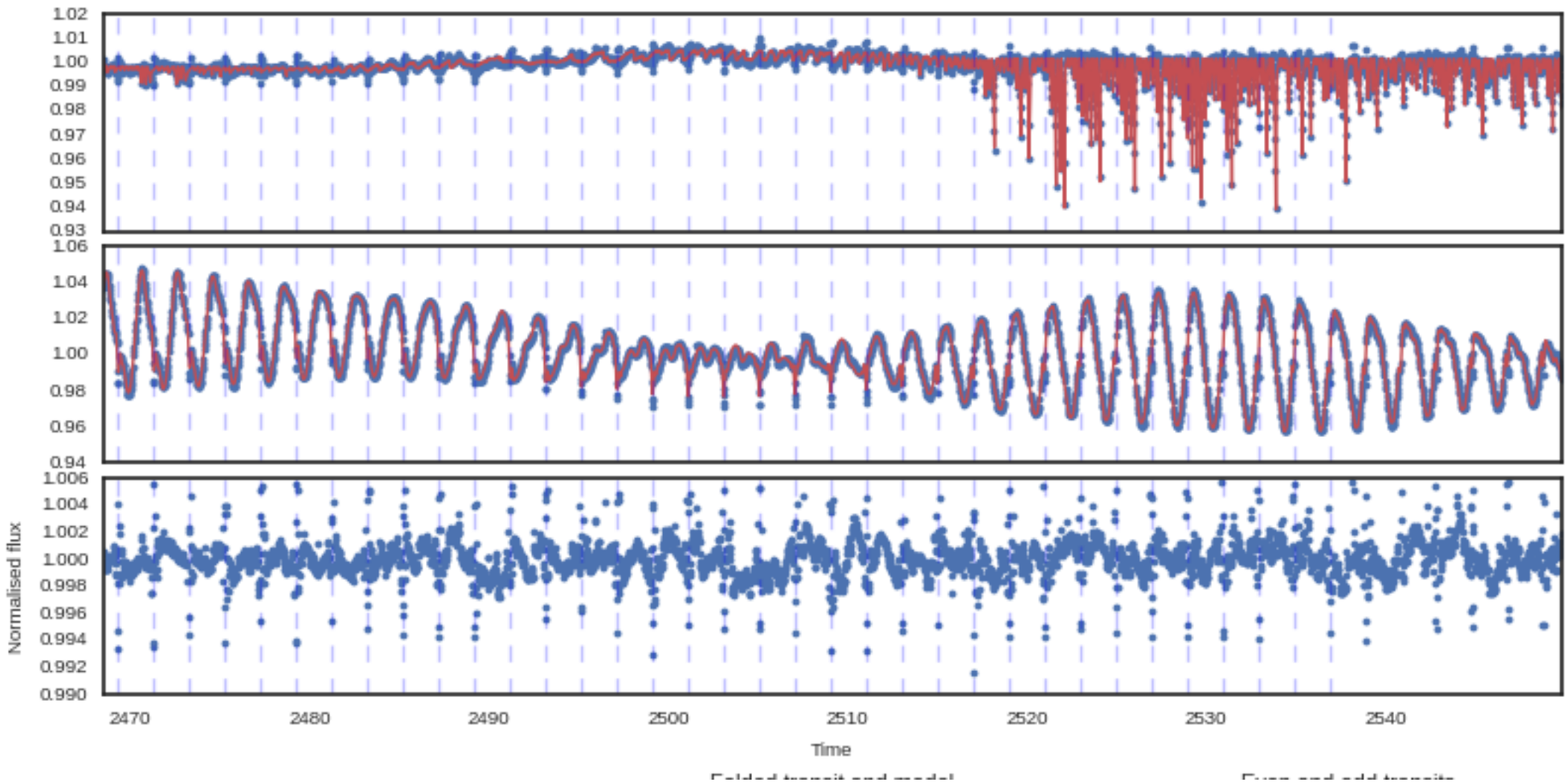
NB: This kind of modelling can give preliminary estimates of rotation period and active regions coverage/distribution and lifetime



Detecting transits in the presence of activity - III

Example from K2 Campaign 7

In a case like this, a-priori information on stellar period would help…



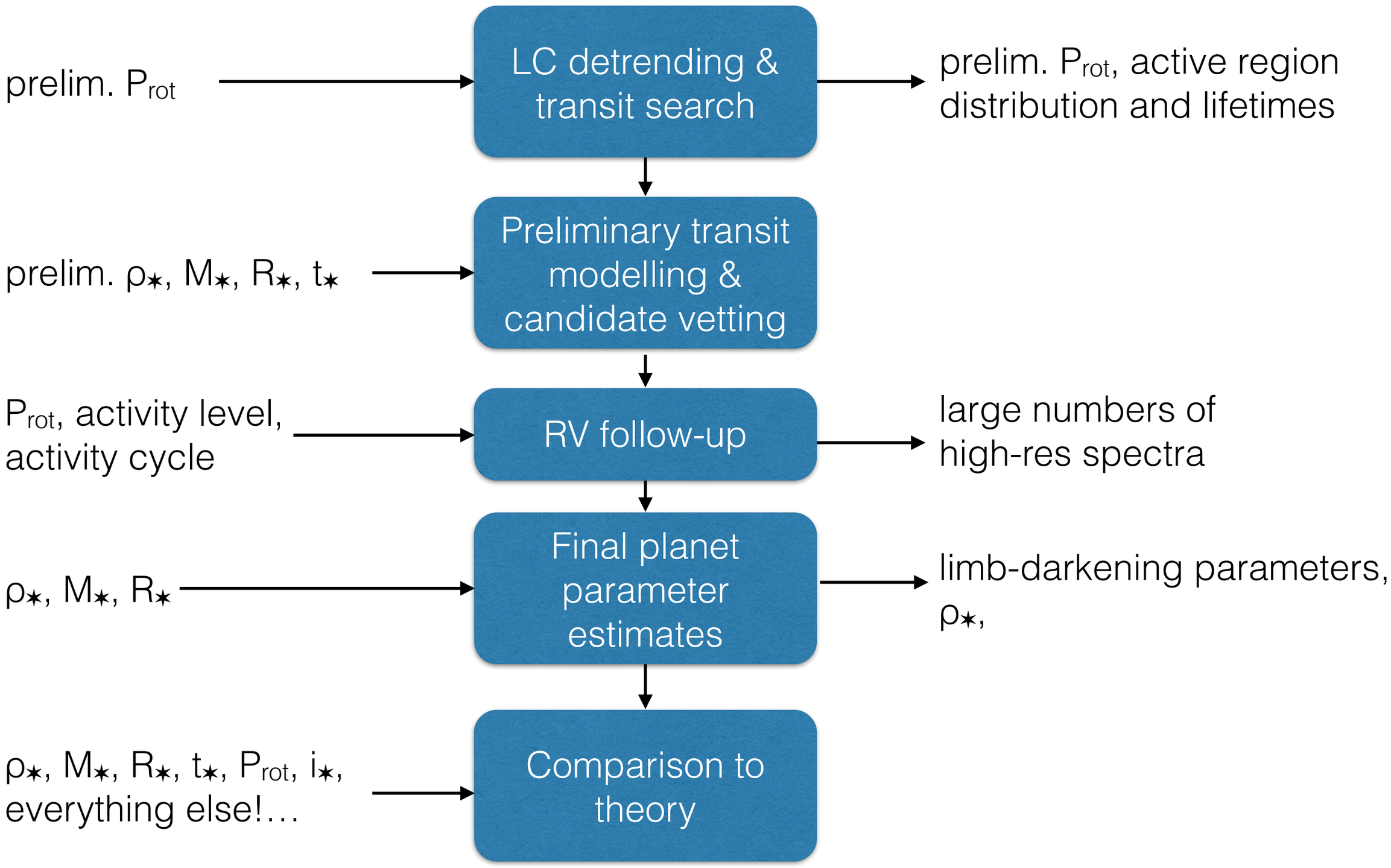
Stellar “noise” in RV

- short-term: pulsations (F-stars) - 15 min
- rotation period:
  - spots “photometric” effect - dominates for active stars
  - convective blue-shift suppression - dominates for “quiet” stars (like the Sun)
- growth and decay of active regions
- activity cycle:
  - variation in activity level leads to long-term RV change
  - if “butterfly” pattern, dominant rotation period also changes

How WP120 can help with RV follow-up

- Estimates of P_{rot}, activity level?
- How stable are the active regions?
- Information on stellar inclination?
- Activity cycle: when will the star be least / most active?

Information exchange between stellar and exoplanet pipelines



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- LDTK: the limb-darkening toolkit: (Parviainen & Aigrain 2015, MNRAS, 453, 3821)
    - Automatic, efficient calculation of custom stellar limb-darkening profiles and model-specific limb-darkening coefficients using the PHOENIX-generated specific intensity spectra
    - Code at https://github.com/hpparvi/ldtk
- Smear photometry of very bright Kepler & K2 stars (Pope et al. 2016, MNRAS, 455, 36L)
    - Thought your favourite object was too bright, or observed only in a few Kepler quarters? We may be able to retrieve it for you…

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- Detrending K2 data while preserving variability using GPs: Aigrain et al. (2016, MNRAS, 459, 2408)
    - Lower systematics than both SAP and PDC, much better preservation of intrinsic stellar signals than PDC or other K2 pipelines
- readily adapted for short cadence data
- Light curves at https://archive.stsci.edu/prepds/k2sc/
- Code at https://github.com/OxES/k2sc