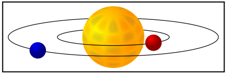
A SONG of seismic host stars



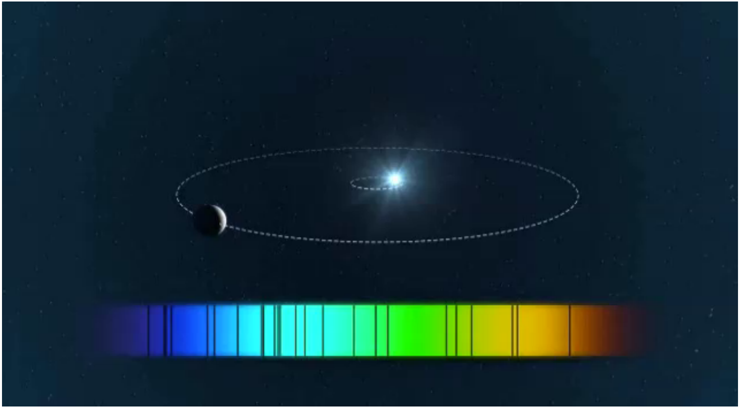
Mia Sloth Lundkvist

SONG workshop, Tenerife
24^{th} of October 2018

Zentrum für Astronomie der Universität Heidelberg, LSW
Stellar Astrophysics Centre, Aarhus University

Detecting exoplanets: Radial Velocities

Credit: ESO



Based on Fischer et al. (2016), Wright (2017), Santos & Buchhave (2017), Gaudi (2013) and Dumusque (2018).

Size of the signal

$$K \approx \left(\frac{2\pi G}{P M_*^2}\right)^{1/3} \frac{m_{\mathrm{p}} \sin i}{\sqrt{1-e^2}} \; .$$

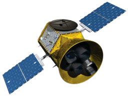
- Jupiter around the Sun: $\sim 12\ \mathrm{m/s}$.
- Earth around the Sun: $\sim 9\ \mathrm{cm/s}$ (currently undetectable).

Size of the signal

$$K \approx \left(\frac{2\pi G}{P M_*^2} \right)^{1/3} \frac{m_{\mathrm{p}} \sin i}{\sqrt{1 - e^2}} .$$

- Jupiter around the Sun: $\sim 12\ \mathrm{m/s}$.
- Earth around the Sun: $\sim 9\ \mathrm{cm/s}$ (currently undetectable).

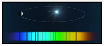
$\Rightarrow$ SONG can do close-in planets around bright stars.



Challenges

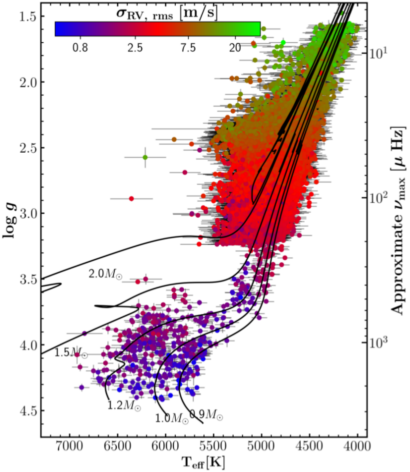
RV jitter due to intrinsic stellar variability:

- p-mode oscillations
- Granulation
- Short-term activity (active regions)
- Long-term activity (magnetic cycles)



p-mode oscillations

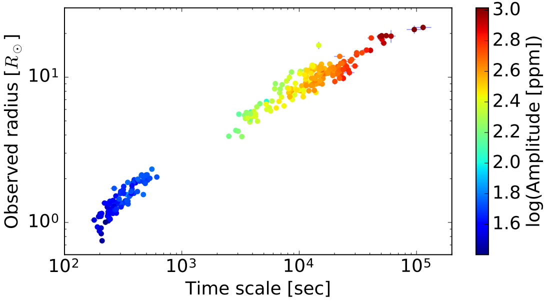
- Variations: ~ 1 m/s on time scale of min-hours.
- Solutions:
  - Integrate for longer than typical oscillation period.
  - Model the jitter caused by the oscillations.



Yu et al. (2018)

Granulation

- Variations: m/s on a time scale of min/hours to days.
- Solution: take several measurements per night of same target.

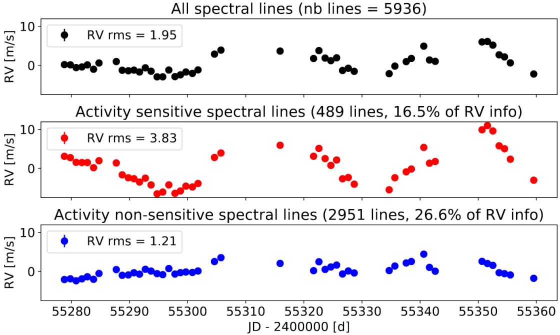


Activity

- Short-term activity variations: centroid shift of lines on a time scale of days to months.
- Long-term activity variations: amplitude and time scale can be similar to that of a Jovian planet (10 m/s over 100's of days to several years).
- Solutions:
  - Avoidance
  - Mitigation

Mitigation of RV jitter from activity

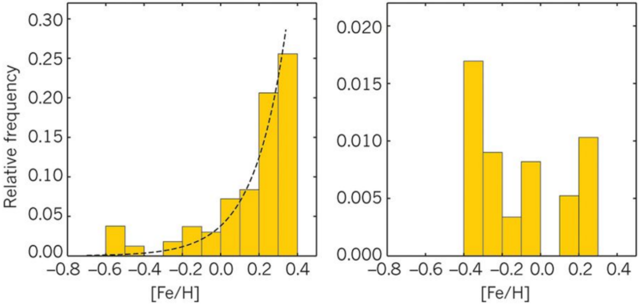
- Correlate RV's with activity indicators.
- Examine line shapes for evidence of non-centre-of-mass line shifts.
  - Line bisector.
  - Shape of individual lines.



Dumusque (2018)

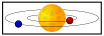
Knowing the host star

- Spectra: T_{eff} and composition (metallicity).



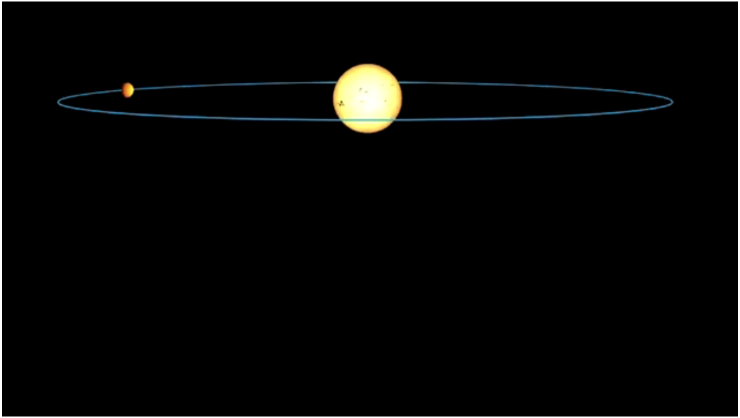
Mayor et al. (2014)

- Asteroseismology: M_*.



Detecting exoplanets: Transits

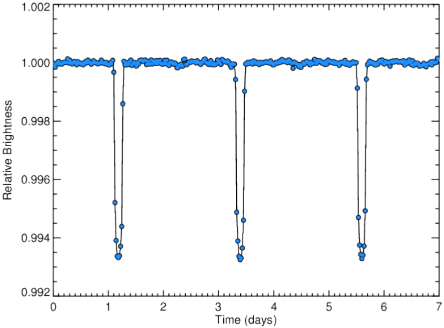
Credit: NASA



Based on Gaudi (2013), Oshagh et al. (2013), Ricker et al. (2015), Borucki (2017), Cameron (2017), Rauer & Heras (2017), Barclay et al. (2018), Deeg & Alonso (2018) and Huang et al. (2018).

Overview

$$\frac{\delta F}{F} \approx \left(\frac{R_p}{R_*}\right)^2 \, .$$

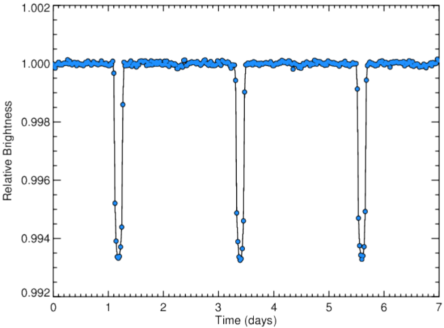


Credit: Andrew Vanderburg

Overview

$$\frac{\delta F}{F} \approx \left(\frac{R_p}{R_*}\right)^2 .$$

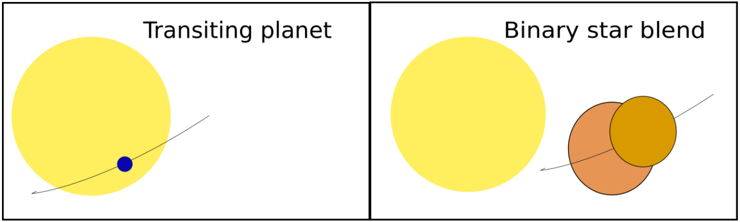
$$\mathrm{SNR} = \frac{(R_p/R_*)^2}{\sigma} .$$



Credit: Andrew Vanderburg

Challenges

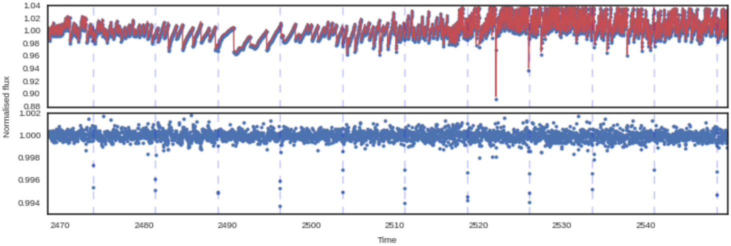
- (Transit probability and temporal coverage)
- False positives
- Stellar activity (spots in transit).



Credit: Vincent Van Eylen

Challenges

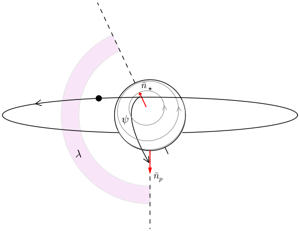
- (Transit probability and temporal coverage)
- False positives
- Stellar activity (spots in transit).



CS19 talk, Suzanne Aigrain

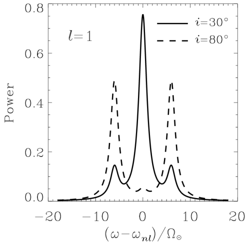
Knowing the host star: asteroseismology

- R_* and age.
- $M_* \Rightarrow$ With both RV and transit detection we can determine $\bar{\rho}_{\rm p}$.
- Results from combining asteroseismology and exoplanet studies:
  - Spin-orbit angle
  - Precise parameters
  - Photo-evaporation



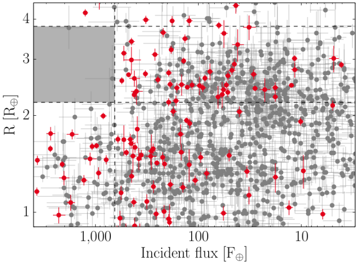
Lund et al. (2014)

Gizon & Solanki (2003)

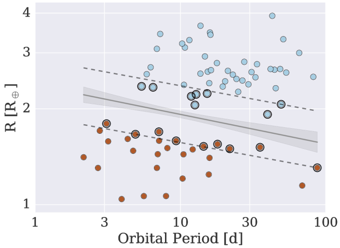


Knowing the host star: asteroseismology – photo-evaporation

- Precise R_p and F_p used to confirm absence of USP planets of sub-Neptune size (evaporation desert).
- Precise R_p used to determine slope of evaporation valley.



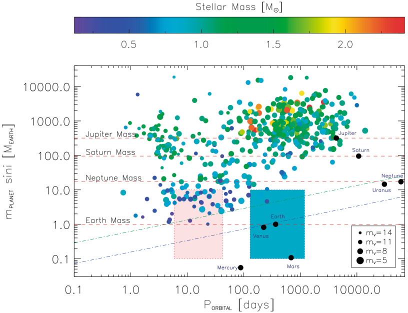
Edt. from Lundkvist et al. (2016)



Van Eylen et al. (2018b)

Role of SONG in light of TESS

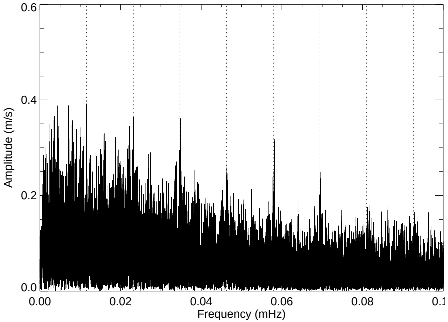
- Follow-up observations to confirm planets.
- Long time series for asteroseismology.
- Focus on precise stellar and planetary parameters of selected USP super-Earths/sub-Neptunes found by TESS.



González Hernández et al. (2018)

SONG and hot super-Earths

- SONG focuses on larger semiamplitudes (order 1 m/s).
- $M_* = 1 \text{ M}_\odot$ and $P = 2 \text{ days} = 0.006\ \mu\text{Hz}$.
- Highest peak: 0.4 m/s.

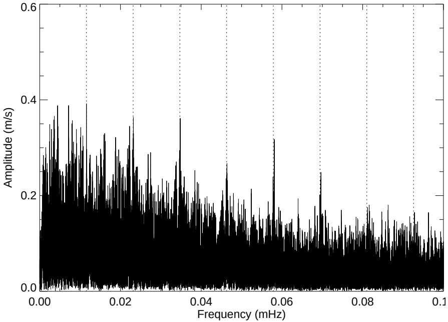


μ Her, credit: Hans Kjeldsen

SONG and hot super-Earths

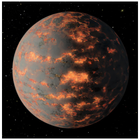
- SONG focuses on larger semiamplitudes (order $1\ \mathrm{m/s}$).
- $M_* = 1\ \mathrm{M}_\odot$ and $P = 2\ \mathrm{days} = 0.006\ \mu\mathrm{Hz}$.
- Highest peak: $0.4\ \mathrm{m/s}$.

$\Rightarrow$ $(m_\mathrm{p} \sin i)_\mathrm{min} \approx 0.8\ \mathrm{M}_\oplus$.



μ Her, credit: Hans Kjeldsen

SONG and hot super-Earths: 55 Cnc e



Credit: NASA

- Solar-like star.
- $P = 0.74$ days,
  $M_\mathrm{p} = 8.0\ \mathrm{M}_\oplus$,
  $R_\mathrm{p} = 1.9\ \mathrm{R}_\oplus$
  Bourrier et al. (2018).
- Figure: $\sim$ 10 nights over two months with SONG.

Credit: Frank Grundahl (SONG)