Simulation of SPIRou radial velocity observations of transiting exoplanets

IRAP PhD Day 2019

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H2020 research and innovation programme
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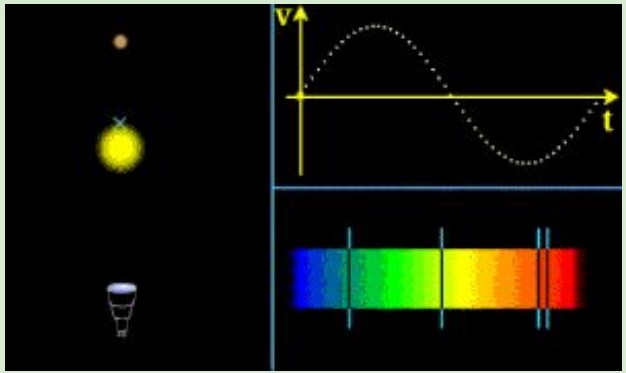
Mass-Radius diagram of Earth analogs and young giants

Goal: Constrain **bulk density**, thus inner composition

Precise mass and radius needed

Radial velocity (RV) method



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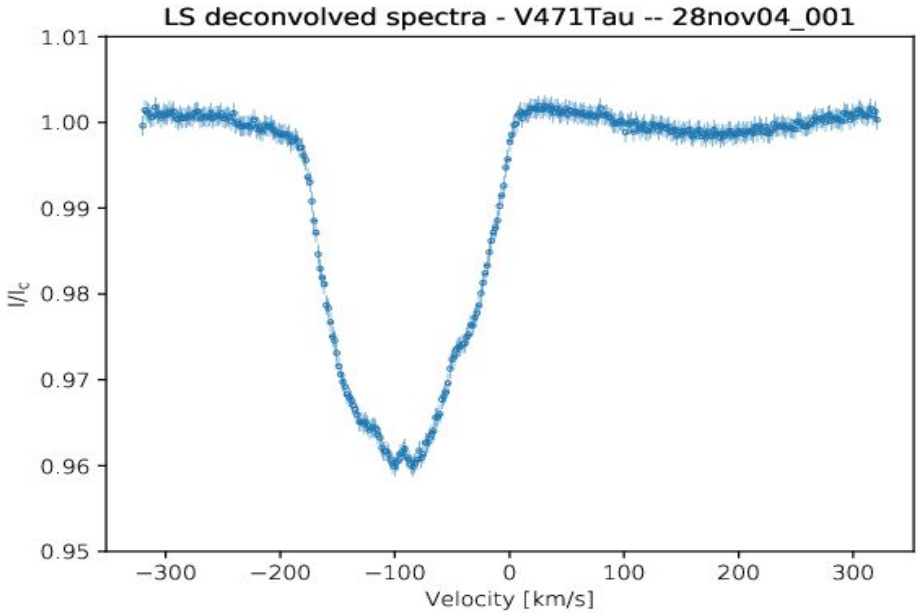

ESPaDOnS observations, Hussain+2006

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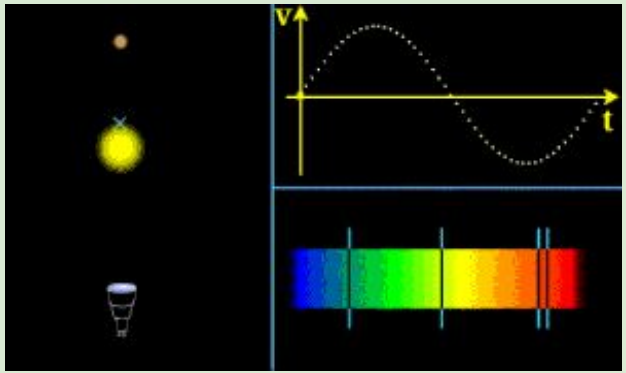

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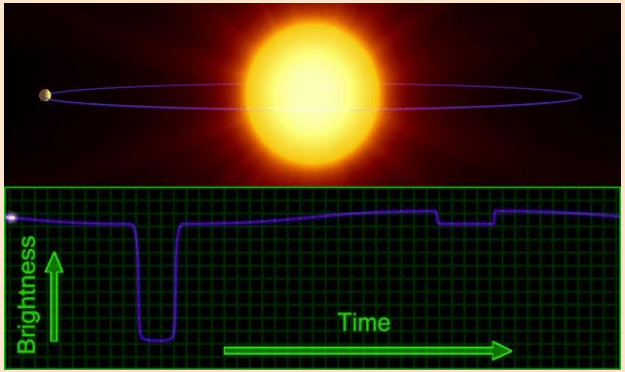
Transit photometry

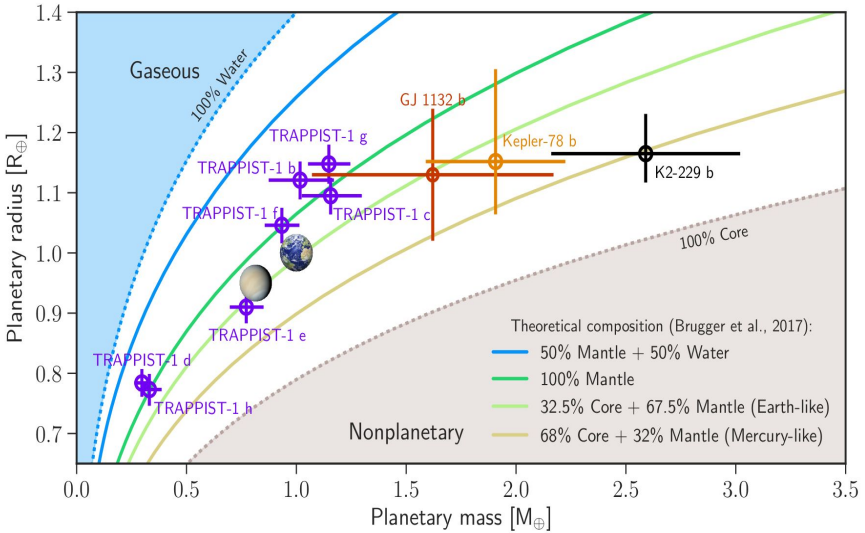


© Spitzer Space Telescope website

Mass-Radius diagram of Earth analogs and young giants

Goal: Constrain **bulk density**, thus inner composition → **precise mass and radius needed**

Only handful Earth-sized planets with precise mass and radius



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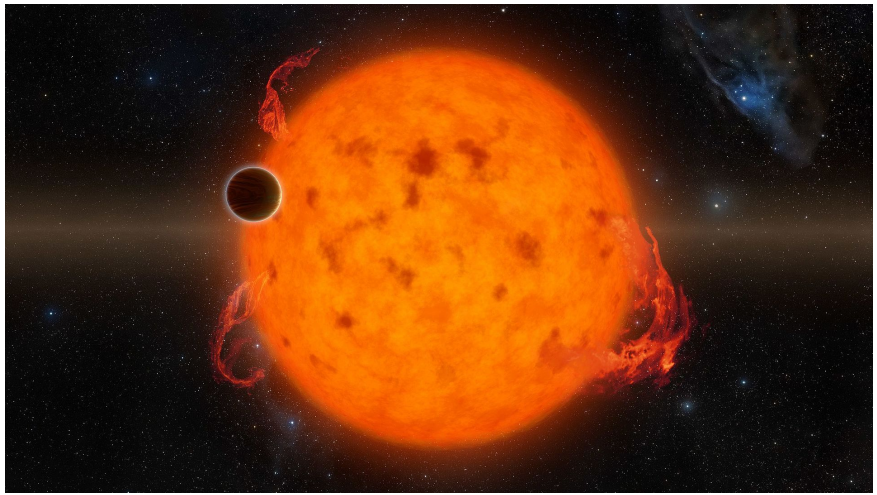
No young (<100 Myr) close-in (<1 AU) giant with precise mass and radius

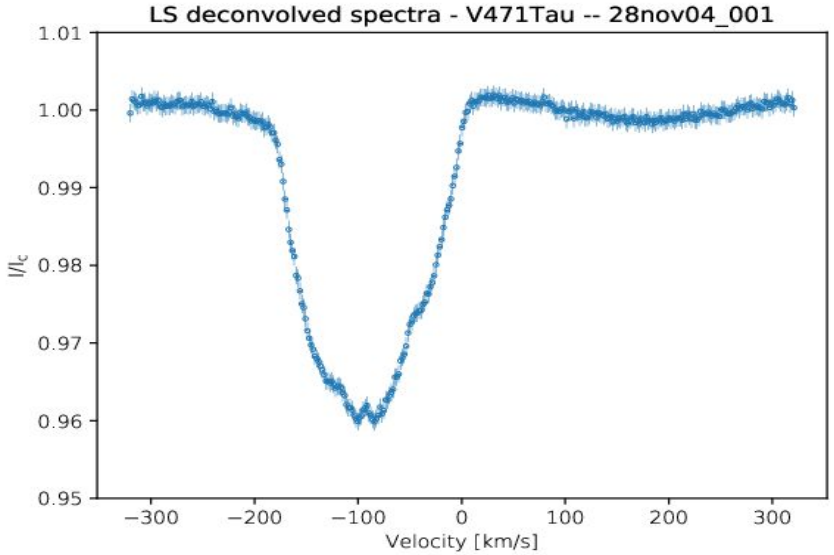


© Artist impression of K2-33, NASA/JPL-Caltech

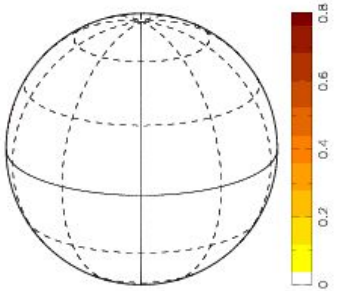
Mass-Radius diagram of Earth analogs and young giants

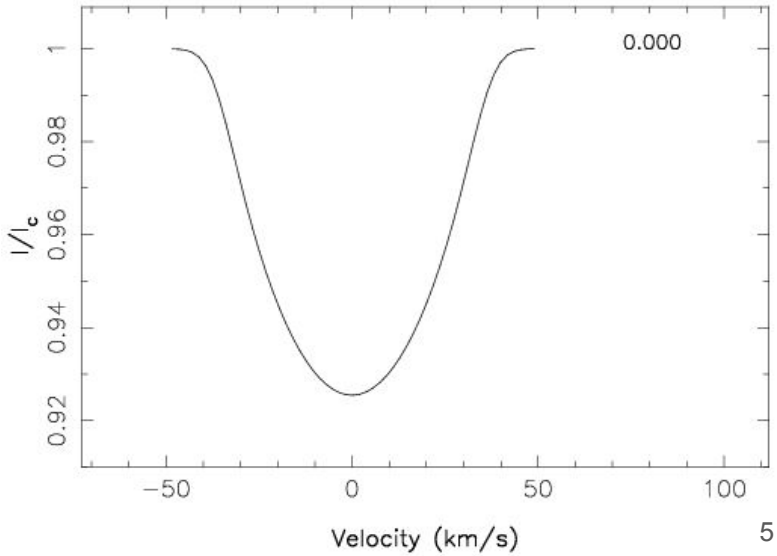
Lack of mass measurement for Earth-sized planets and young close-in giants!

- RV signature for Earth-sized planets: < 1 m/s
- **Stars are active → generation of RV signals**



ESPaDOnS observations, Hussain+2006

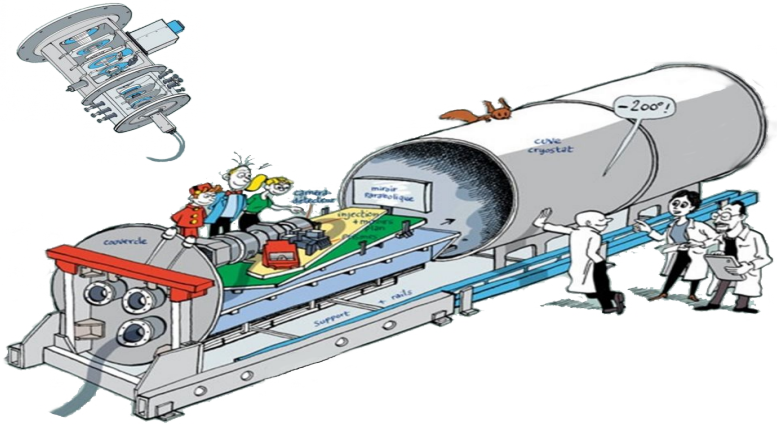




Constraining the M-R diagram with SPIRou

SPIRou - Spectropolarimètre InfraRouge

Spectral range	nIR (YJHK bands)
Resolution	75 000
RV precision	Goal: 1 m/s (~2 m/s)



© Jean-Yves Duhoo, Le journal SPIROU

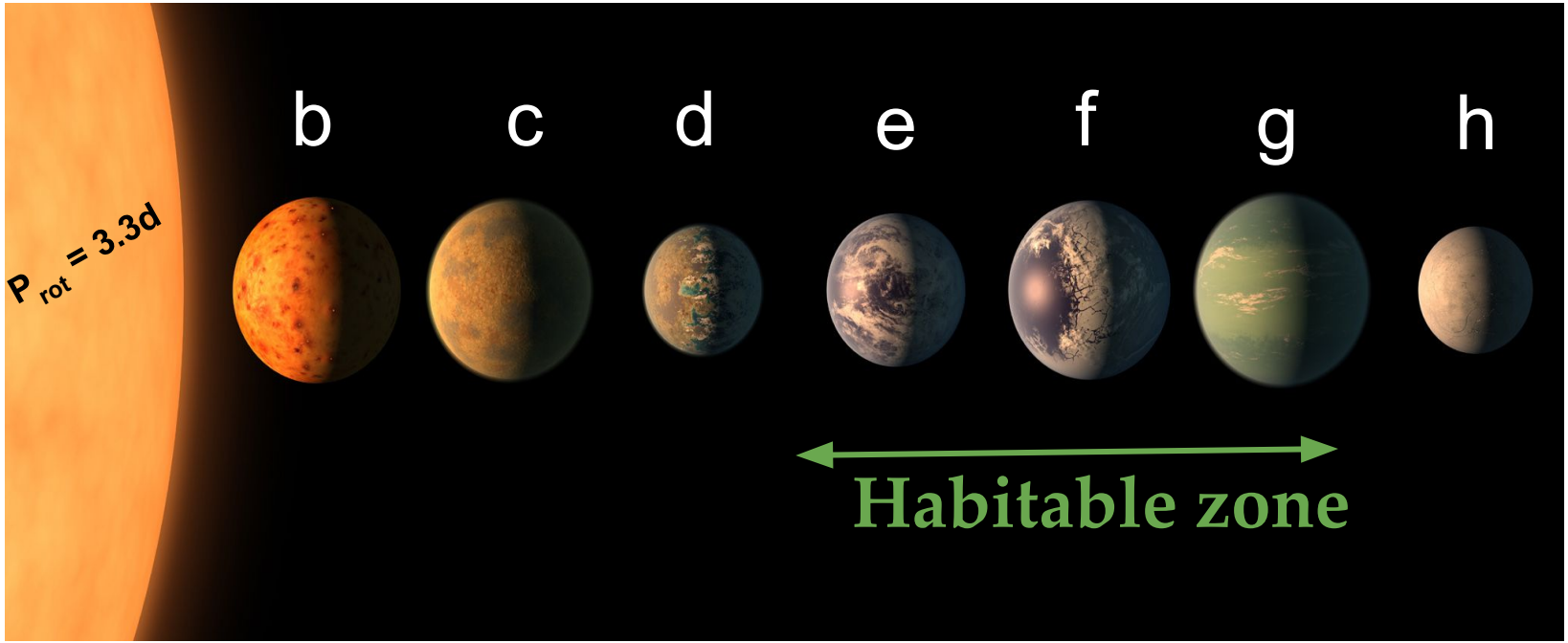
SLS-TF: SPIRou Legacy Survey Transit Follow-up: 75 nights

Mesuring the mass of Earth-sized planets around M dwarfs and young close-in giants

TRAPPIST-1 - Representative of the SLS-TF targets

Goal: Simulate SPIRou RV observations of a representative targets of the SLS-TF: TRAPPIST-1

Can we recover the masses of the TRAPPIST-1 planets with SPIRou?



Planet masses constrained through transit timing variations

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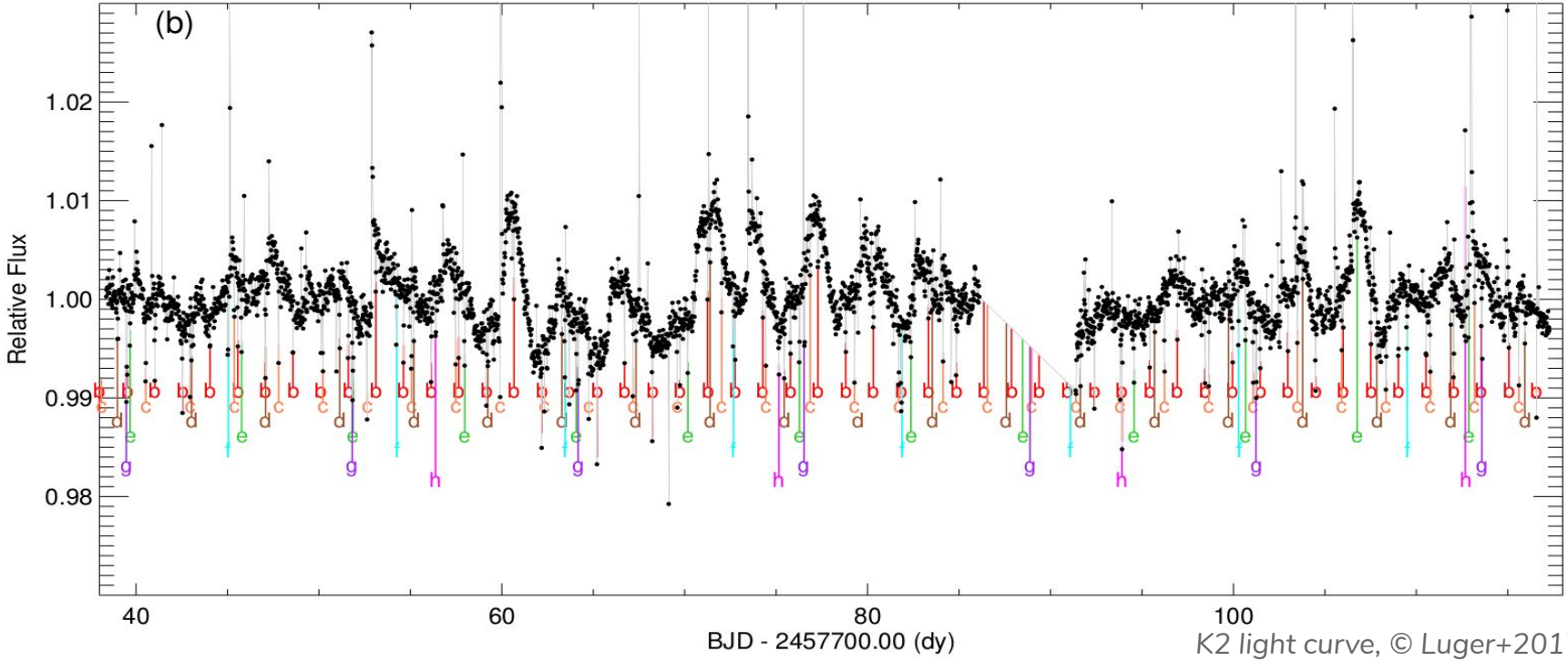
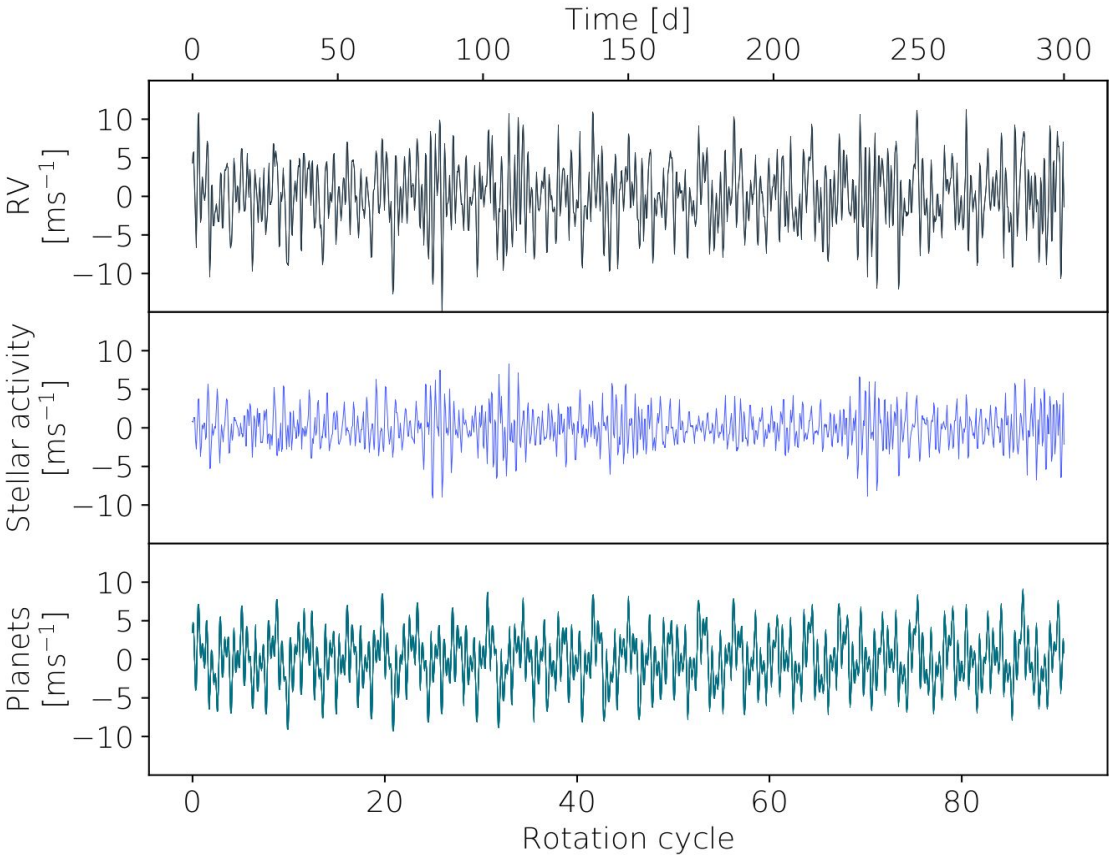
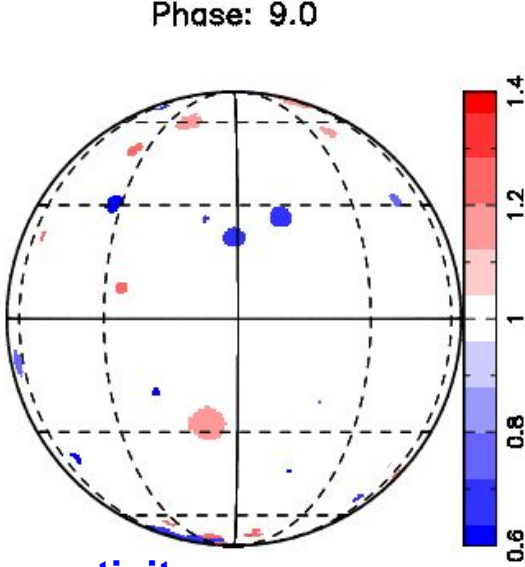


K2 light curve, © Luger+2017b

Simulation of SPIRou RV observations of TRAPPIST-1



Total RV curve

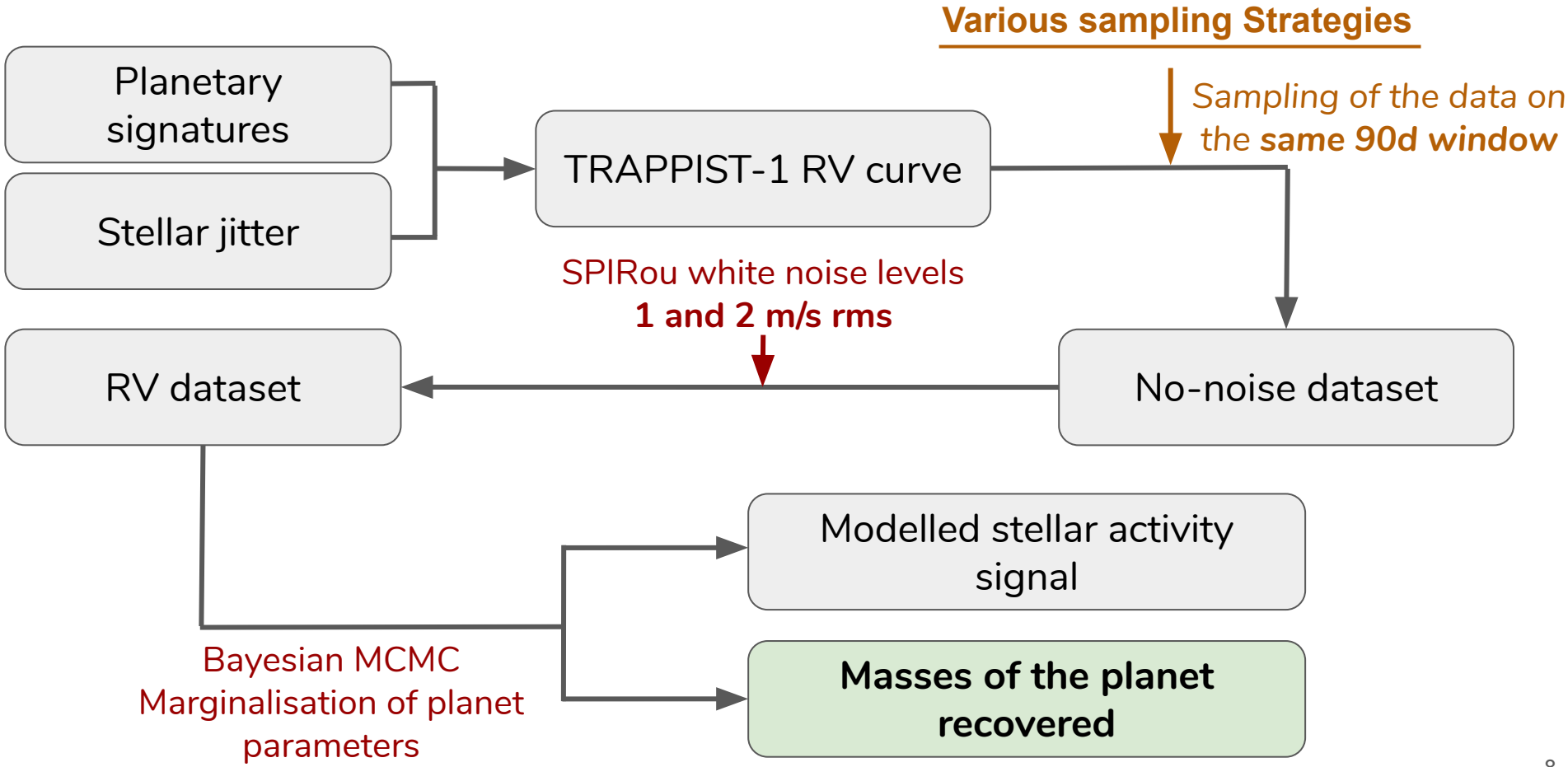


Stellar activity curve
Statistically compatible with K2 light curve

Planet RV curve
Sum of 7 independent planet RV components

Klein & Donati 2019, Submitted

Simulation of SPIRou RV observations of TRAPPIST-1

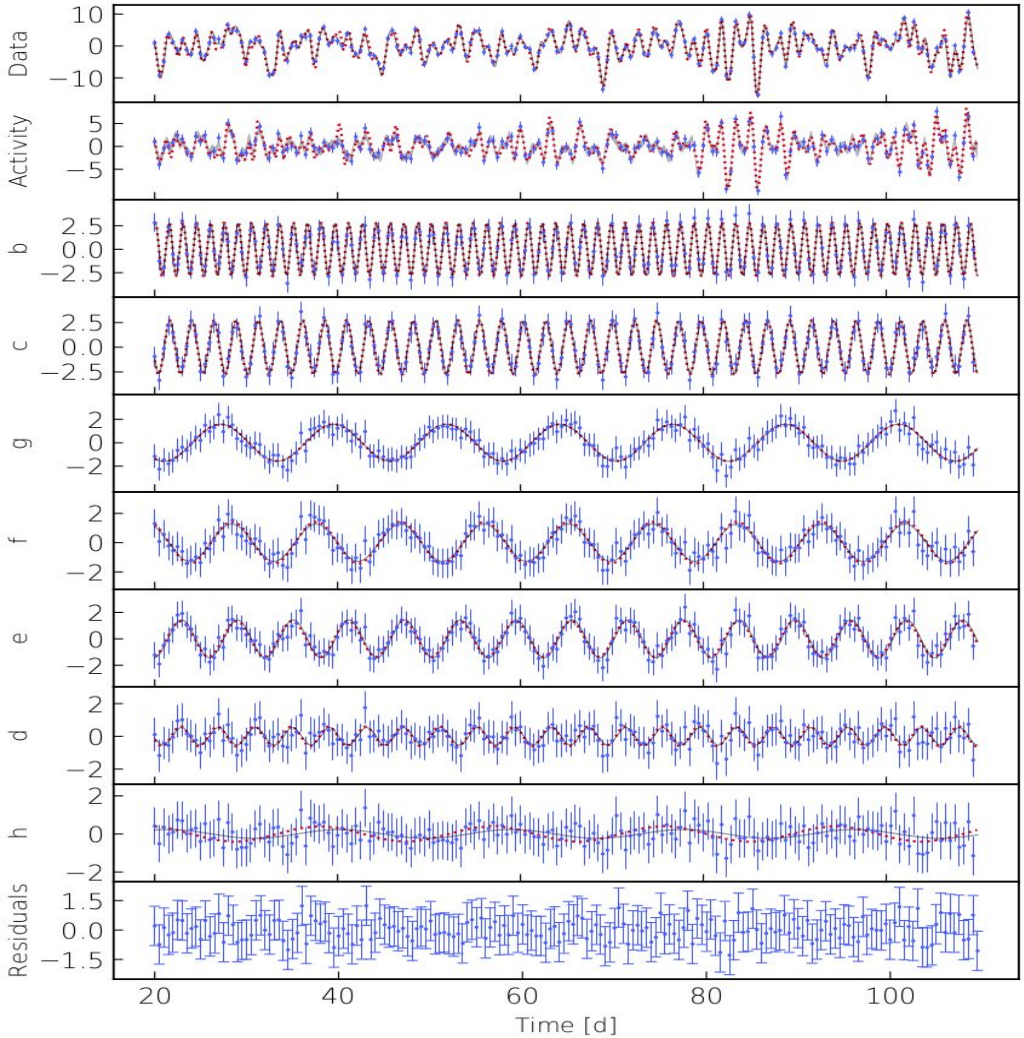


Results - Fit to the data

Assuming unrealistic high-cadence sampling

Earth-sized planets recovered with precision > photometry

Mars-sized planets completely drowned into stellar activity



Klein & Donati 2019, Submitted

Results - Impact of sampling

White noise of 1 m/s
Average on 50 signals with different realisation of white noise

Sampling	Good weather	Detection threshold (σ)						
		b	c	g	f	e	d	h
Even	100 %	12	24	10	12	11	2	1
SPIRou: 1 pt/n on all nights *+ SPIP: 1 pt/n on all nights*	85 % 50 %	11	15	8	8	8	2	1
SPIRou: 1 pt/n on ***bright time only*** *+ SPIP: 1 pt/n on all nights*	85 % 50 %	8	9	5	5	5	2	1
SPIRou: 1pt/n on all nights	85 %	6	6	4	4	5	2	1

Fair detection

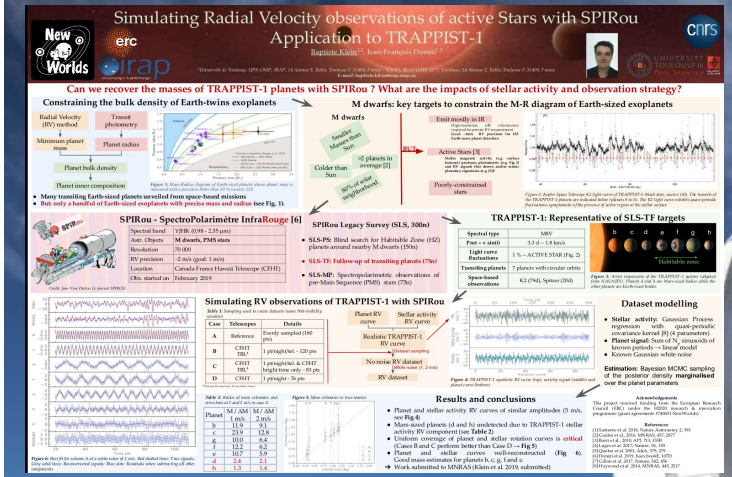
Inaccurate mass estimate

No detection

- **Good mass estimates for planets b and c**
- Uniform coverage of planets and activity curves is **critical** to accurately recover the planet masses

Take-home message

- TRAPPIST-1 K2 light curve suggests a stellar activity signal of **~5 m/s** - as strong as planet signal!
- RV jitter particularly harms the detection of planets with (i) **small RV amplitudes** and (ii) **orbital periods close to harmonics of the rotation period**
- **Dense coverage of planet and stellar rotation curves is critical to accurately recover the planet masses -- In particular for rapidly rotating active stars (adaptive strategy)**
- Good mass estimates for planets with RV semi-amplitude ≥ RV jitter/5 can be obtained - independent from photometric mass estimates!
- Application to a ~10 Myr close-in giant to be observed with SPIRou in 2019a (klein+2019 in prep)



Thank you!