Stellar Properties and the Effects that Stars and Exoplanets Have on Each Other

Dr. Heather Cegla

CHEOPS Fellow

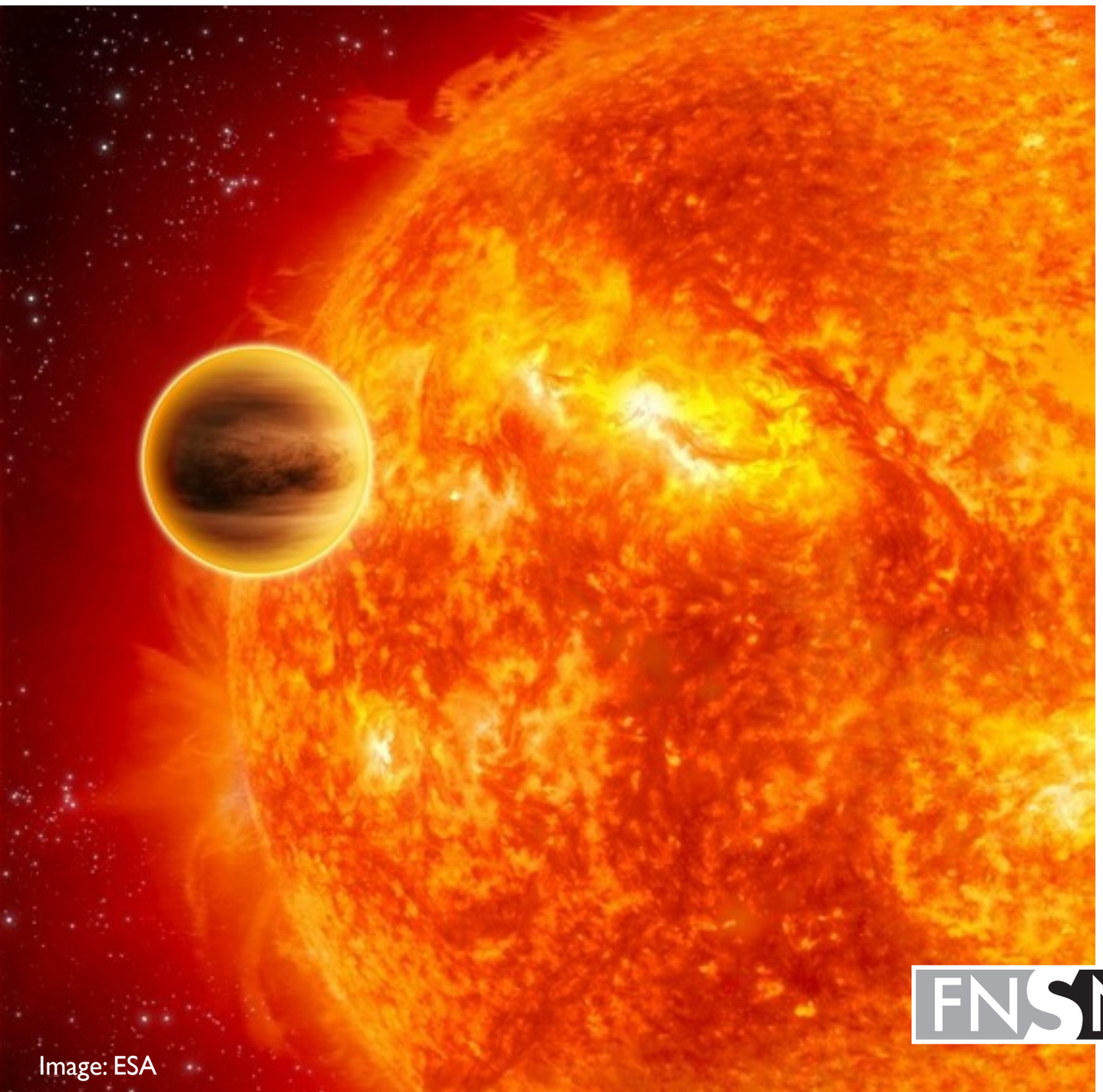
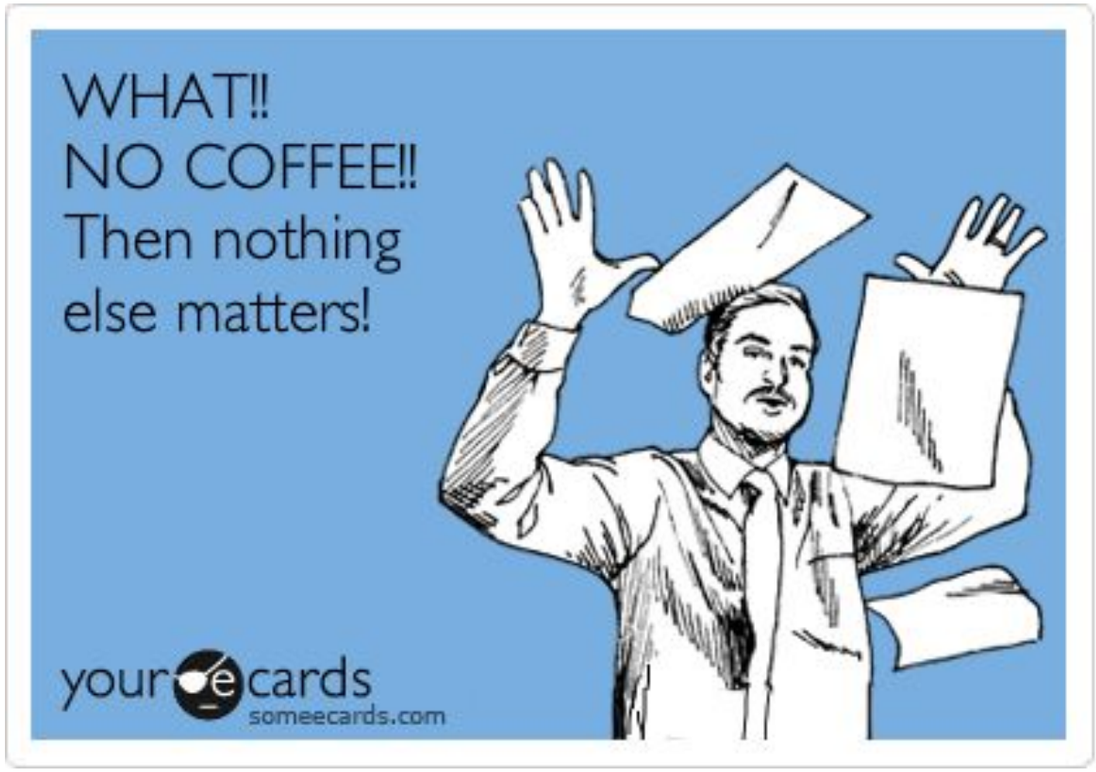


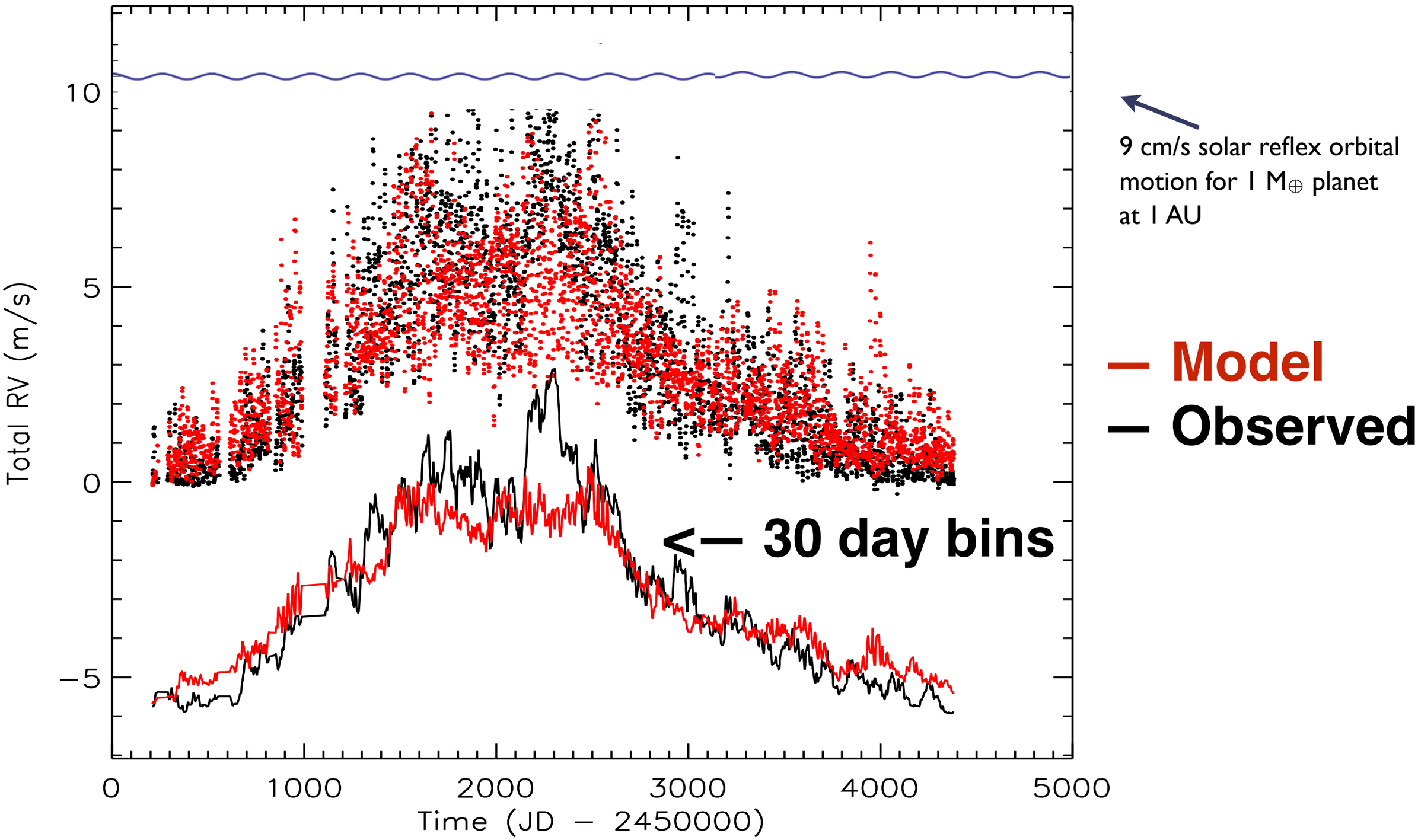
Image: ESA



FNSNF PlanetS National Centre of Competence in Research UNIVERSITÉ DE GENÈVE

Astrophysical 'Noise'

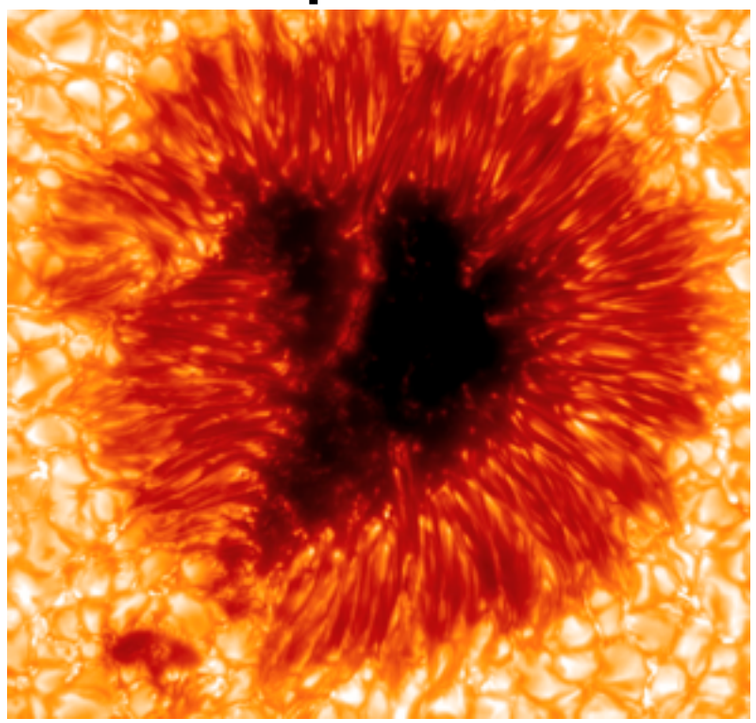
- Magnetic Activity Cycles (years)

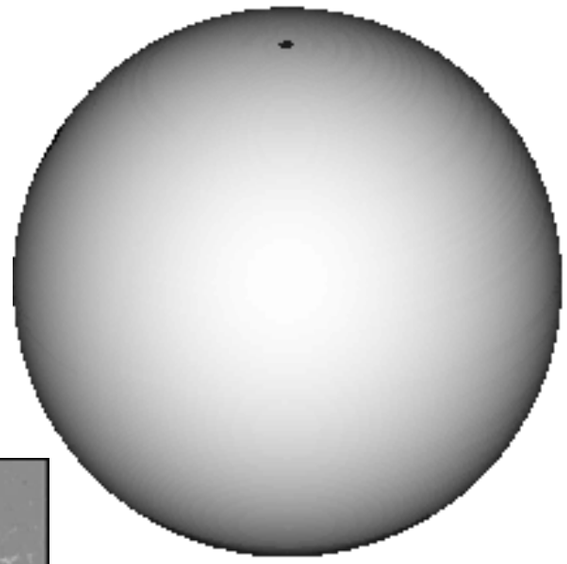


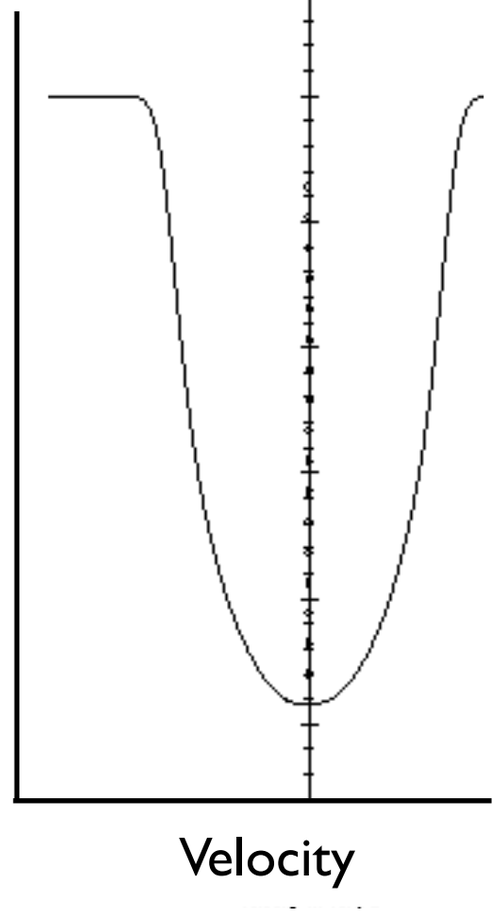
Borgniet et al. 2015

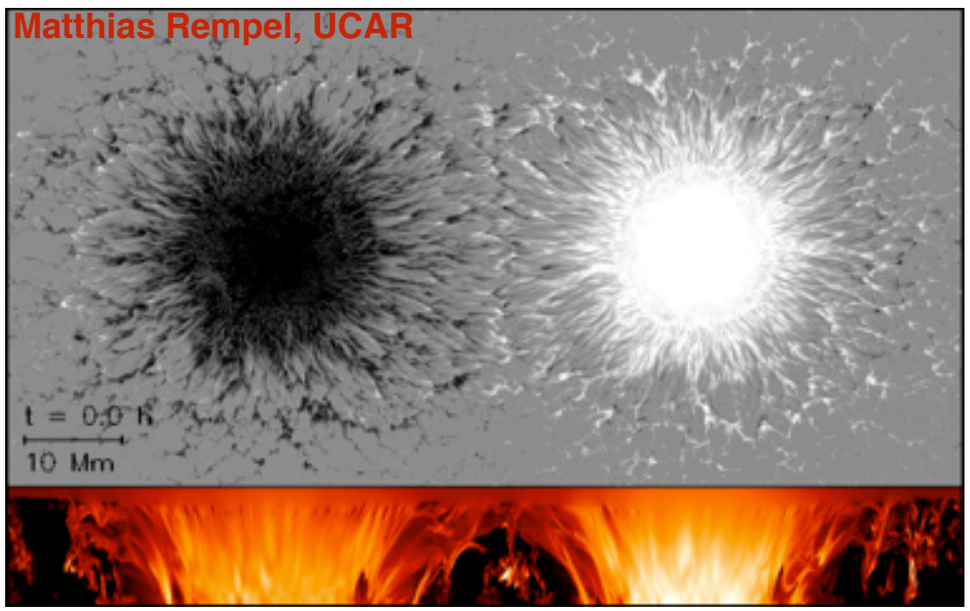
Astrophysical ‘Noise’

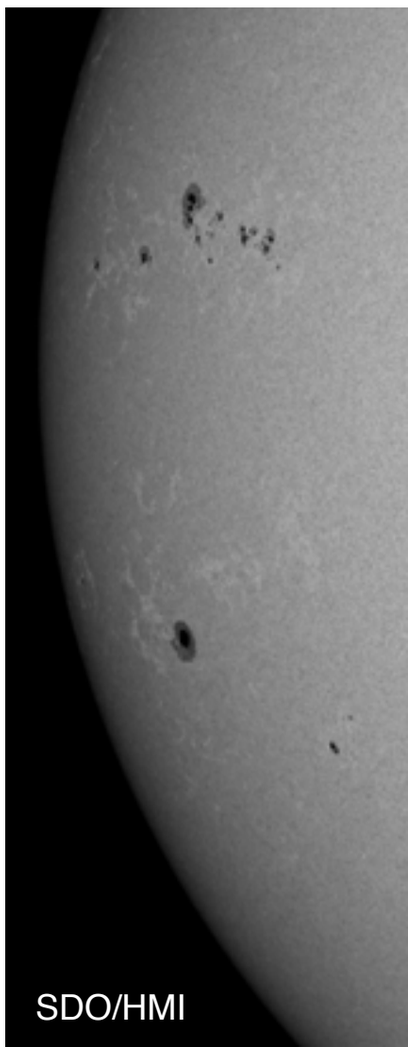
- Magnetic Activity Cycles (years)
- Starspots, Faculae (days)





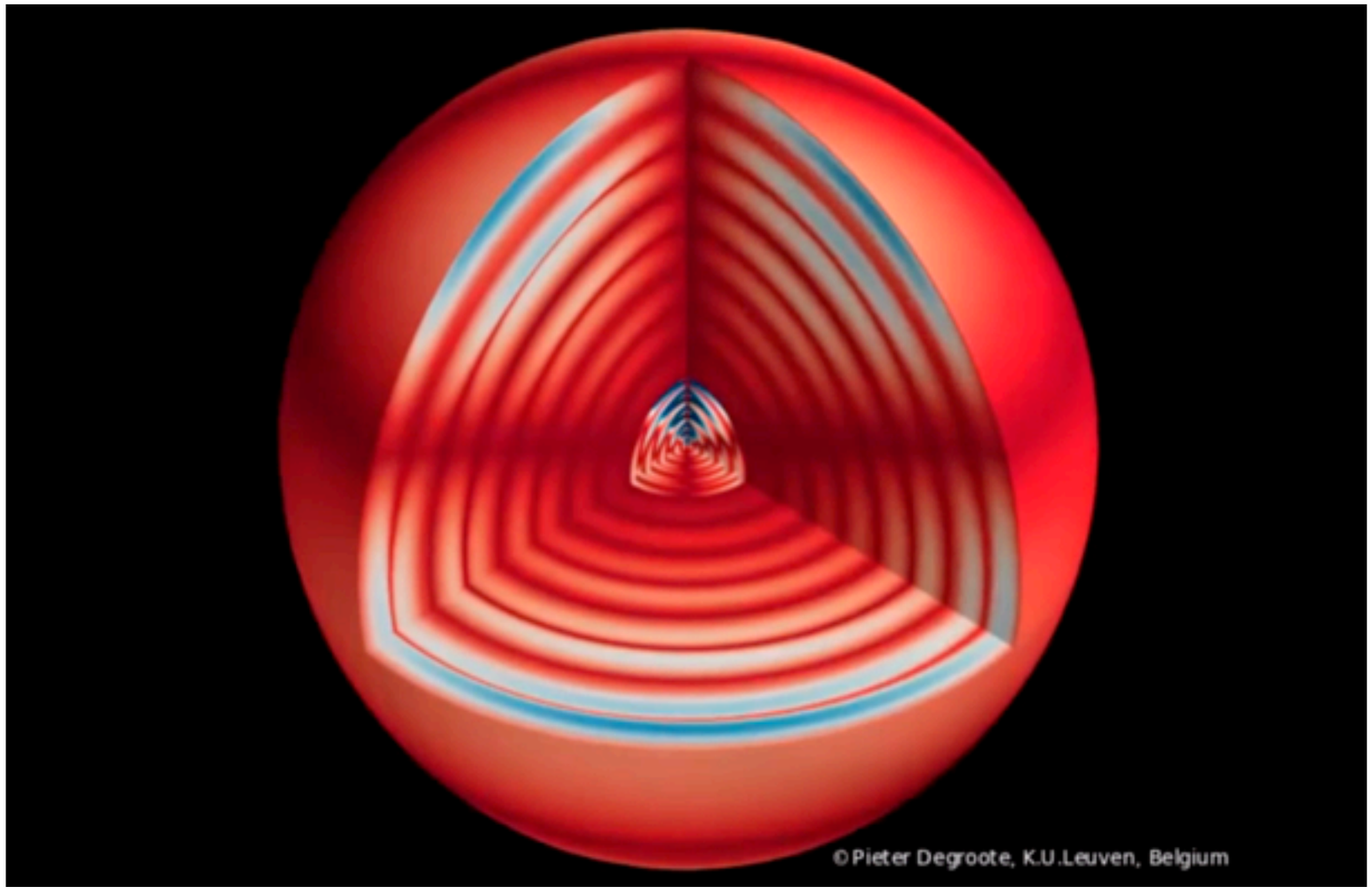






Astrophysical ‘Noise’

- Magnetic Activity Cycles (years)
- Starspots, Faculae (days)
- Stellar Oscillations (minutes)



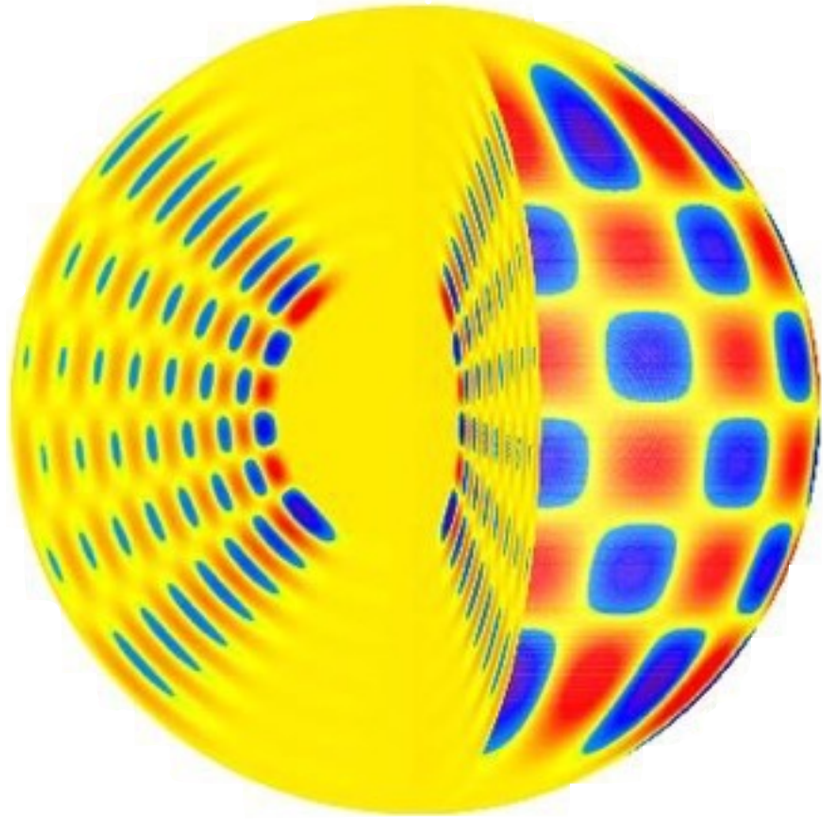
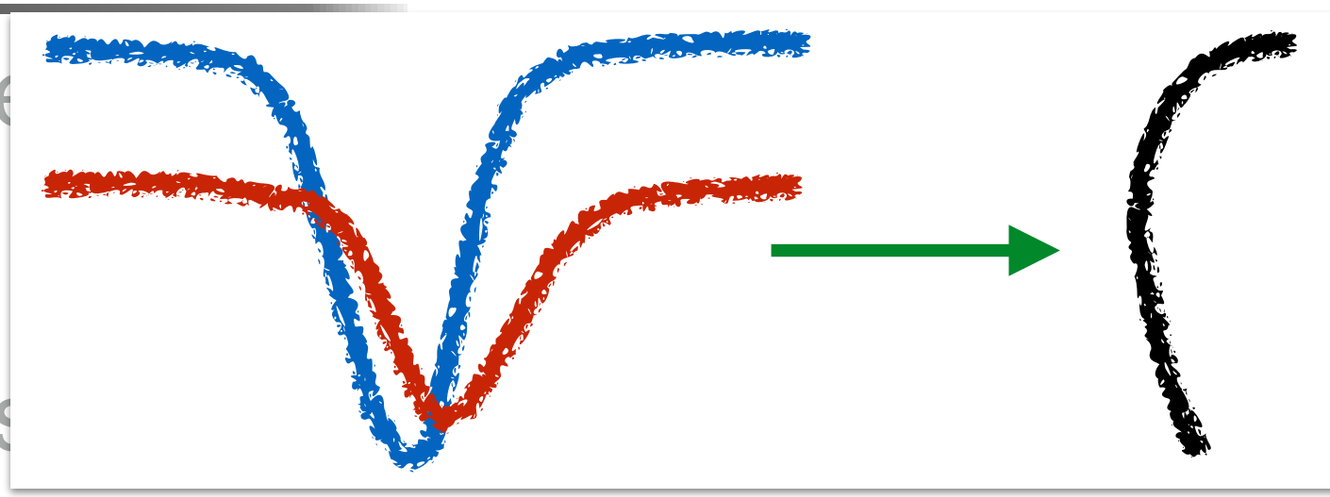
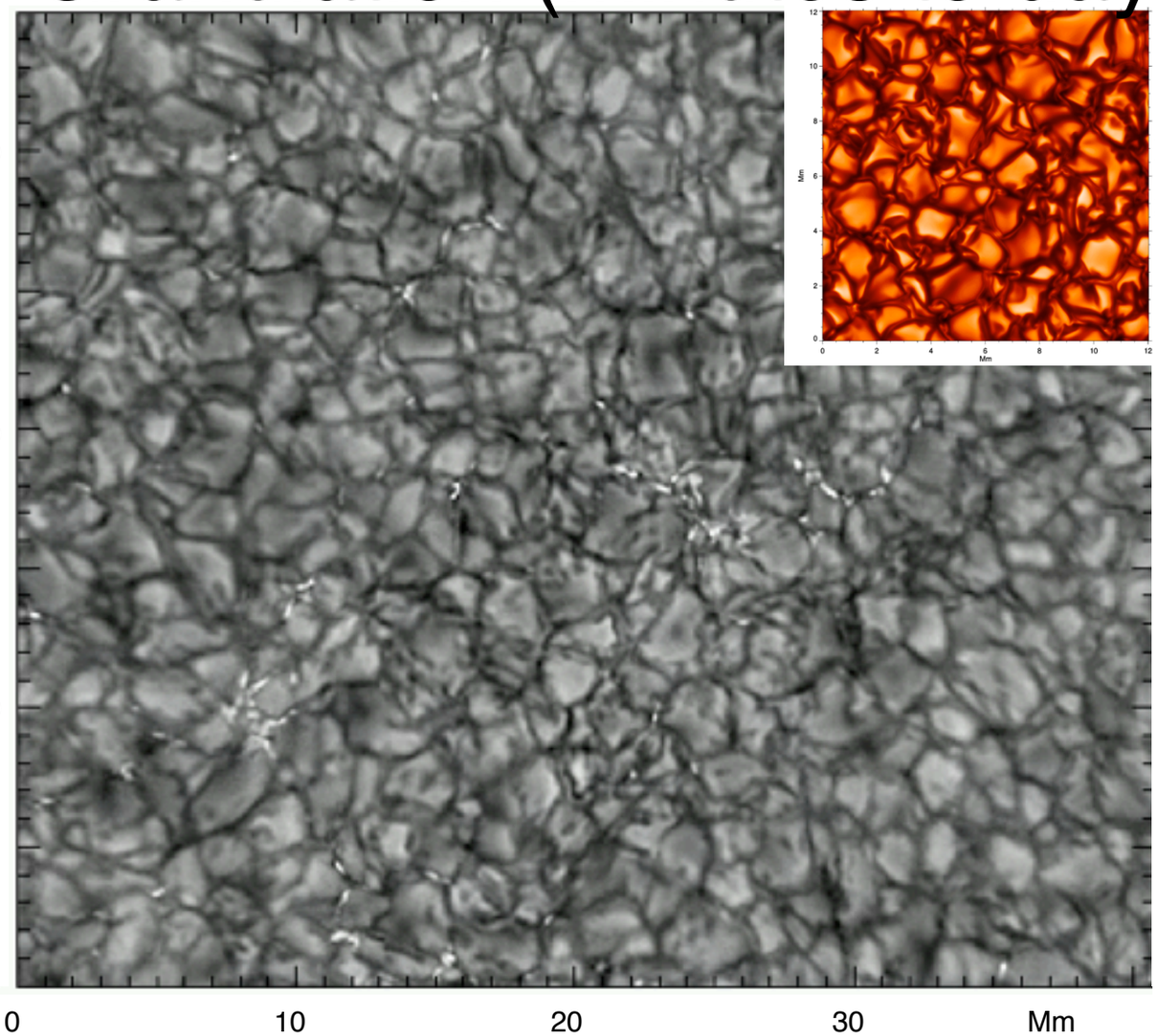


Image credit: Kiepenheuer Institute for Solar Physics (KIS)

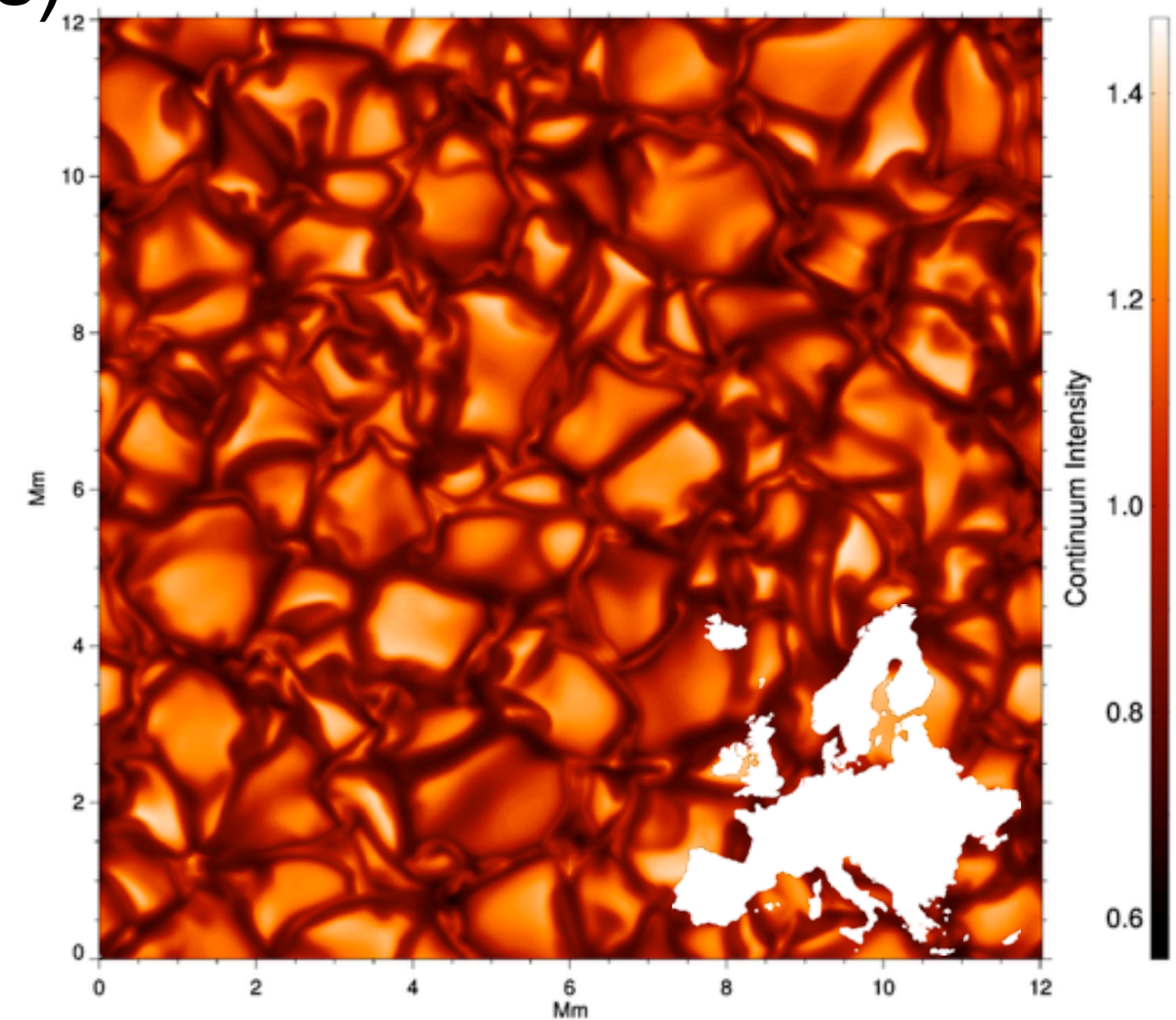
Astrophysical ‘Noise’

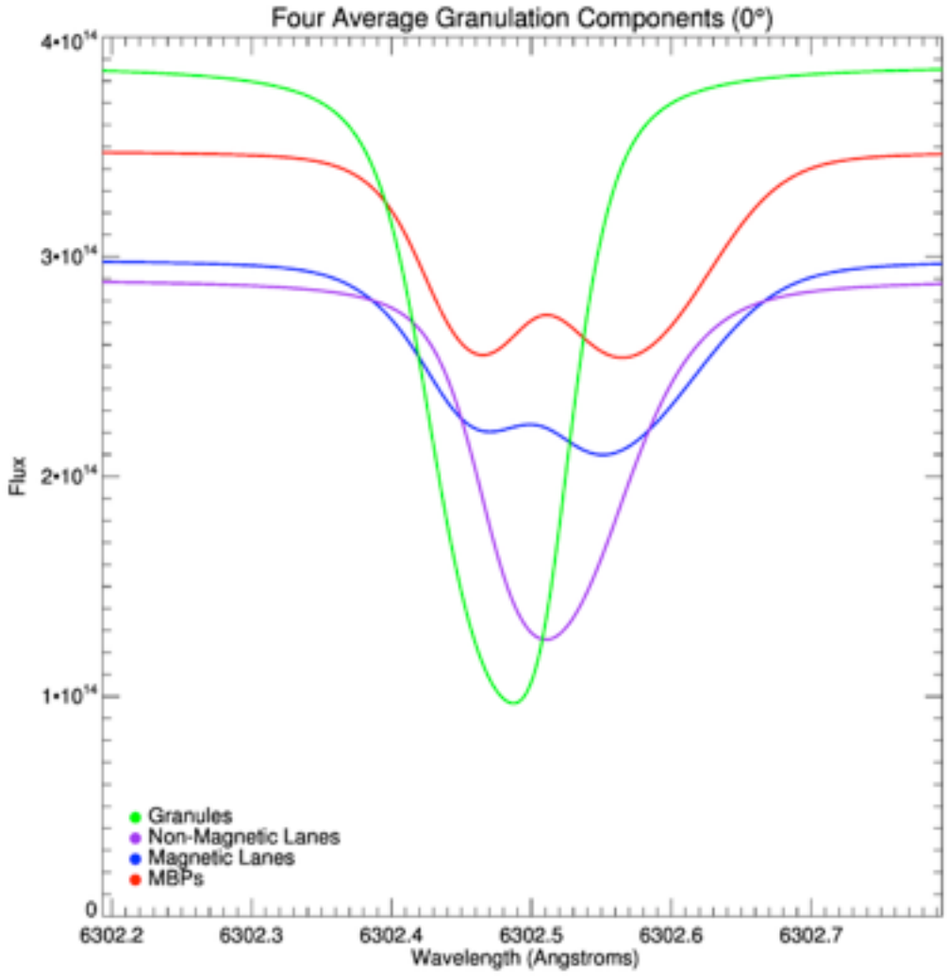
- Magnetic Activity Cycles (ye
- Starspots, Faculae (days)
- Stellar Oscillations (minutes
- Granulation (minutes to days)

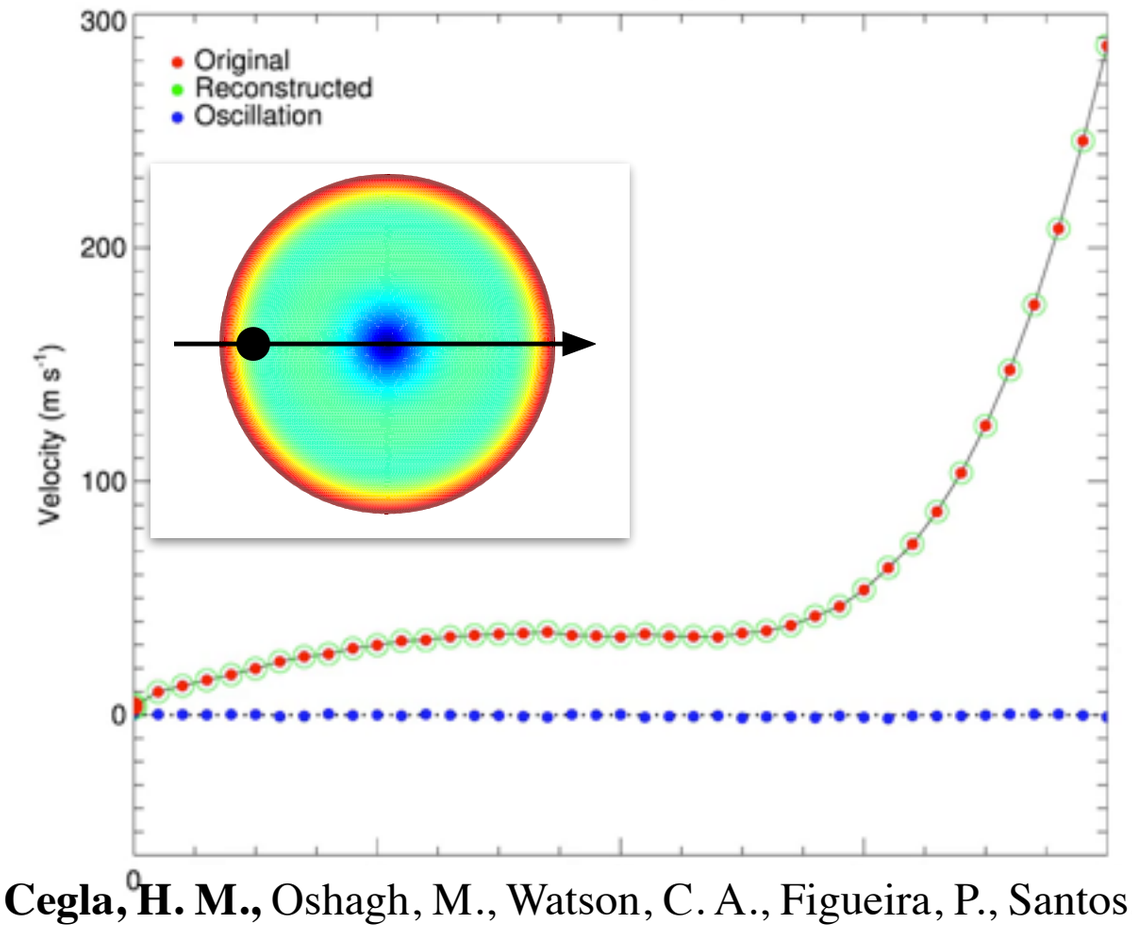


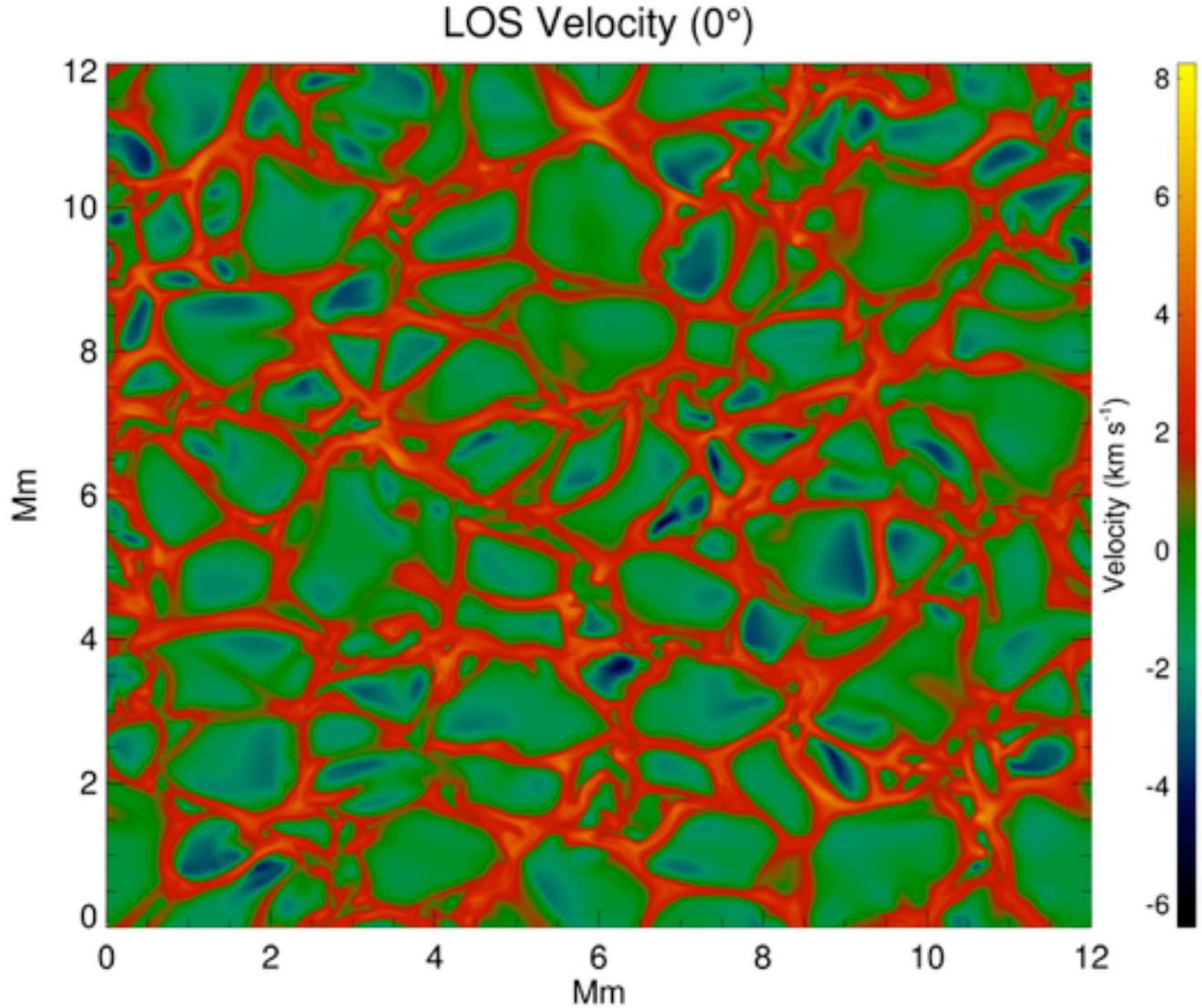


Cegla, H. M. et al. 2013, ApJ, 763, 95







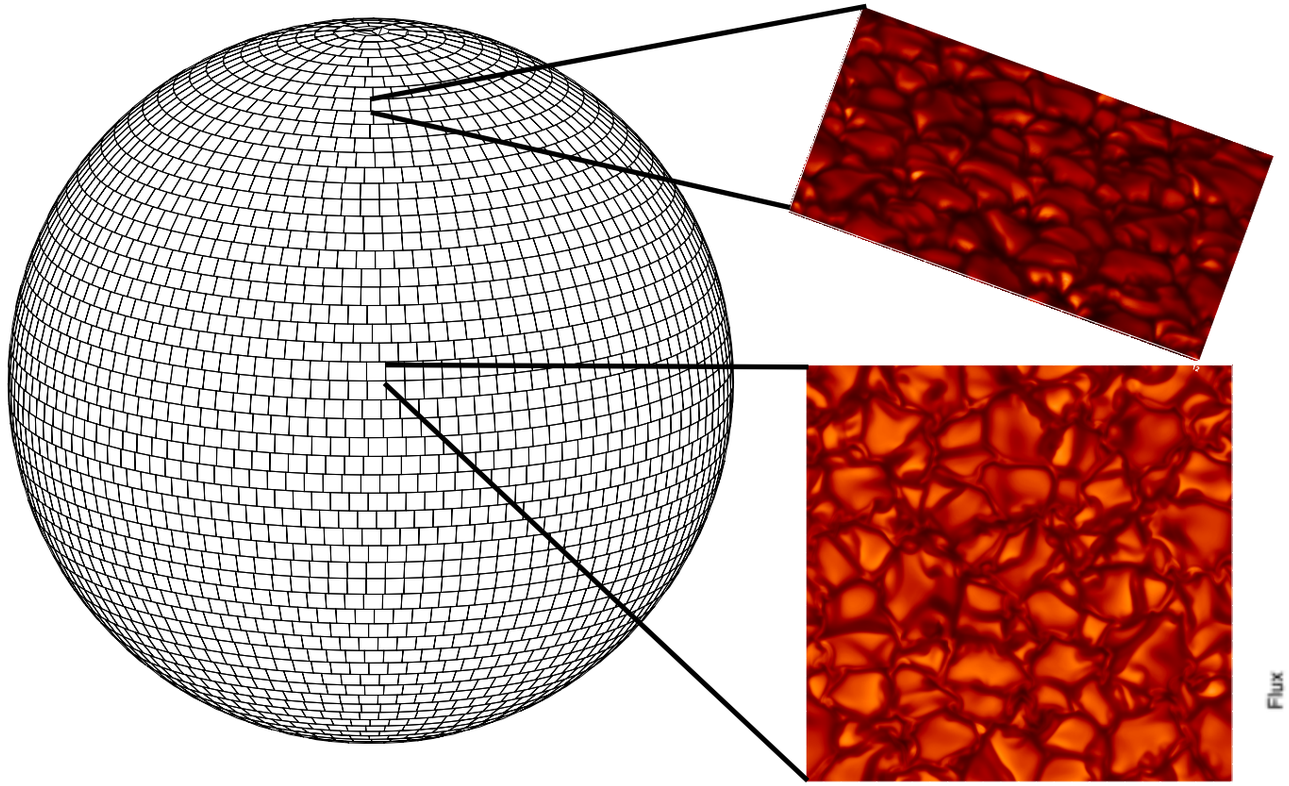


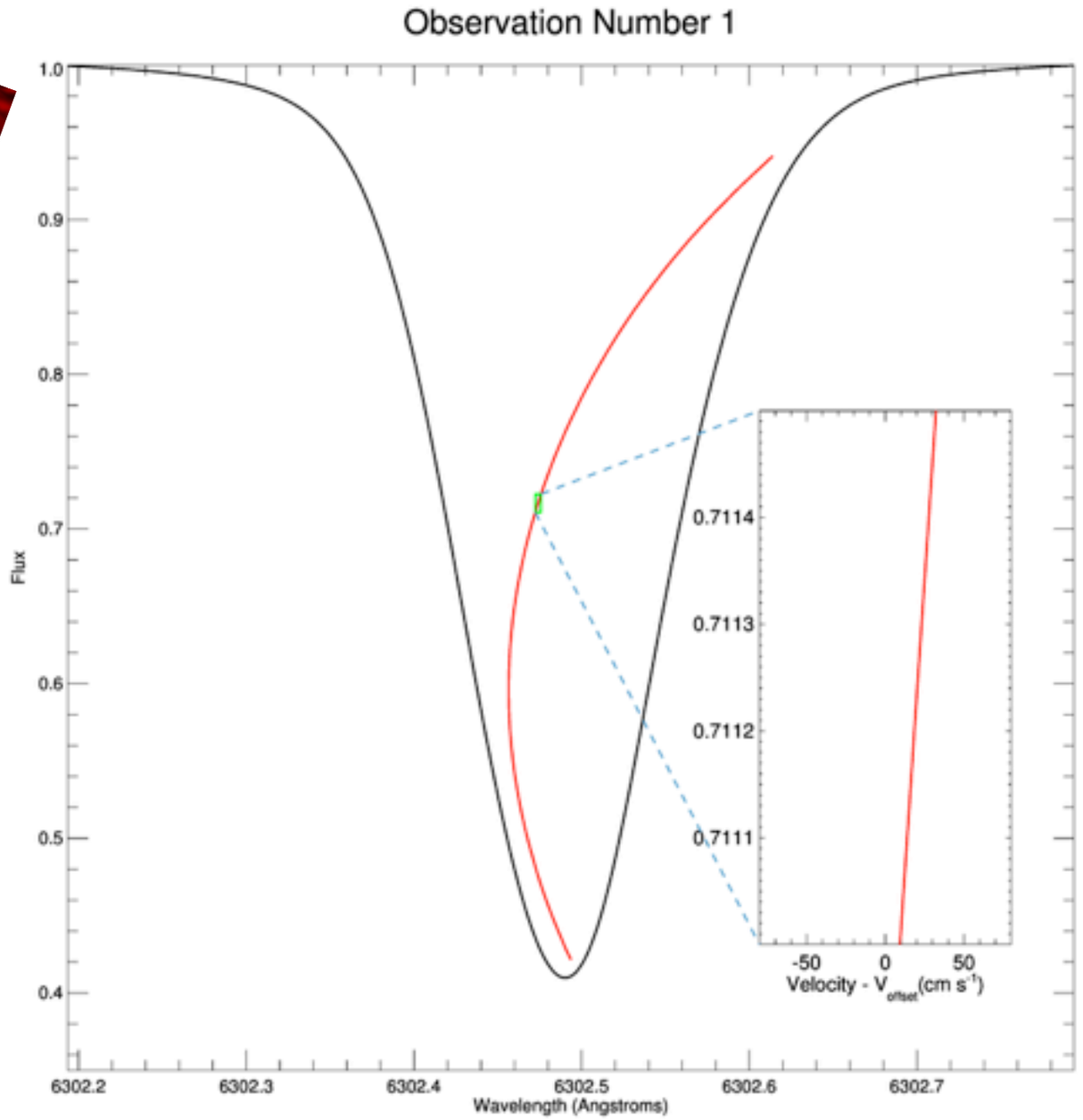
Cegla, H. M. et al 2015, CSSS, 18, 567

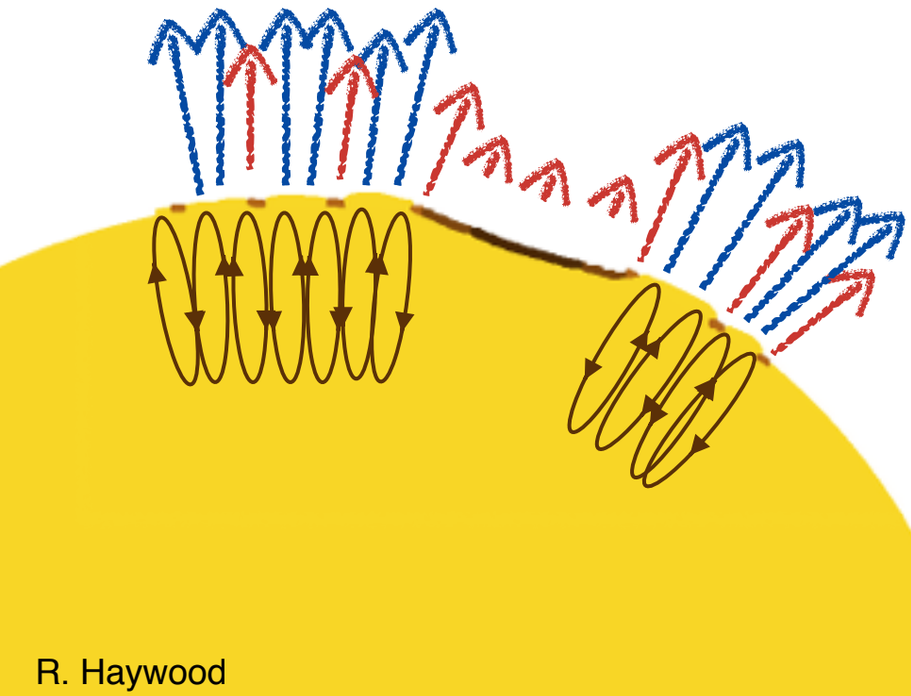
Cegla, H. M. et al., in prep

Cegla, H. M., Oshagh, M., Watson, C. A., Figueira, P., Santos, N. C. **2016a**, ApJ, 819, 67

Astrophysical ‘Noise’







R. Haywood

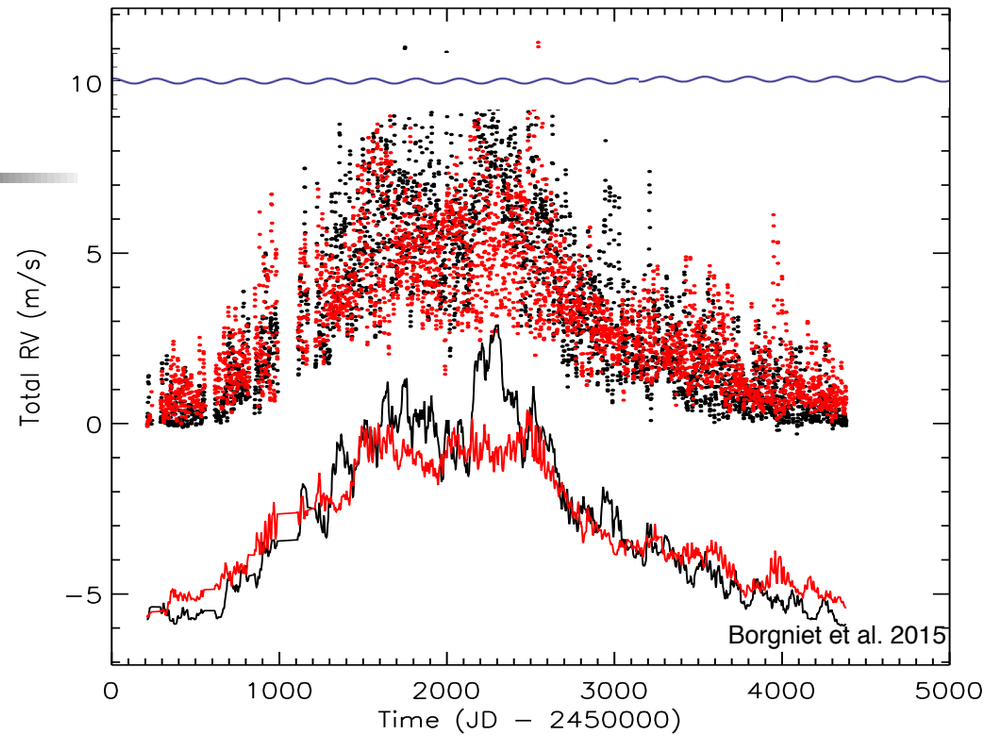
Cegla, H. M., Shelyag, S., Watson, C. A., Mathioudakis, M. **2013**, ApJ, 763, 95

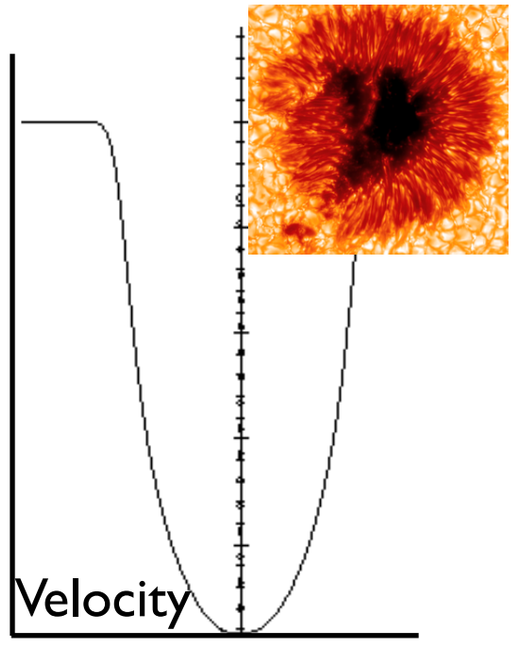
Cegla, H. M., Watson, C. A., Shelyag, S., Mathioudakis, M. **2015**, CSSS, 18, 567

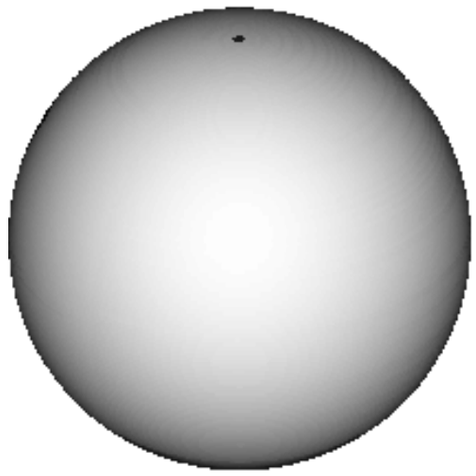
Cegla, H. M., Watson, C. A., Shelyag, S., Mathioudakis, M., Moutari, M., in prep

Astrophysical ‘Noise’

- Magnetic Activity Cycles (years)
- Starspots, Faculae (days)
- Stellar Oscillations (minutes)
- Granulation (minutes to days)
- Flares, CMEs (minutes to days)
- Meridional Flows (days)?
- Variable Gravitational Redshift ?







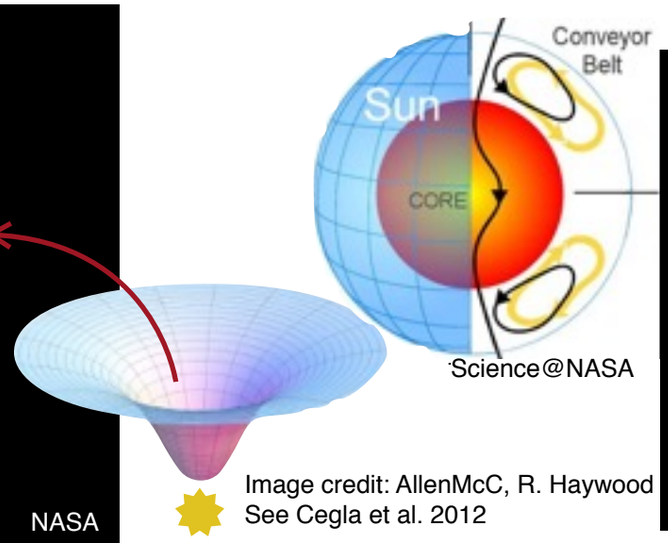
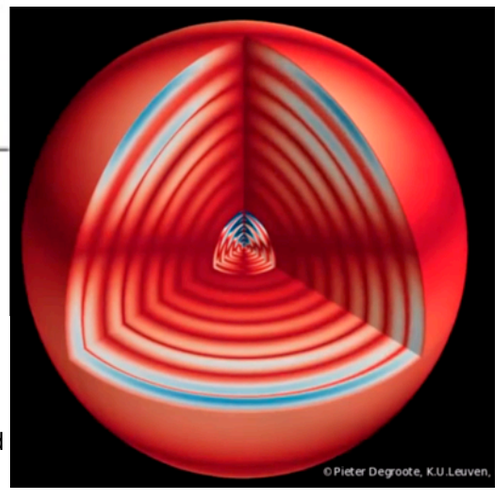
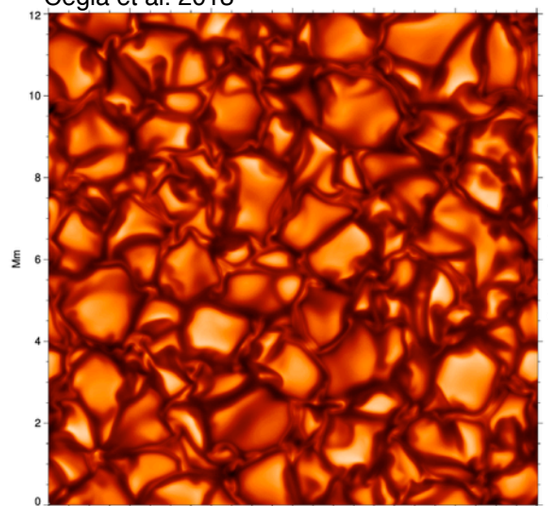
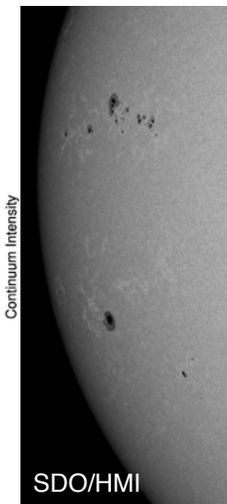


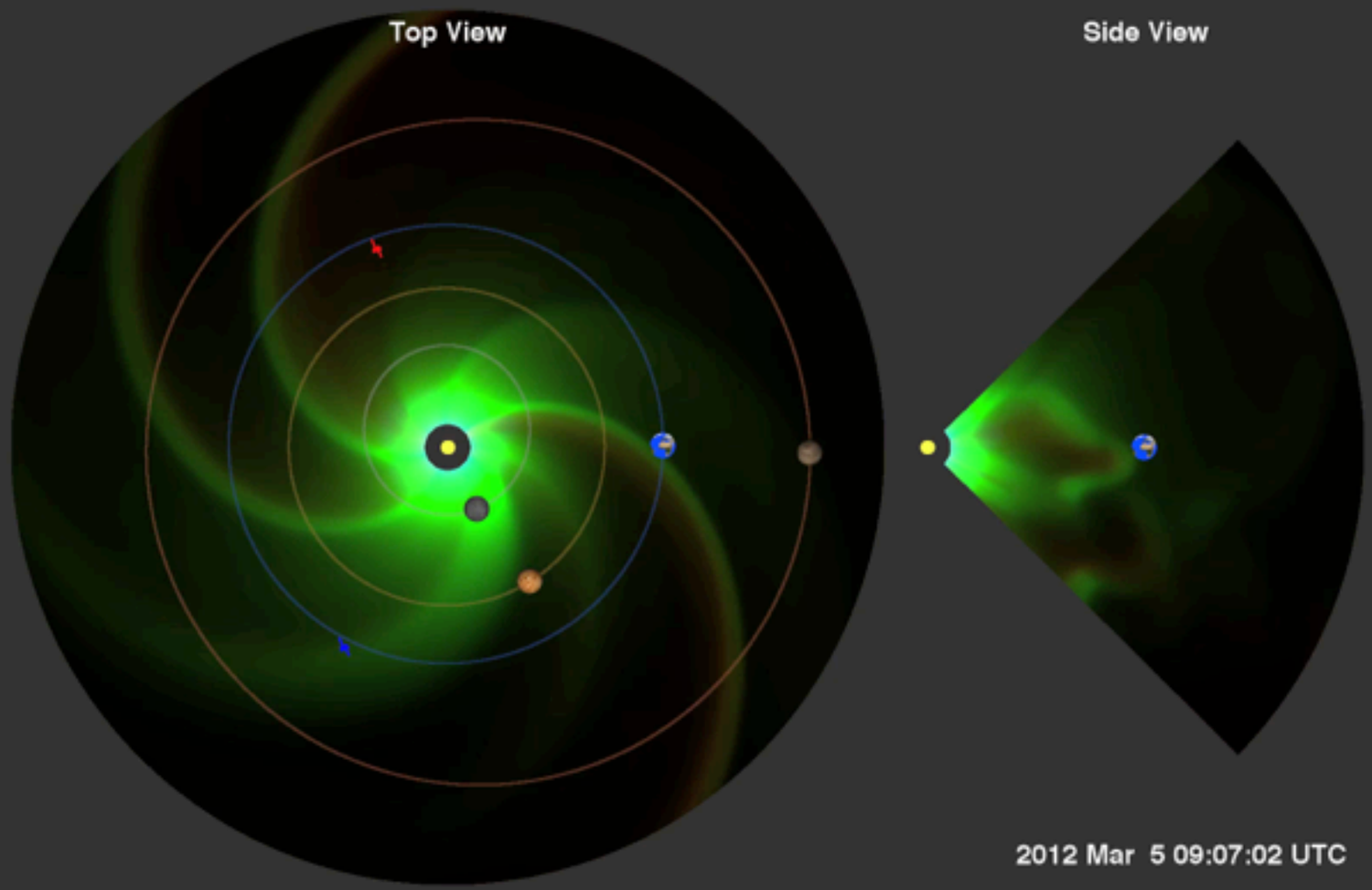
Image credit: AllenMcC, R. Haywood
See Cegla et al. 2012

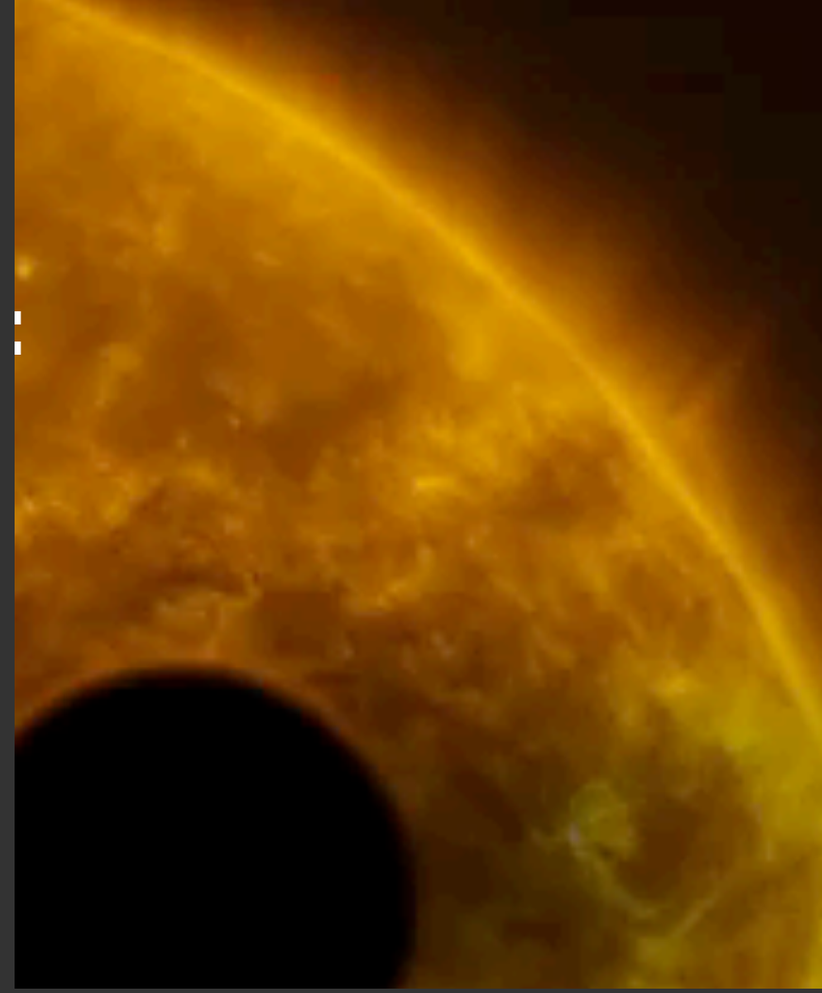


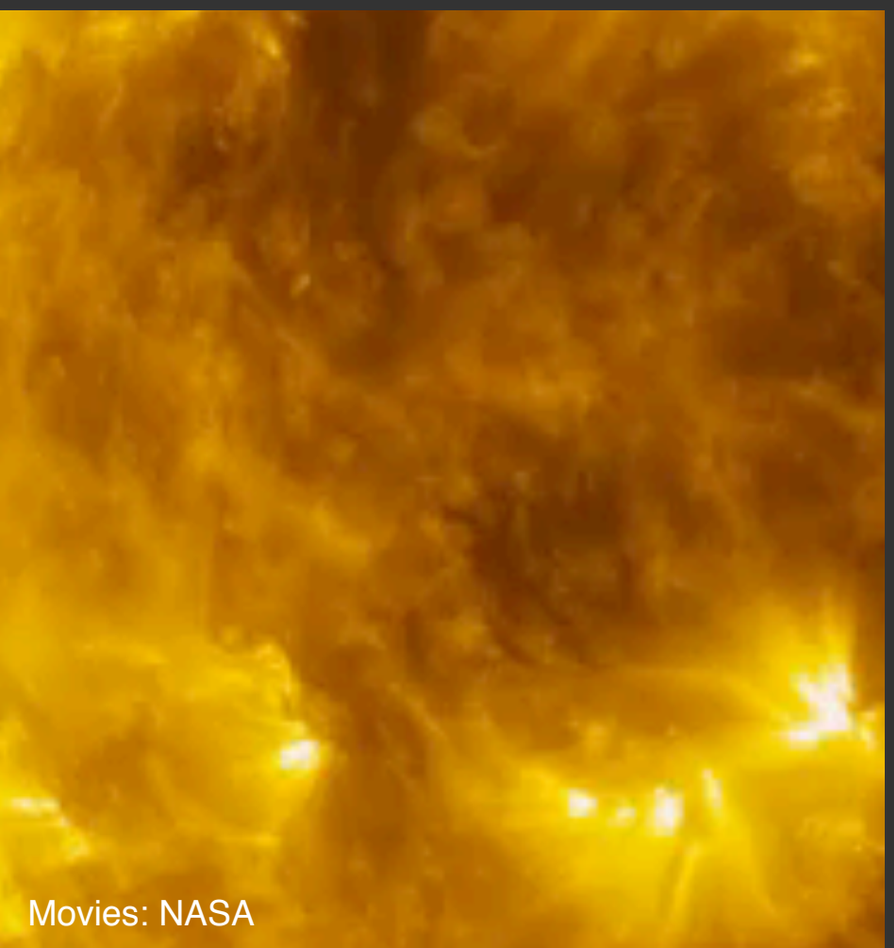
Cegla et al. 2013

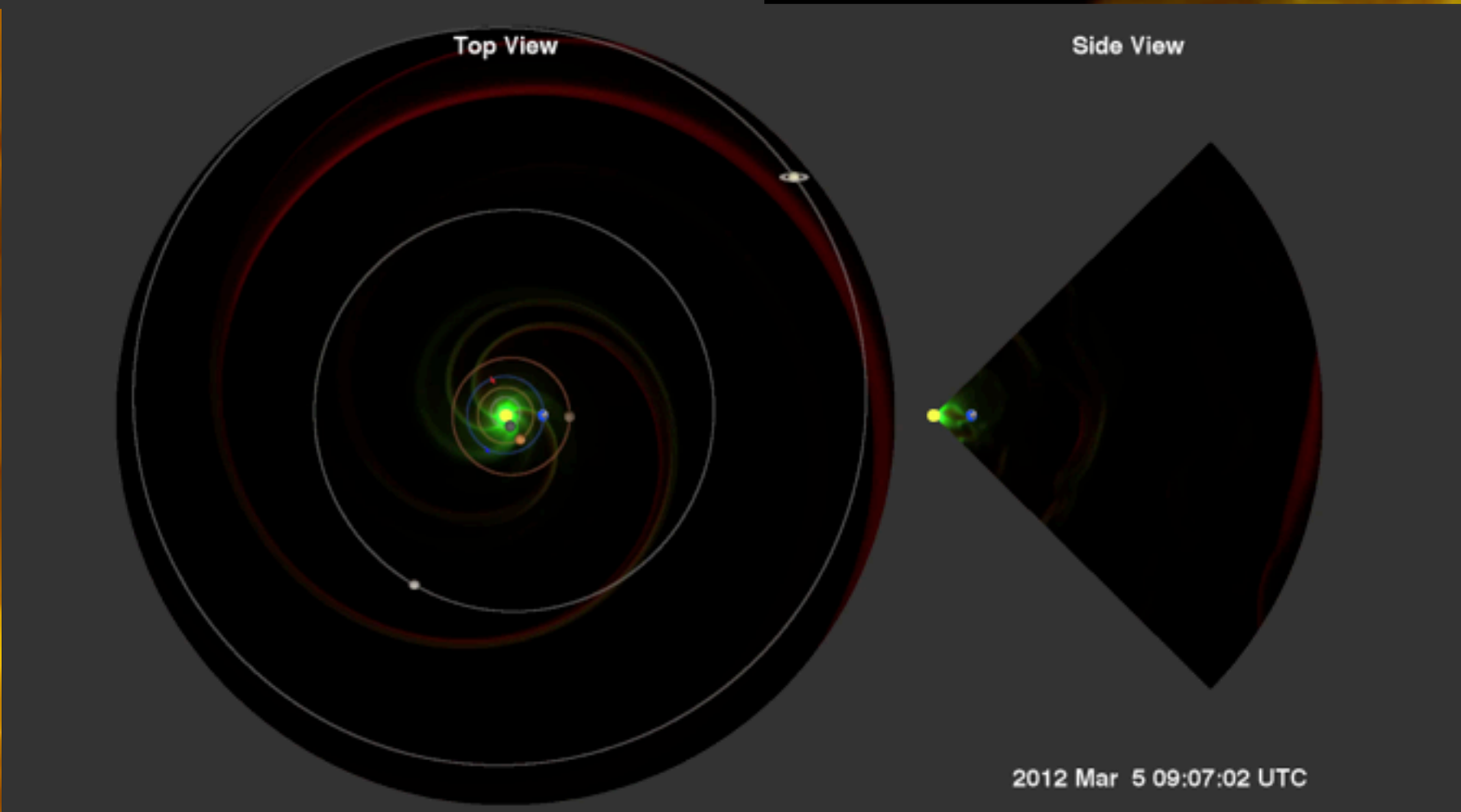





Top View
Side View
2012 Mar 5 09:07:02 UTC

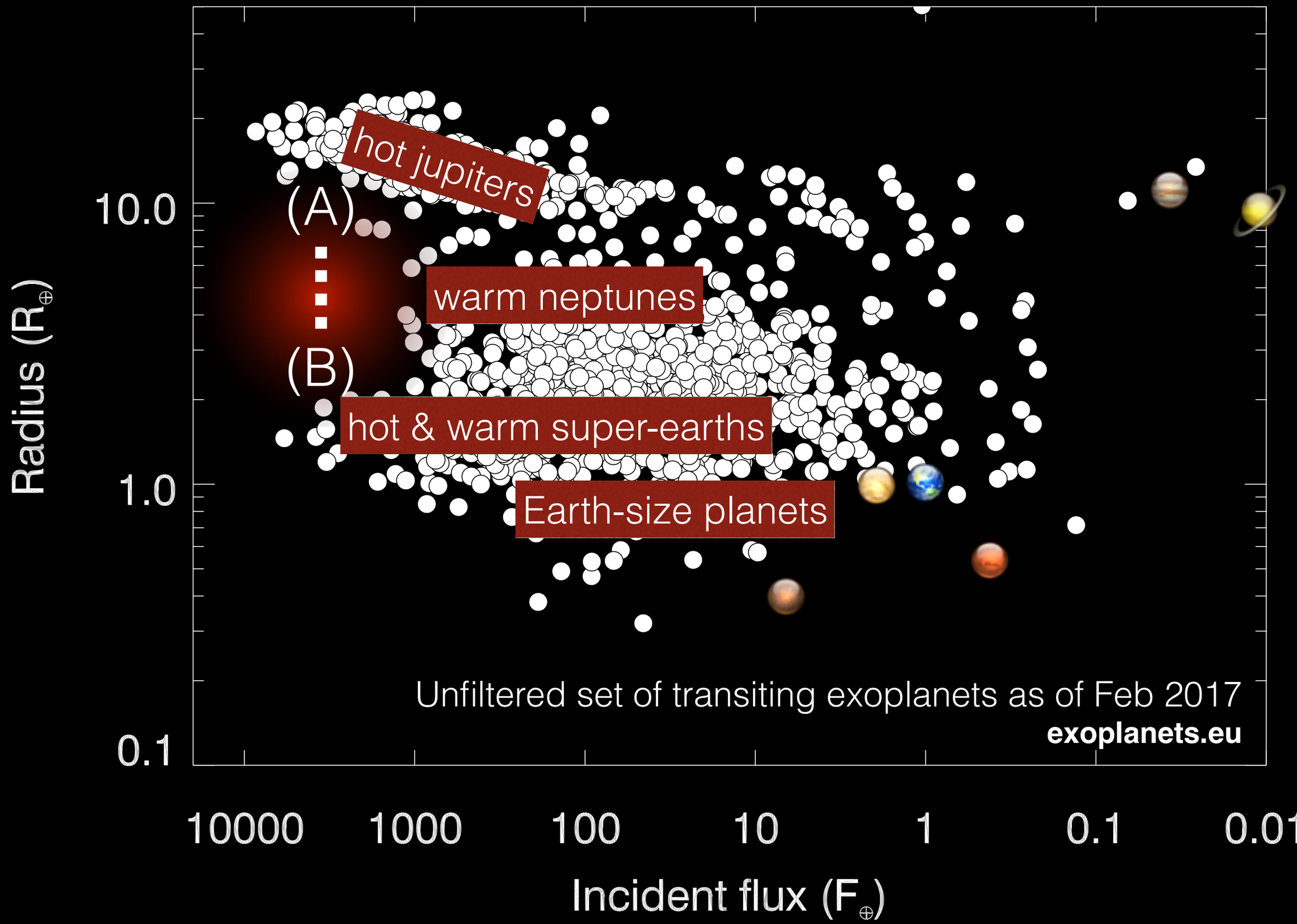



Movies: NASA


Top View
Side View
2012 Mar 5 09:07:02 UTC

A dearth of close-in, intermediate-mass planets

Lecavelier (2007) • Penz et al. (2008) • Davis & Wheatley (2009) • Ehrenreich & Désert (2011)
Owen & Jackson (2012) • Lopez et al. (2012) • Beauté & Nesvorný (2013) • Mazeh et al. (2016)

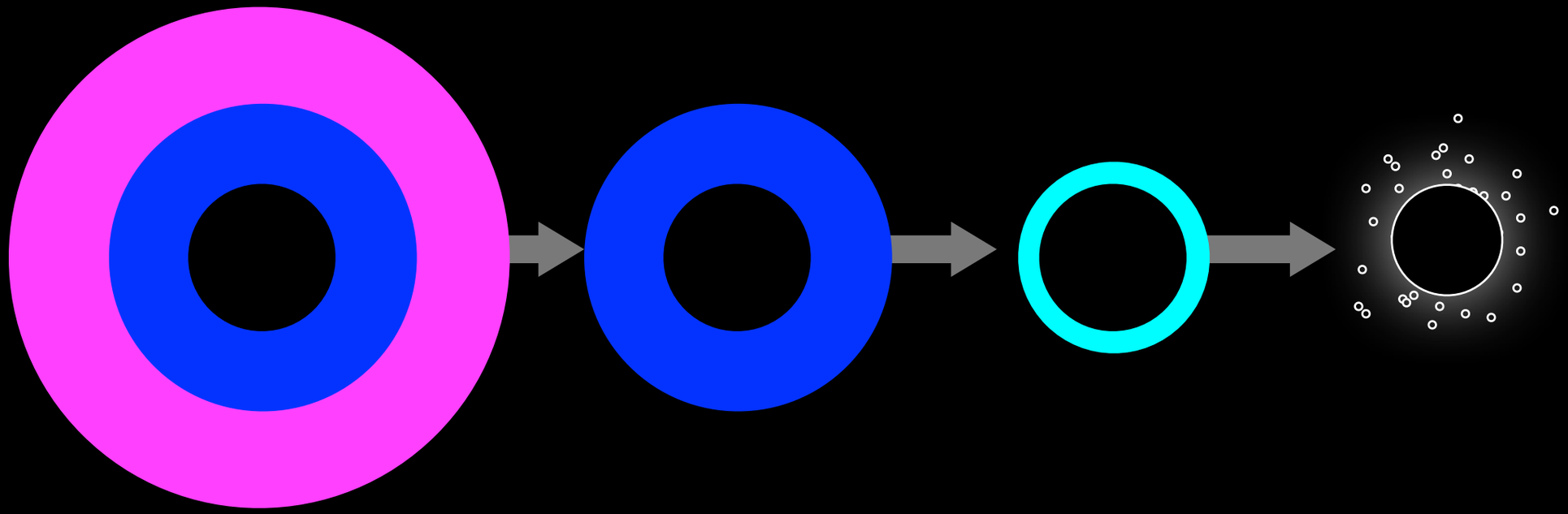


Slide: D. Ehrenreich

Evaporation

Atmospheric “evaporation”

(A)



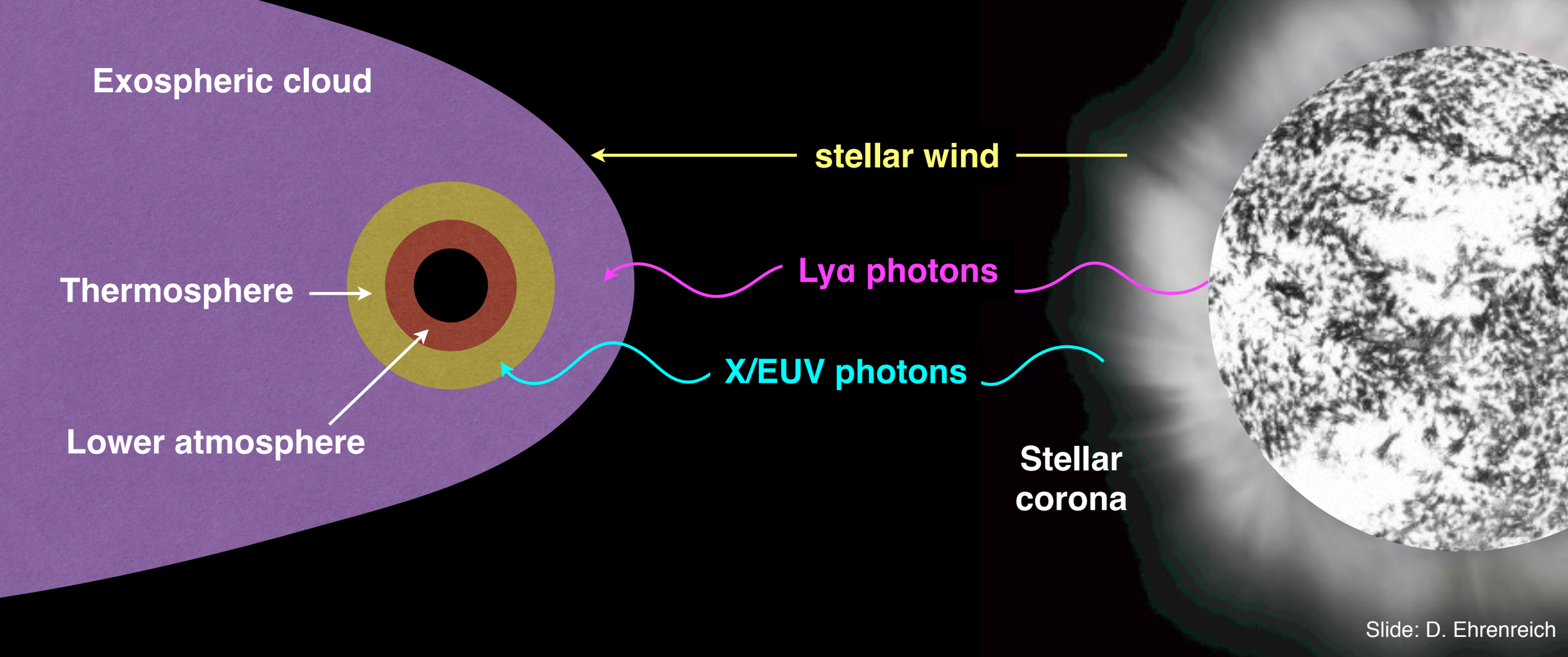
(B)

- hydrogen/helium envelope
- thin atmosphere
- ice mantle/volatile envelope
- solid core (rocks+metals)

Slide: D. Ehrenreich

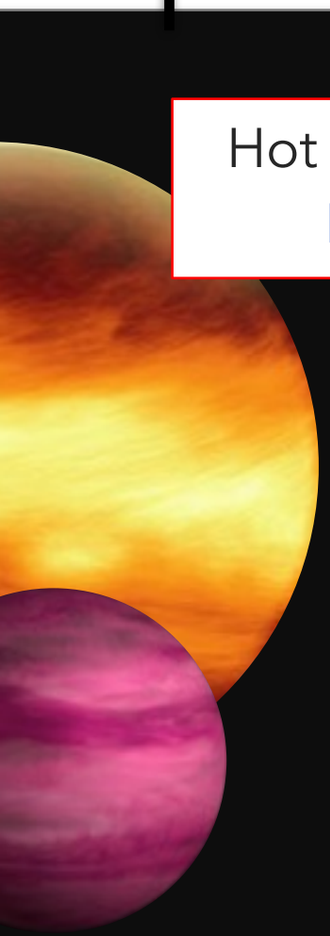
Evaporation

- Tremendous **X/UV** energy deposited in atmospheres of close-in planets
- Leads to expansion & hydrodynamical thermal escape of **exospheres**
- Escaping atoms (hydrogen) repelled & ionised, sculpting large envelopes



Slide: D. Ehrenreich

Stellar irradiation and close-in planets



Hot Jupiter WASP12b
Fossati+ 2010

Hot Jupiter HD189733b
Lecavelier+ 2010

Hot Jupiter HD209458b
Vidal-Madjar+ 2003

Warm Jupiter 55 Cnc b
Ehrenreich+ 2012

Warm Neptune GJ436b
Kulow+2014, Ehrenreich+2015
Lavie+2017

exoplanets.org

100
10
1
0.1
0.01
Planetary Radius [Earth Radii]
Semi-Major Axis [Astronomical Units (AU)]

Slide: V. Bourrier

Stellar irradiation and close-in planets

Desert of sub-Jupiter size planets

e.g. Lecavelier+2007, Davis & Wheatley 2009

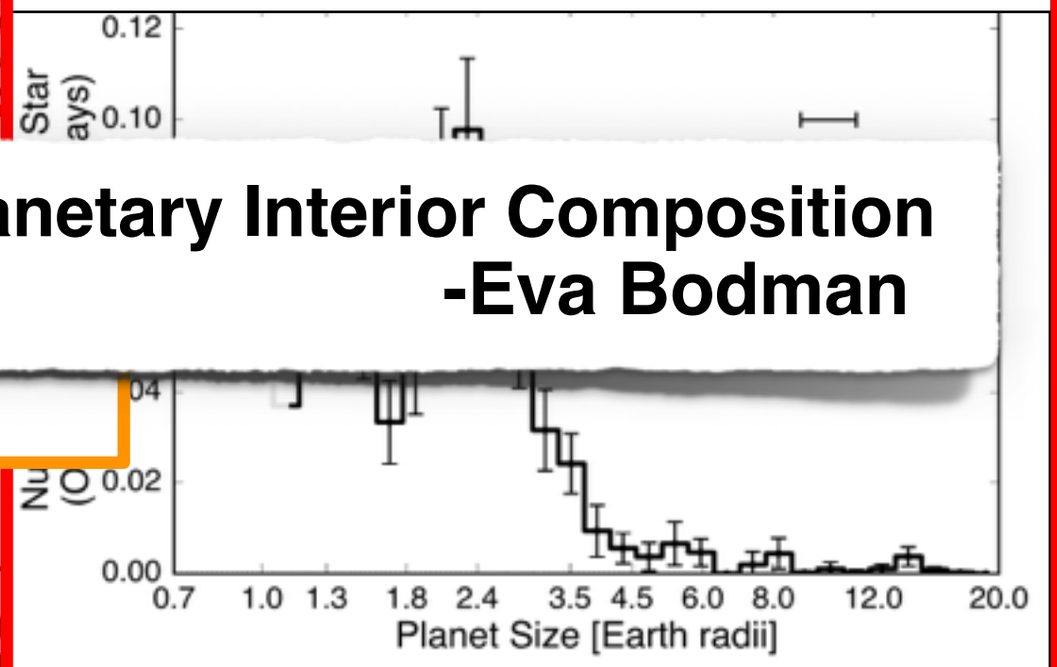
Lack of hot super-Earths

How Planetary Properties and Stellar Irradiation Set Atmospheric Structure
-Thomas Beatty

Two populations of small planets

Fulton+ 2017

$R < 1.5\ R_{earth}$ and $R = 2–3\ R_{earth}$



Using Disintegrating Planets to Study Planetary Interior Composition
-Eva Bodman

Kepler-10 b

Ultra-short period planets

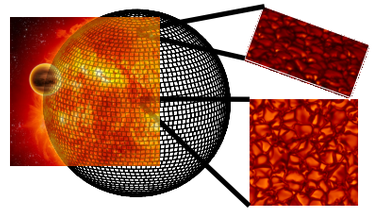
Small rocky planets, periods < 1 day

Role of evaporation supported by many theoretical studies

(eg Lopez et al. 2012, Jin et al. 2014, Kurokawa & Nakamoto 2014, Owen & Wu 2017)

Slide: V. Bourrier

Summary…



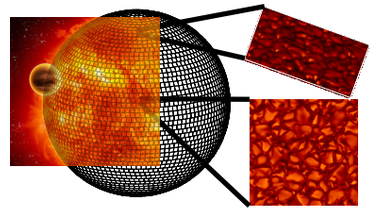
- Stellar properties impact planet properties
  - Stellar surface phenomena alter RVs and LCs
    - Impacts planet detection/confirmation/characterisation
    - Need to diagnose stellar noise and disentangle
  - Stars can alter close-in planets and vice versa

<u>Know thy star, know thy planet</u>

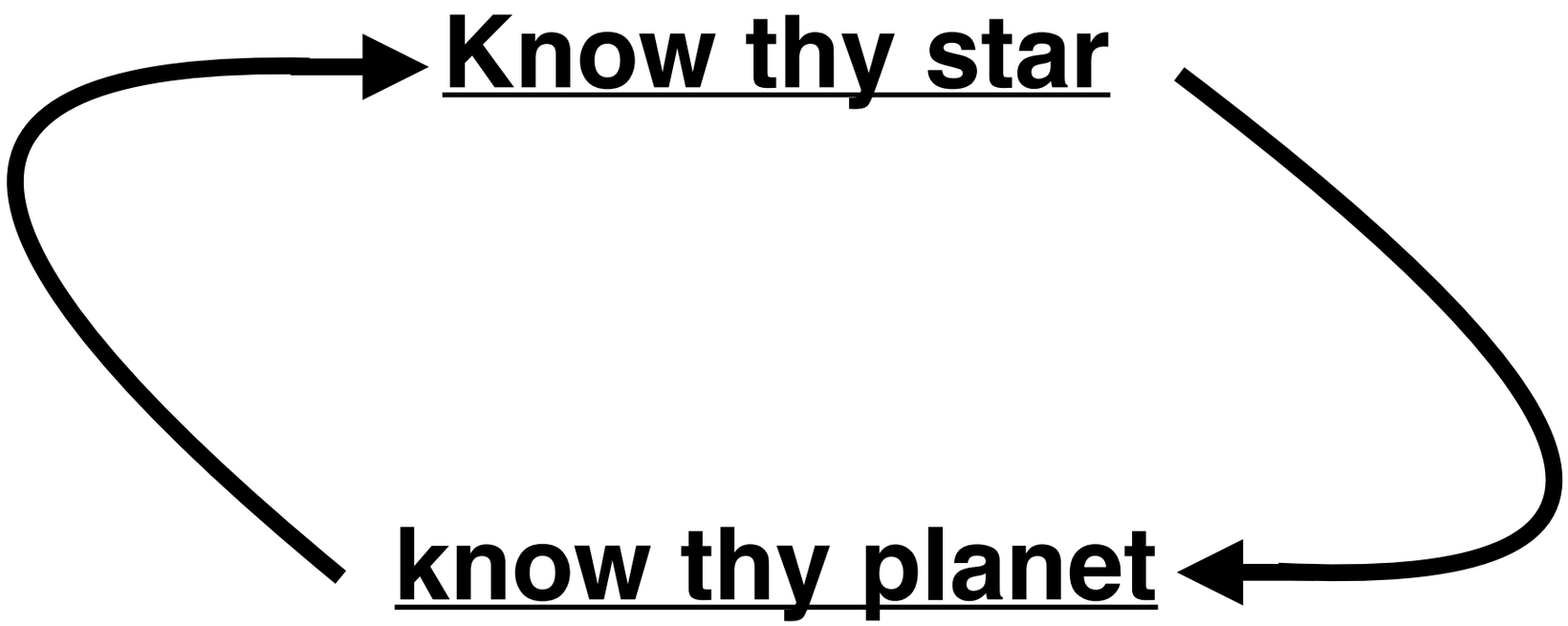
- …but exoplanet observations feed the other way

H. M. Cegla

Summary…

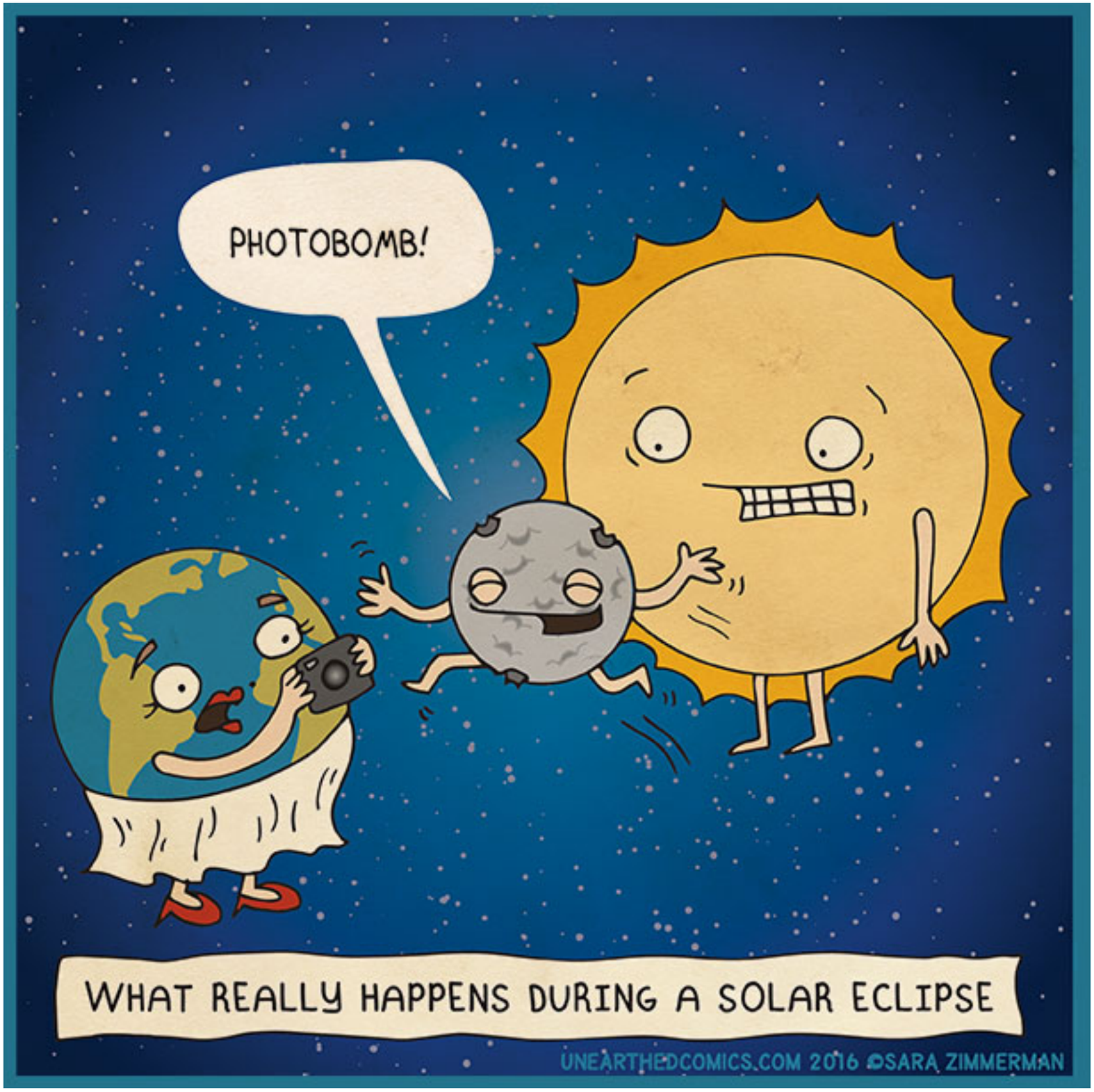


- Stellar properties impact planet properties
  - Stellar surface phenomena alter RVs and LCs
    - Impacts planet detection/confirmation/characterisation
    - Need to diagnose stellar noise and disentangle
  - Stars can alter close-in planets and vice versa

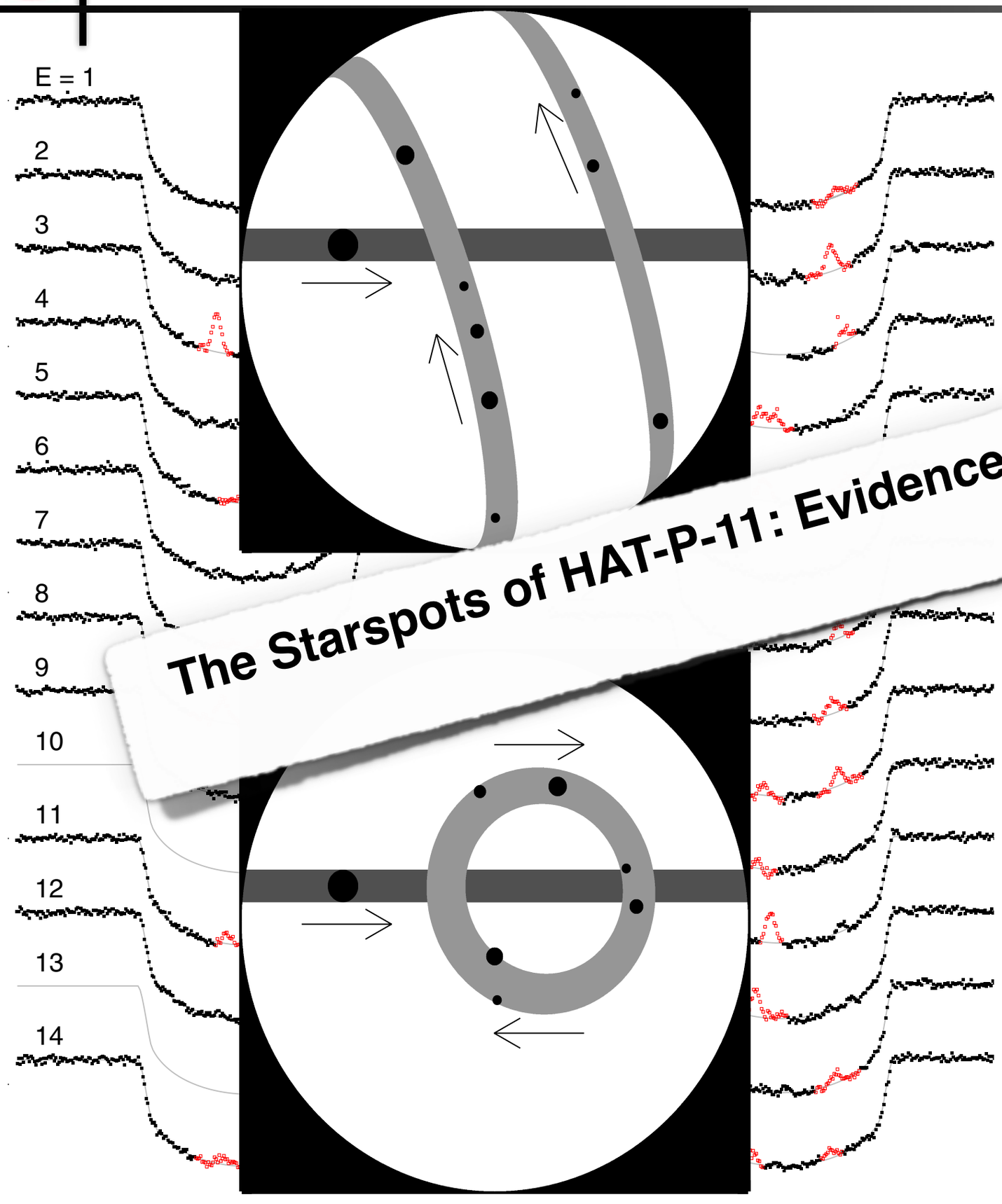


H. M. Cegla

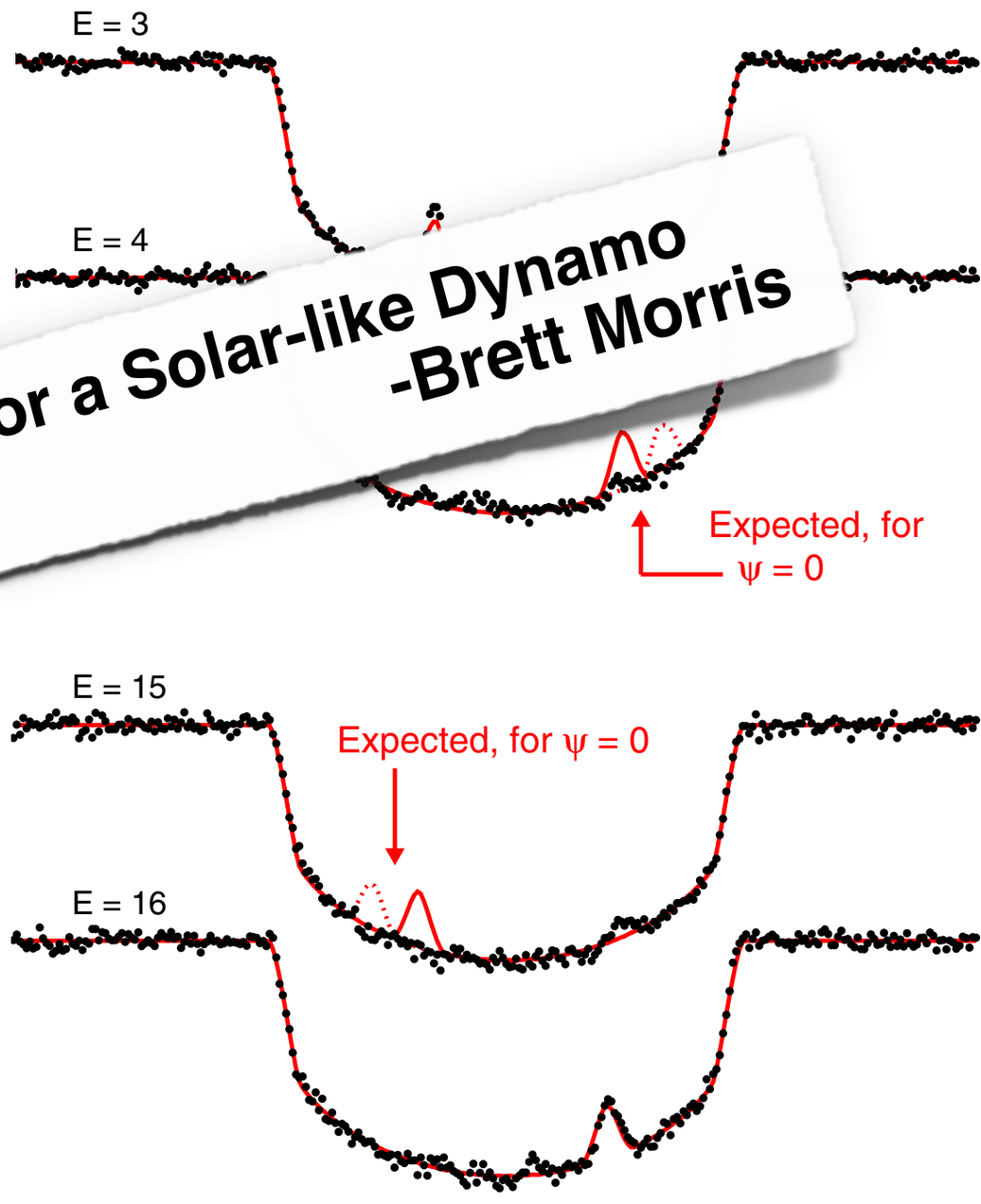
Planets as Probes of Stellar Parameters



Planets as Probes: HAT-P-11



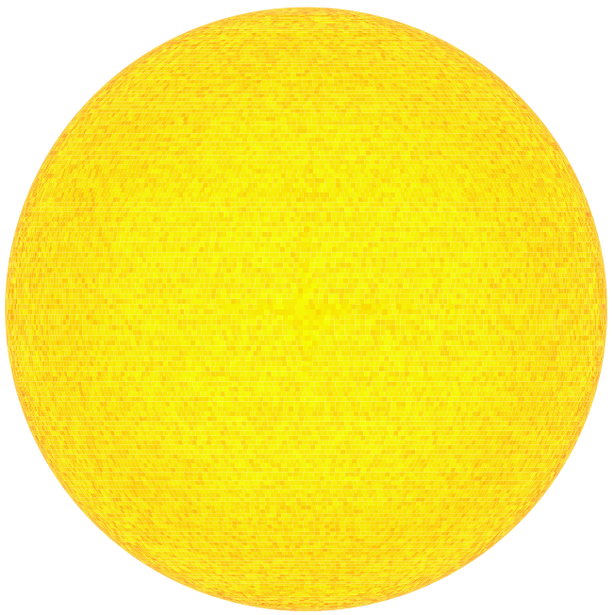
The Starspots of HAT-P-11: Evidence for a Solar-like Dynamo
-Brett Morris



Sanchis-Ojeda, R., & Winn, J. N. 2011, ApJ, 743, 61

The Rossiter-McLaughlin effect

RELOADED



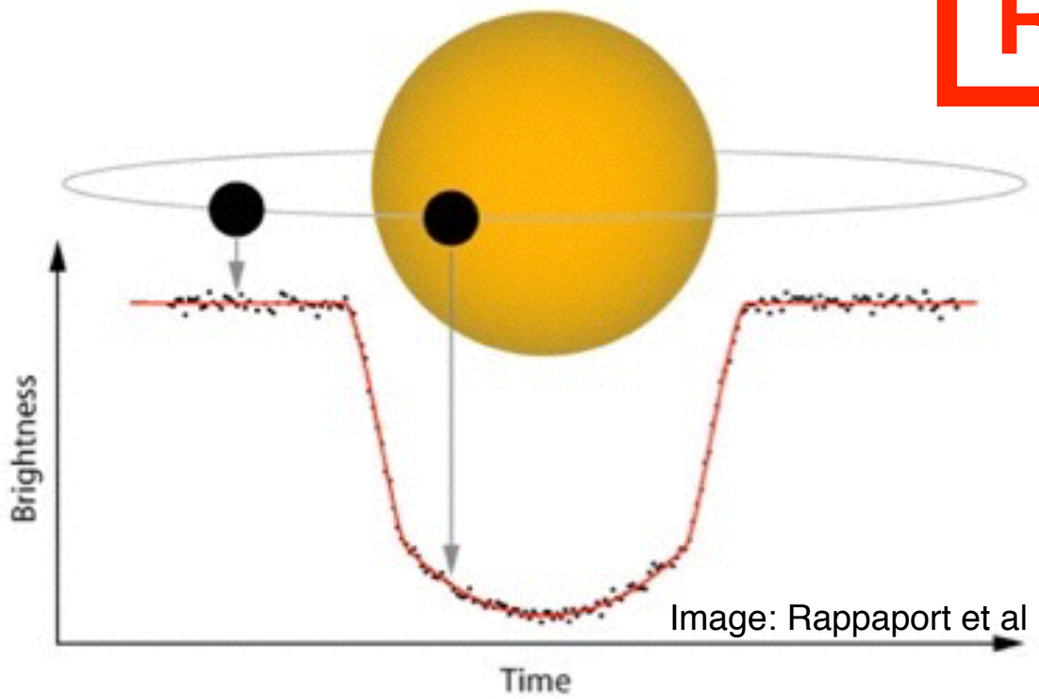
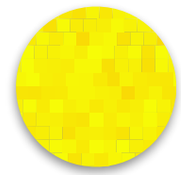
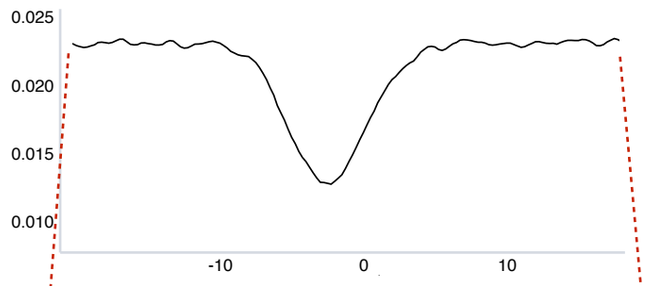
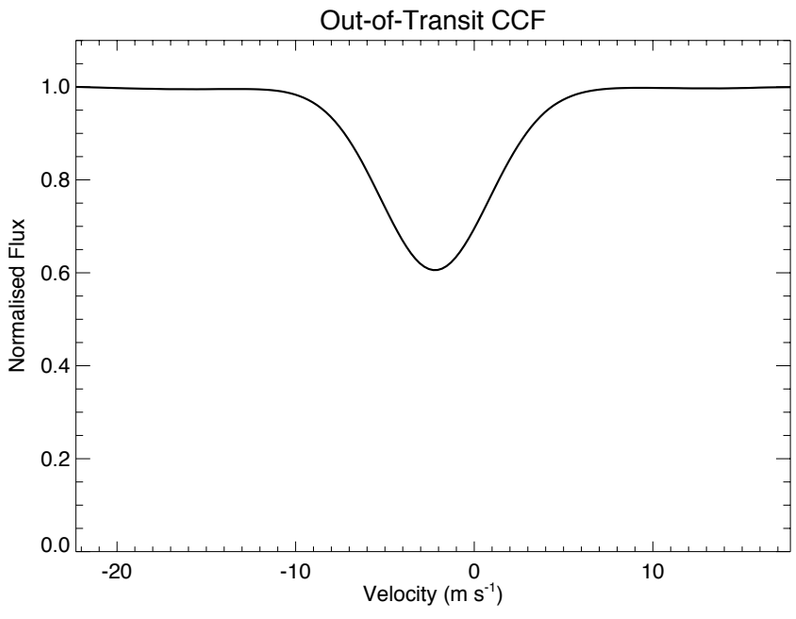
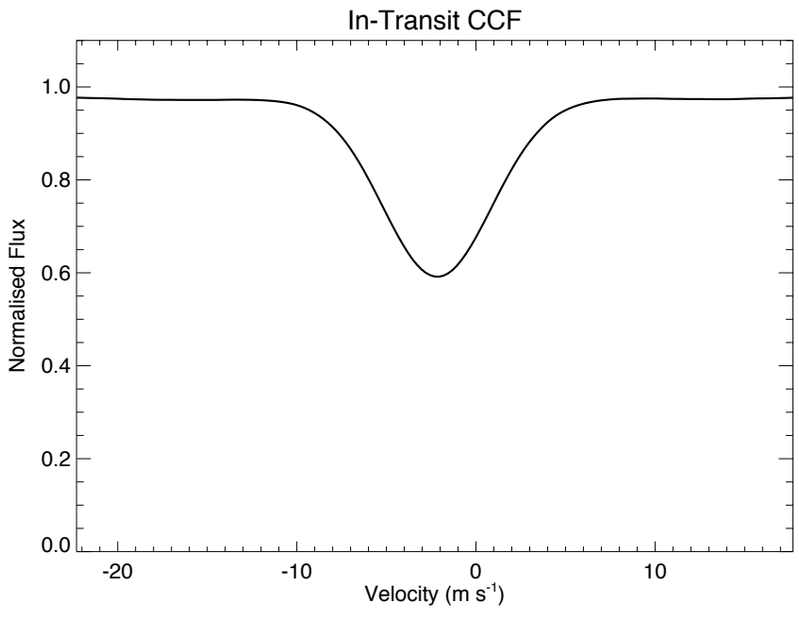


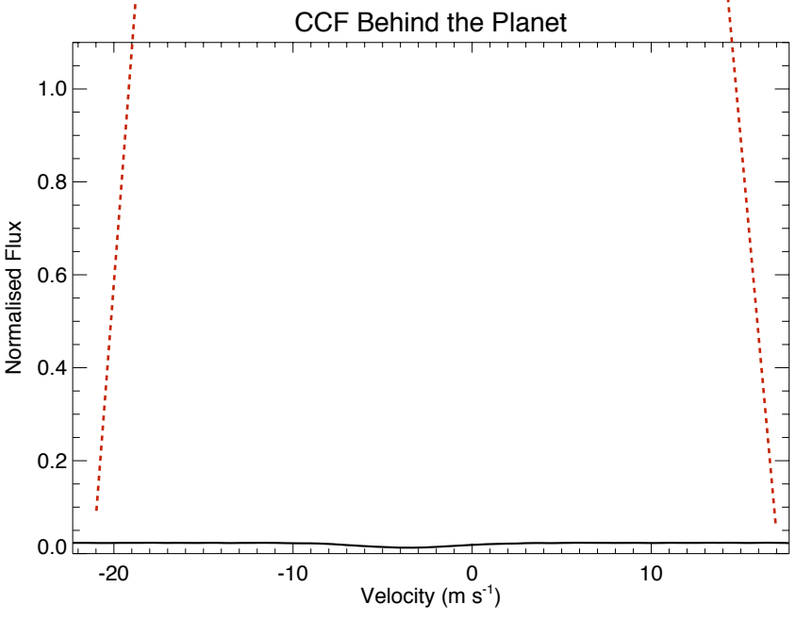
Image: Rappaport et al





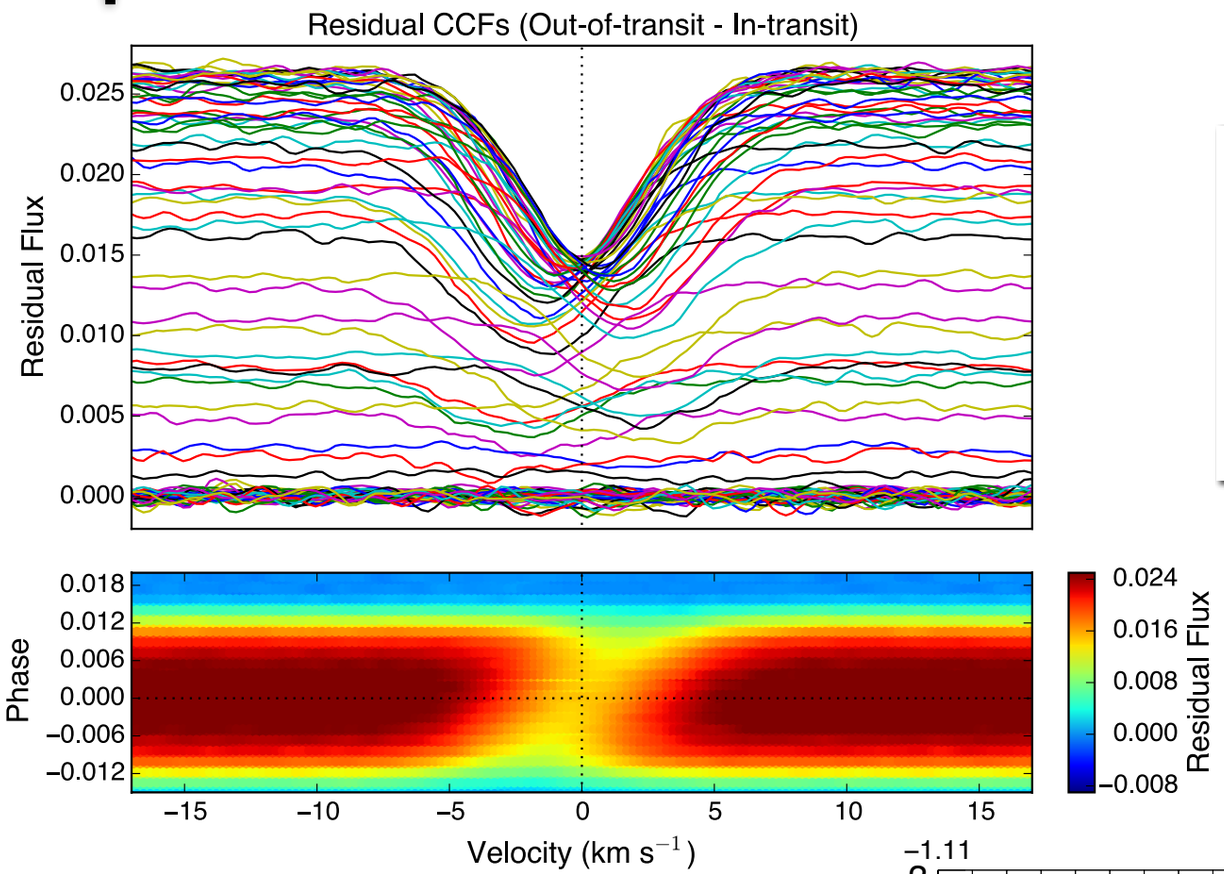


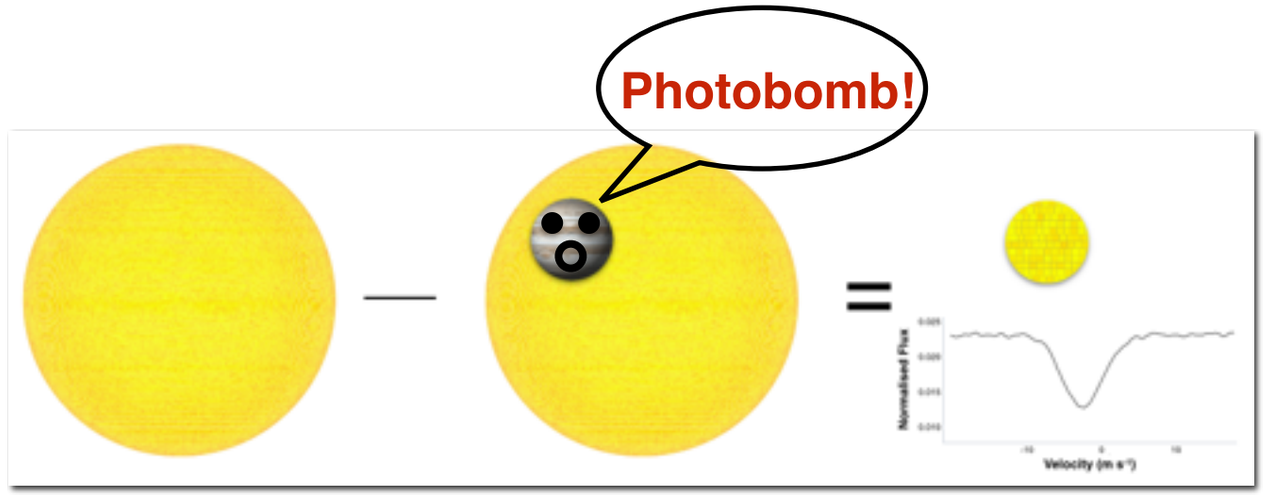




Cegla, H. M., Lovis, C., Bourrier, V., Beeck, B., Watson, C. A, Pepe, F. **2016b**, A&A, 588, A127

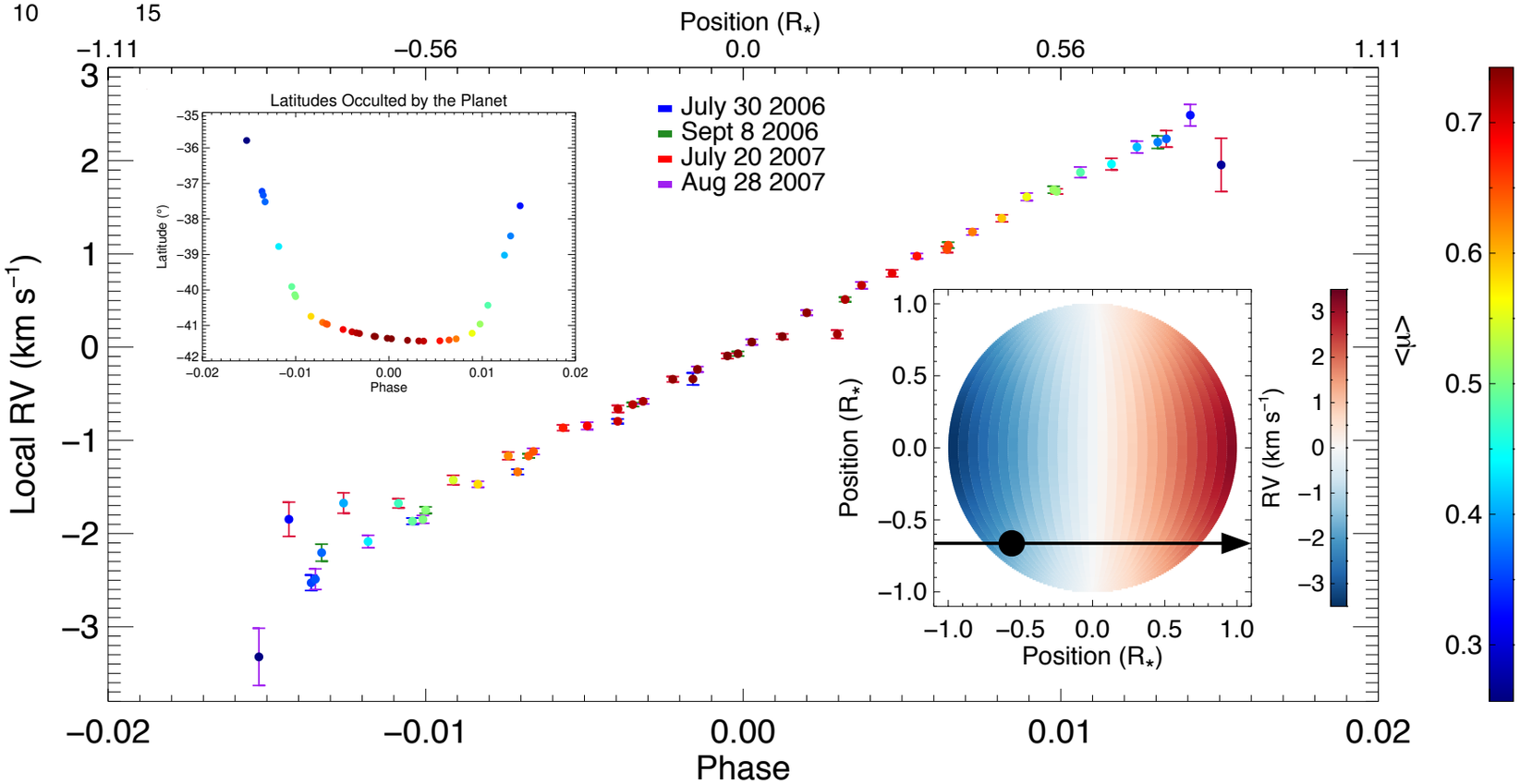
Planets as Probes: HD 189733



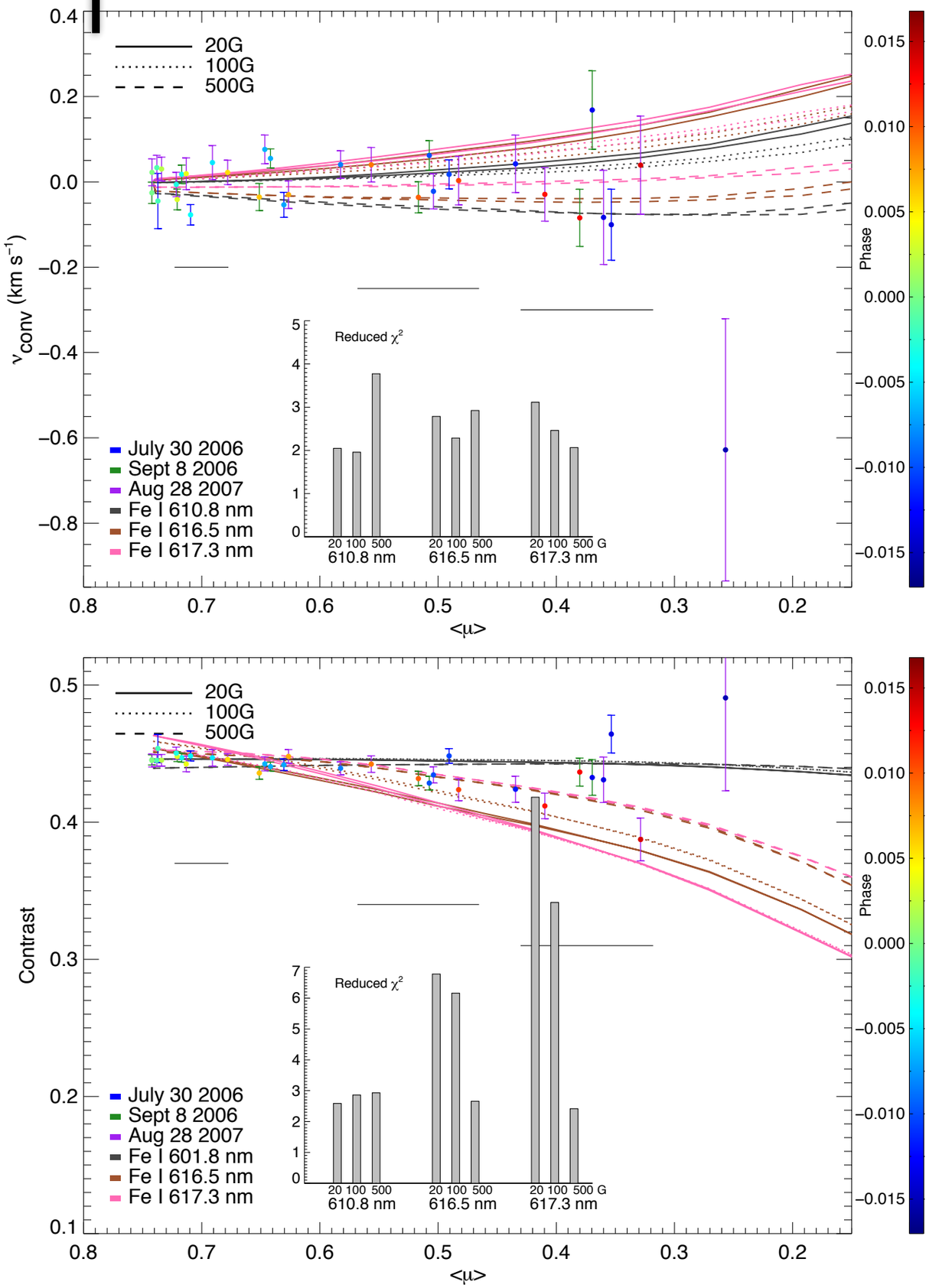


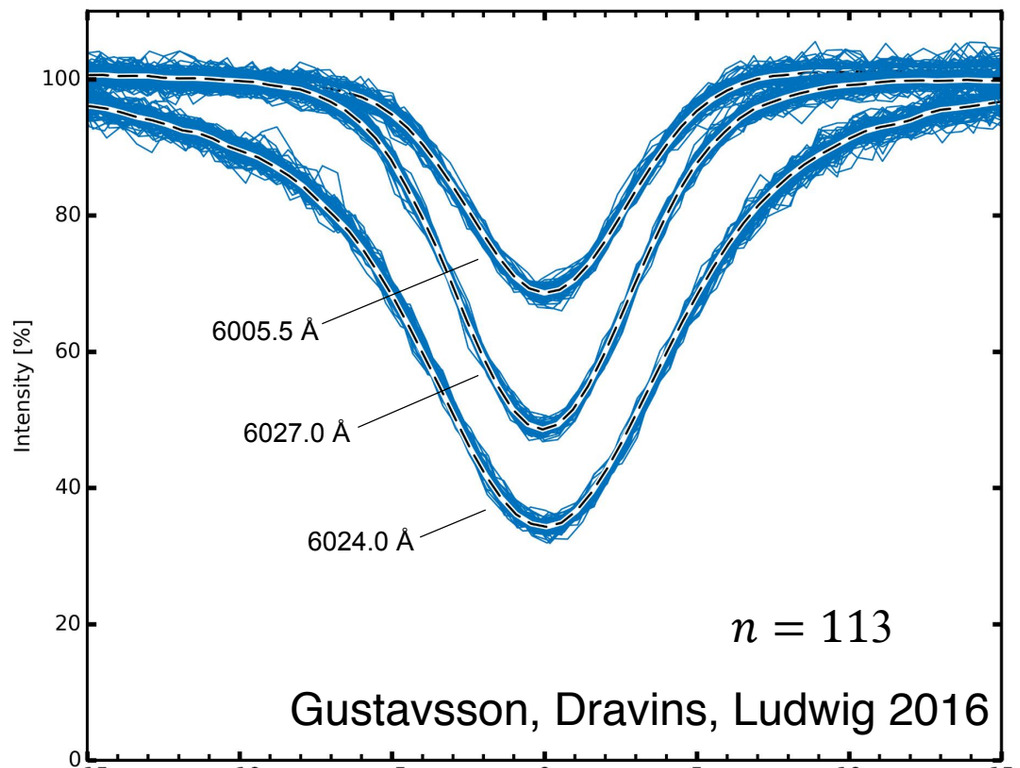
Cegla, H. M., et al. **2016b**, A&A

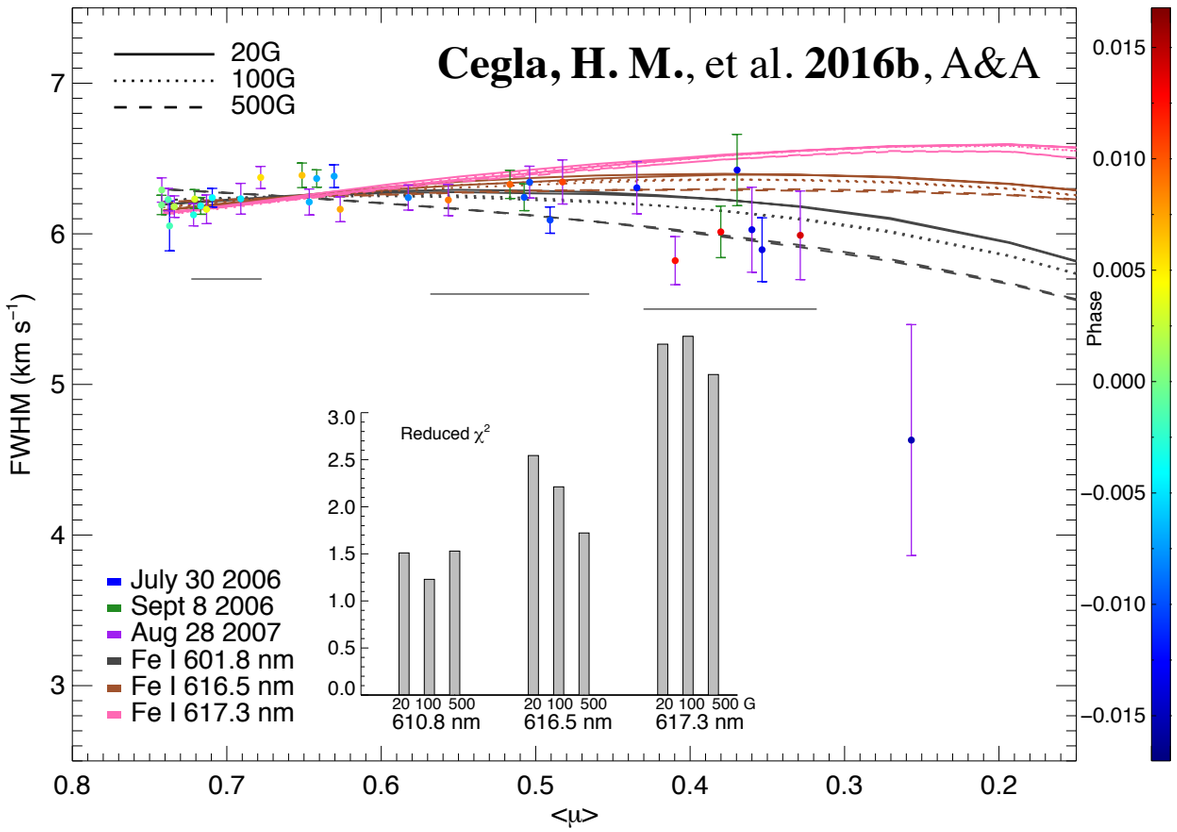
- $v_{eq} \approx 4.5^{+0.5}_{-0.4}$ km s^{-1}
- α : 0.3-0.9; > 0.1
- $i_{\star} \approx 92^{+12}_{-14}$ °
- $\lambda \approx -0.4 \pm 0.2$°
- $\psi \approx 7^{+12}_{-4}$ °



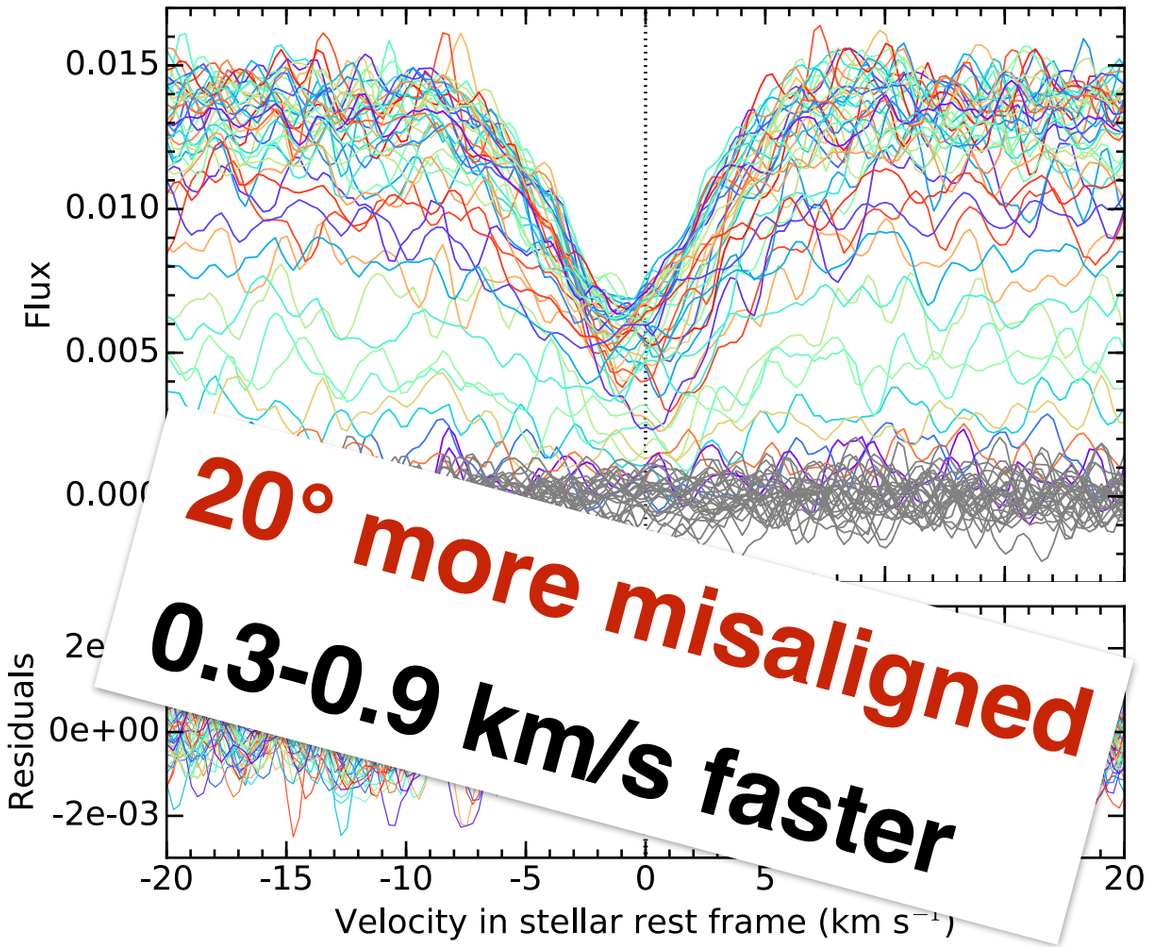
Planets as Probes: HD 189733

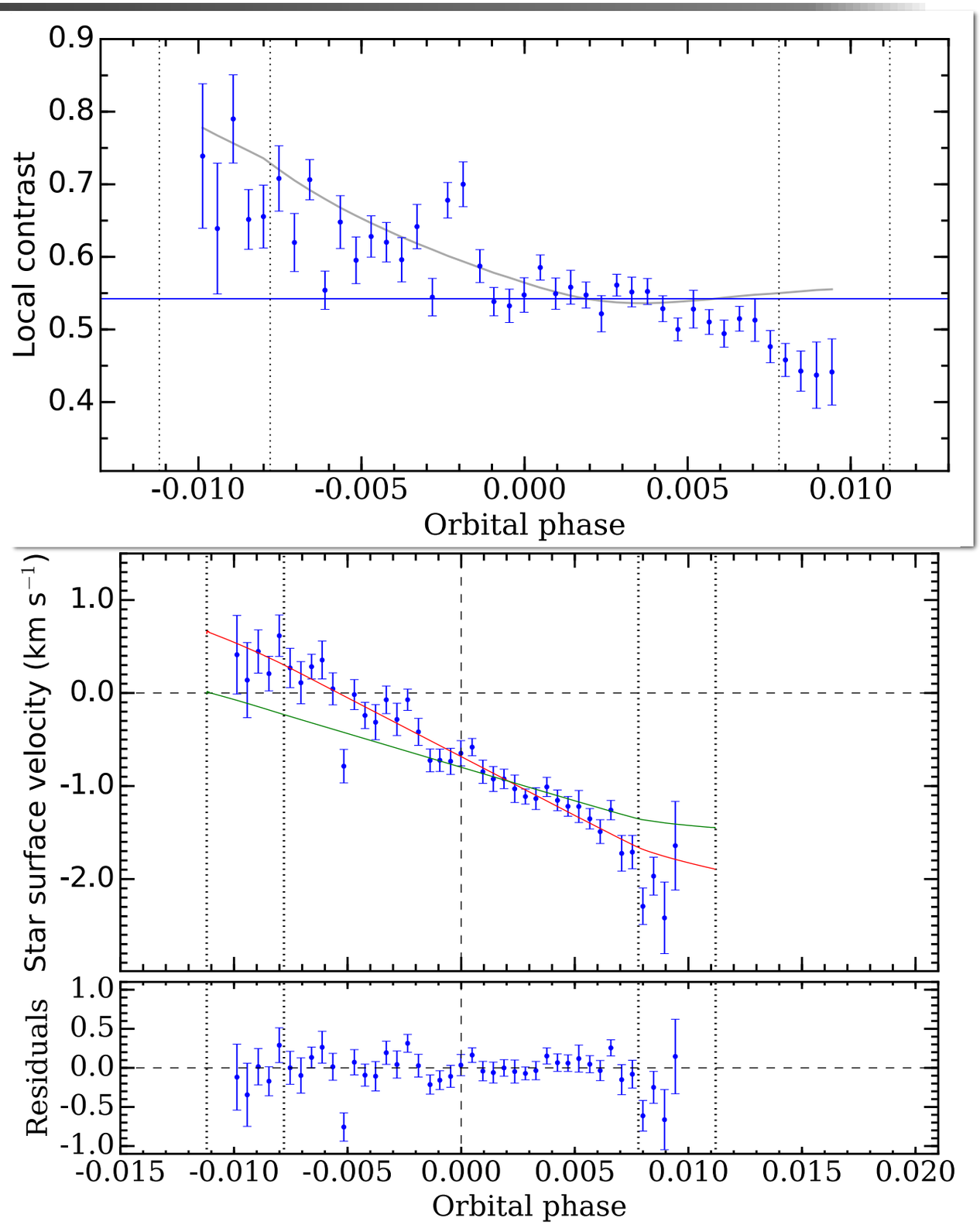






‘Reloaded RM’: Wasp-8



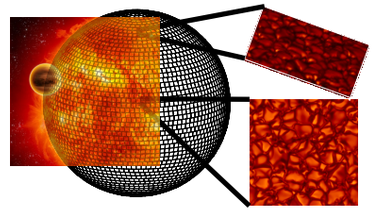


$\lambda \approx -143 \pm 2^{\circ}$ and

$v\sin i \approx 1.90 \pm 0.05$ km/s

Bourrier, V., **Cegla, H. M.**, Lovis, C., Wyttenbach, A. **2017**, A&A, 599, A33

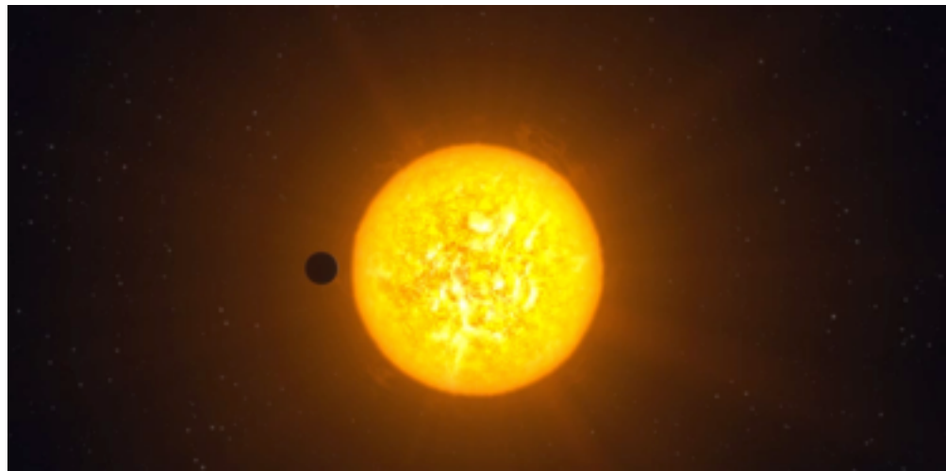
Summary



- Stellar properties impact planet properties
  - Stellar surface phenomena alter RVs and LCs
    - Impacts planet detection/confirmation/characterisation
    - Need to diagnose stellar noise and disentangle
  - Stars can alter close-in planets and vice versa

<u>Know thy star, know thy planet</u>

- …but exoplanet observations feed the other way
  - Use planets as probes of stellar astrophysics
  - Study planetary evolution/dynamics



H. M. Cegla