

Understanding exoplanet atmospheres with numerical models

Thomas Konings ...on behalf of all team members of Prof. Leen Decin

PhD student KU Leuven

ESO Belgian day 08/12/2022

Planetarium of the Royal Observatory of Belgium



KU LEUVEN



European Research Council
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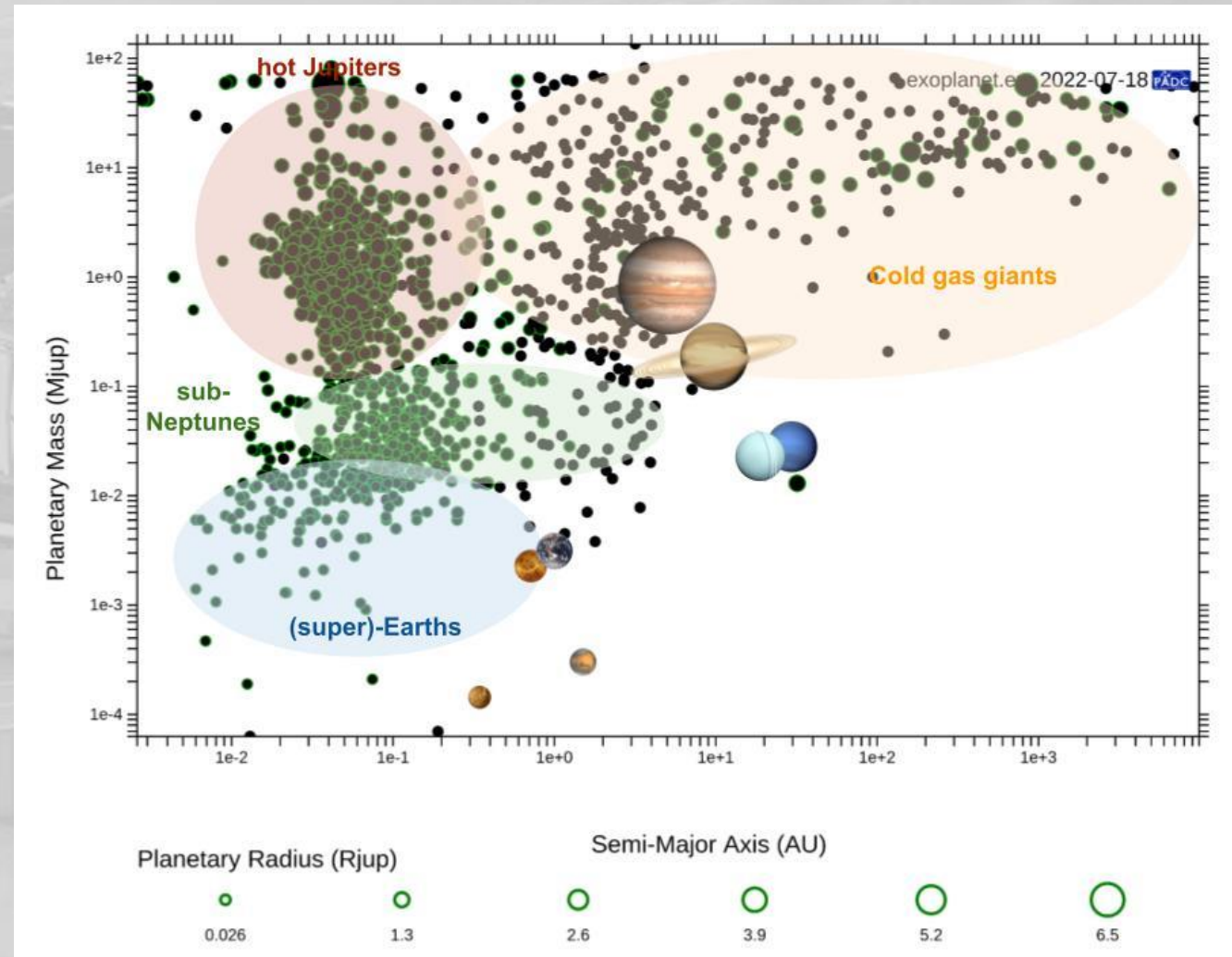


MARIE CURIE ACTIONS



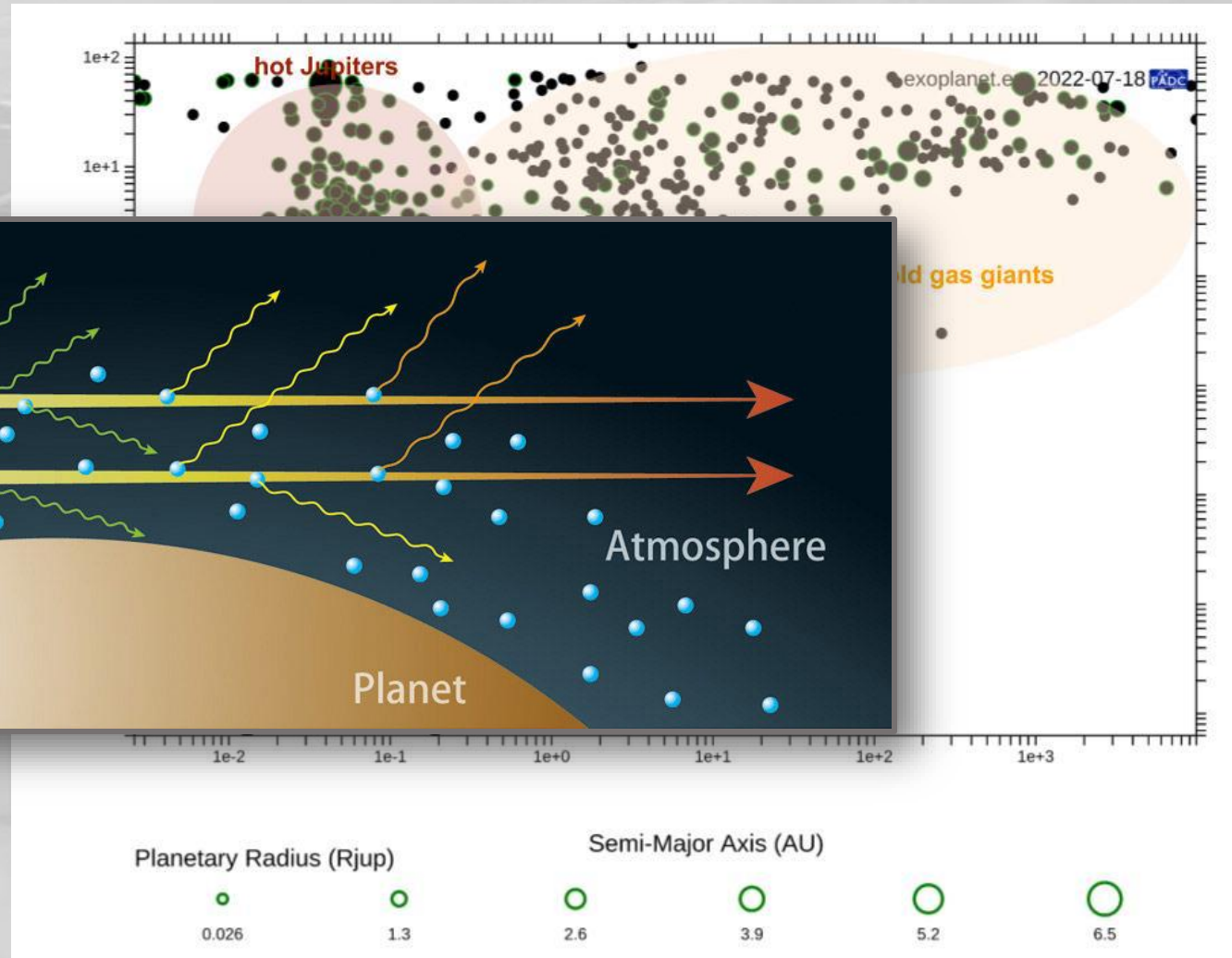
Exoplanet demographics

- Zoo of 5200+ exoplanets
 - Hot Jupiters, Super-Earths, Cold gas giants, Lava worlds, ...
- Observed sample not representative for population
 - ~1% Hot Jupiters
 - ~5-10% gas giants
 - ~50% have Super-Earths
- ESO's RV planet hunters: HARPS, ESPRESSO, CORALIE, ...



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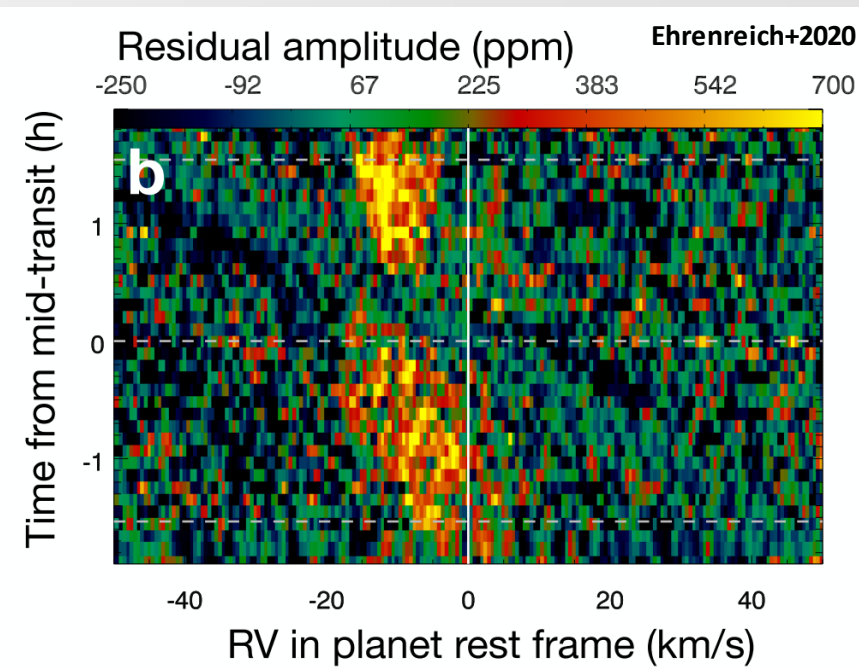
- Observed
- represented

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- ESO's RV planet hunters: HARPS, ESPRESSO, CORALIE, ...

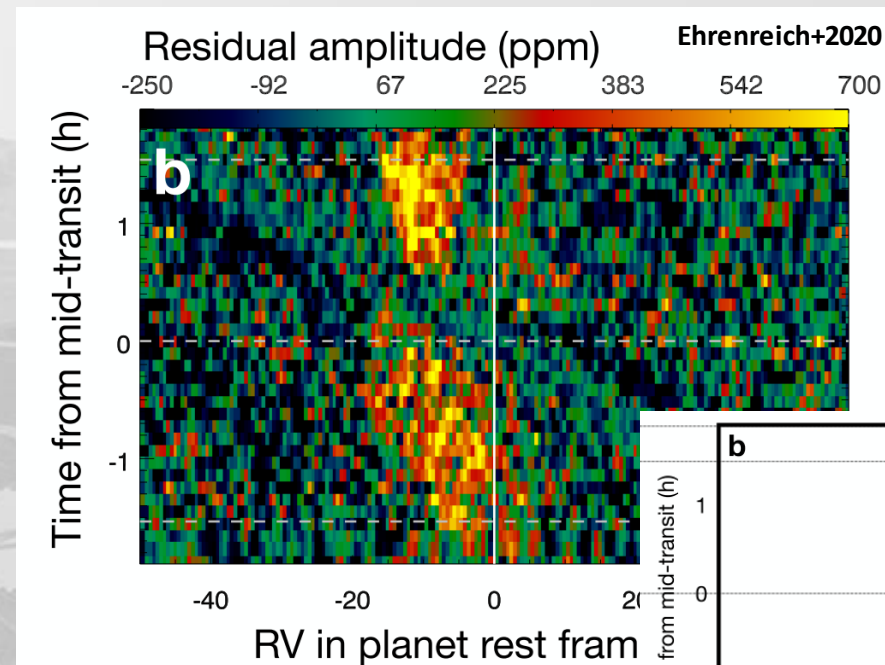
Milestones with ESO: WASP-76b (Ehrenreich et al., 2020)

- ESPRESSO spectrograph on VLT
- (mostly) blue-shifted ($RV < 0$) Fe absorption
 - Indication of atmospheric winds



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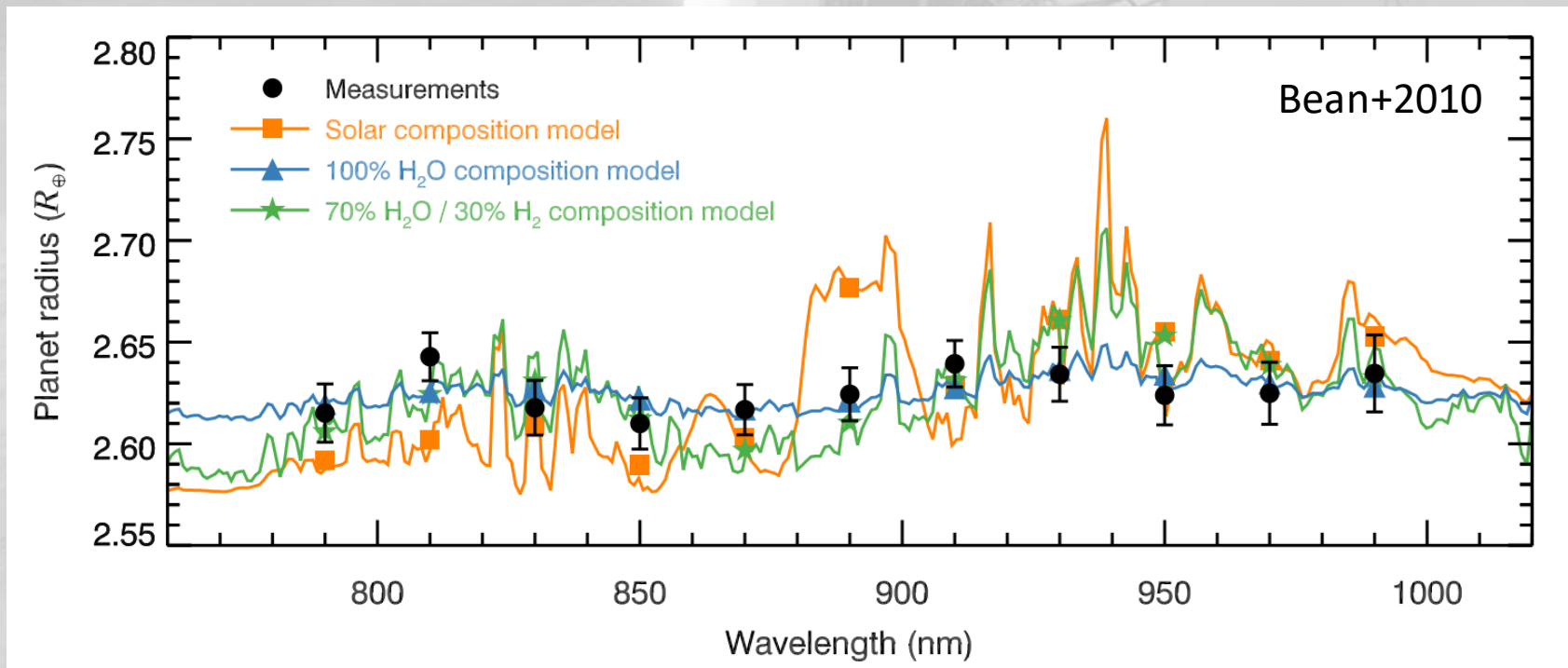
Model of Ehrenreich et al., 2020

1. Neutral iron is vaporized on dayside ($\sim 2700\text{K}$)
2. Atmospheric winds advect dayside to nightside
3. Neutral iron condenses on nightside ($\sim 1800\text{K}$)

Milestones with ESO:

GJ 1214b* (Bean et al., 2010)

- FORS2 spectrograph on VLT
- Observations of a... flat line (• Measurements)

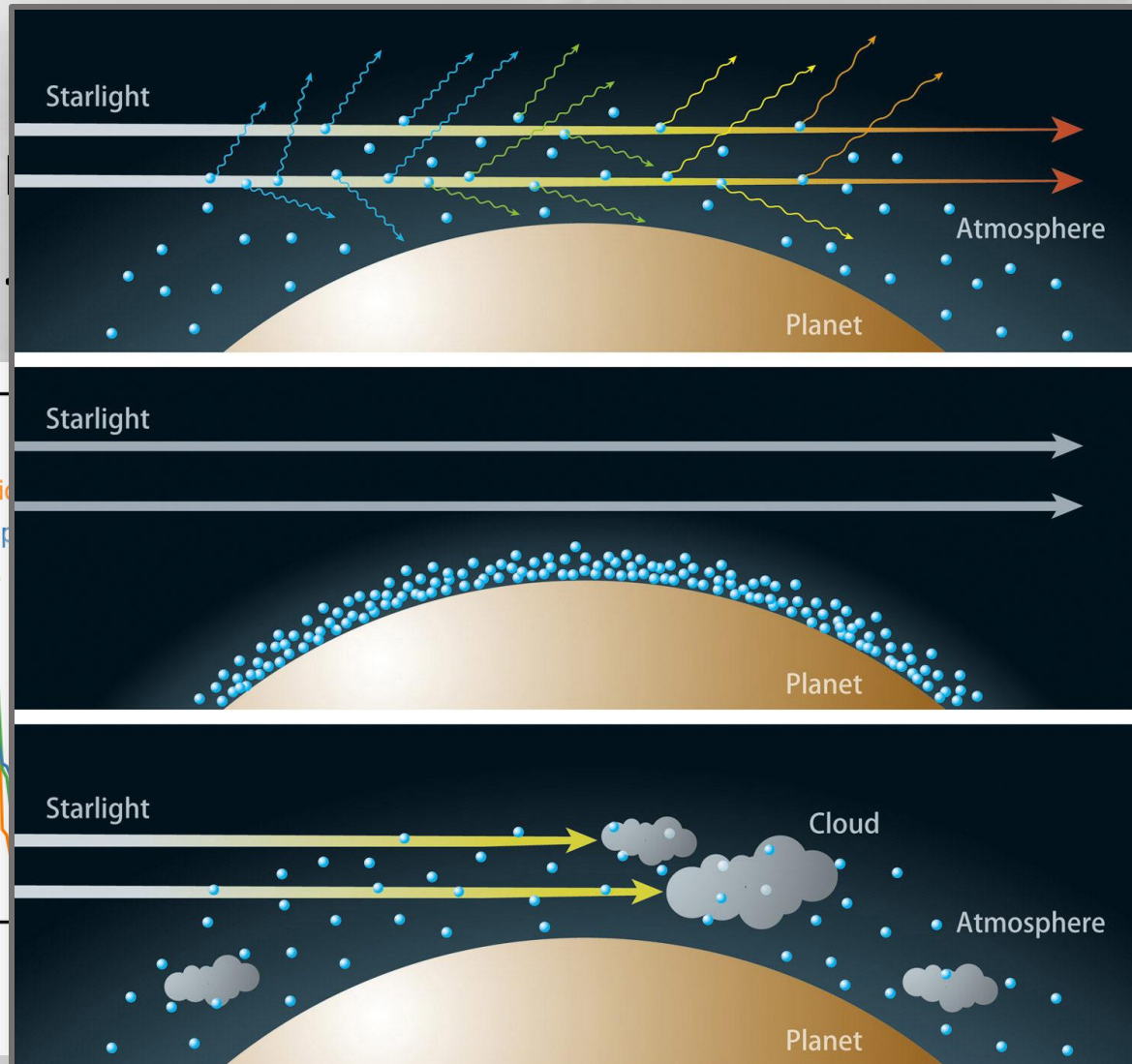
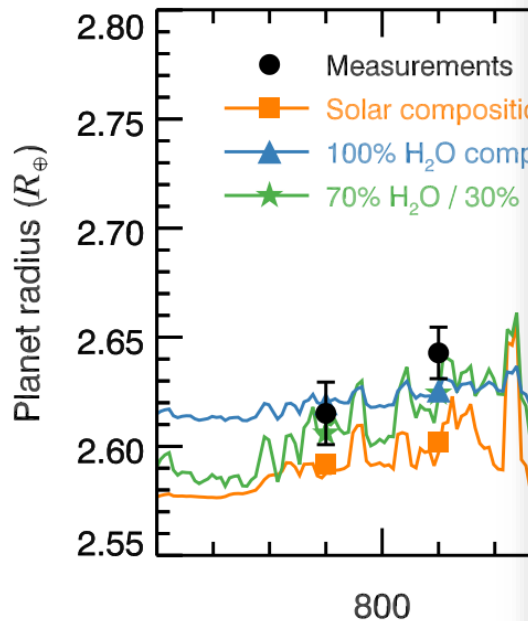


* The detection of this planet was confirmed by HARPS on the ESO 3.6 m telescope at La Silla, Chile.

Milestones with ESO:

GJ 1214b*

- FORS2 spectrograph
- Observations of a



Possible scenarios

1. Extended **hydrogen** atmosphere
2. **Heavy elements** that compress the atmosphere
3. High-altitude **cloud/haze** layer obscuring the view

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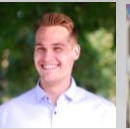
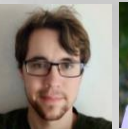
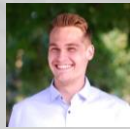
Work done at the Institute of Astronomy

in the research group of Prof. Leen Decin

Modelling a planetary atmosphere



- Star-planet interactions
- Climate/circulation
- Cloud formation
- Planetary mass loss
- Chemistry
- ...



*

Improve
theory/models

Observations

Match with
theory/models

Data analysis*
(retrieval)

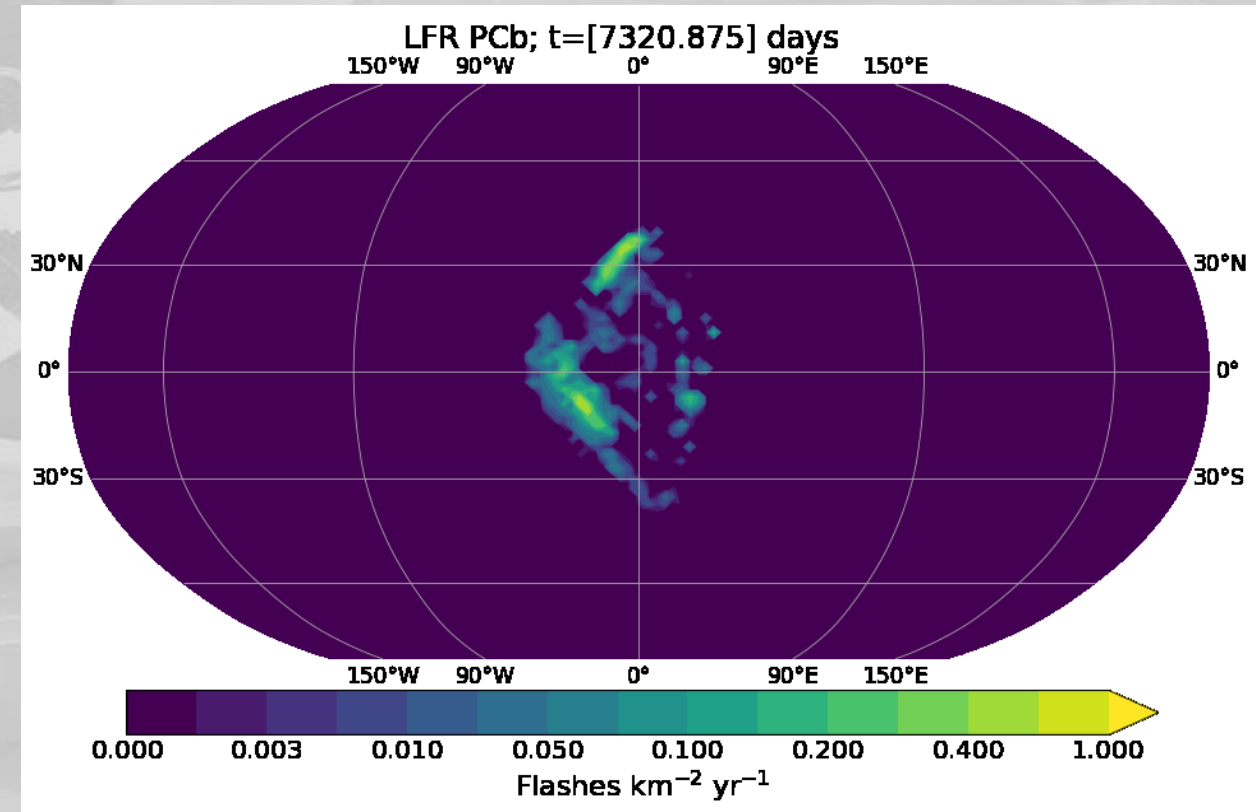
Chemistry in Earth-like planet atmospheres

Marrick Braam

Braam et al., 2022 MNRAS, 517(2), 2383–2402



- Tidally-locked planets have a permanent irradiated day-side
- Convective instabilities form clouds and thunderstorms (inc. lightning!)
- Intense lightning leads to perturbations of the atmospheric chemistry



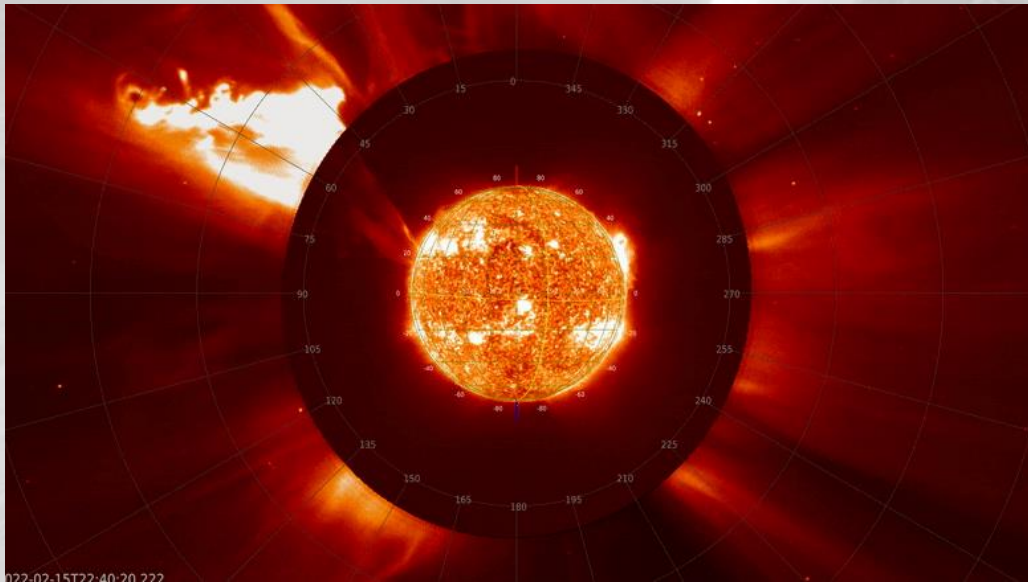
Hot Jupiters: Impact of stellar flares

Thomas Konings

Konings et al., 2022 A&A 667, A15



"Know thy star, know thy planet"



- Like the Sun, other planet-hosting stars can flare
- Orbiting planets are affected by these sudden **energetic flashes** of radiation



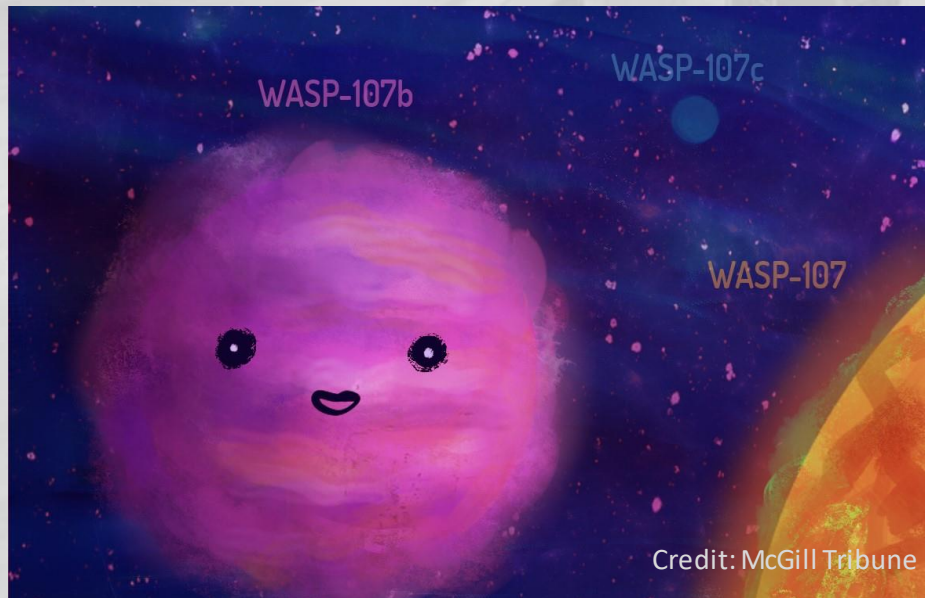
"... repeated flaring can **permanently** alter the chemical composition of the atmosphere."

James Webb Space Telescope (JWST)

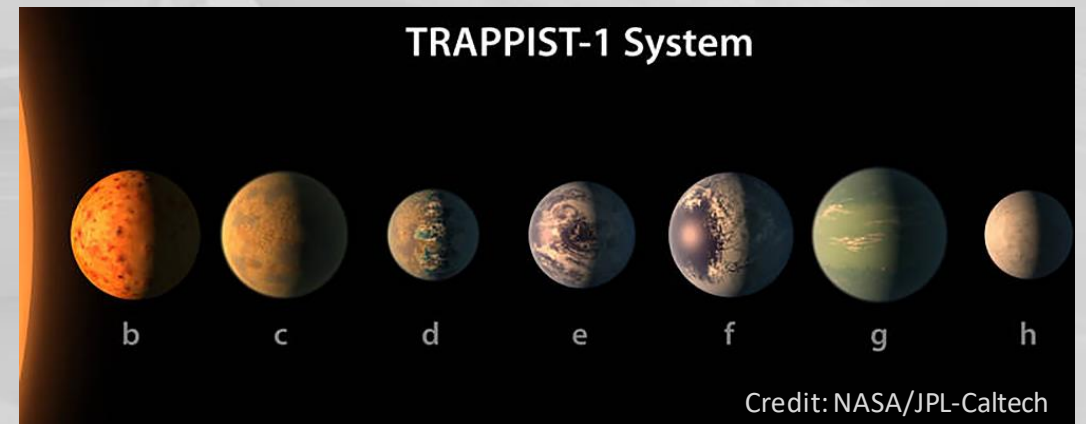
Linus Heinke, associate member of MIRI Exoplanet GTO



- Data reduction & retrieval analysis
- Transit of WASP-107b scheduled for January 19th, 2023



- Thermal emission of TRAPPIST-1b
- Observations scheduled for October/November 2023

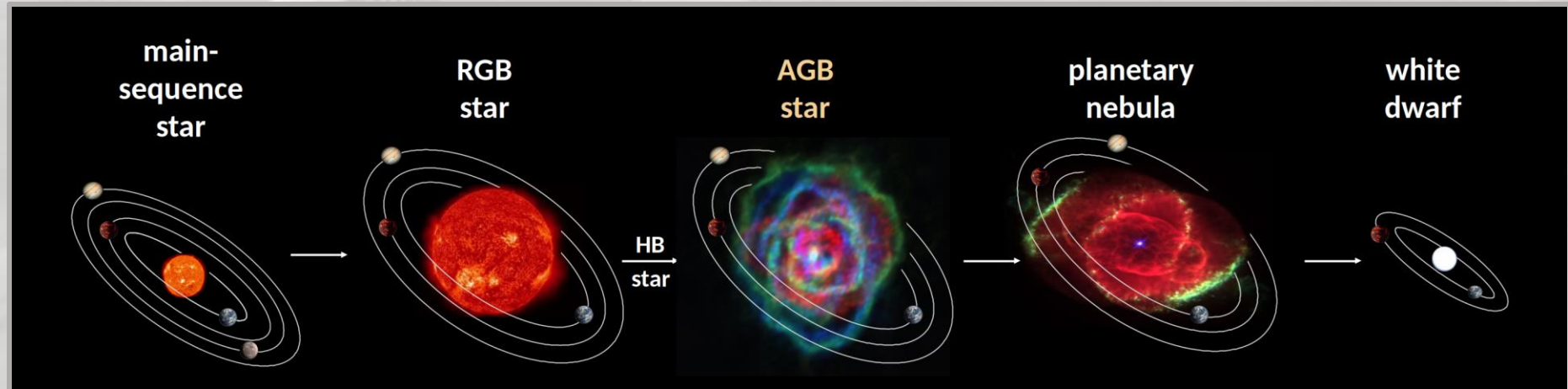


Planets around evolved stars

Mats Esseldeurs & Thomas Konings



Exoplanet demographics mainly around main-sequence stars

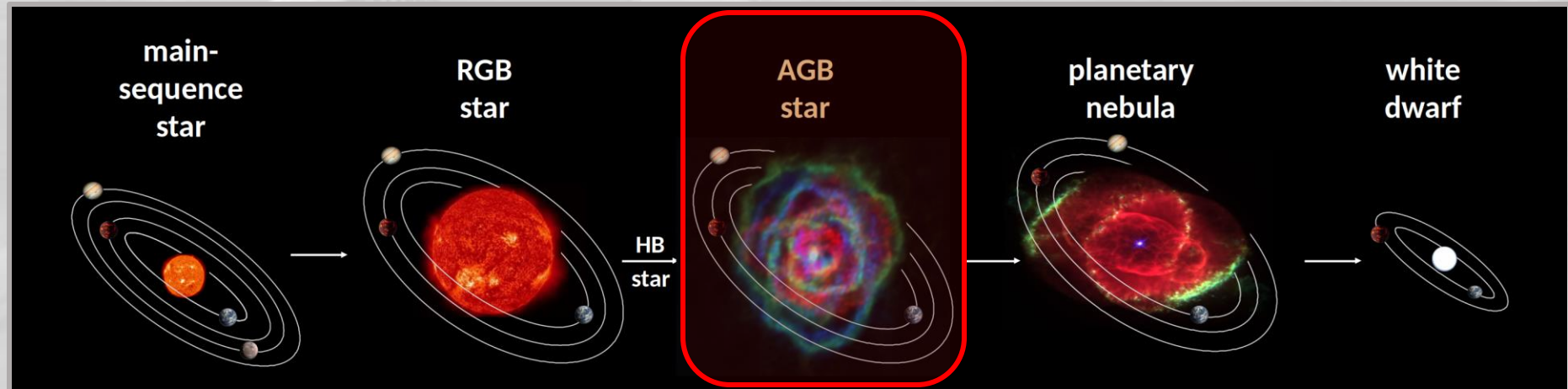


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AGB stars

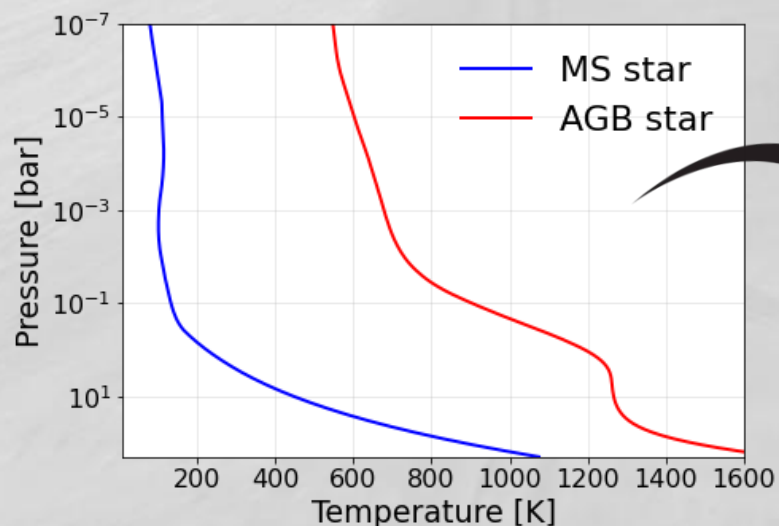
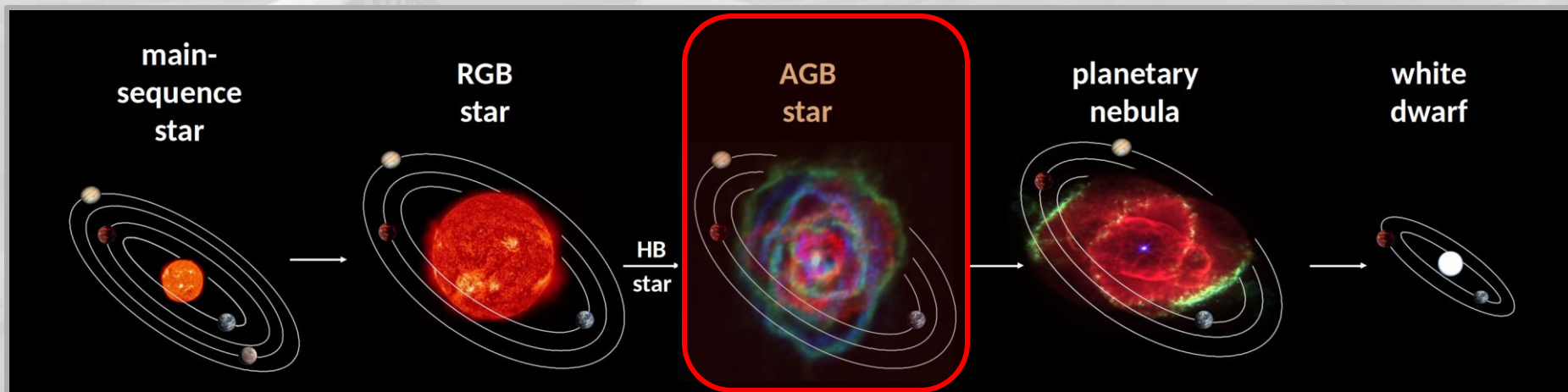
- Mass loss of $10^{-7} - 10^{-4} M_{\text{Sun}}/\text{yr}$
- Luminosity of $10^2 - 10^5 L_{\text{Sun}}$
- Duration of $10^5 - 10^7$ years

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Exoplanet demographics mainly around main-sequence stars



A gas giant at 5 AU will heat up to temperatures of a hot Jupiter around an AGB star

AGB stars

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Planets around evolved stars

Atacama Large Millimeter Array (ALMA)

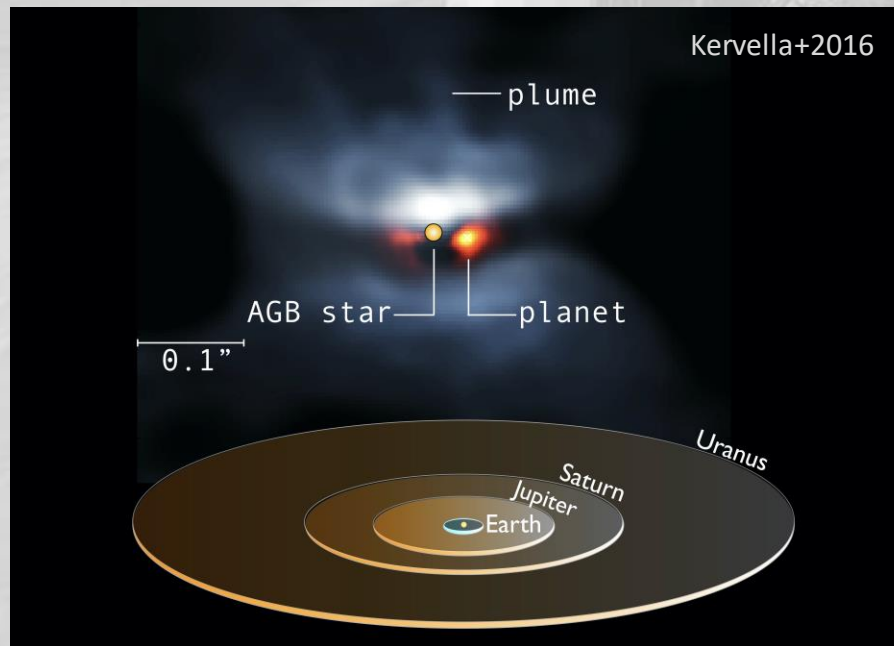


Talk of **Silke Maes**

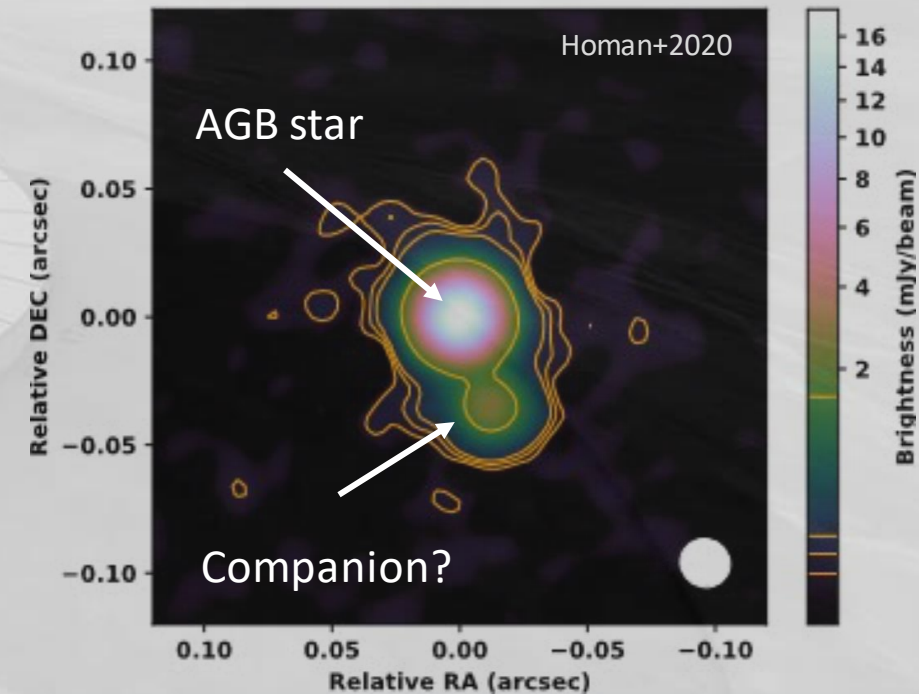
"Studying the complexities of stellar outflows"

- Asymmetries in outflows of evolved (AGB) stars
- Molecular emission (e.g. CO, SiO) blobs

L₂ Pup



π^1 Gru



The future of exoplanet science: METIS @ELT

- METIS (Mid-IR ELT Imager and Spectrograph)

- High-contrast direct imaging
- High-resolution spectroscopy

- Science

- Planetary demographics
- Atmospheric properties
- ...

METIS



Prof.
Denis
Defrère





Thank you!