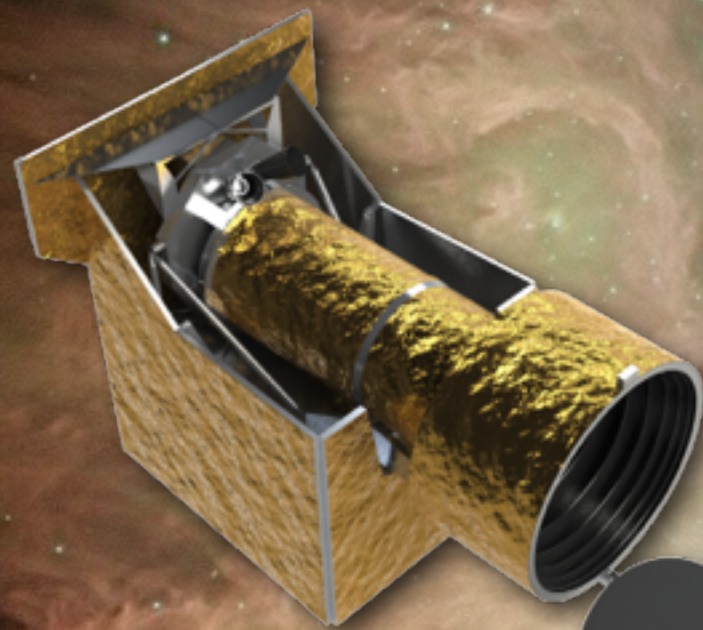


# CHEOPS

## CHARACTERIZING EXOPLANETS SATELLITE



**David Ehrenreich**  
CHEOPS Mission Scientist

 **esa's first small-class mission**



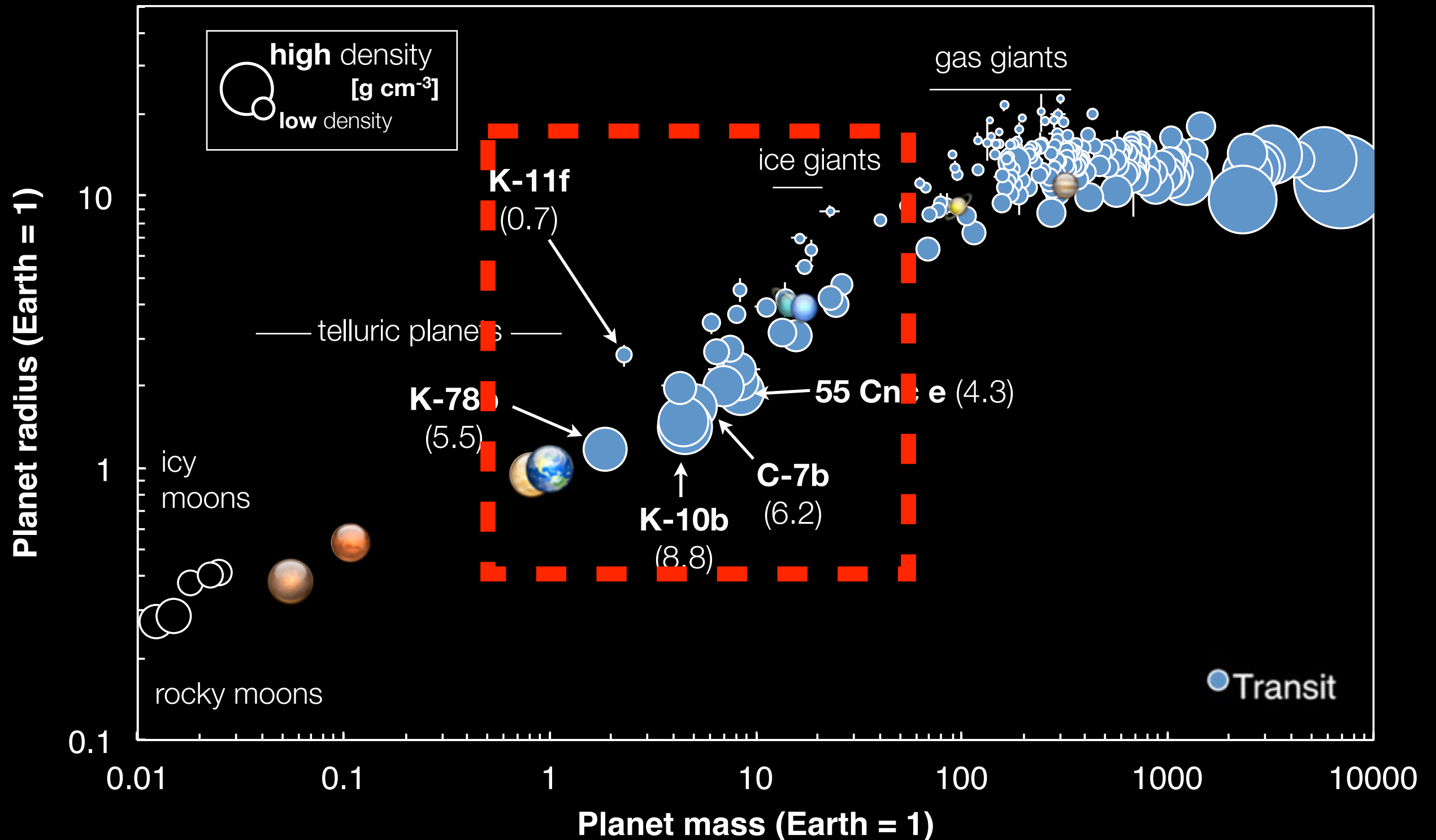
**UNIVERSITÉ  
DE GENÈVE**



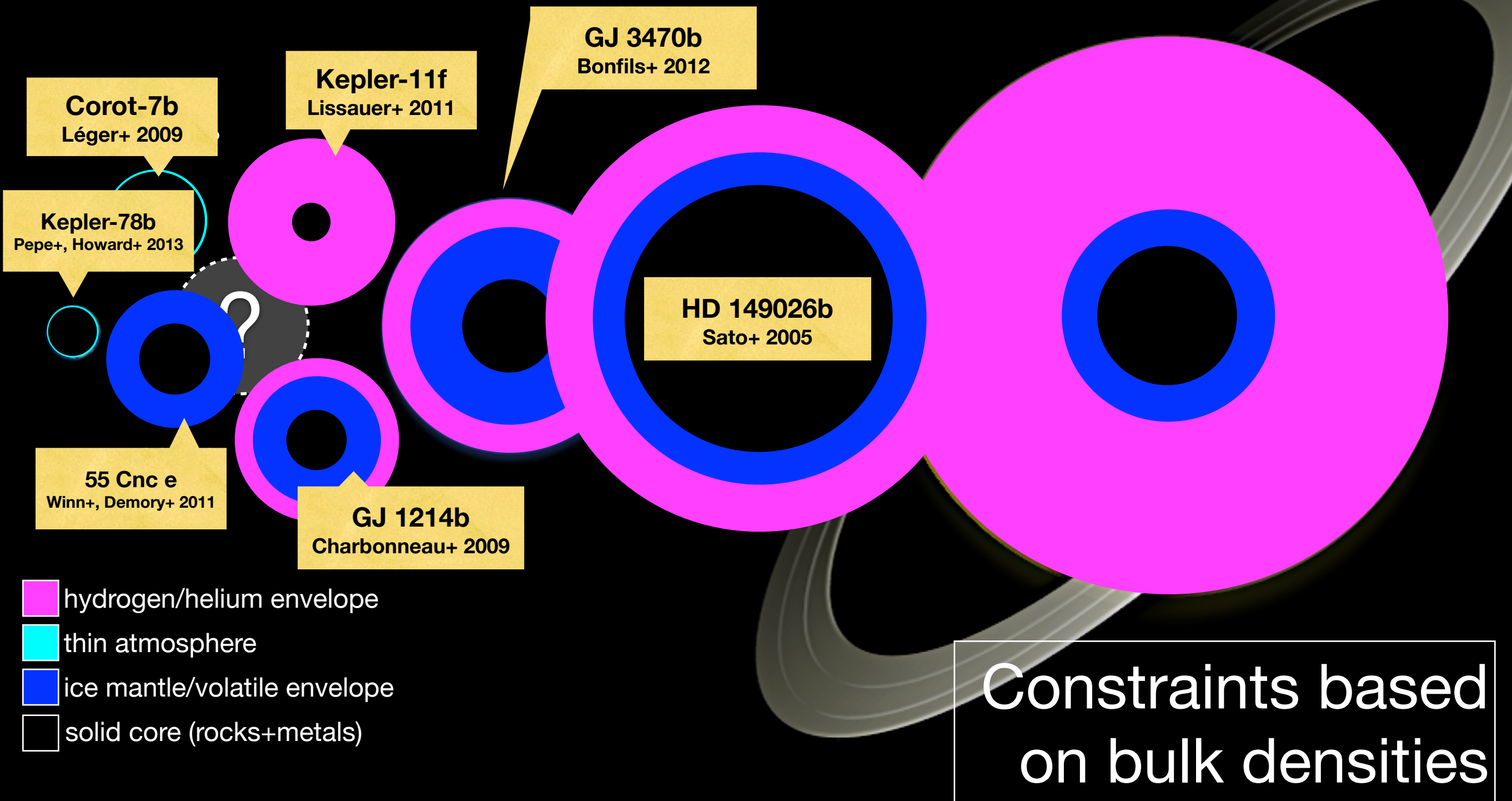


# Mass-radius diagram

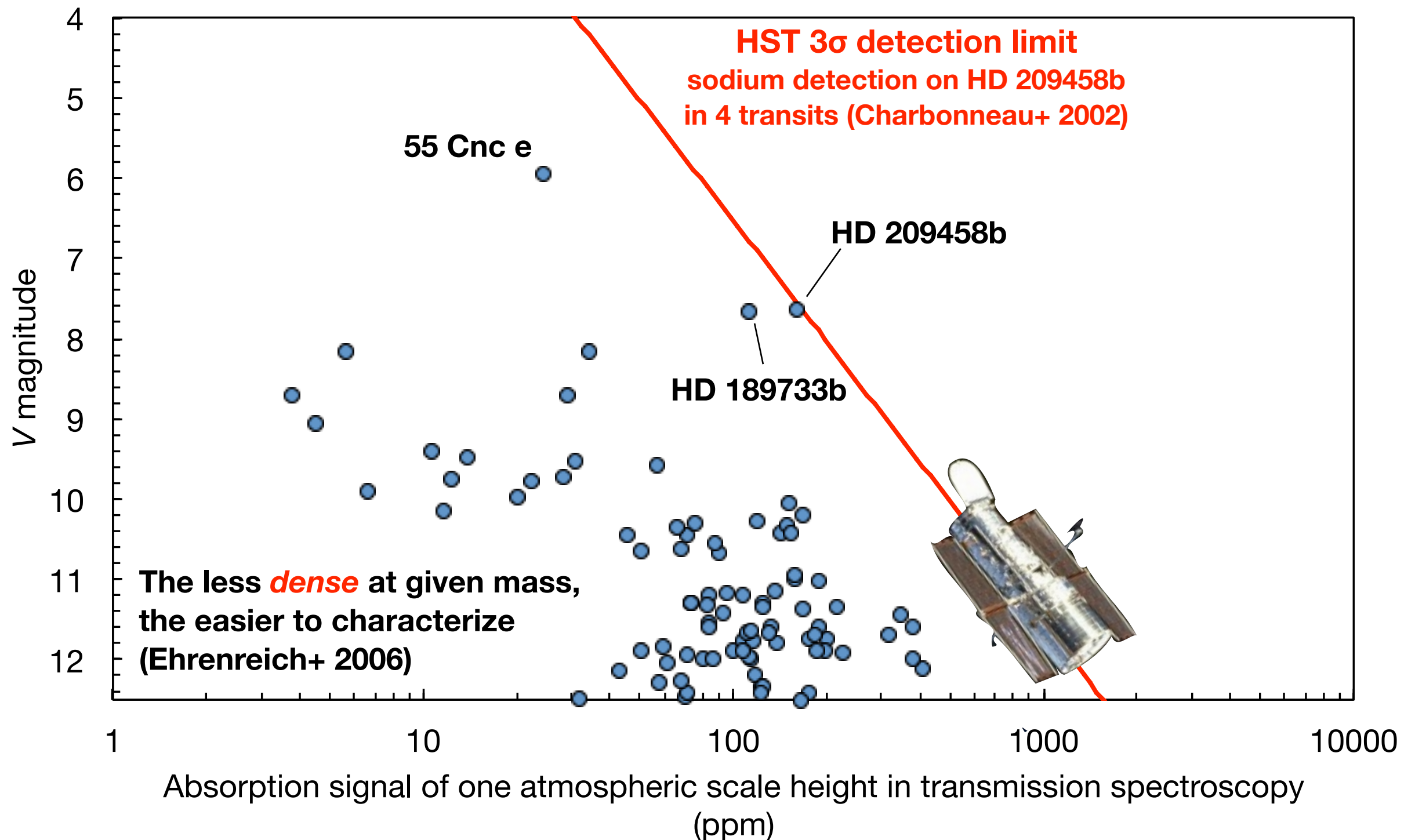
Apparent continuity of masses for exoplanets



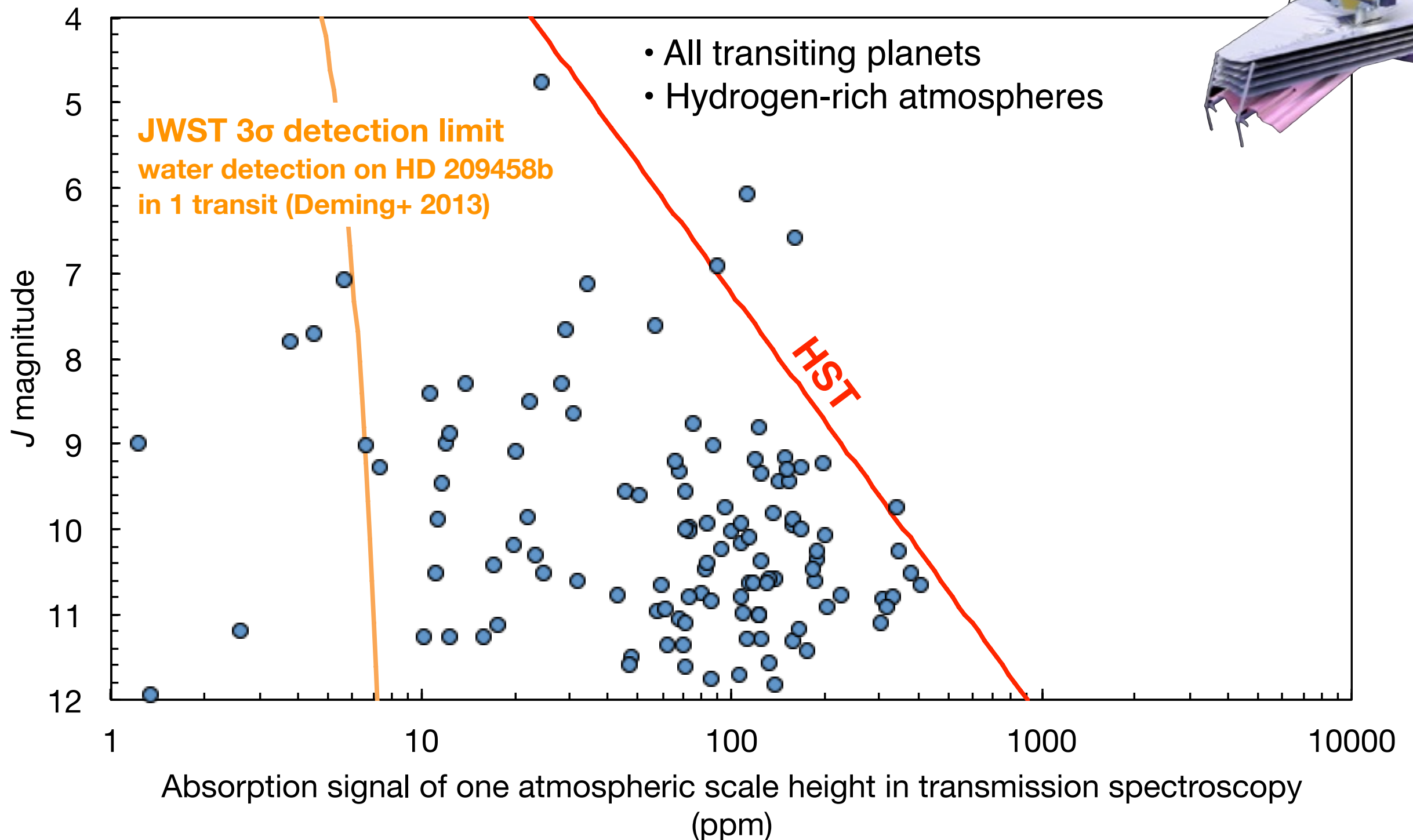
# What are exoplanets made of?



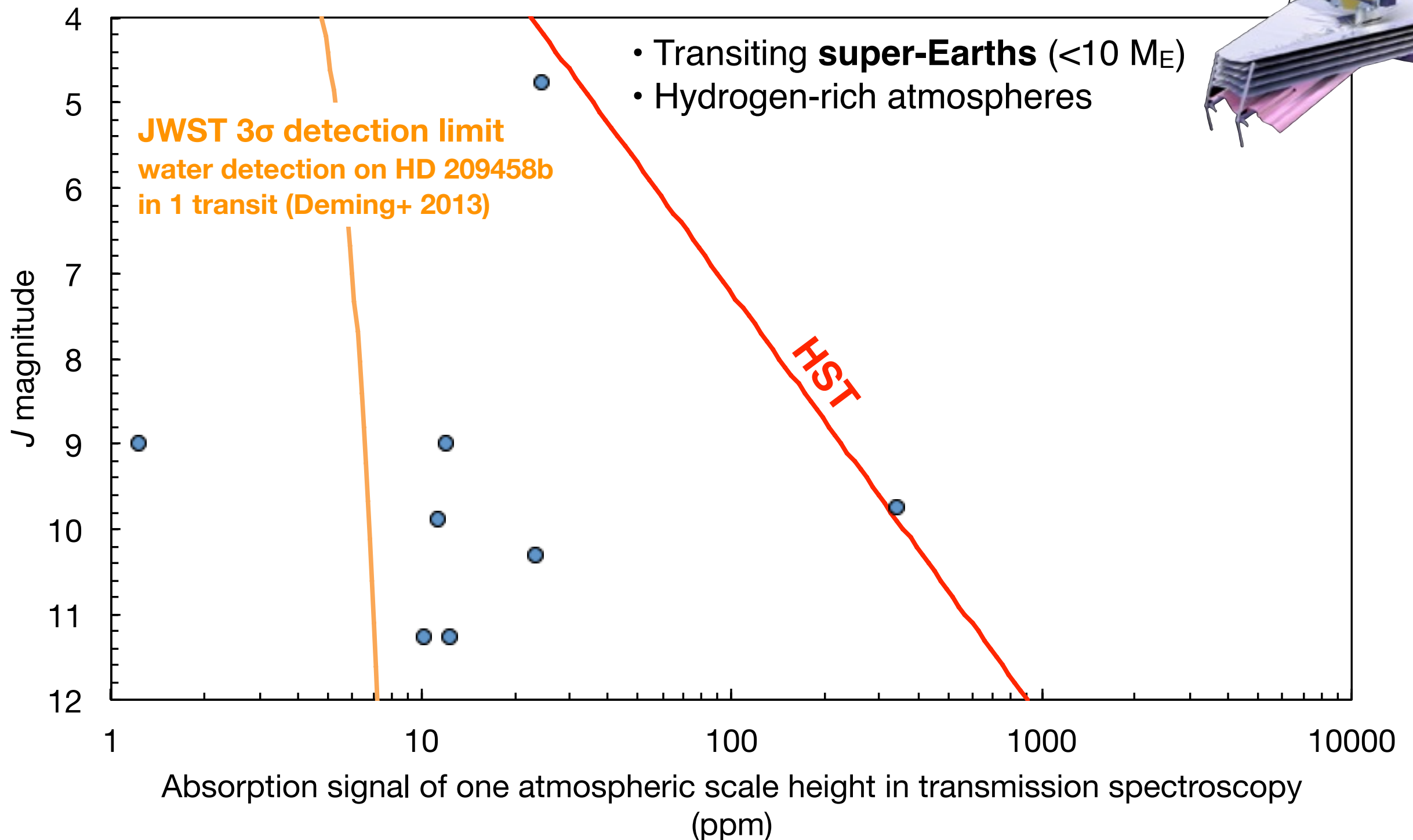
# Which planets are the **golden targets** for atmospheric characterisation?



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# Which planets are the **golden targets** for atmospheric characterisation?

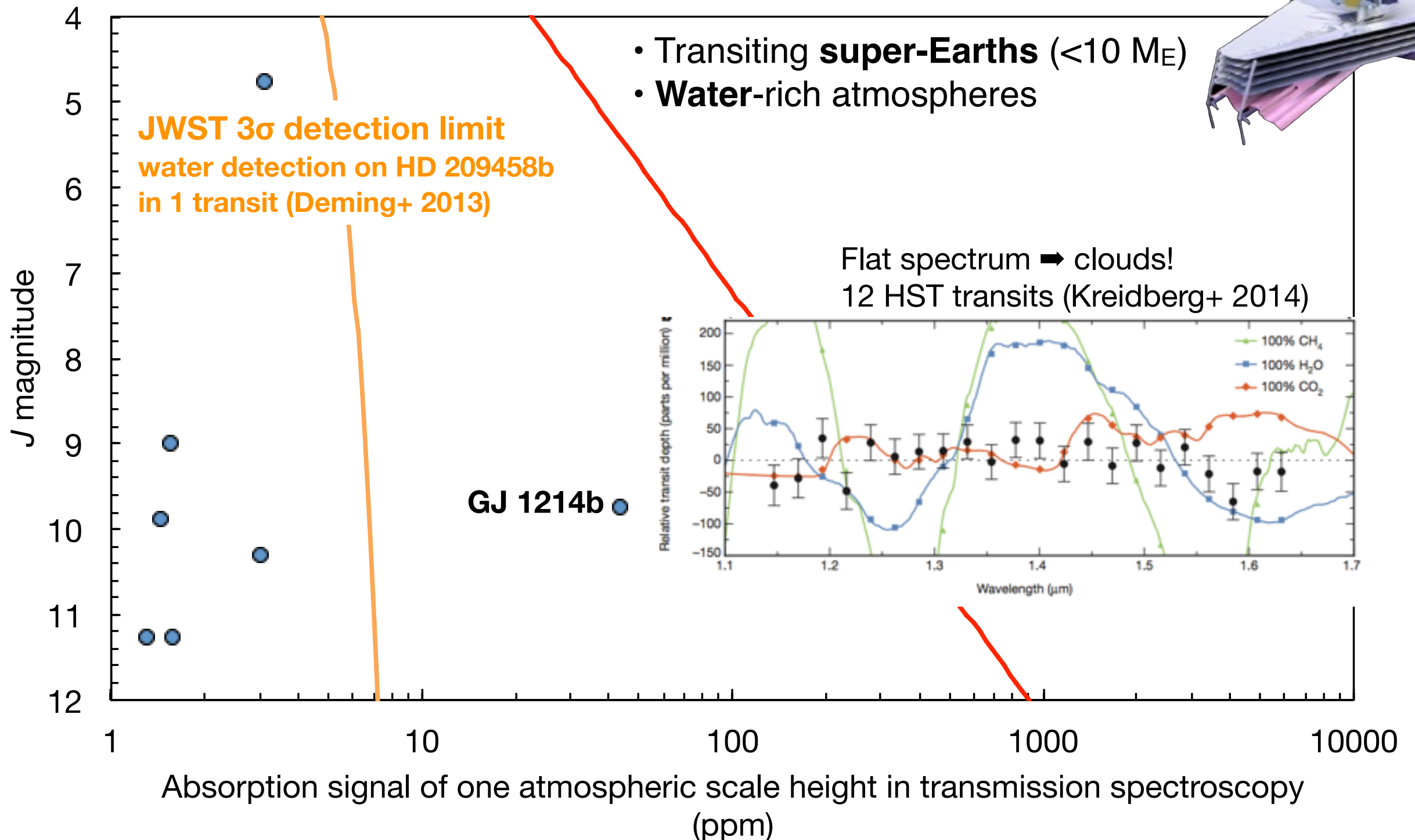
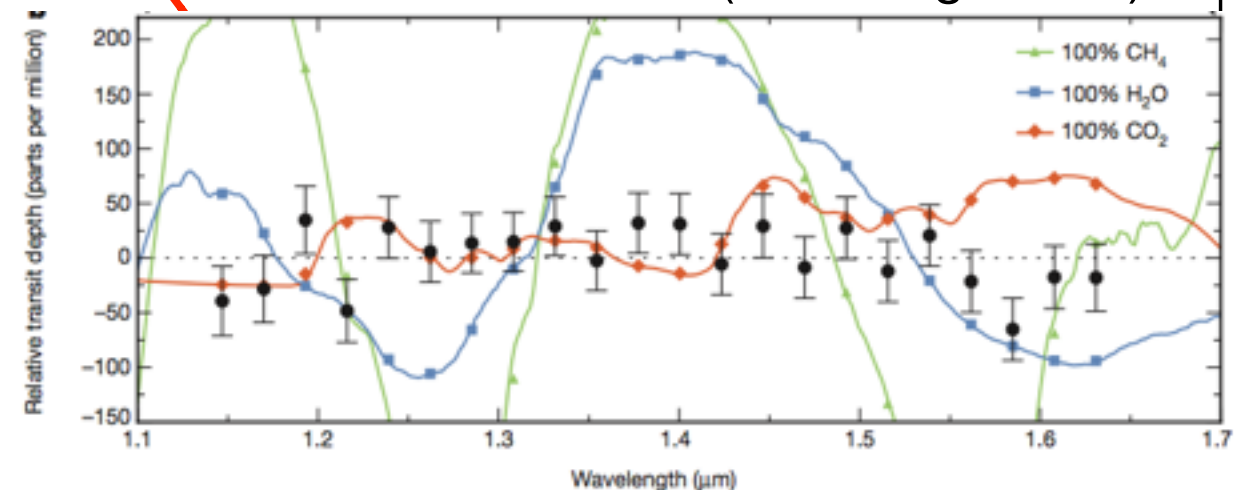


- Transiting **super-Earths** ( $<10 M_E$ )
- **Water-rich** atmospheres

**JWST  $3\sigma$  detection limit**  
water detection on HD 209458b  
in 1 transit (Deming+ 2013)

Flat spectrum  $\Rightarrow$  clouds!  
12 HST transits (Kreidberg+ 2014)

GJ 1214b



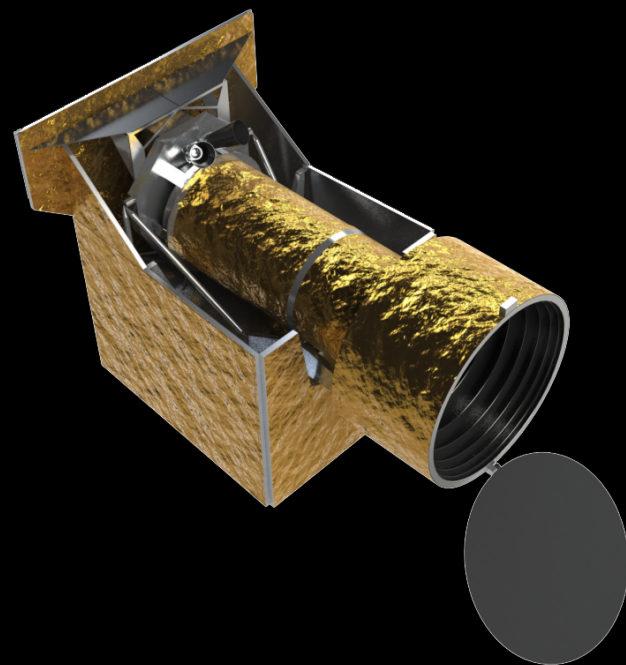


Goal: transiting Earths, more super-Earths, more Neptunes

# Targets: bright stars

Better knowledge of the stars

Better knowledge of the planets



**CHEOPS**

Adopted by ESA  
(2017)



**TESS**

(2017)



**PLATO**

Selected by ESA (M3)  
(2024)

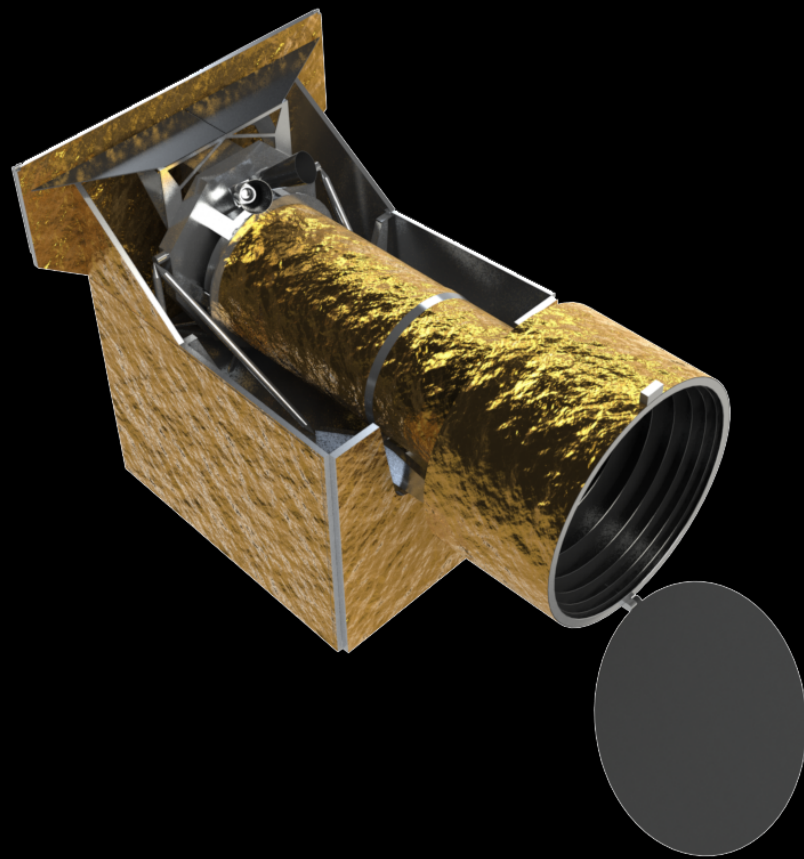




# **CHEOPS** main science goals

What **CHEOPS** will do:

- ➔ Perform 1<sup>st</sup>-step characterization of super-Earths & Neptunes  
Measure accurate radii & bulk densities of super-Earths & Neptunes orbiting bright stars
- ➔ Provide golden targets for future atmospheric characterization



How **CHEOPS** will do it:

**CHEOPS** is a photometer,  
built to achieve a photometric precision  
similar to *Kepler*  
while observing much brighter stars  
located almost anywhere on the sky

# CHEOPS strategy: follow-up



Ground-based transit surveys  
NGTS (2014)



Ground-based RV surveys  
HARPS, HARPS-N, HIRES, SOPHIE (*on going*)  
ESPRESSO (2017)

TESS  
(2017)



K2  
(2014)

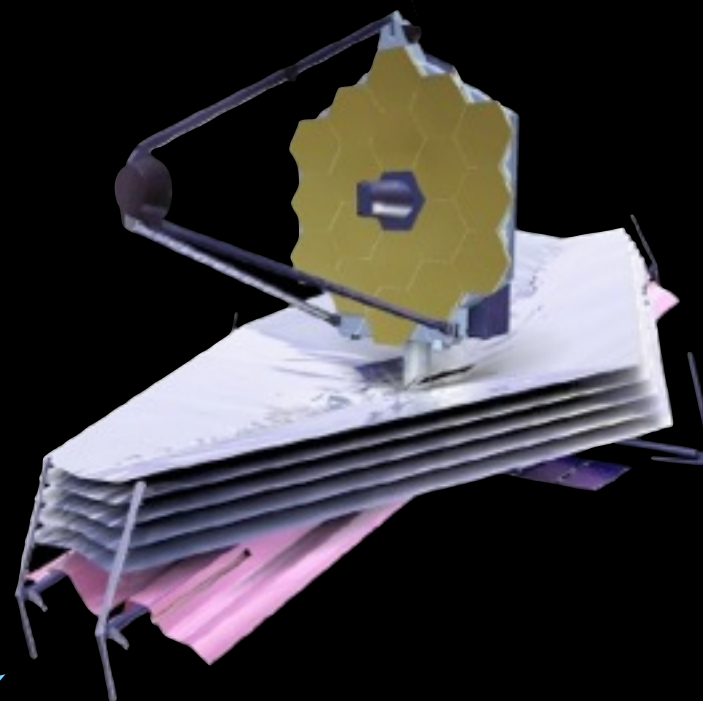
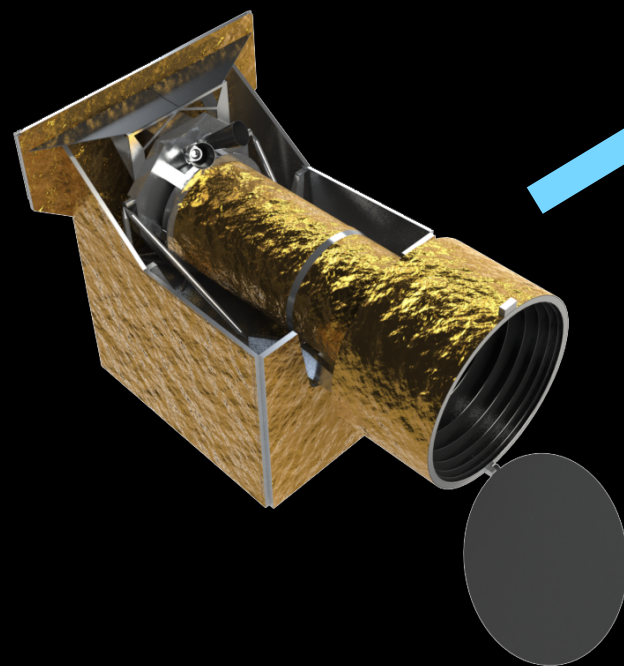
Measure accurate light curves for Neptunes

Detect the transit of known super-Earths

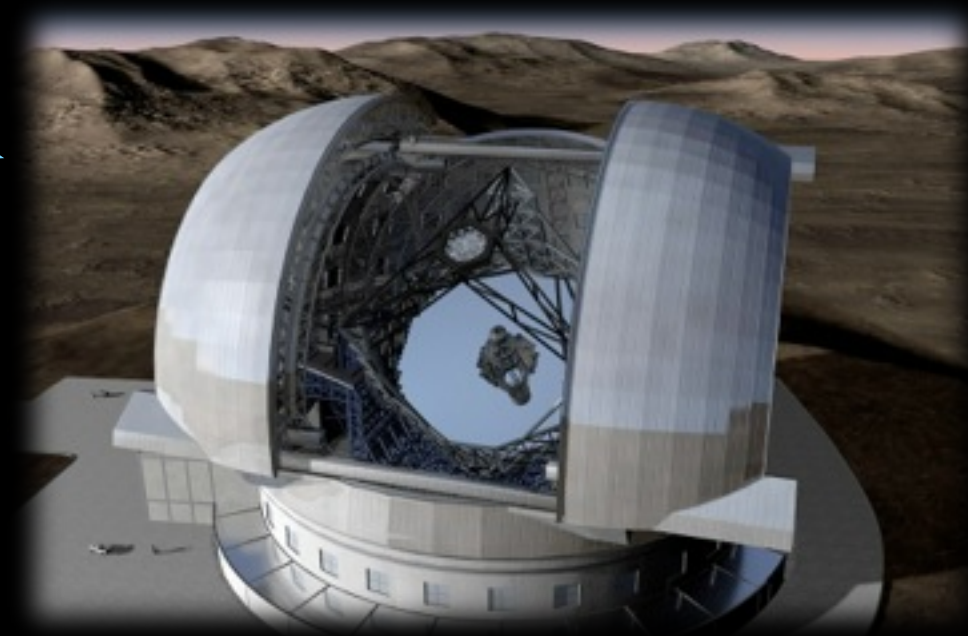
**20% open time  
(3.5-yr mission)**



# CHEOPS legacy



**JWST**  
**2018**



**E-ELT,**  
**GMT, TMT**  
**~2020**

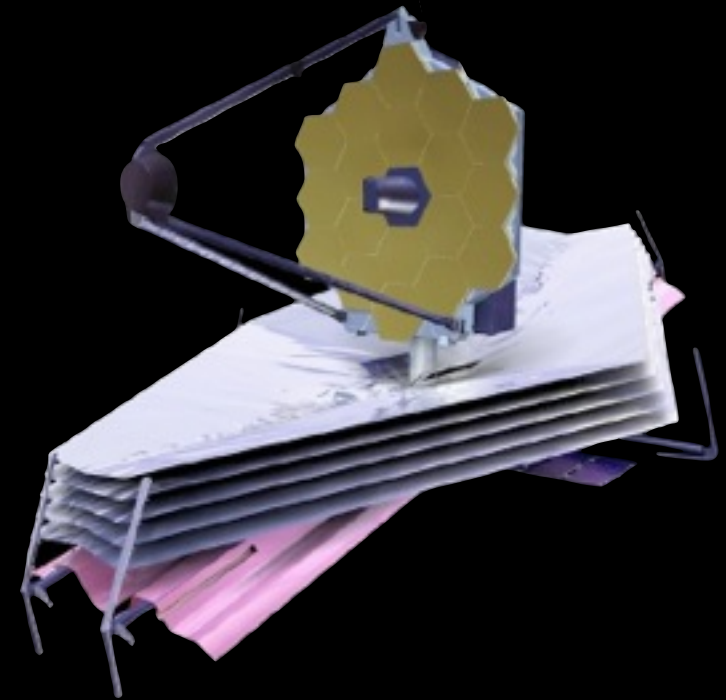
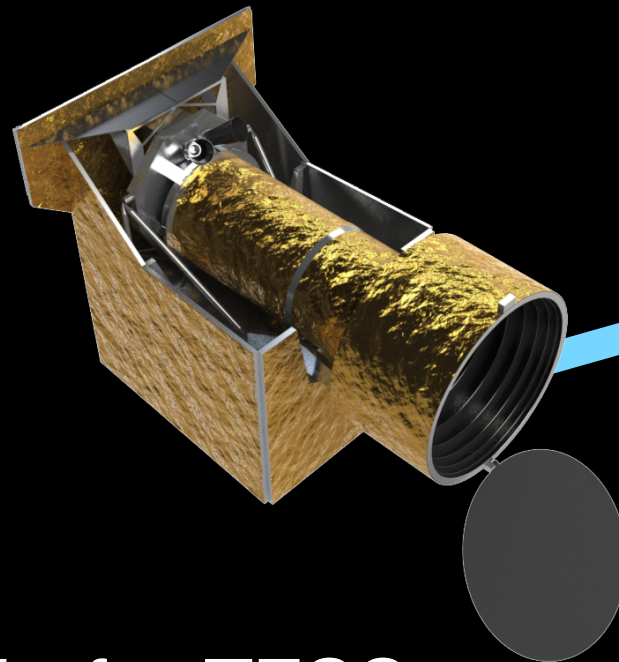




# CHEOPS prescreening for JWST

What TESS can do for CHEOPS:

- Provide targets for CHEOPS follow-up



Maximize science impact  
of *JWST* transit  
observations

What CHEOPS can do for TESS:

- Validate TESS long-period candidates
- Precise radii & densities for TESS planets: thick atmospheres?
  - Planet parameters vs. cloud correlation?
- Obtain long-baseline TTVs for TESS planets



# CHEOPS requirements

 **esa**'s first small mission

- **Science**

➡ First mission dedicated to exoplanet follow-up

- **Cost**

➡ Total *CHEOPS* cost ~ 100 M€

➡ ESA cost < 50 M€ (fixed)

- Platform
- Detector
- Launch

- **Schedule**

➡ Developed and launched within **4 years**



# *CHEOPS* consortium

Small mission, large organization





# *CHEOPS* consortium

## Small mission, large organization

Switzerland   
Mission Lead  
Instrument Team  
Science Operations Center



PI: Prof. Willy Benz, U. Bern



# *CHEOPS* consortium

## Small mission, large organization

Switzerland   
Mission Lead  
Instrument Team  
Science Operations Center



 Germany  
Focal Plane Assembly

 Belgium  
Baffle

 Italy  
Optics

 Austria  
Digital Processing Unit

 Hungary  
Radiators

# *CHEOPS* consortium

## Small mission, large organization

Switzerland   
Mission Lead  
Instrument Team  
Science Operations Center

Sweden   
Data simulator

UK   
Mission Operations Center

France   
Data Reduction Software

Portugal   
Mission Planning, Archive,  
& Data Reduction Software

 Germany  
Focal Plane Assembly

 Belgium  
Baffle

 Italy  
Optics

 Austria  
Digital Processing Unit

 Hungary  
Radiators





# *CHEOPS* consortium

## Small mission, large organization

 Switzerland

University of Bern (project lead)  
University of Geneva  
Swiss Space Center (EPFL)  
ETH Zürich

 Austria

Institut für Weltraumforschung, Graz

 Belgium

Centre Spatial de Liège  
Université de Liège

 France

Laboratoire d'astrophysique de Marseille

 Germany

DLR Institute for Planetary Research

 Hungary

Konkoly Observatory

 Italy

Osservatorio Astrofisico di Catania – INAF  
Osservatorio Astronomico di Padova – INAF  
Università di Padova

 Portugal

Centro de Astrofisica da Universidade do Porto  
Deimos Engenharia

 Sweden

Onsala Space Observatory, Chalmers University  
University of Stockholm

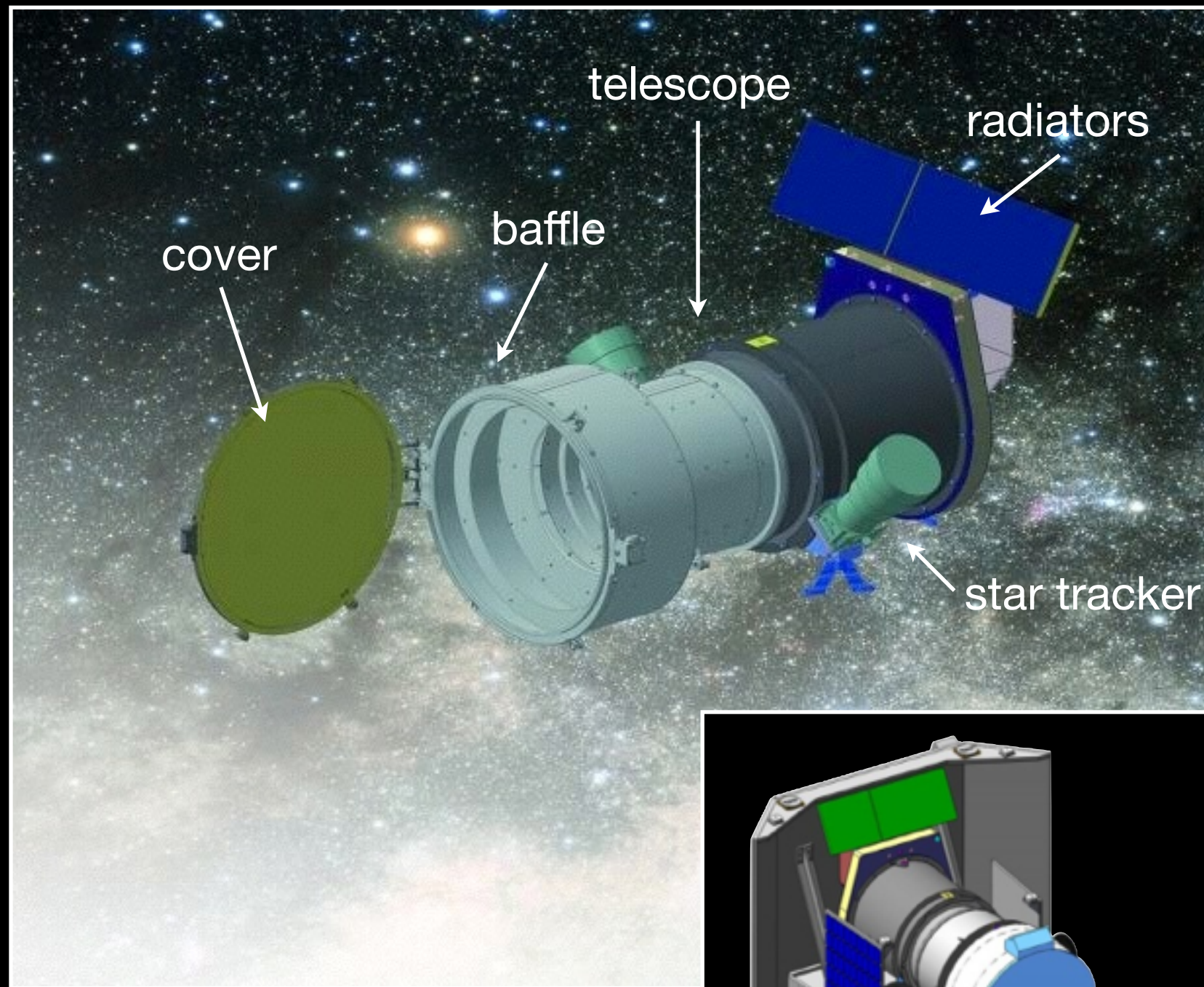
 UK

University of Warwick



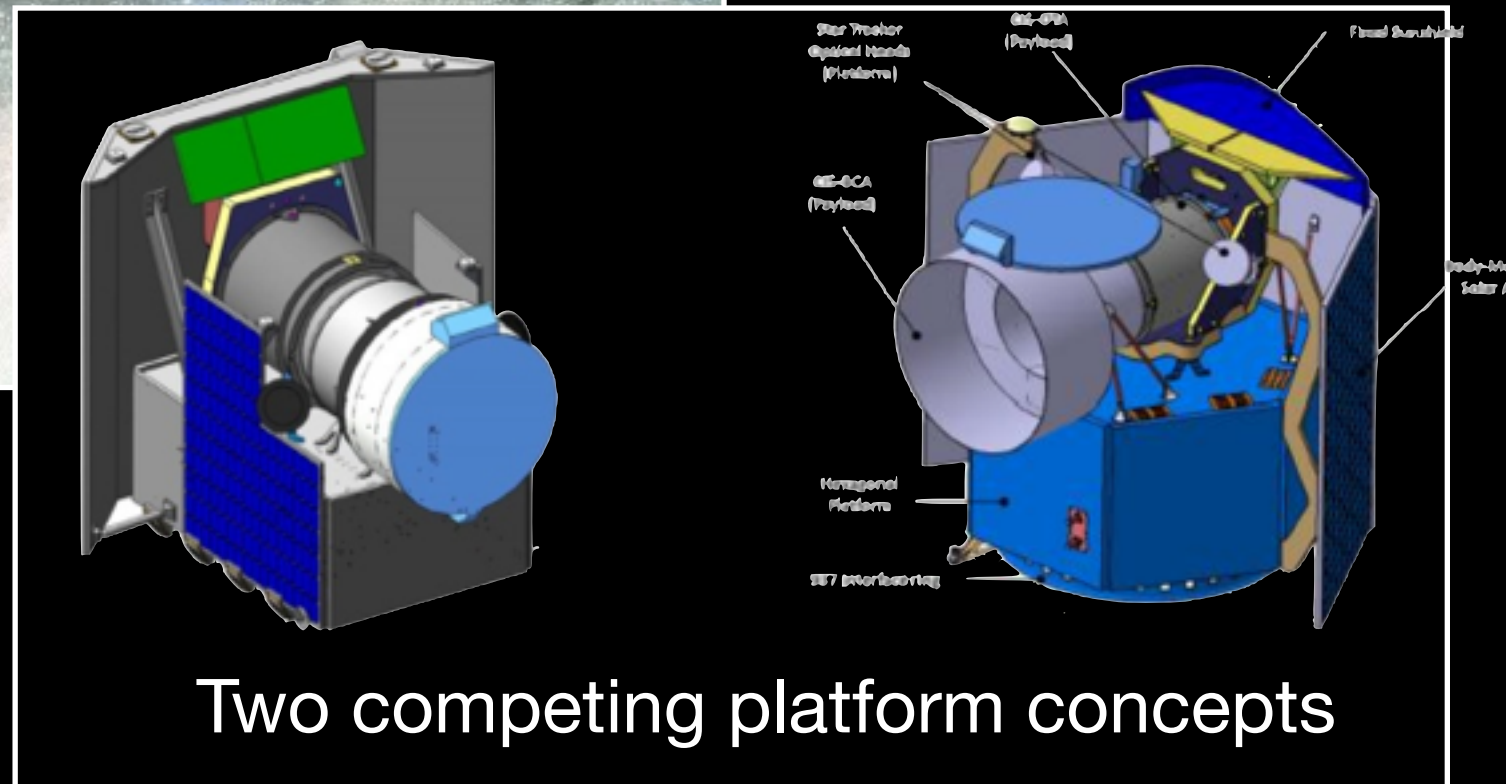


# CHEOPS spacecraft



← instrument

platform  
↓

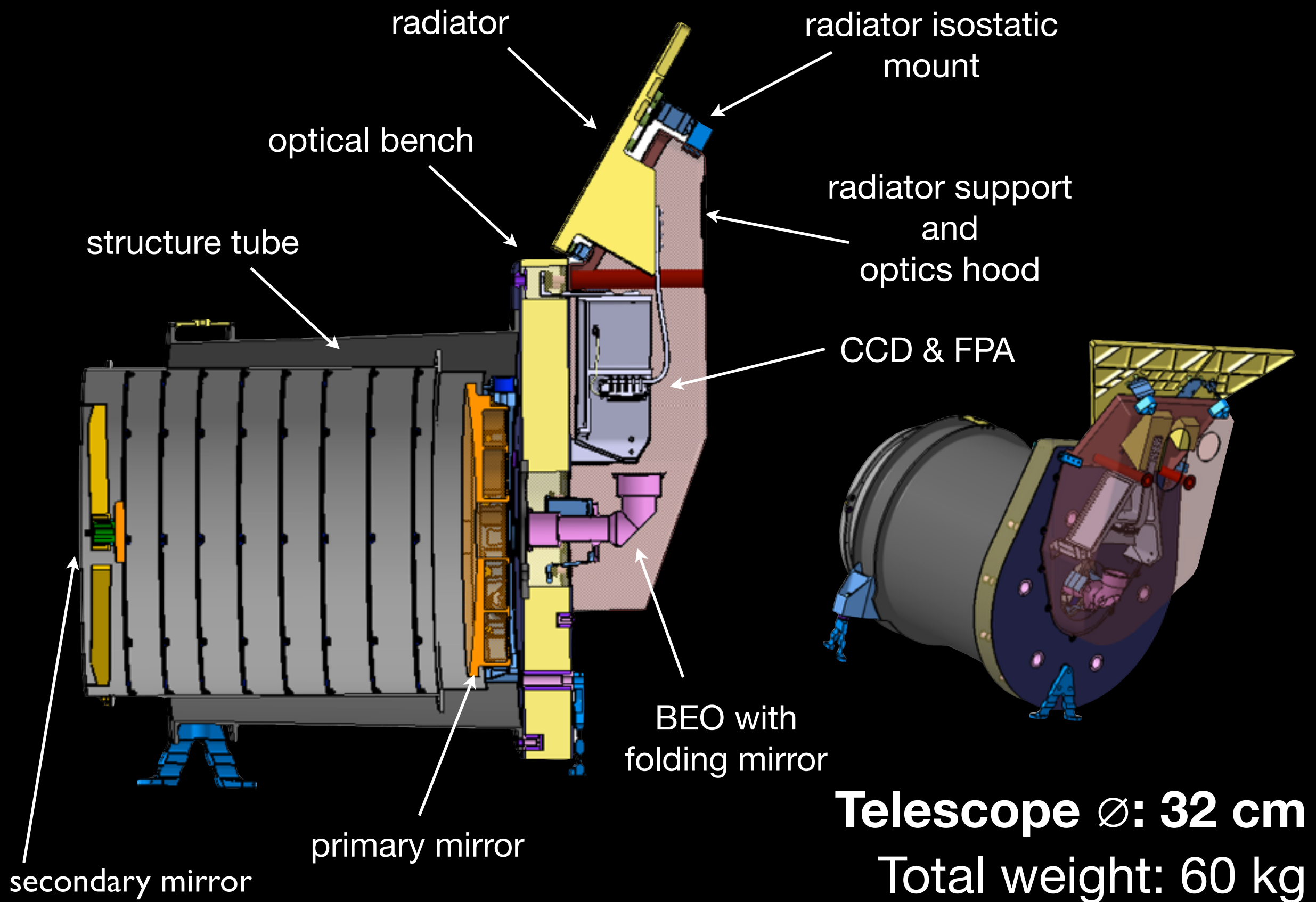


Total weight: 250 kg  
Total length: 1.3 m





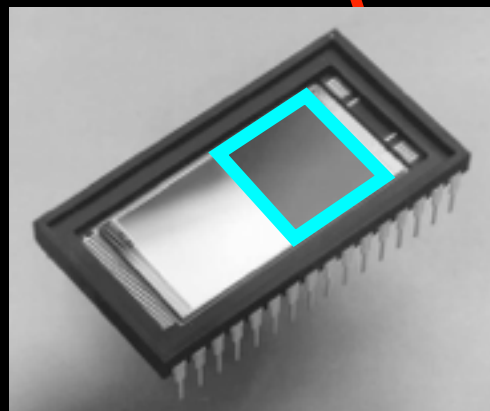
# CHEOPS instrument system





# CHEOPS data acquisition

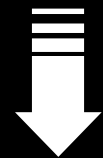
telescope  
FoV: 20'



e2v

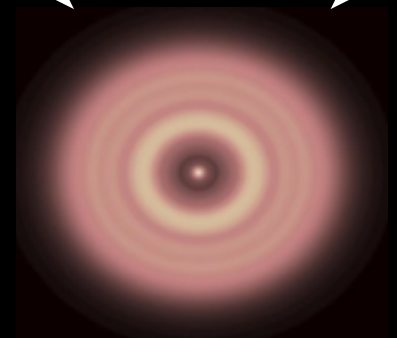
CCD 1k x 1k

subarray image  
200×200 pixels  
(4 arcmin<sup>2</sup>)



stacked &  
downloaded  
to the ground  
**1 min<sup>-1</sup>**

30 pixels (30")



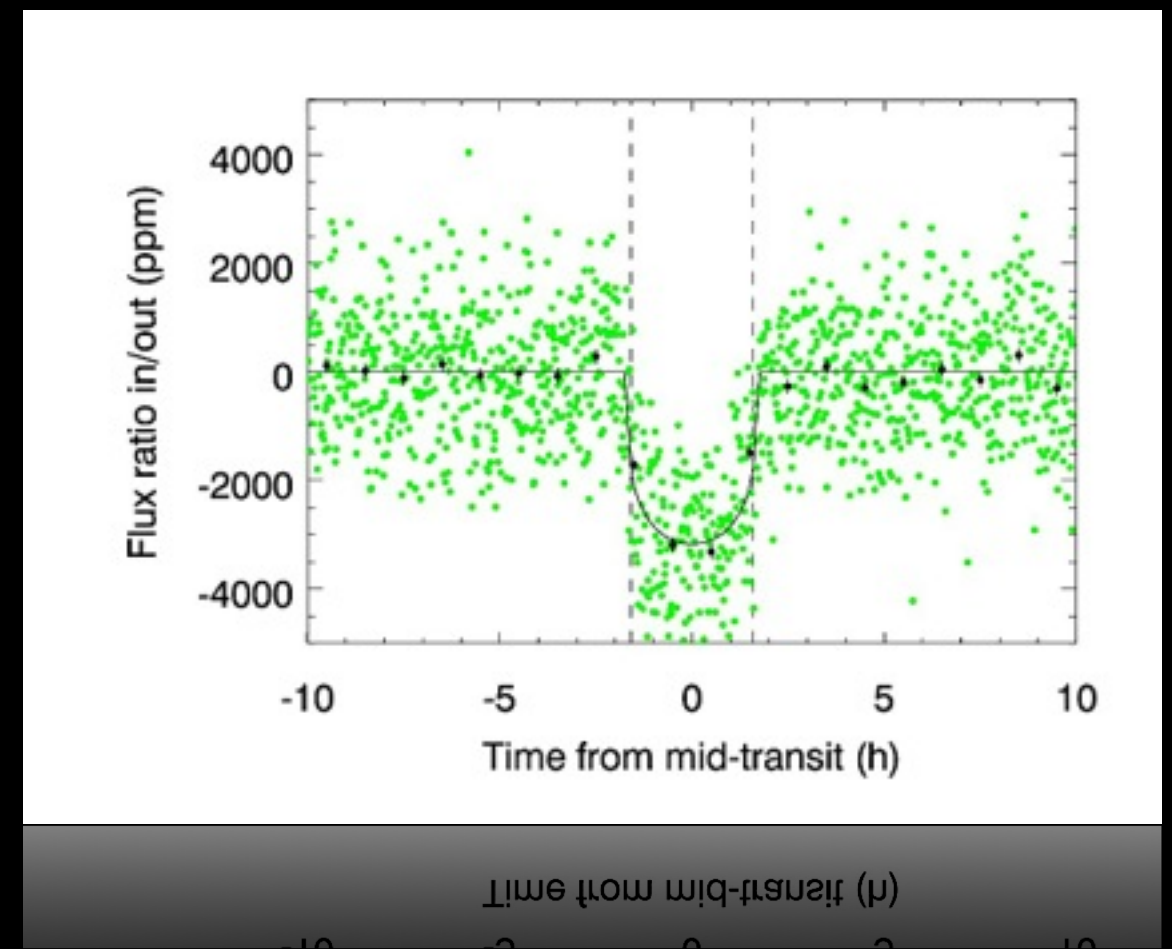
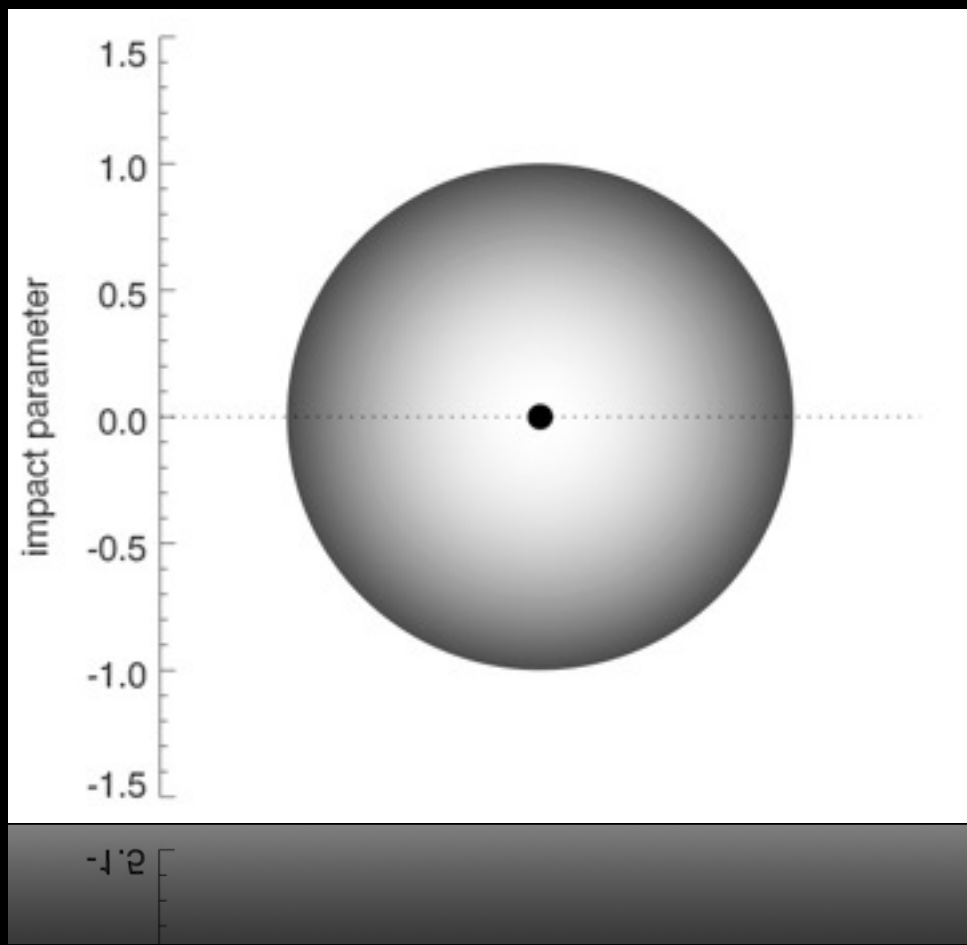
defocused PSF

**CHEOPS** photometric precision

Pointing stability: 8" (rms) jitter  
p-flat precision: 0.1 % pixel-to-pixel

# *CHEOPS* performances

- *CHEOPS* will measure highly accurate signals
  - ➔ 20 ppm accuracy over 6 hours for G-type stars with  $V < 9$  mag
  - ➔ 85 ppm accuracy over 3 hours for K-type stars with  $V < 12$  mag

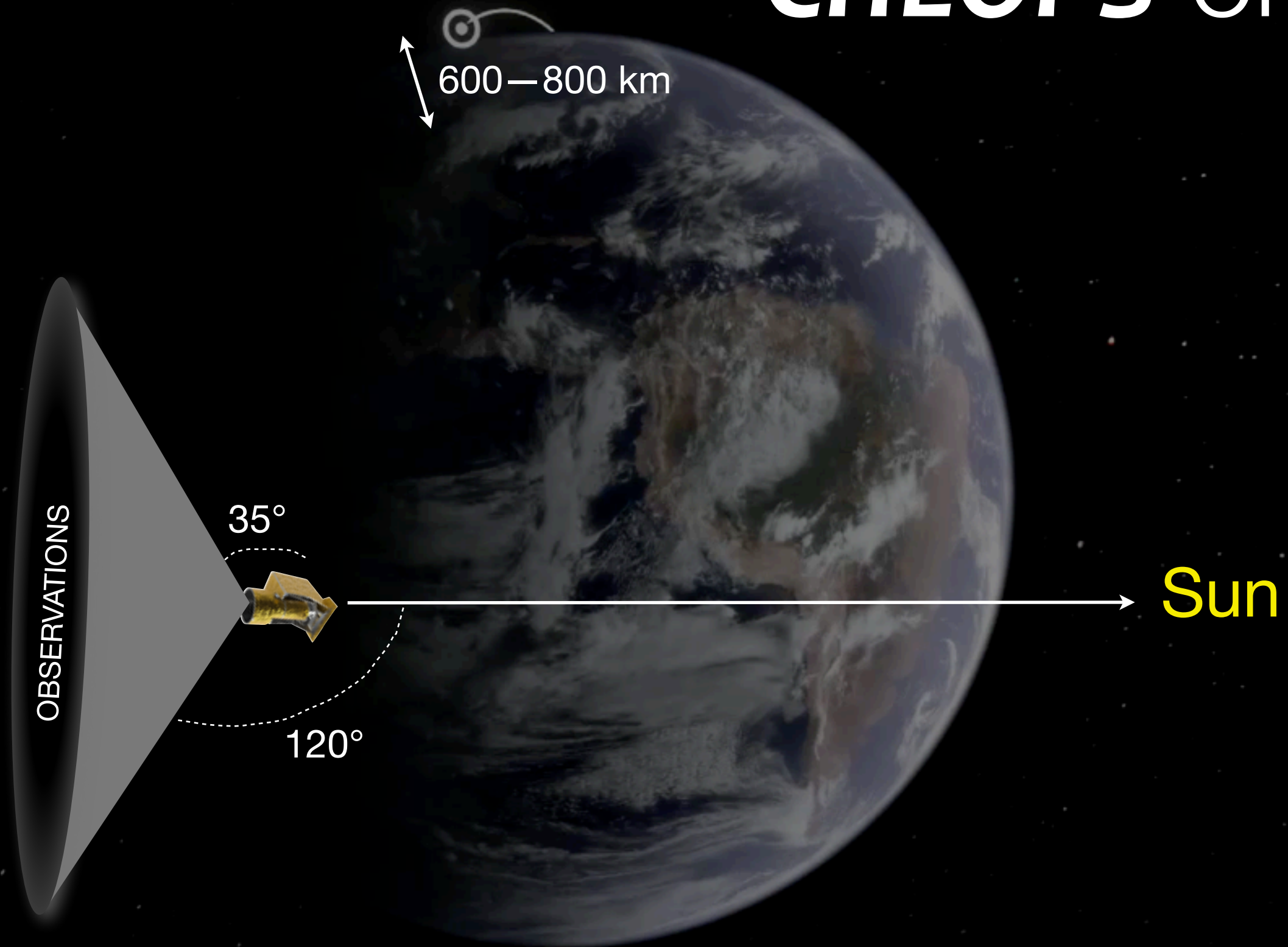


# **CHEOPS** performances

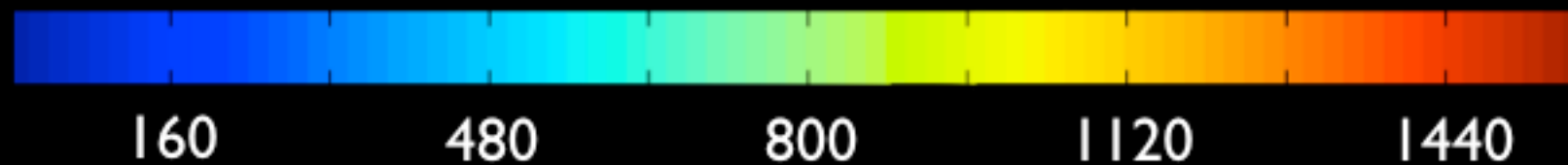
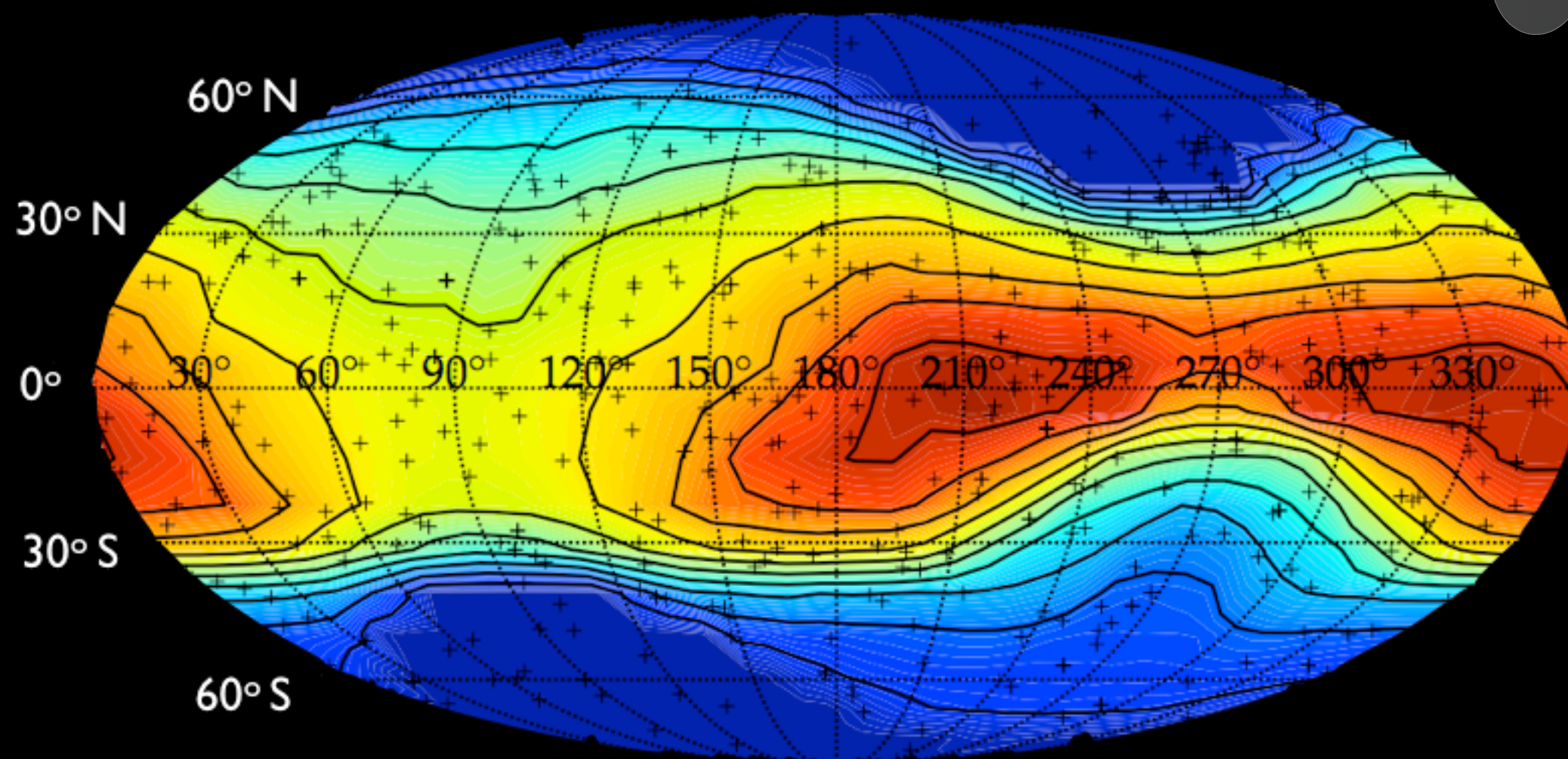
- **CHEOPS** will measure highly accurate signals for stars with  $6 < V < 12$ 
  - ➔ 20 ppm accuracy over 6 hours for G-type stars with  $V < 9$
  - ➔ 85 ppm accuracy over 3 hours for K-type stars with  $V < 12$
- **CHEOPS** can point at any location over more than 50% of the sky
  - ➔ 50% of the whole sky shall be accessible for 50 days (>50% efficiency)
  - ➔ 25% of the whole sky shall be accessible for 13 days (>80% efficiency)



# ***CHEOPS*** orbit



# CHEOPS sky



Observing time / year (hours)

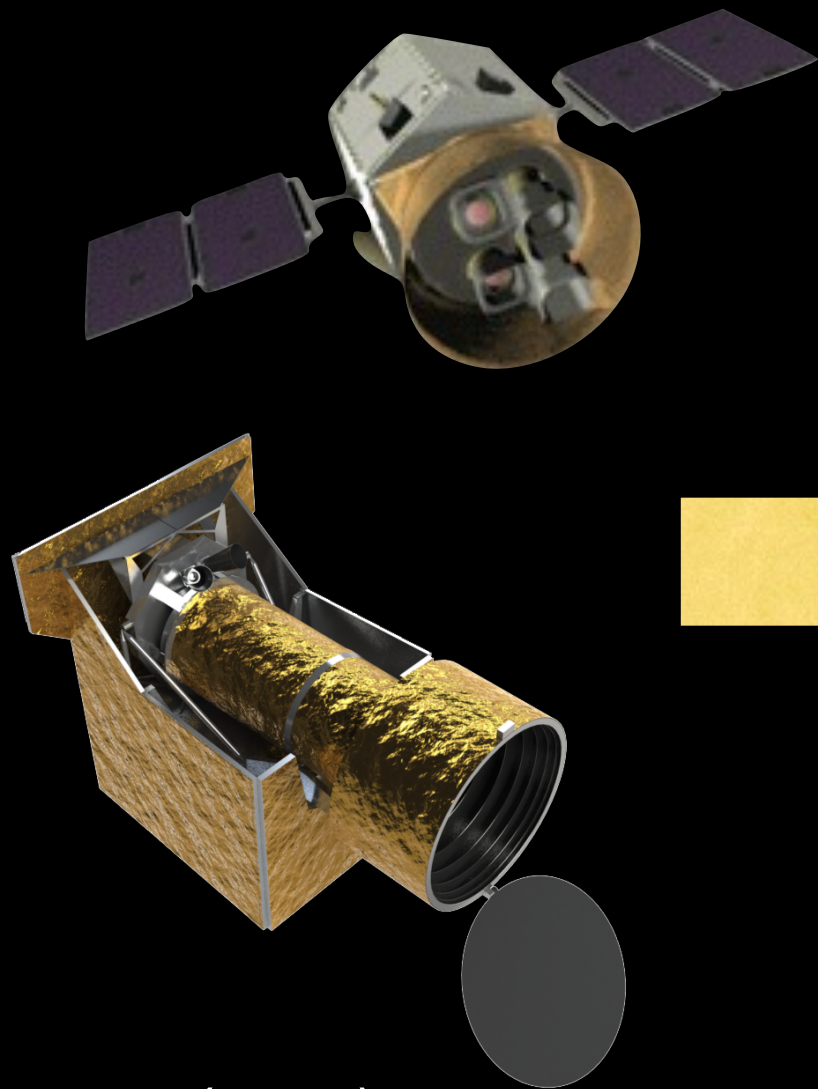


# CHEOPS summary

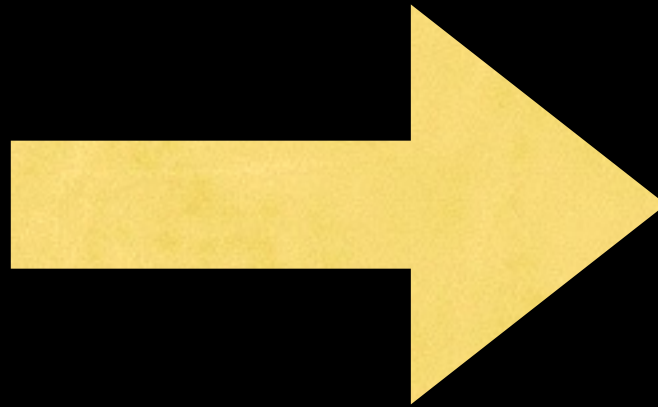
- **CHEOPS** is Europe's next exoplanet mission (2017)
- **CHEOPS** is a follow-up machine,  
*Knowing when to look at a star makes CHEOPS extremely efficient*
  - ➔ provide a first-step characterization of low-mass exoplanets
  - ➔ collect the golden targets for future in-depth characterization
  - ➔ 20% open time for high-precision photometry science
- **CHEOPS** Definition Study Report  
<http://sci.esa.int/cosmic-vision/53541-cheops-definition-study-report-red-book/>







(2017)



*PLATO*  
(2024)