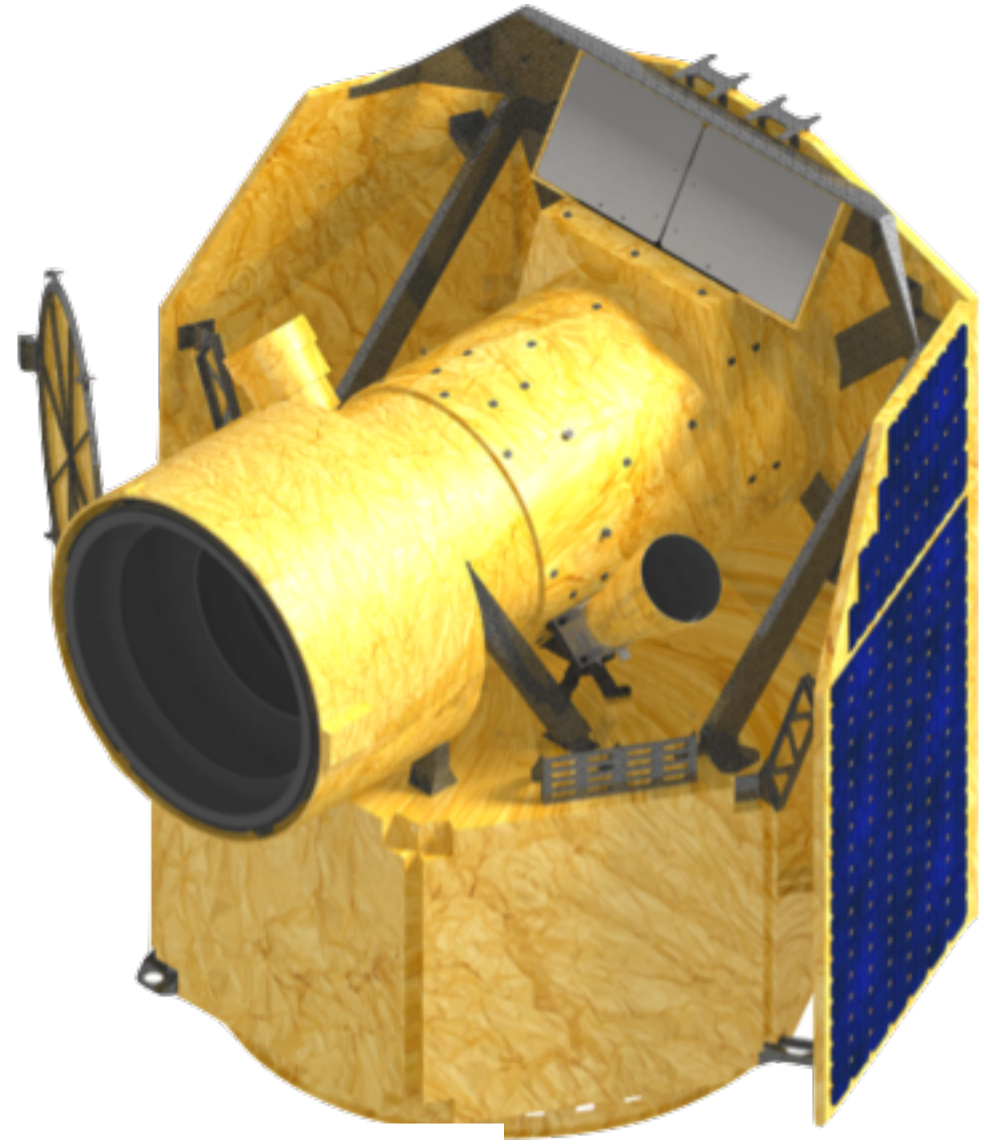
# CHEOPS: CHaracterising ExOPlanets Satellite.

Budapest, 28 October 2015

Yann Alibert




UNIVERSITÄT BERN

space science esa

Admatis

deim ENGENHARIA

INAF ISTITUTO NAZIONALE DI ASTROFISICA NATIONAL INSTITUTE FOR ASTROPHYSICS

INTA

Università degli Studi di Padova

University of Cambridge

EPFL École Polytechnique Fédérale de Lausanne

ioa

ia instituto de astrofísica e ciências do espaço

Centro de Astrofísica da Universidade do Porto

IWF Institut für Weltraumforschung

ICE

institut für astrophysik Universitätssternwarte Wien

DLR Deutsches Zentrum für Luft- und Raumfahrt e.V. in der Helmholtz-Gemeinschaft

CSL Centre Spatial de Liège

Université de Genève

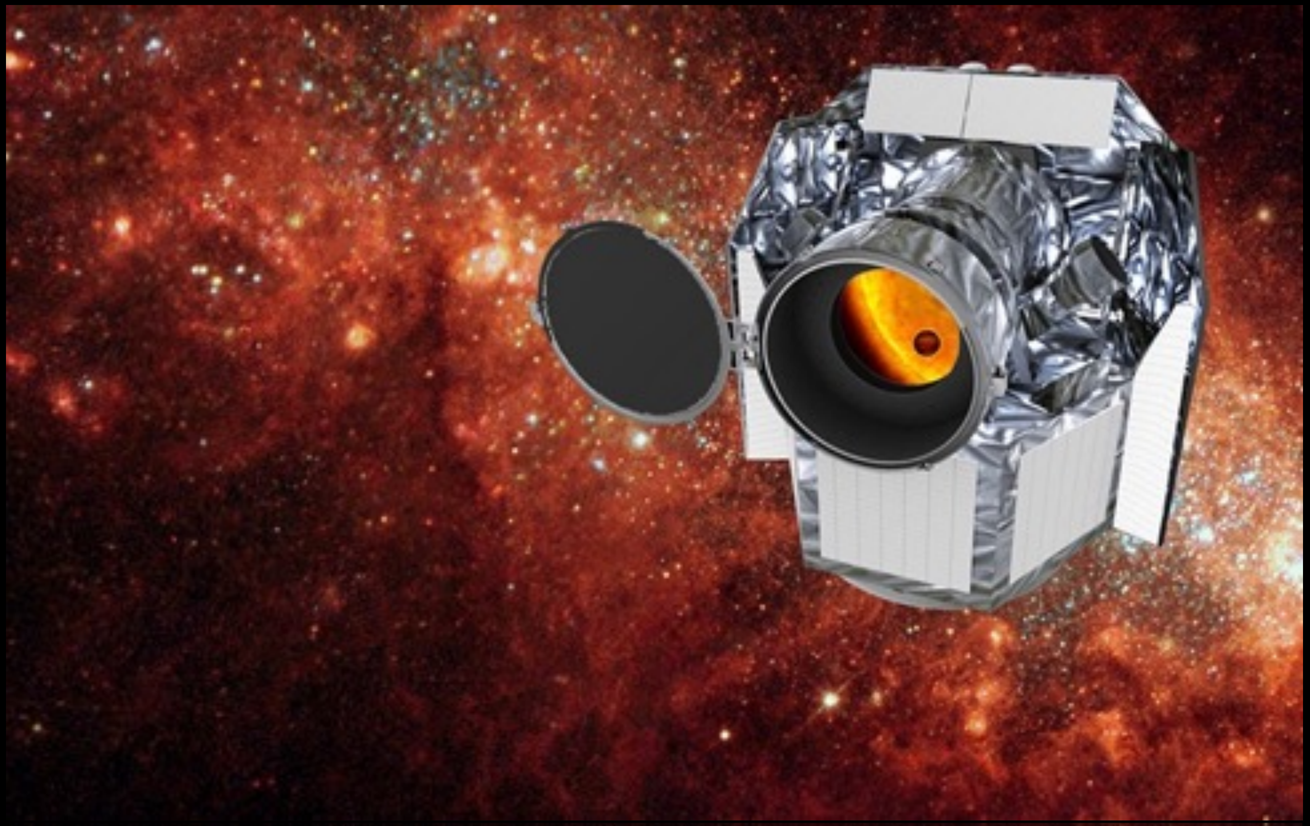
LAM Laboratoire d'Astrophysique de Marseille

ETH Eidgenössische Technische Hochschule Zürich Swiss Federal Institute of Technology Zurich

University of St Andrews Scotland's first university

Université de Liège

# ESA's first small-class mission
# Joint project ESA–CMC



# Requirements of a small mission

CHEOPS

- ESA S-class mission in Cosmic Vision 2015-2025
- Science: top rated science in any area of space science
- Cost to ESA not to exceed 50 M€ **(platform+launch+detector)**
- Schedule: developed and launched within 4 years

| Milestone | Time |
|---|---|
| call issued | March, 2012 |
| proposal due | June, 2012 |
| mission selection | October, 2012 |
| mission adoption | February, 2014 |
| launch ready | end 2017 |
| nominal lifetime | 3.5 years |

# CHEOPS mission consortium

| | |
|---|---|
| Switzerland | University of Bern (project lead)<br>University of Geneva<br>Swiss Space Center (EPFL)<br>ETH Zürich |
| Austria | Institut für Weltraumforschung, Graz<br>University of Vienna |
| Belgium | Centre Spatial de Liège<br>Université de Liège |
| France | Laboratoire d’astrophysique de Marseille |
| Germany | DLR Institute for Planetary Research |
| Hungary | Konkoly Observatory<br>ADMATIS |
| Italy | Osservatorio Astrofisico di Catania – INAF<br>Osservatorio Astronomico di Padova – INAF<br>Università di Padova |
| Portugal | Centro de Astrofisica da Universidade do Porto<br>Deimos Engenharia |
| Spain | Instituto de Astrofísica de Canarias<br>Centro de Astrobiologia – INTA<br>Institut de Ciènces de l’Espai, CDTI, GMV |
| Sweden | Onsala Space Observatory, Chalmers University<br>University of Stockholm |
| UK | U. Cambridge, U. Warwick, U. St Andrews |

# CHEOPS mission consortium

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Switzerland
**Mission lead**
**Instrument team**
**Science operations centre**

**PI: Willy Benz, U. Bern**

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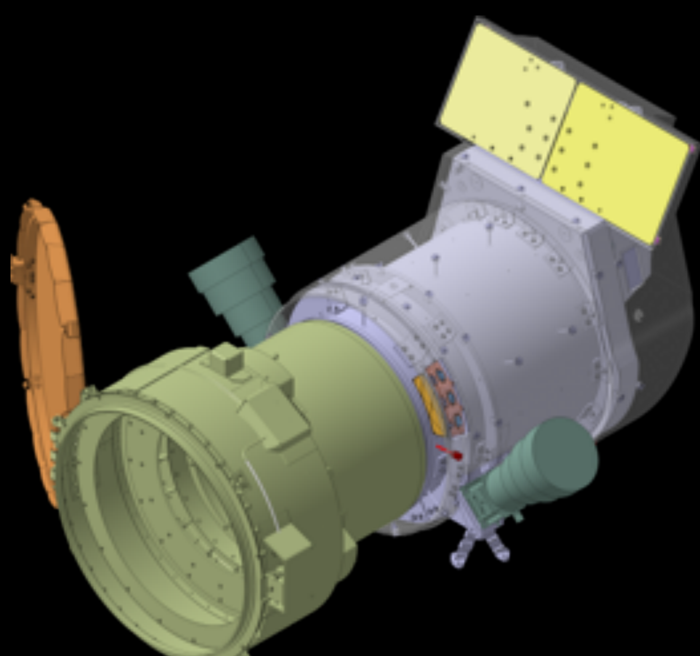
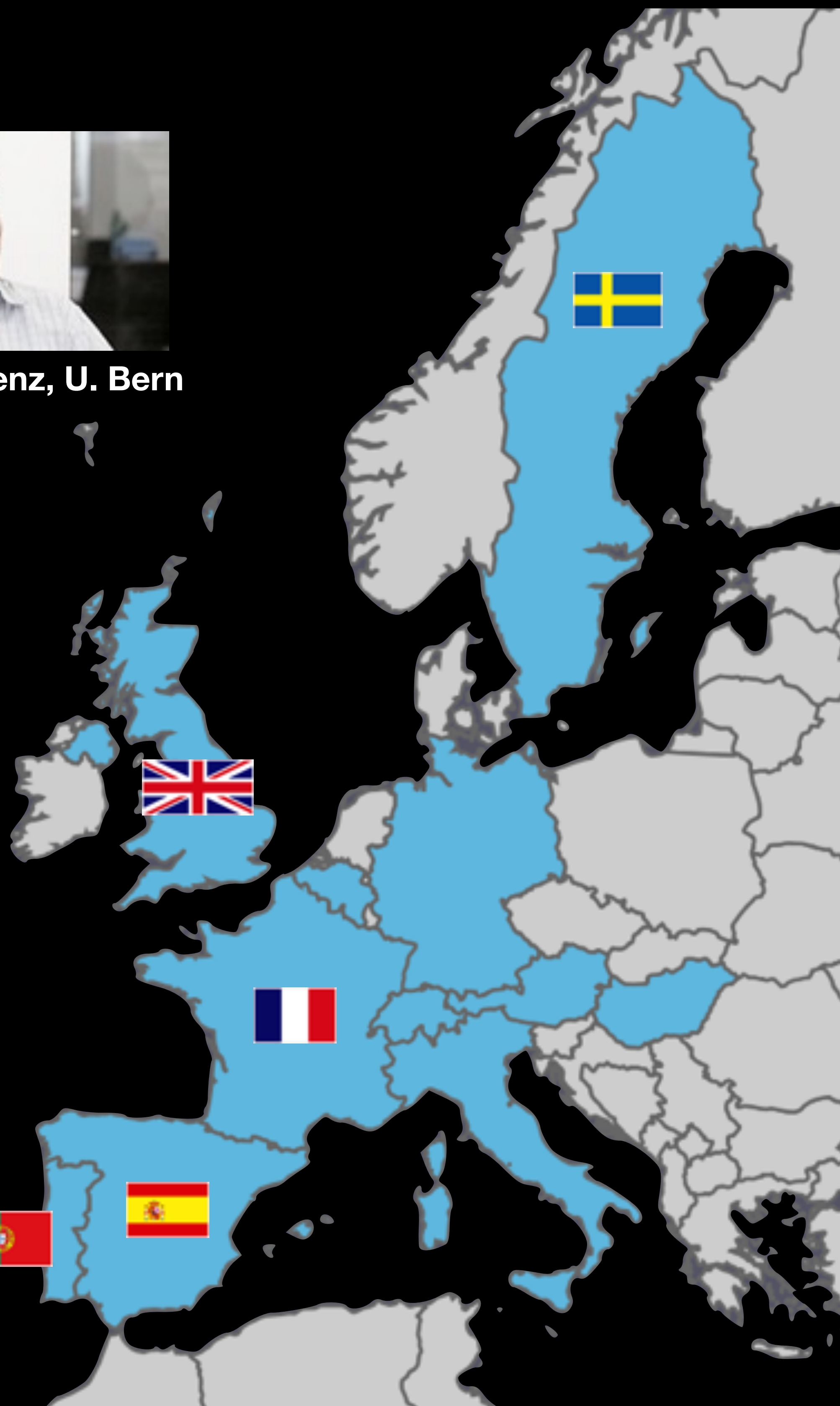


CHEOPS instrument
32-cm Ritchey-Chrétien telescope



**Hardware contribution**

Germany
**Focal plane assembly**

Belgium
**Baffle**

Italy
**Optics**

Austria
**Digital processing unit**

Hungary
**Radiators**

# CHEOPS mission consortium

Switzerland
**Mission lead**
**Instrument team**
**Science operations centre**

Sweden
**Data flow simulator**

UK
**Quick look**

France
**Data reduction pipeline**

Portugal
**Mission planning, archive, & data reduction pipeline**

Spain
**Mission operations centre**

**Hardware contribution**

Germany
**Focal plane assembly**

Belgium
**Baffle**

Italy
**Optics**

Austria
**Digital processing unit**

Hungary
**Radiators**

# Science team

CHEOPS

**D. Queloz**
**Science Team Chair**

 Y. Alibert

 R. Alonso

 D. Barrado

 F. Bouchy

 A. Brandeker

 J. Cabrera

 A. Cameron

 S. Charnoz

 A. Erikson

 D. Gandolfi

 M. Gillon

 M. Güdel

 K. Heng

 H. Lammer

 J. Laskar

 C. Lovis

 M. R. Meyer

 I. Pagano

 G. Piotto

 R. Ragazzoni

 I. Ribas

 S. Sousa

 G. Szabó

 T. Spohn

 V. Van Grootel

CHEOPS

**C. Broeg**
**Project Manager**

CHEOPS

**A. Fortier**
**Instrument Scientist**

CHEOPS

**D. Ehrenreich**
**Mission Scientist**

# Science team activities

CHEOPS

**Working group coordinators**

- Target selection
- Stellar target properties
- Light curve analysis
- Performance monitoring
- Physics of planets
- Dynamics of systems

**Christophe Lovis**

**Sérgio Sousa**

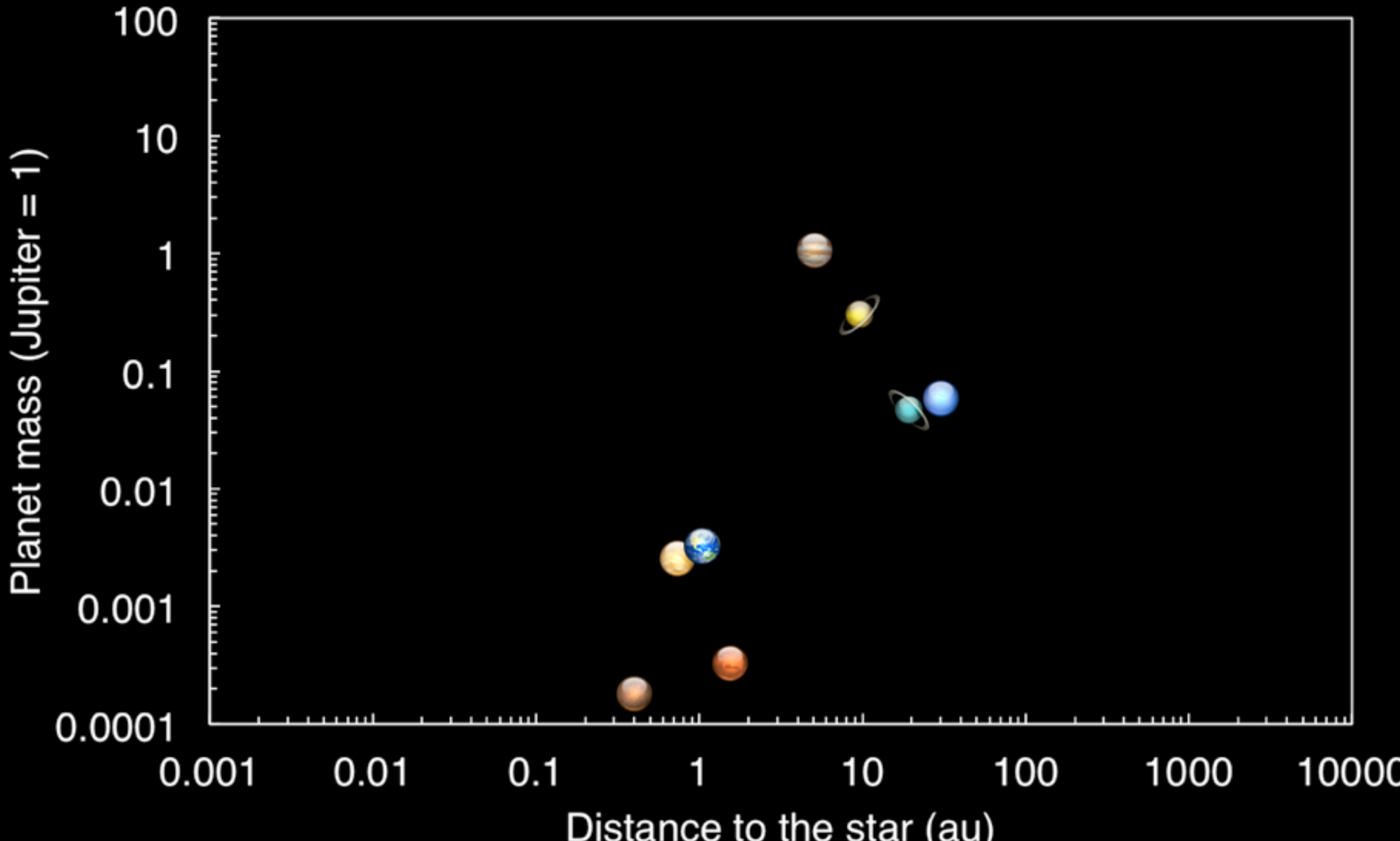
**Michaël Gillon**

**Andrea Fortier**

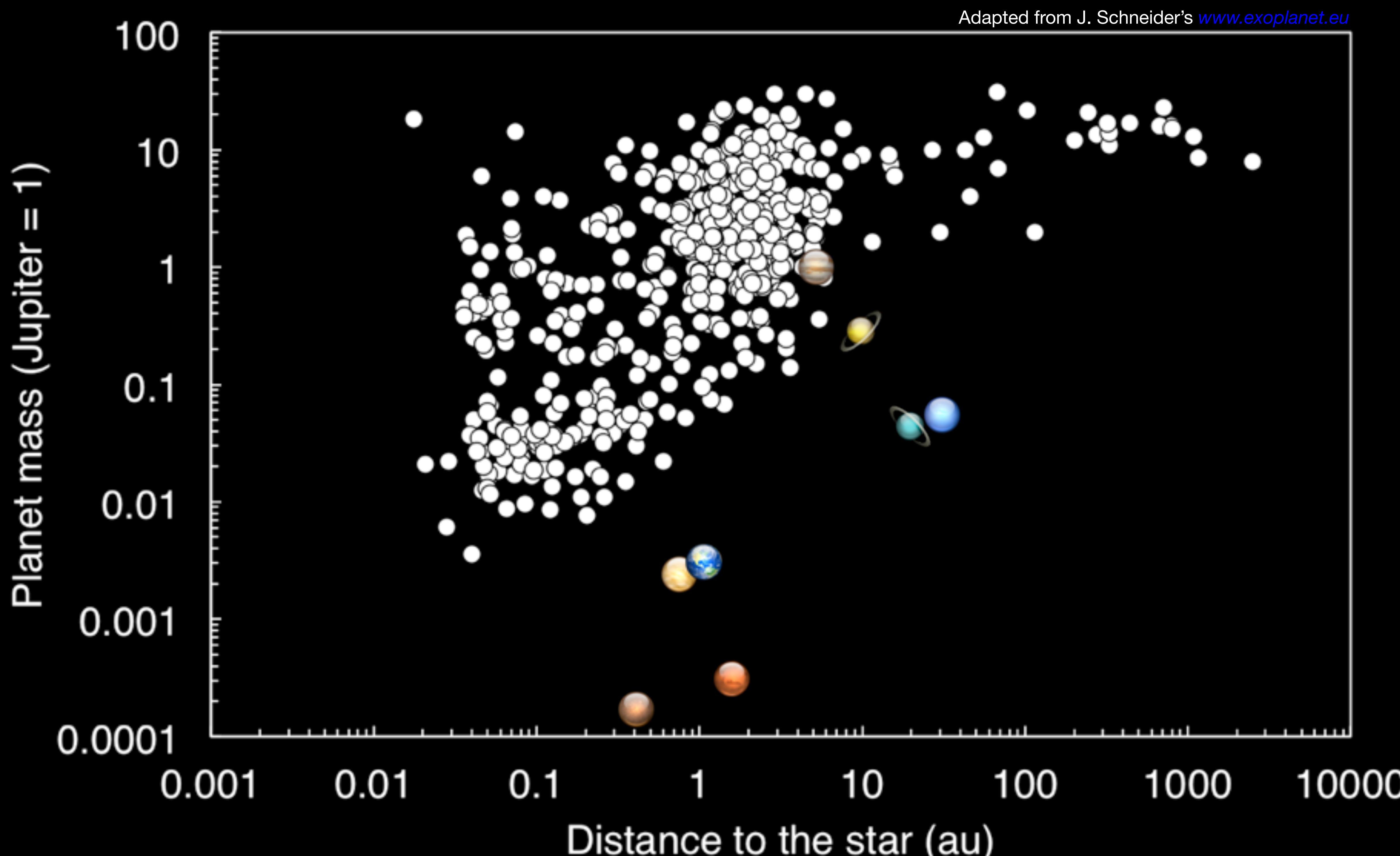
**Yann Alibert**

**Giampaolo Piotto**

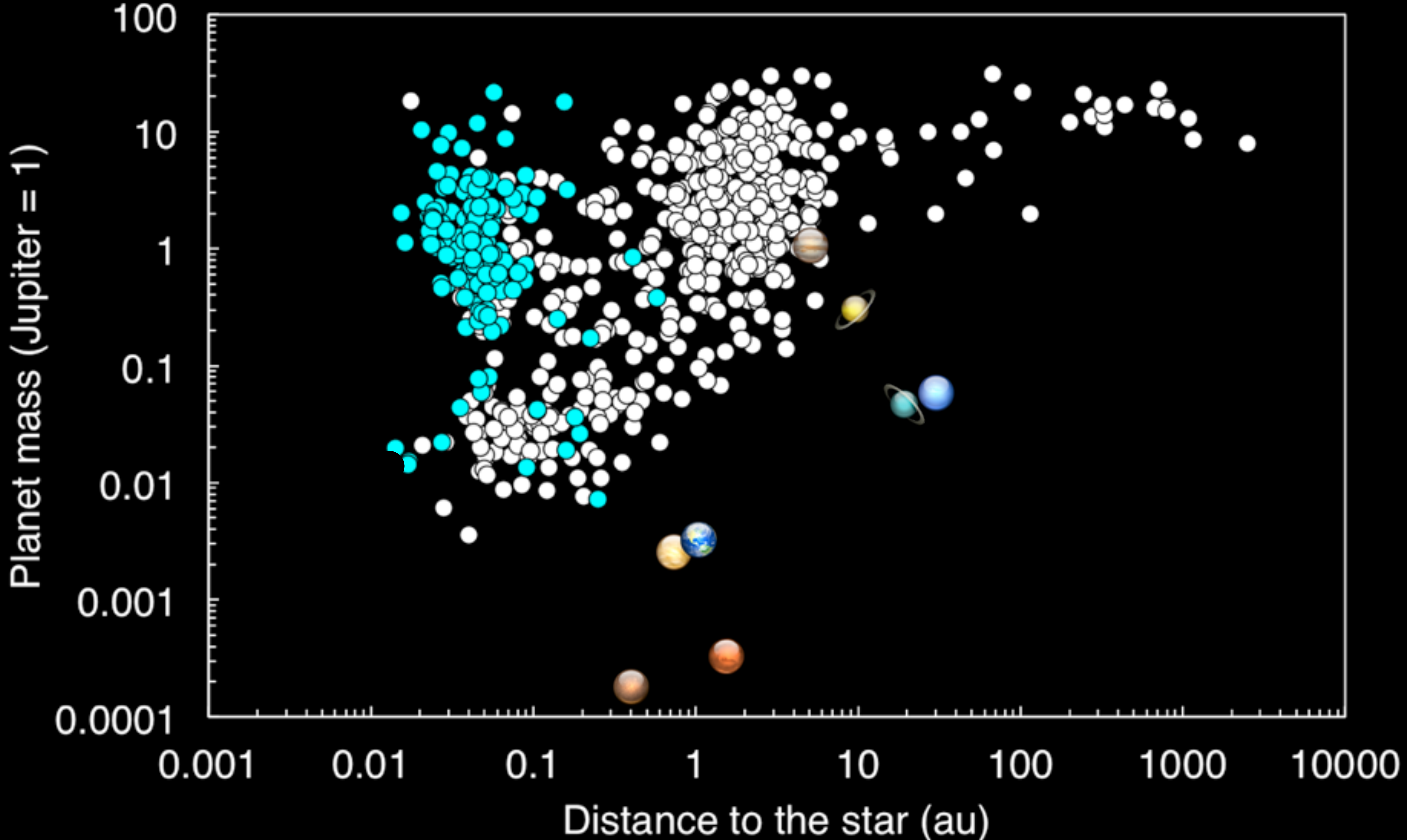
# **Eight** Solar System planets



# **thousands** of exoplanets



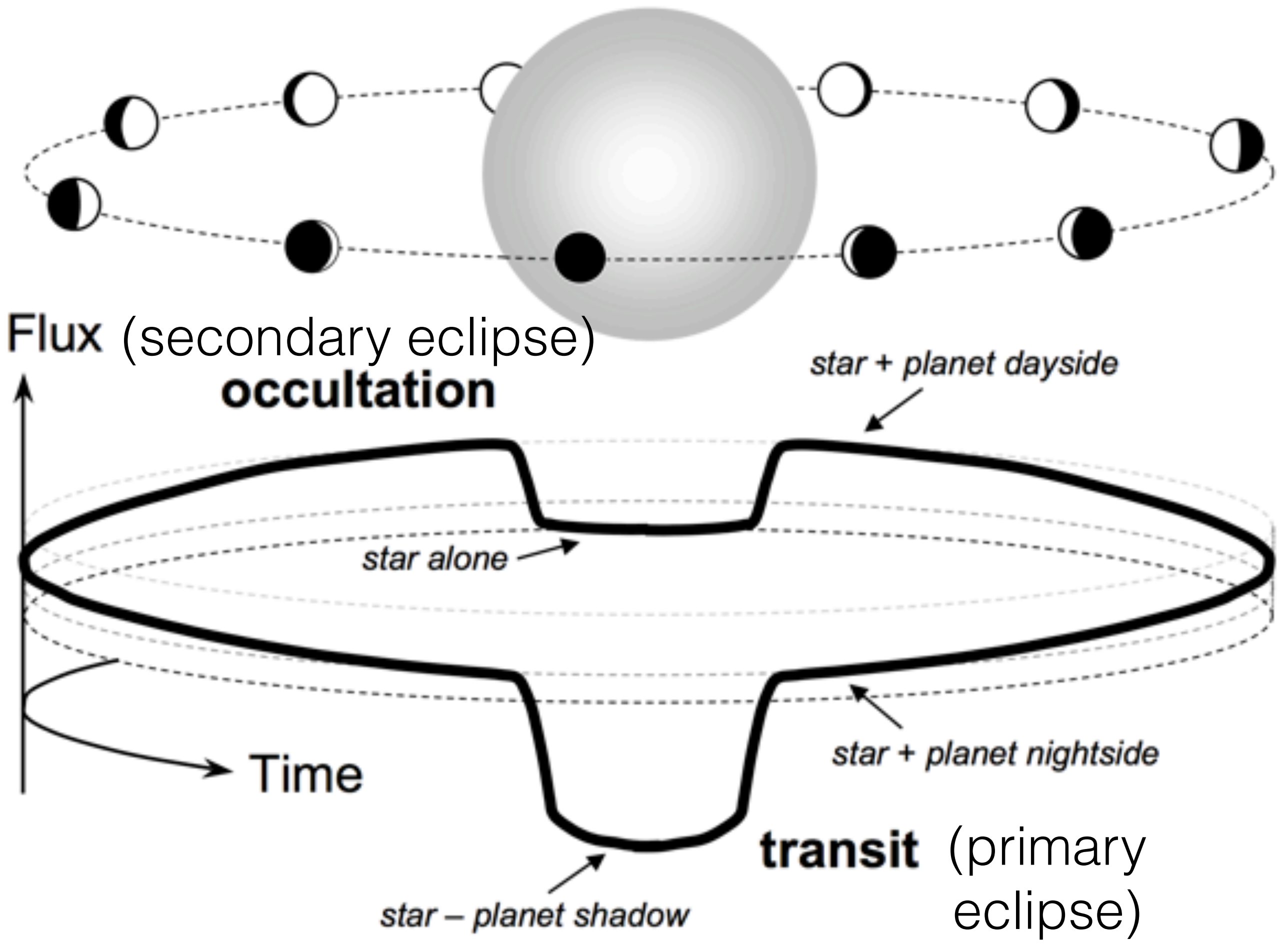
# 30-40% transit (as seen from Earth)



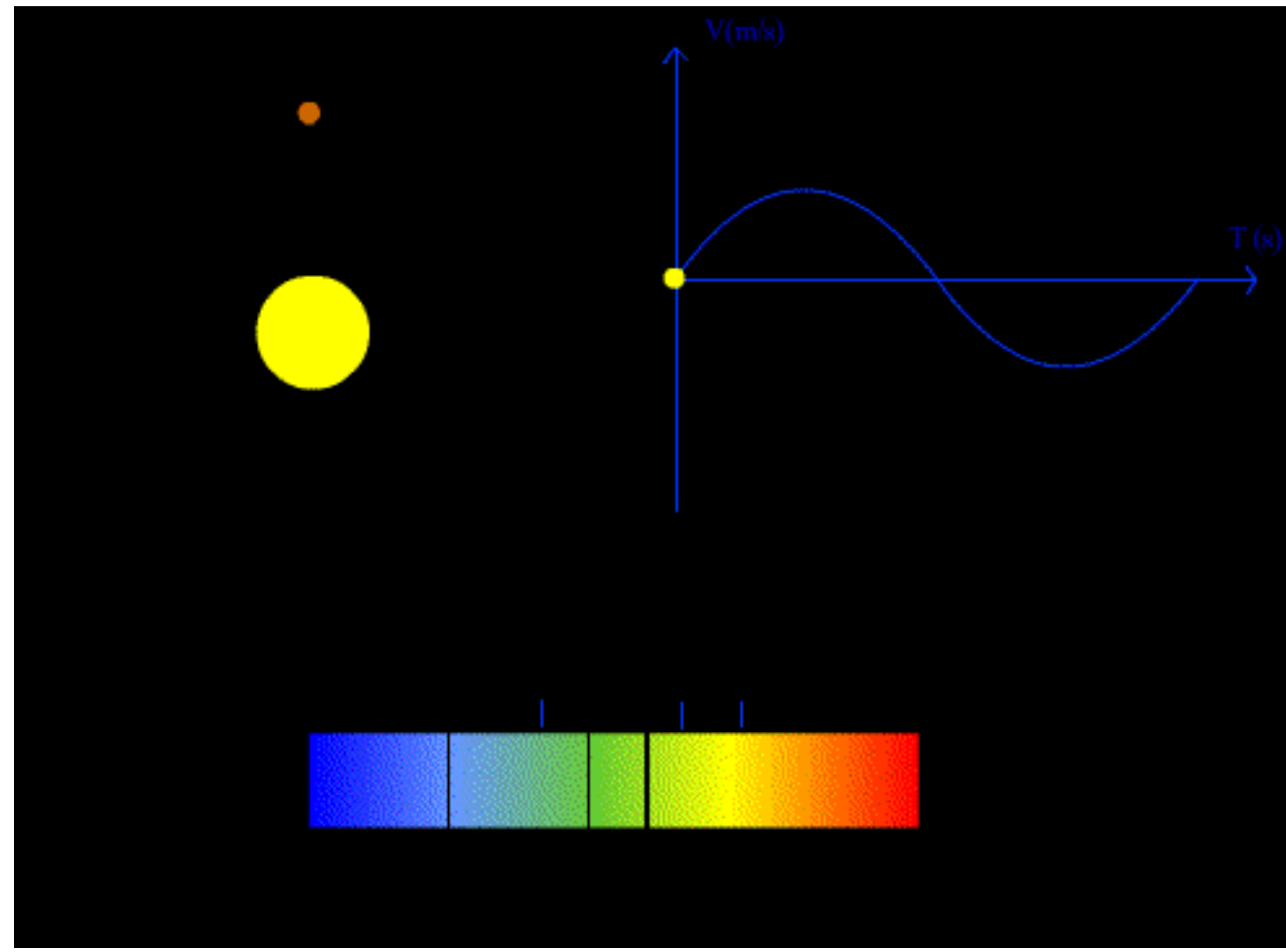
# Why transiting planets?



## The transit technique




## The radial velocity technique



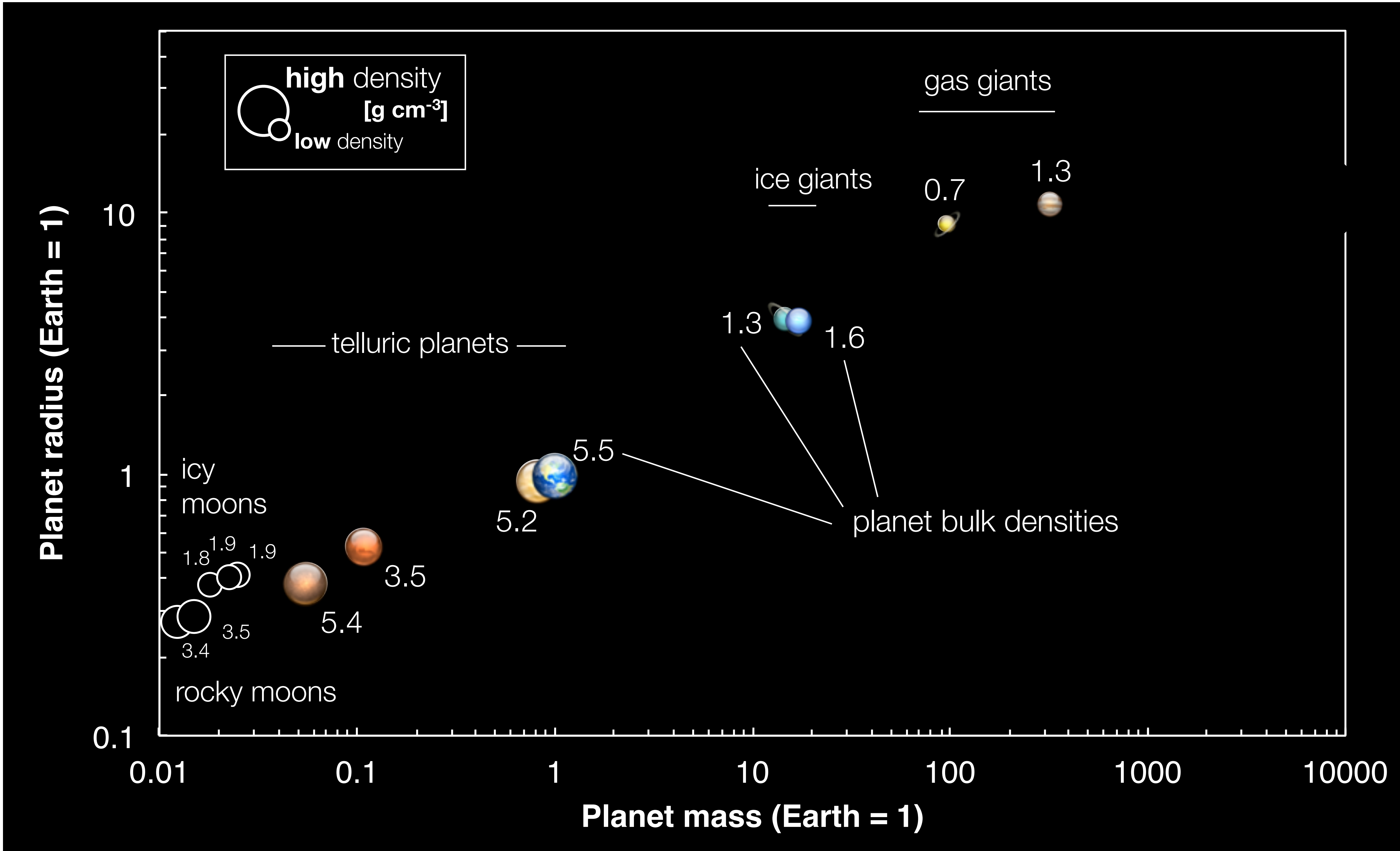

➨ **radius of the planet**

➨ **Mp *sin(i)***

**Mp & Rp ➨ ρp**

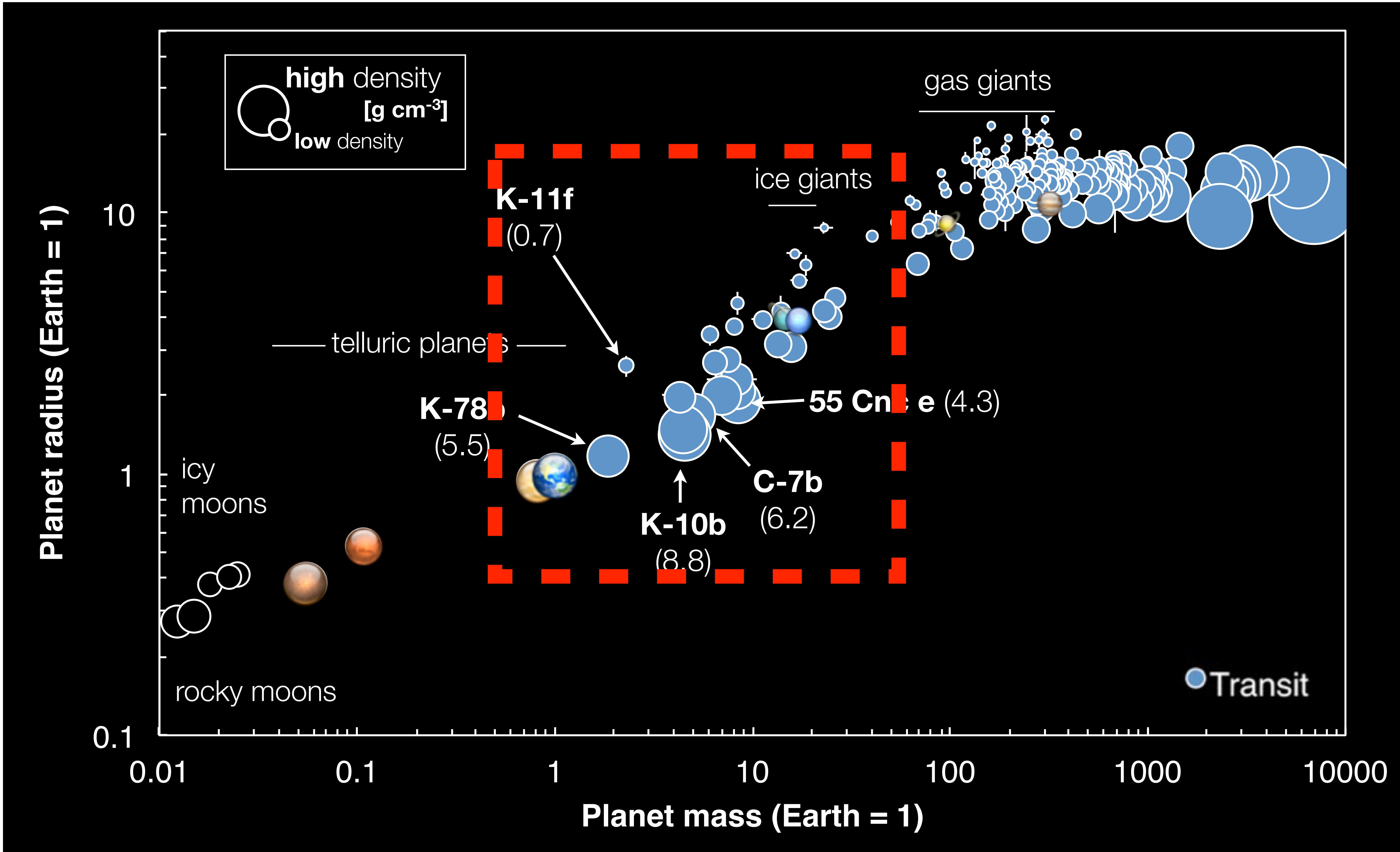
# Mass-radius diagram

## 3 distinct families in the Solar System

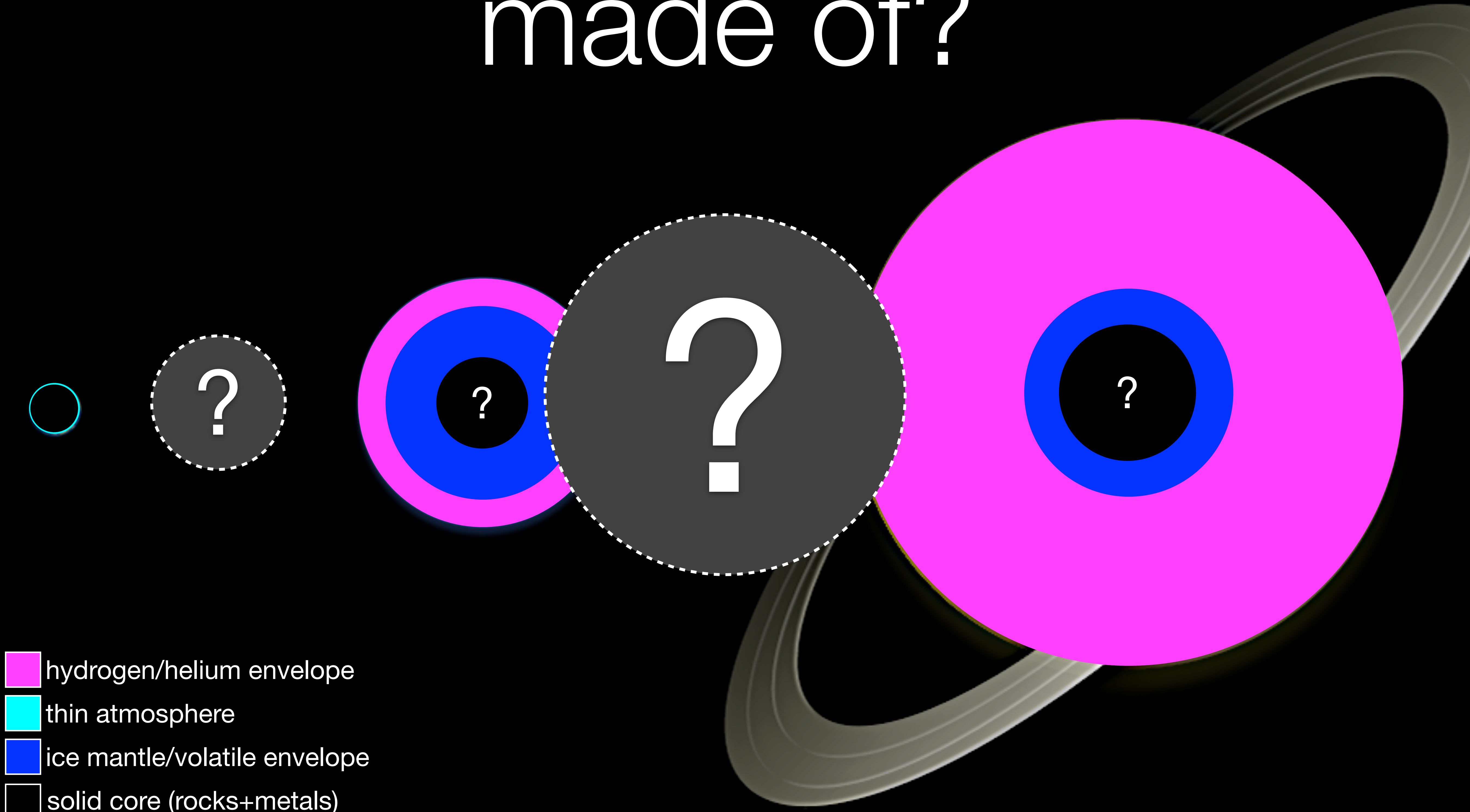


# Mass-radius diagram

## Apparent continuity of masses for exoplanets



# What are exoplanets made of?



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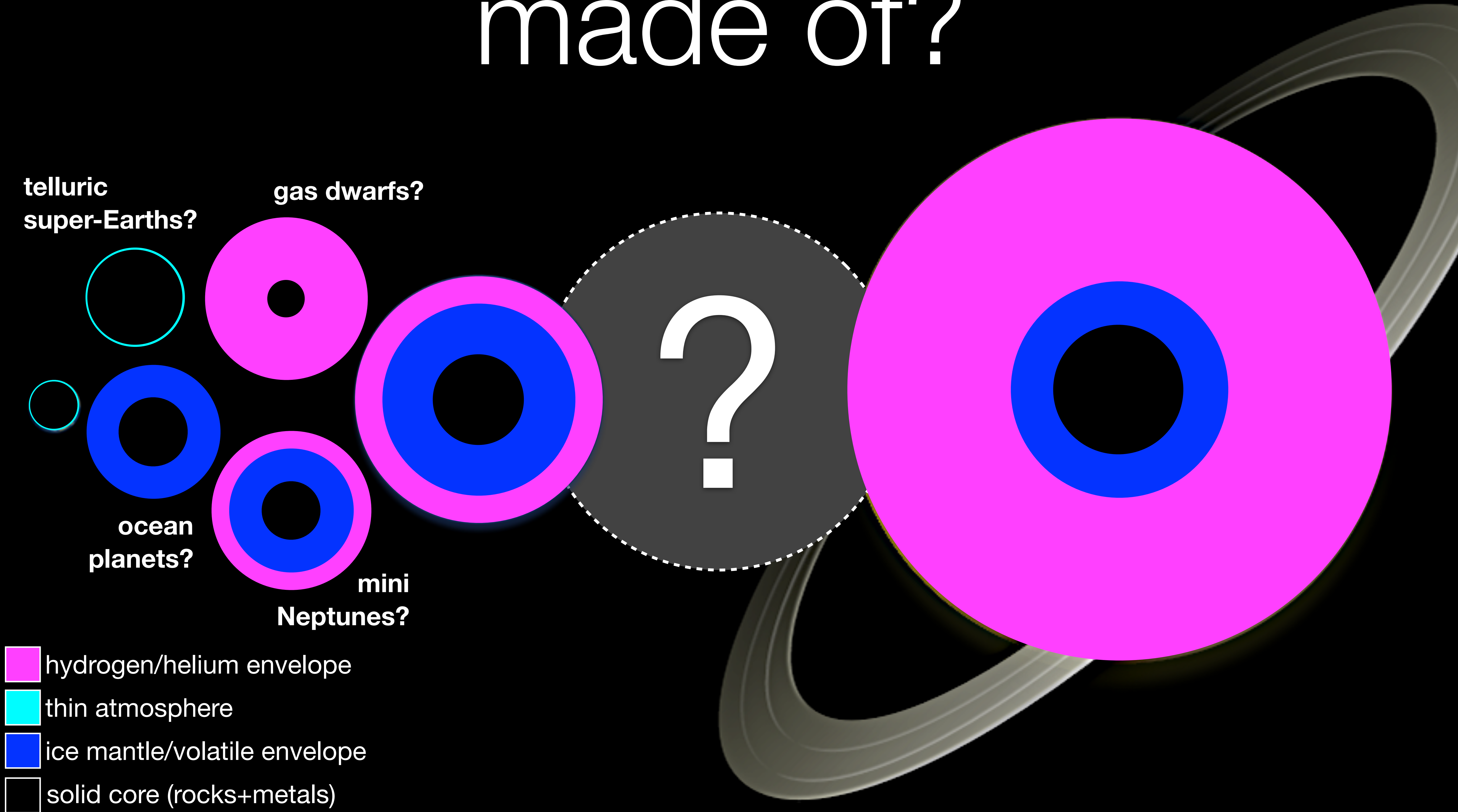
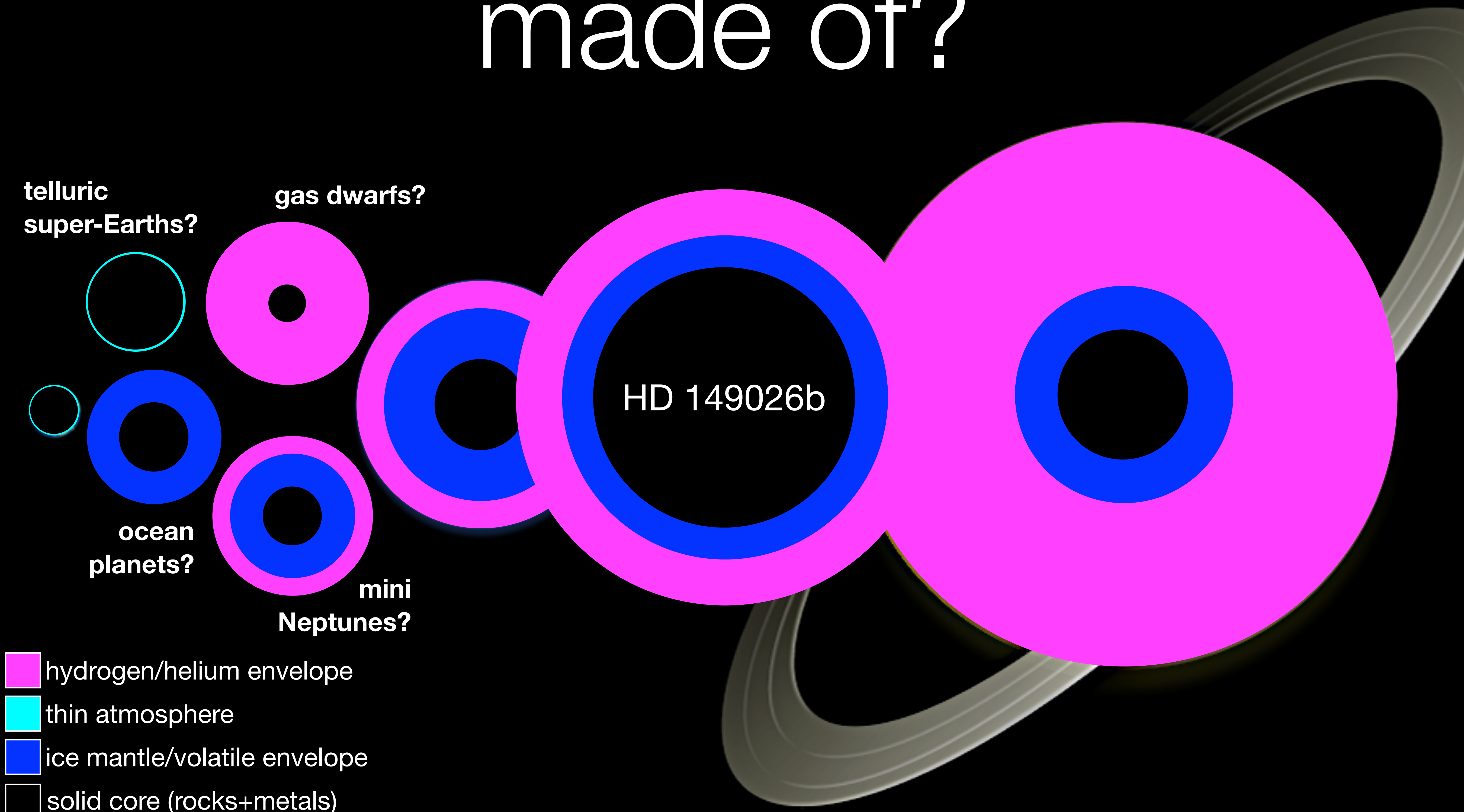
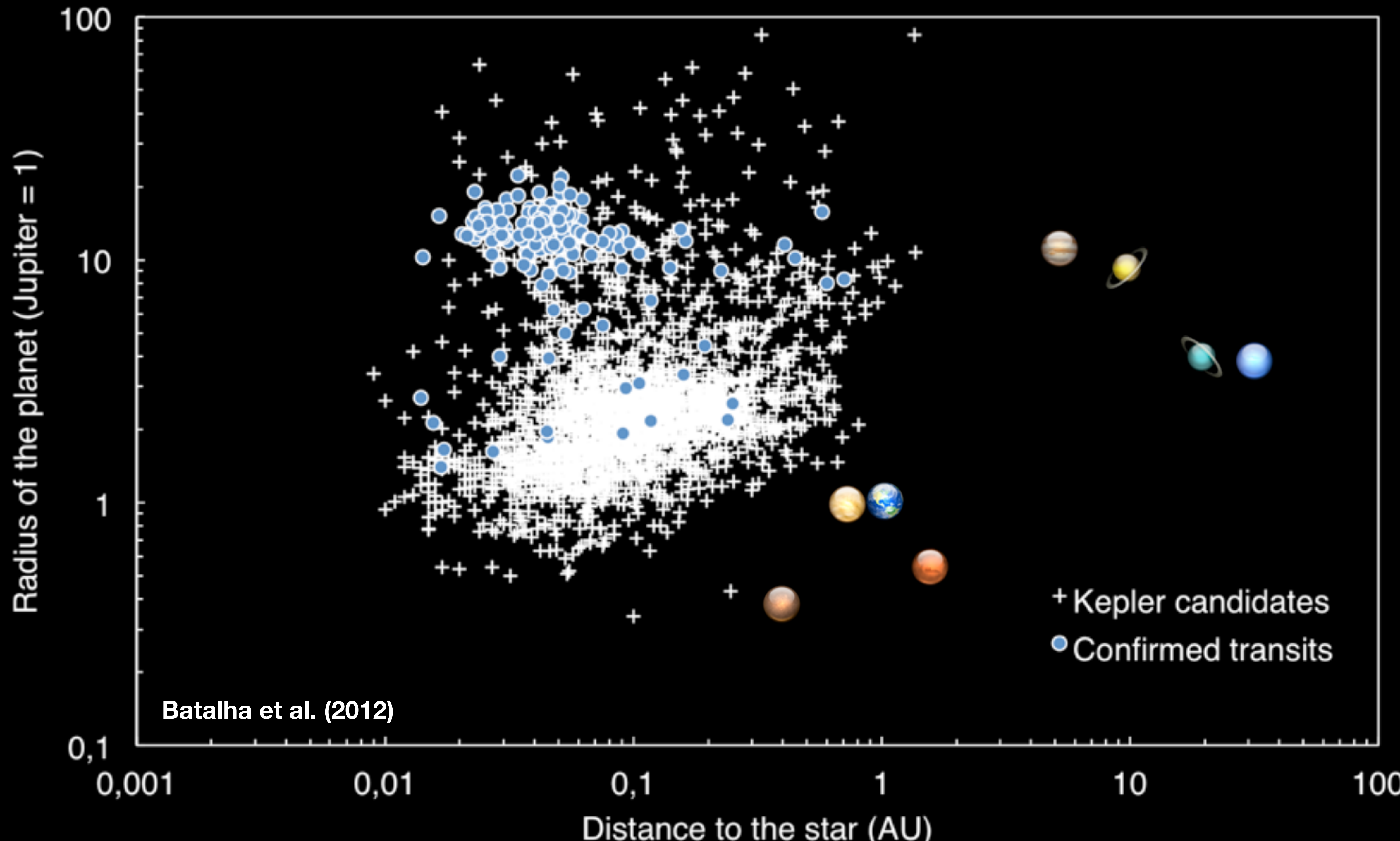


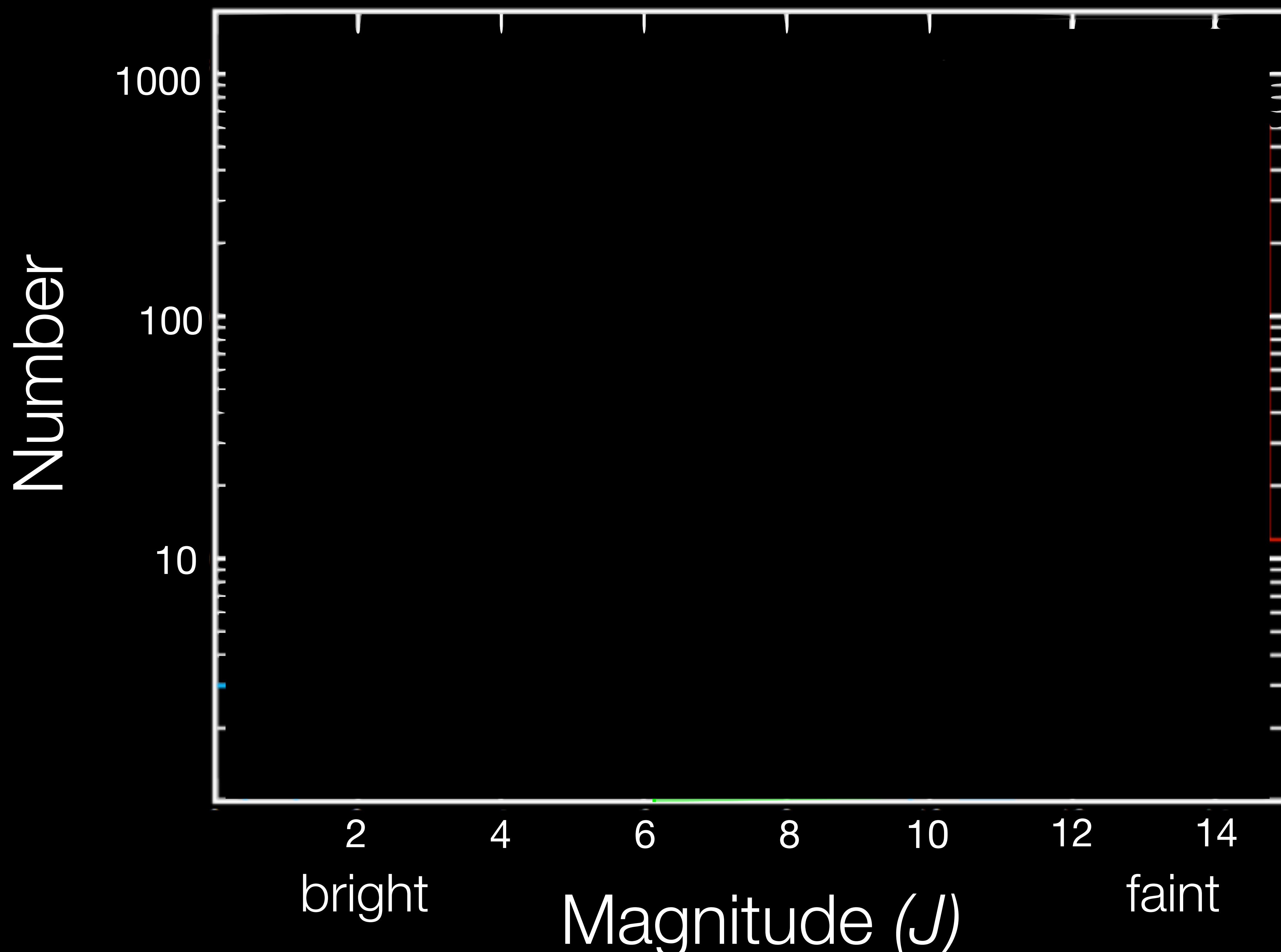
# What are exoplanets made of?



# The *Kepler* revolution

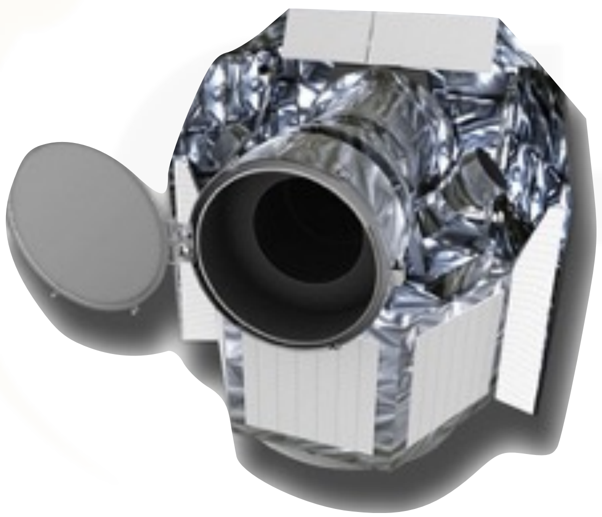


# We need bright transits



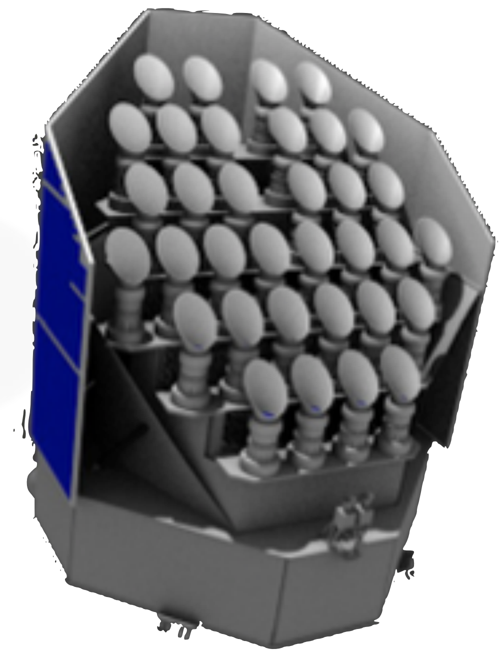
# Targets: bright stars

Better knowledge of the stars
Better knowledge of the planets



**CHEOPS**

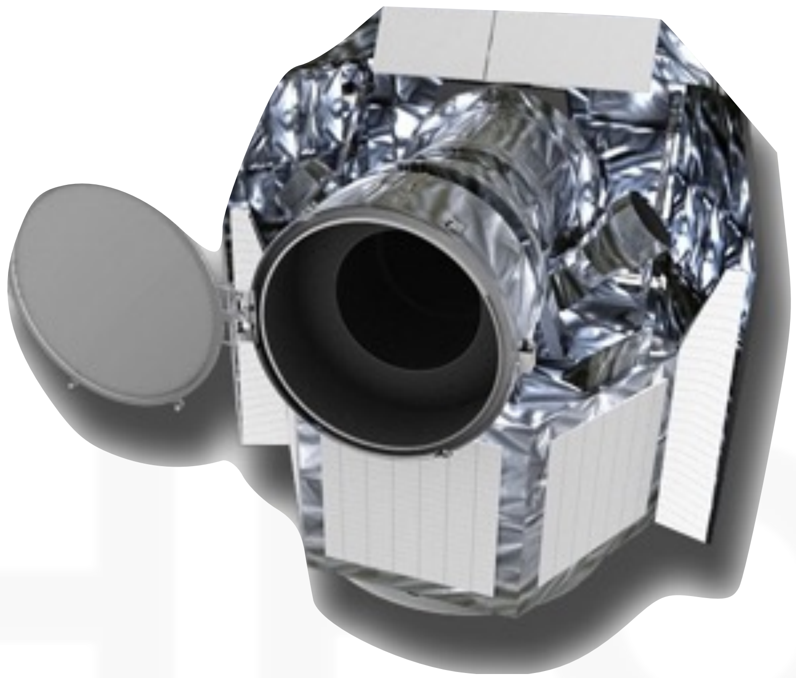
*TESS*



*PLATO*

**H. Rauer's talk**

# ***CHEOPS*** main science goal

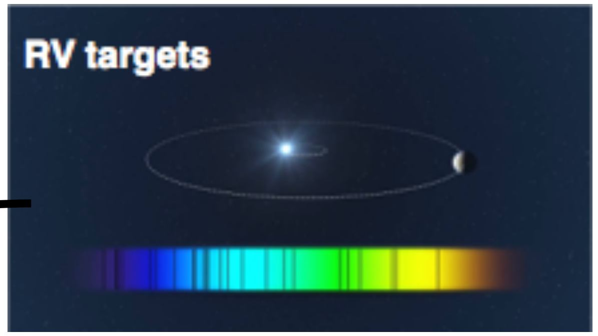


***CHEOPS*** will measure accurate radii & bulk densities of super-Earths & Neptunes orbiting bright stars, provide golden targets for future in-depth atmospheric characterization

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

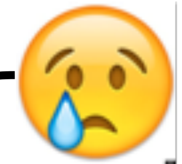
# CHEOPS concept in one slide

Two sets of targets



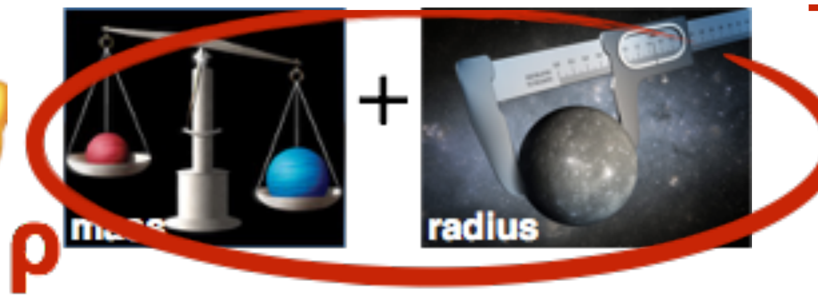

- bright stars (6<V<9)
- close-in planets
- S/N > 5
- an Earth-like planet could be detected!

transit?



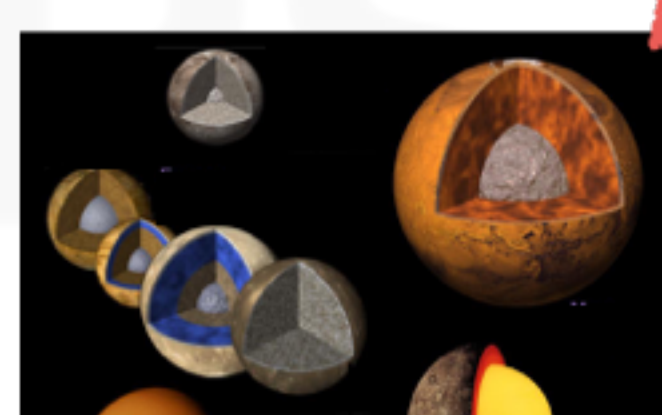
no … well, maybe next one …

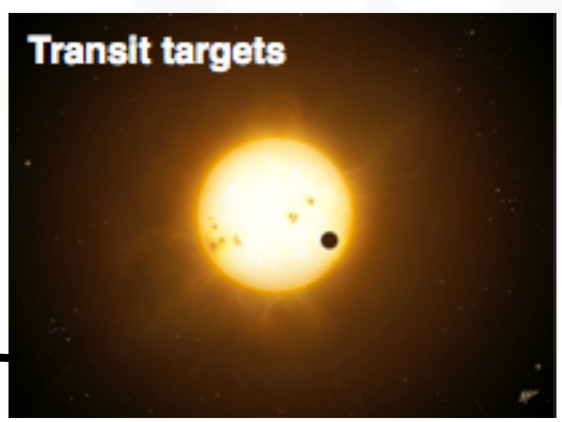
+ models




ρ

composition

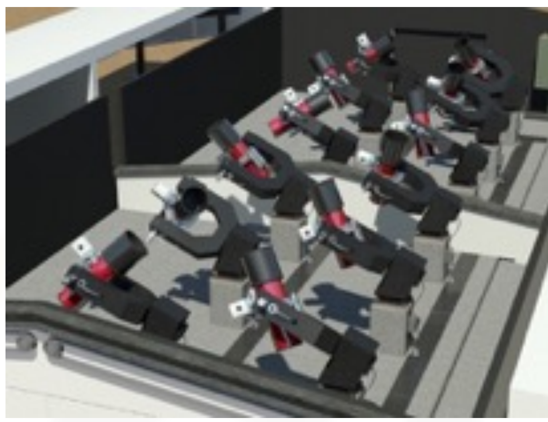





+ ground RVs

- fainter stars (9<V<12)
- close-in planets Neptune-like planets
- S/N > 30
- excellent radius determination

# ***CHEOPS*** strategy: follow-up

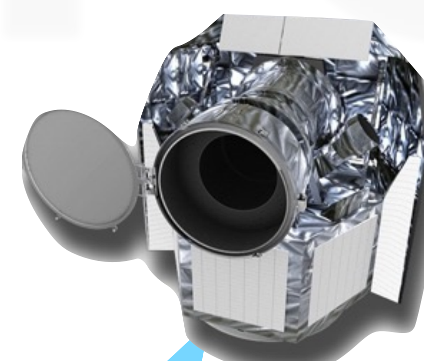


Ground-based transit surveys
NGTS

*TESS*
*(2017)*

*K2*

**Measure accurate light curves for Neptunes**



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

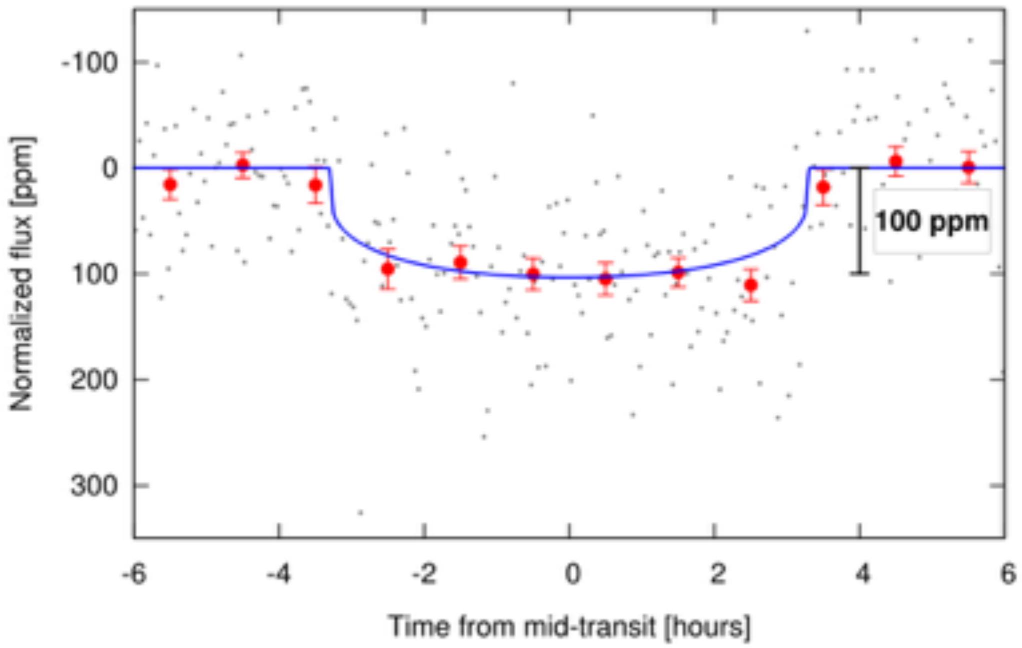
**20% open time**
(3.5-yr mission)

# Photometric accuracy

- CHEOPS Science Requirements

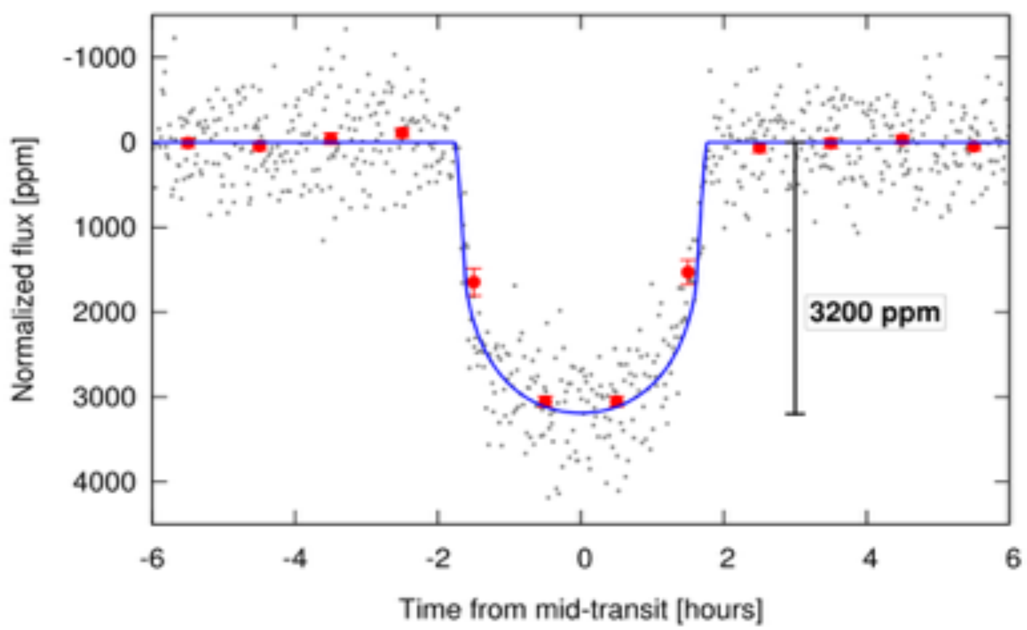
**Photometric accuracy for Earth and Super-Earth detection: 20 ppm over 6 hour transit**

6<V<9, G5 dwarf stars, $P_{planet}$ ~ 50 days → primary target coming from RV surveys

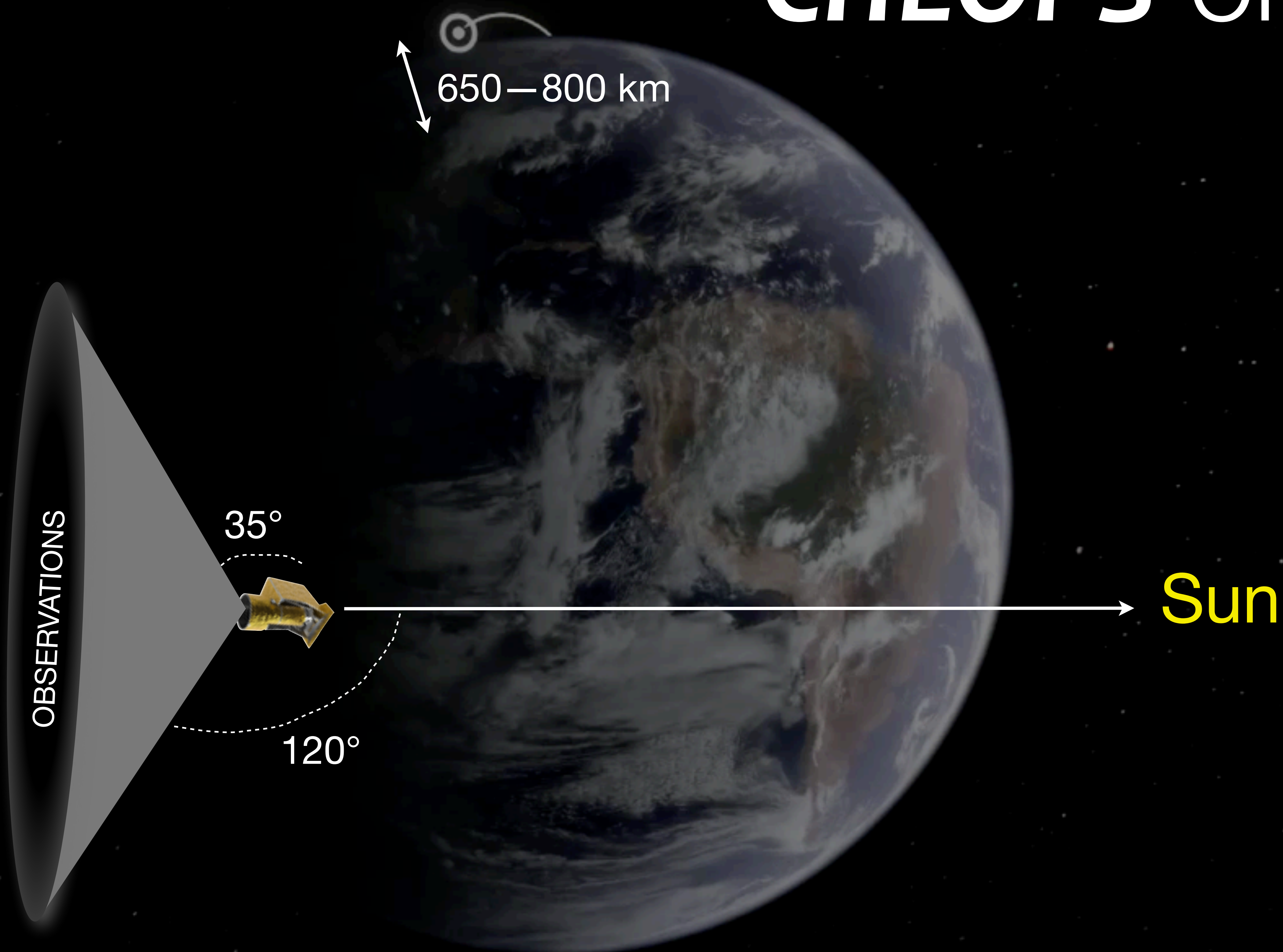



**Photometric accuracy for Neptune characterisation: 85 ppm over 3 hour transit**

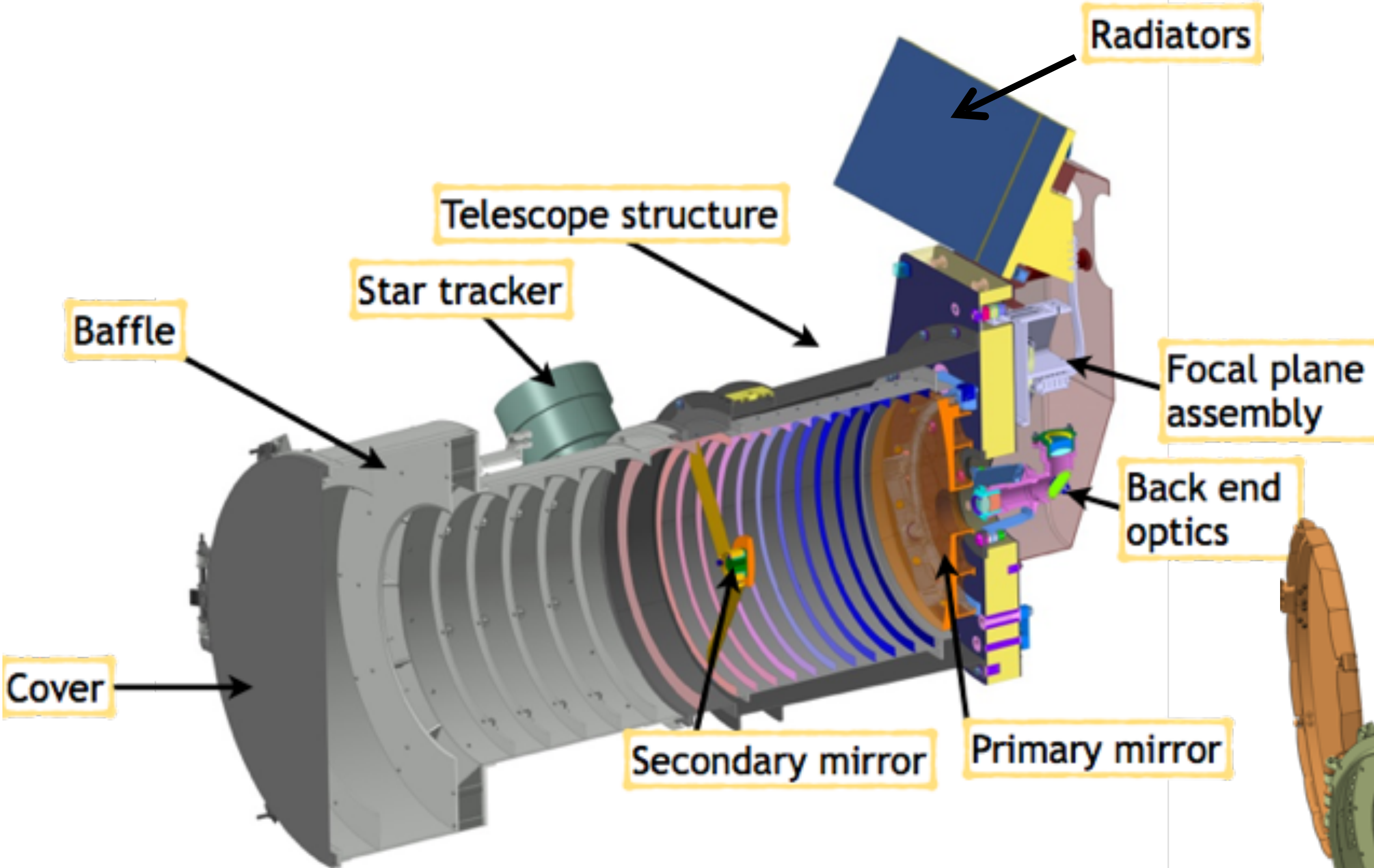
9<V<12, K dwarf stars, $P_{planet}$ ~ 13 days → primary targets coming from NGTS survey



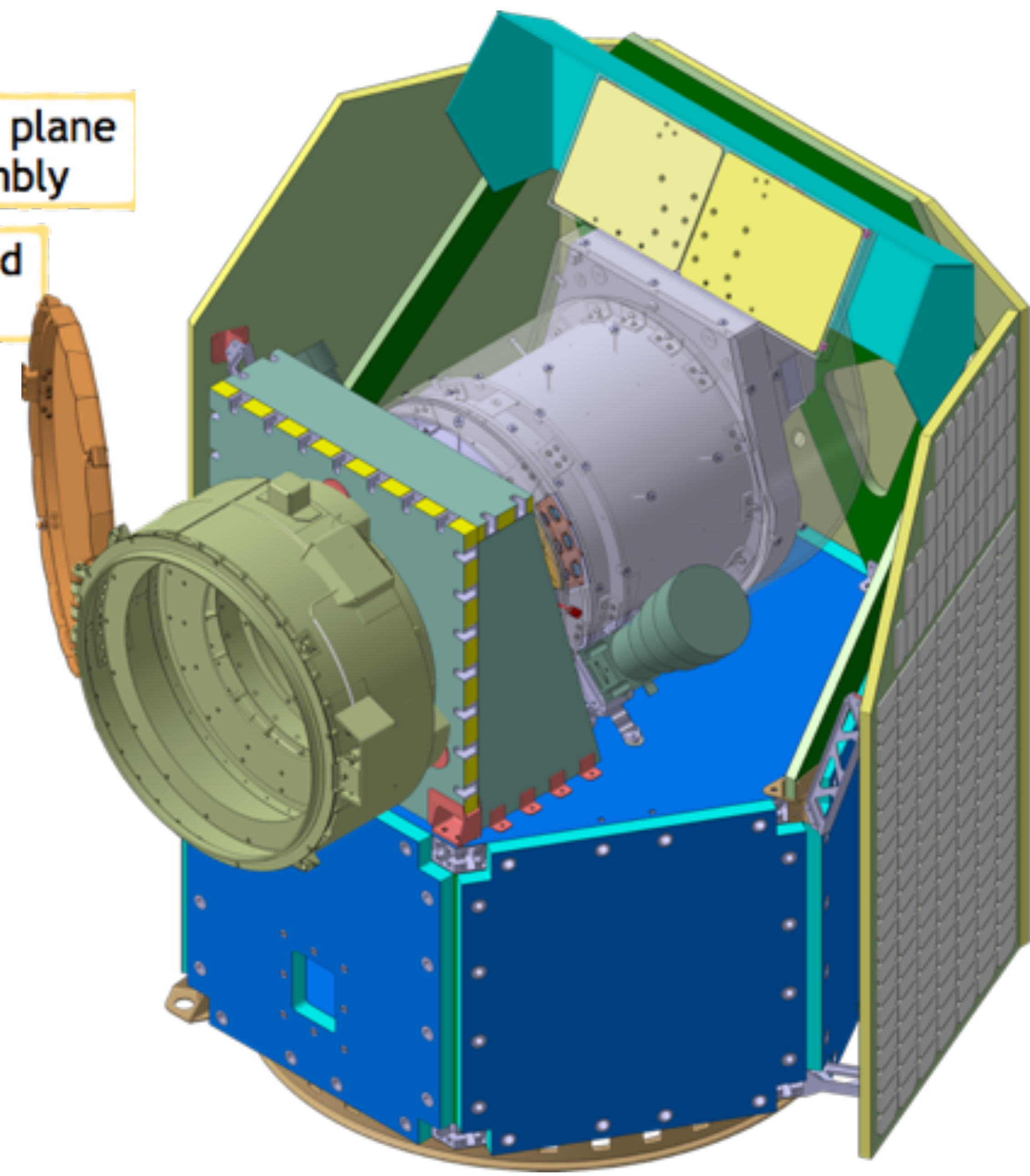
# *CHEOPS* orbit



# CHEOPS Instrument




## Platform

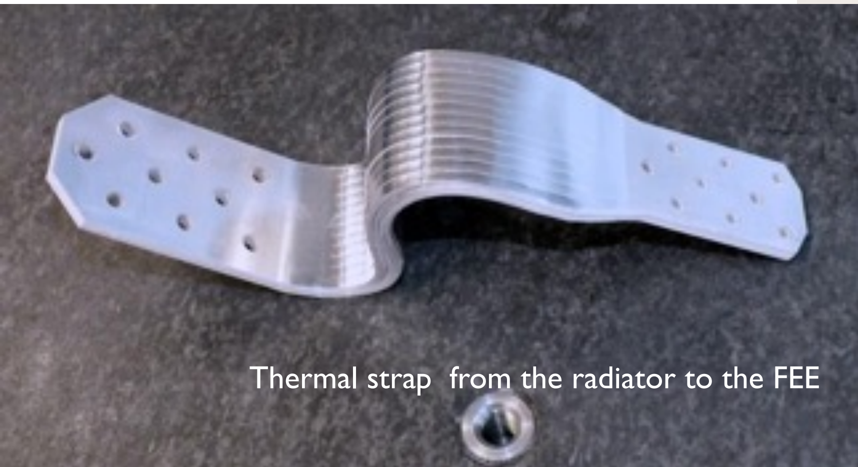


## CHEOPS Instrument System

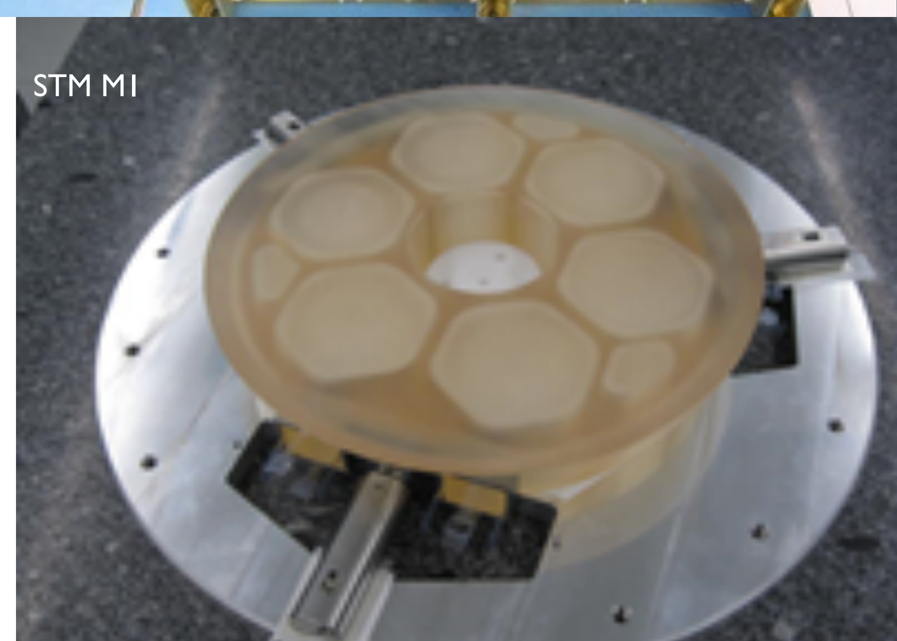
- 30 cm effective diameter on axis telescope
- payload mass: 60 kg
- total mass (payload + platform): 280 kg

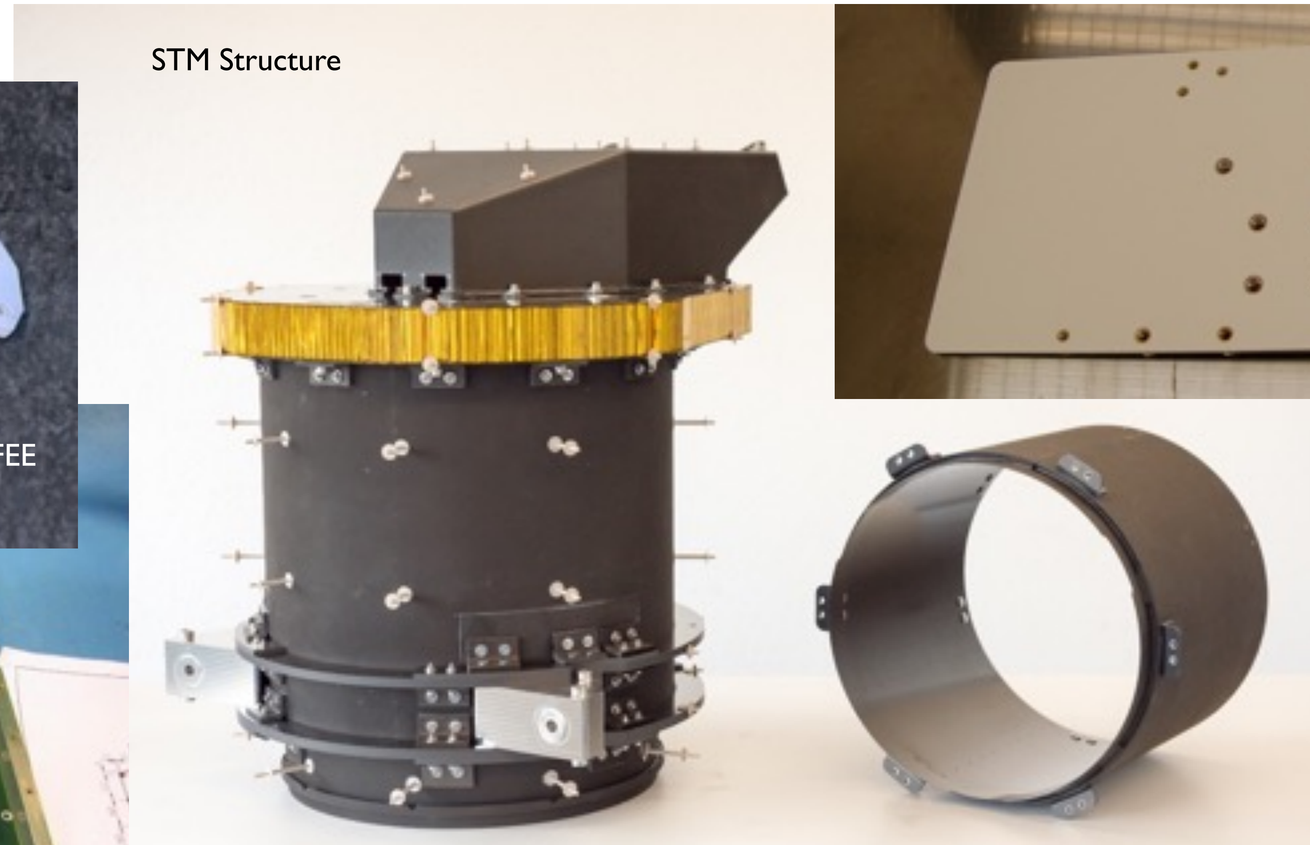
# CHEOPS Instrument System

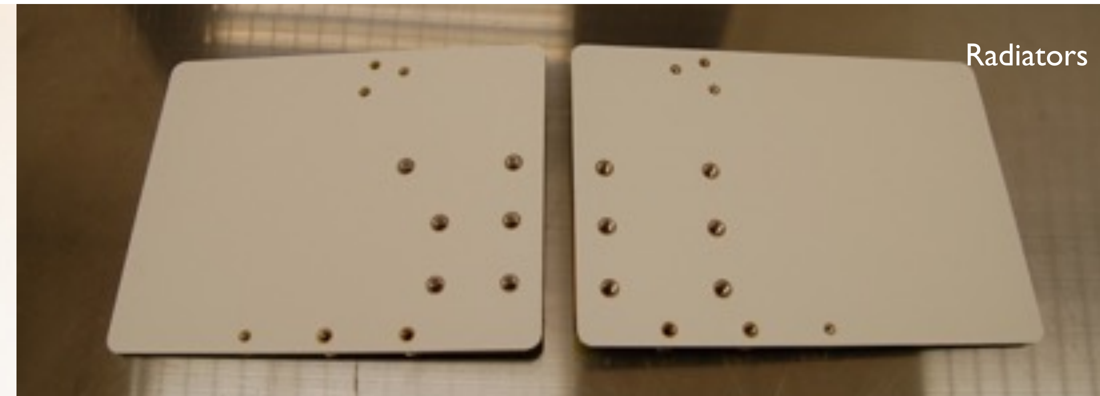
## STRUCTURAL AND THERMAL MODEL COMPONENTS



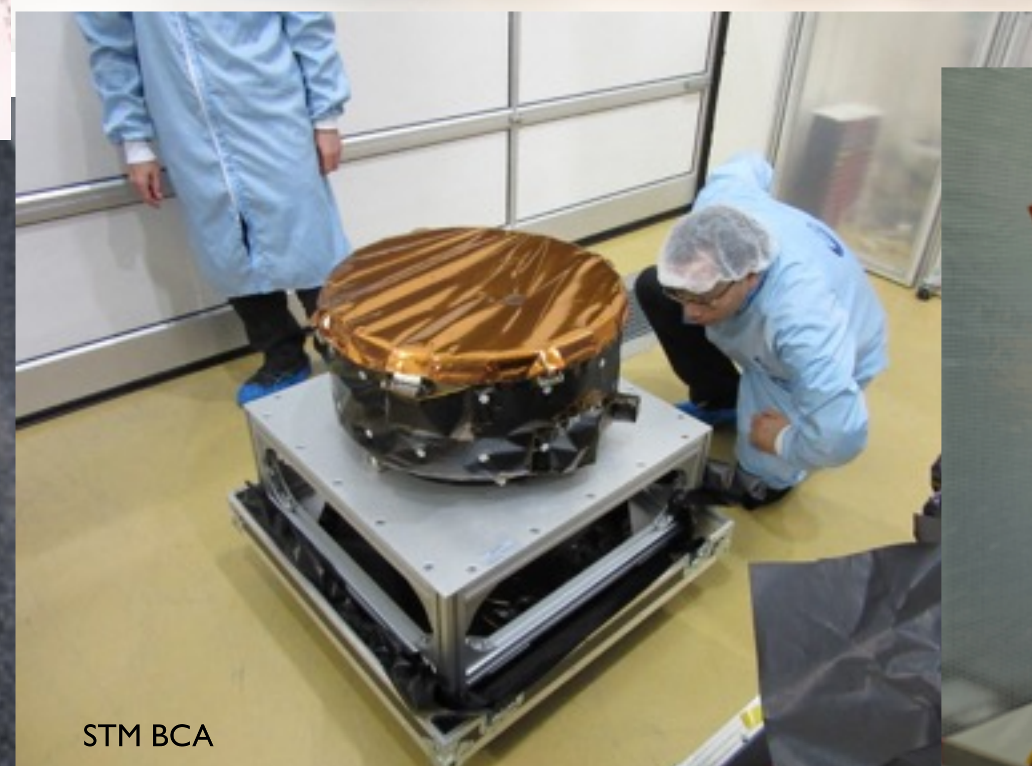


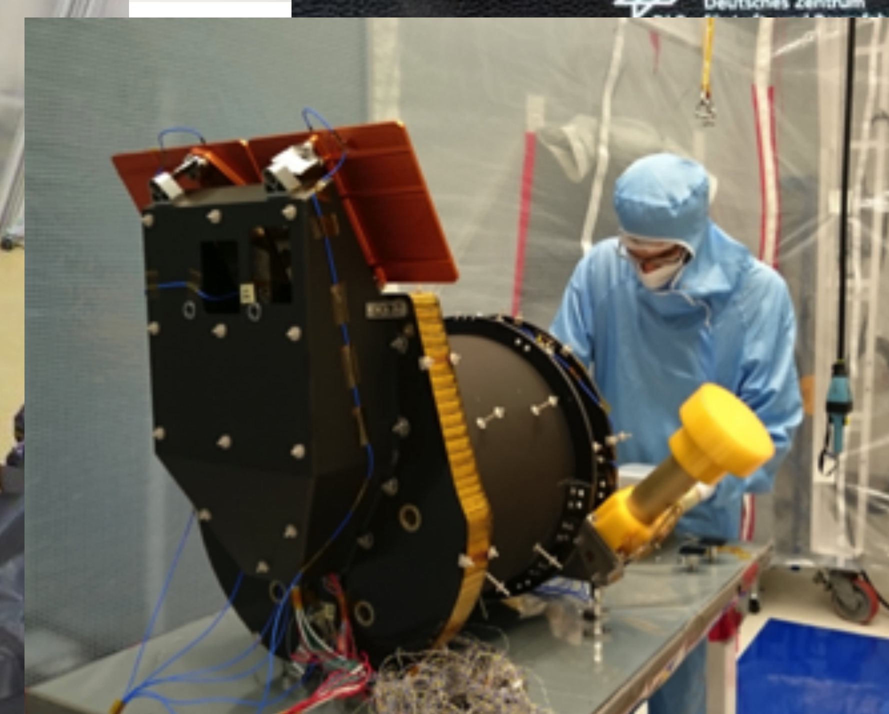


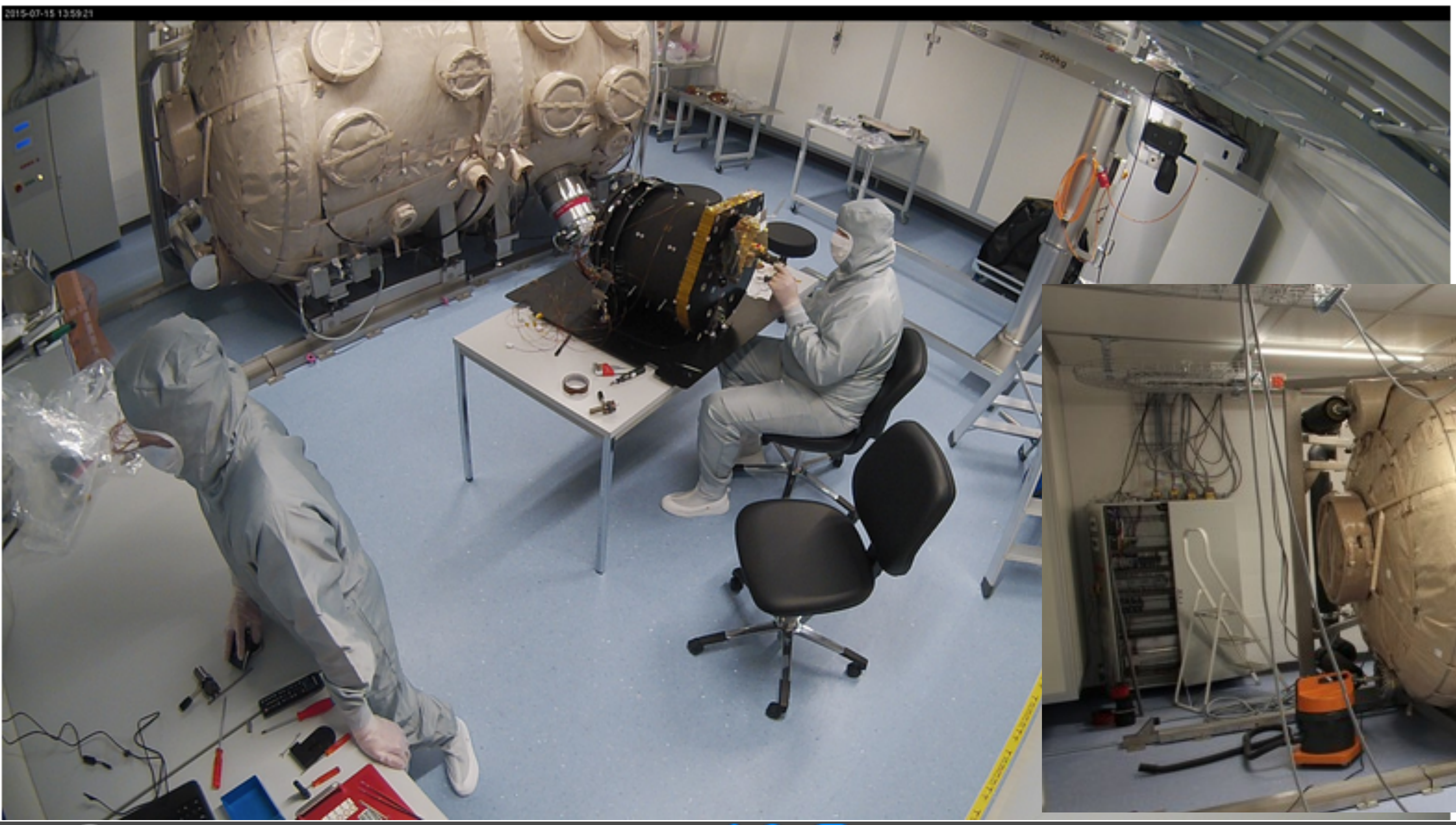


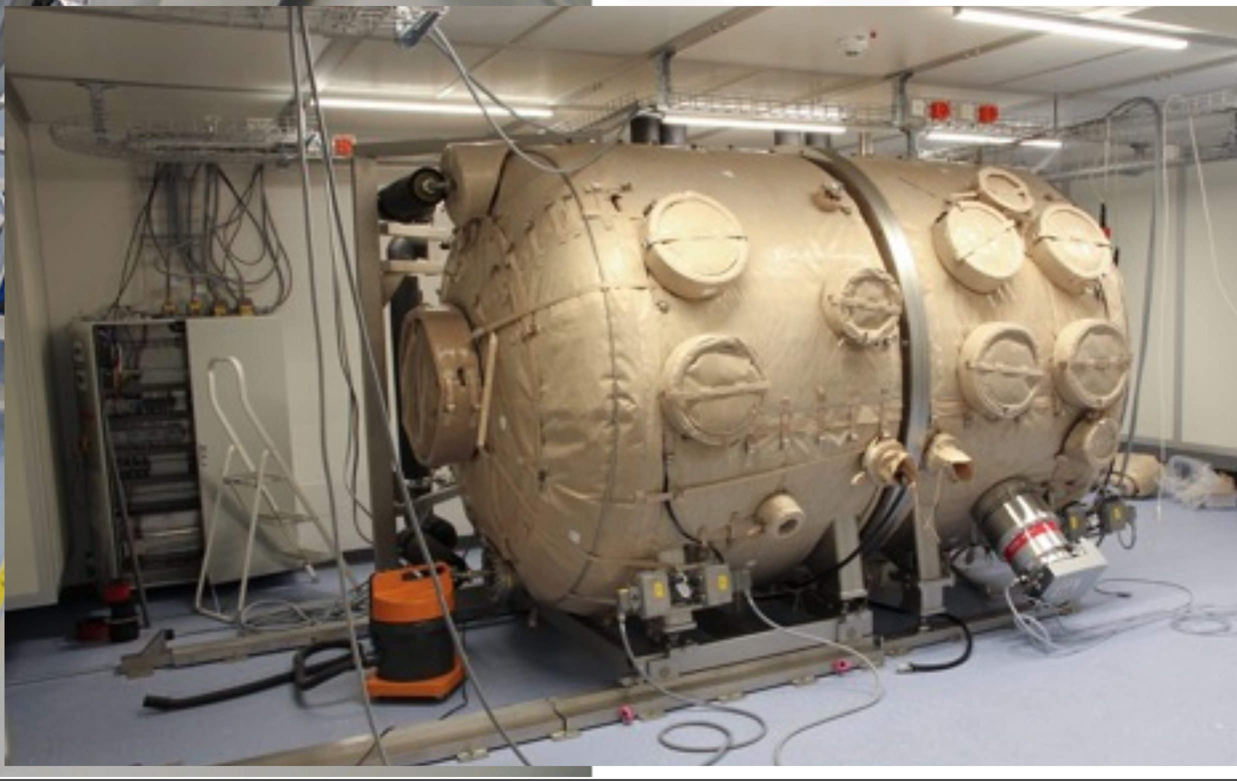


# Lab @ UniBe

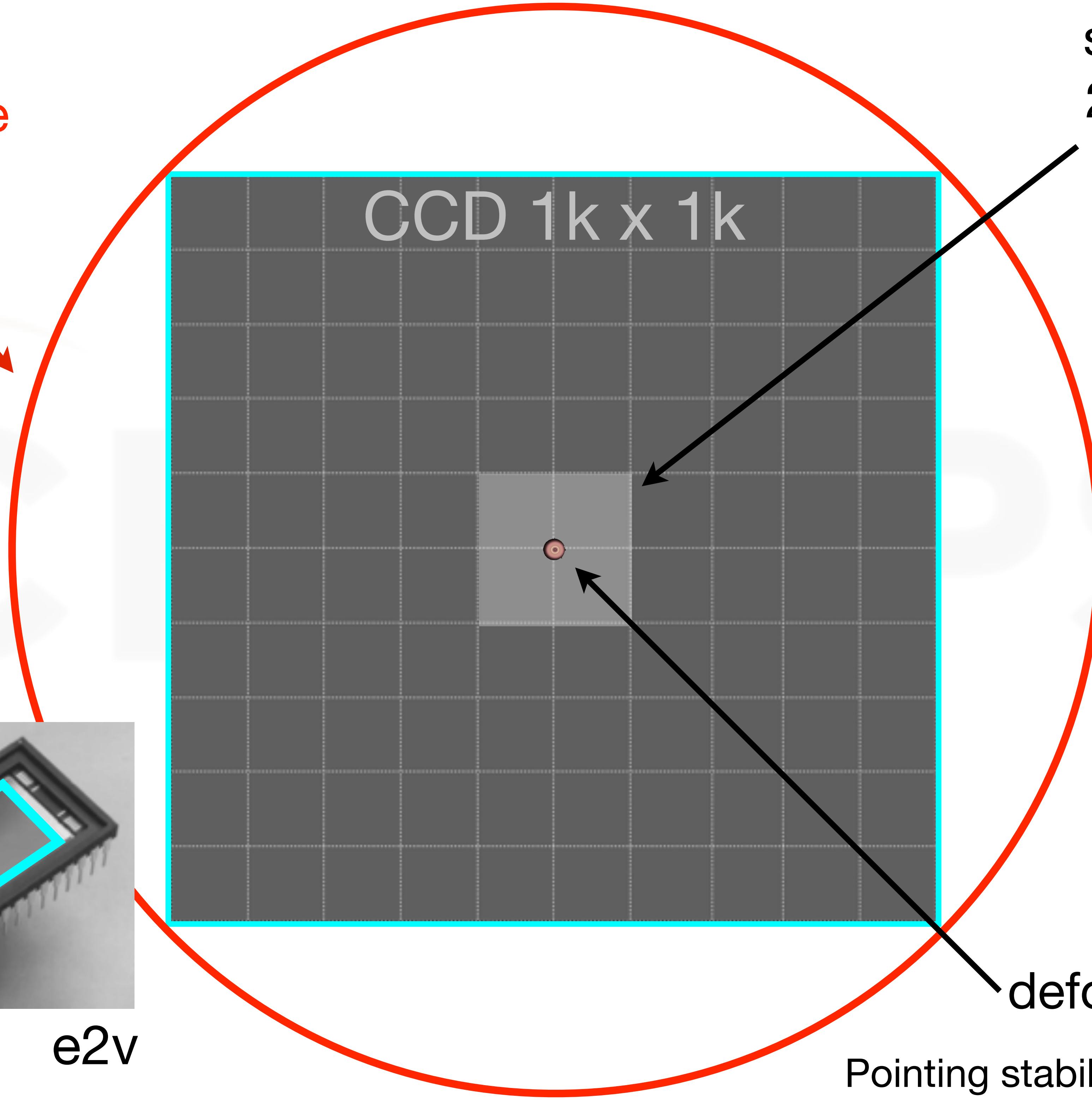
- Clean room and TVC ready
- Tests on Structural Thermal Model components (test components) have been tested a few weeks ago





# Focal plane

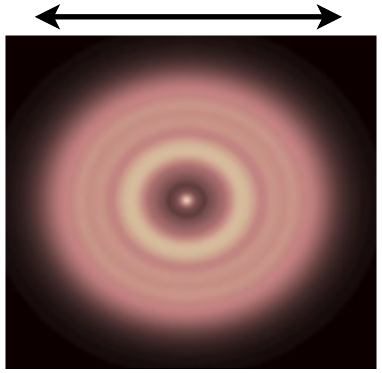
telescope FoV: 20’



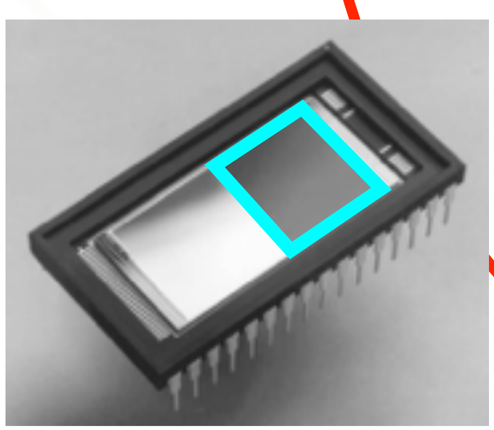

subarray image 200×200 pixels (4 arcmin$^2$)

stacked & downloaded to the ground 1 min$^{-1}$

30 pixels (30”)



defocused PSF

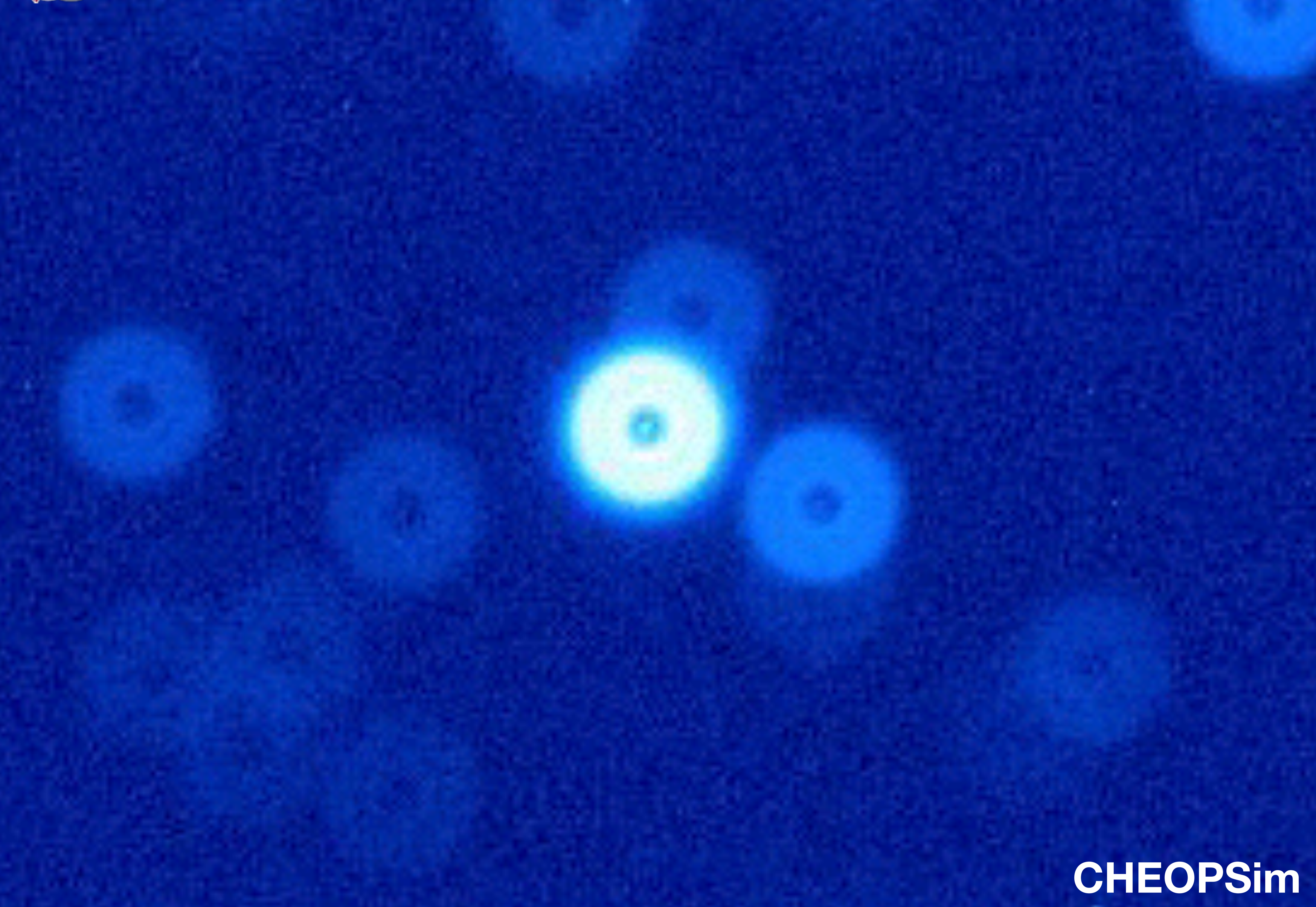


e2v

Pointing stability: 4” (rms) jitter
p-flat precision: 0.1% pixel-to-pixel

# Observation simulation

CHEOPS



# CHEOPS nominal duration

- **What to expect?**

- After 3.5 years of operations we would have observed:
  - ~ 150 RV targets → **how many transits?**
  - ~ 110 already known transiting planets

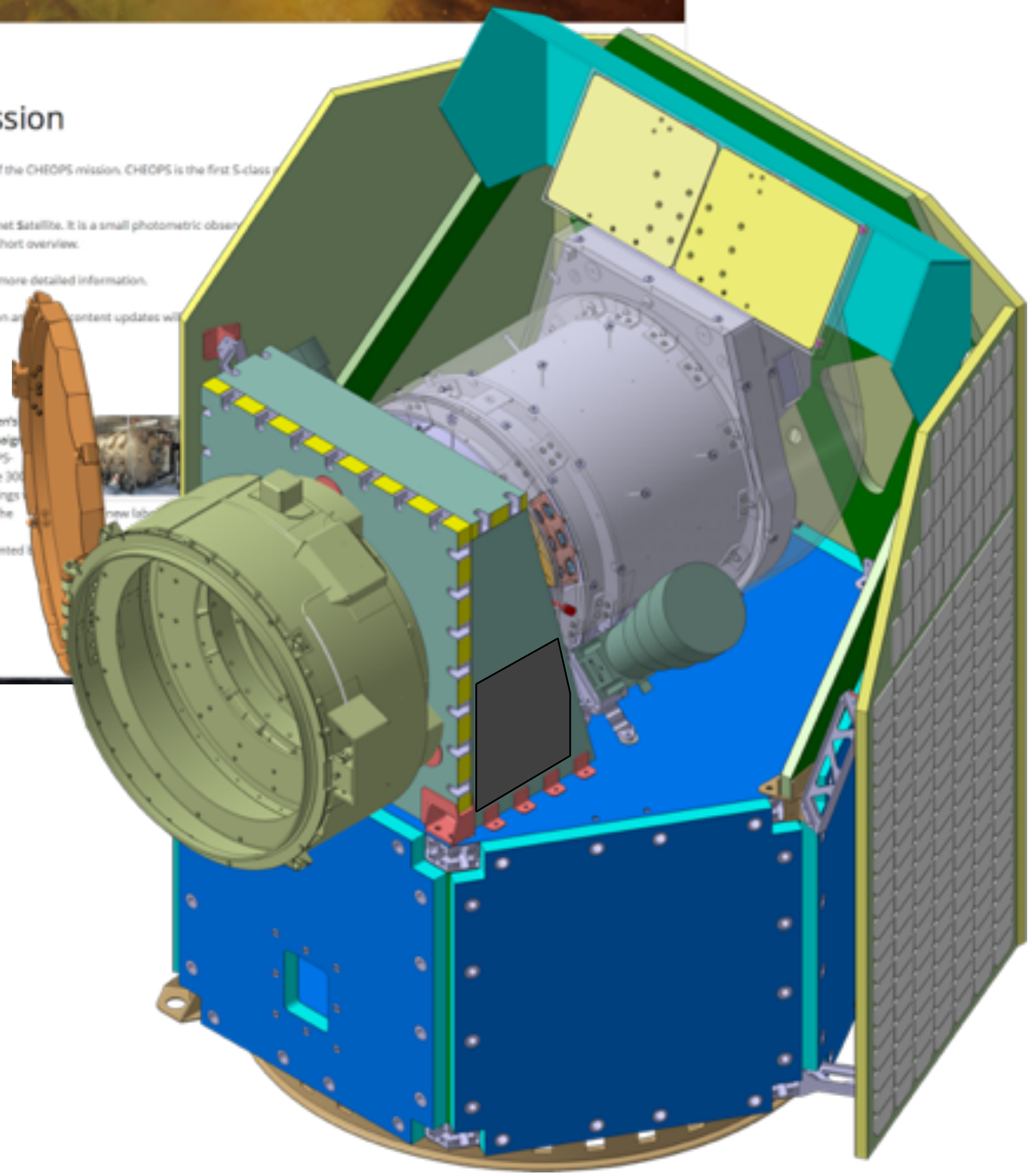
# CHEOPS Open Time

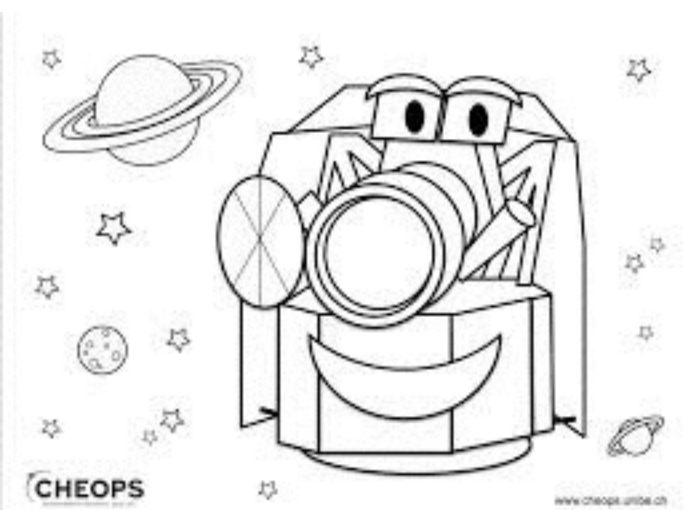
- 20% open time for the community
  - ~6'100 hours, equivalent to 600-800 "nights"
- Competitively attributed by ESA
  - 1 Announcement of Opportunity/year
- Cycle 1: Announcement of Opportunity
  - mid-2017

# Outreach

- CHEOPS website
  - CHEOPS paper model for download
  - Transit simulator paper model for download
- School plate
  - drawing collection information online
  - Location of school plate defined (detailed interface on-going)
  - Drawing format defined
  - First Swiss drawings collected

**http://cheops.unibe.ch/**

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# *CHEOPS* is a photometric observatory looking at one object at a time

- ***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*** can point at any location over more than 50% of the sky
  - ➡ Can choose the best targets for transit search
  - ➡ Can confirm transiting planets on longer orbits (e.g., for *TESS*)
  - ➡ Can search for additional planets
  - ➡ Can measure phase curve of short period giant planets
  - ➡ Can detect TTV in planetary systems
  - ➡ Can search additional objects (moons, rings, …)

- ***CHEOPS*** will have 20% time opened to the community