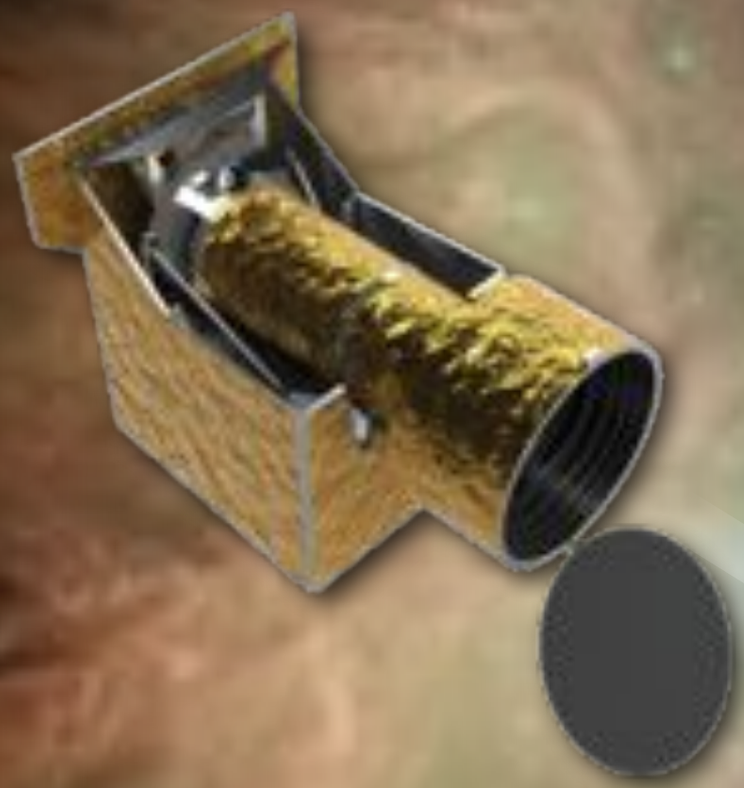
CHEOPS

CHARACTERIZING EXOPLANETS SATELLITE



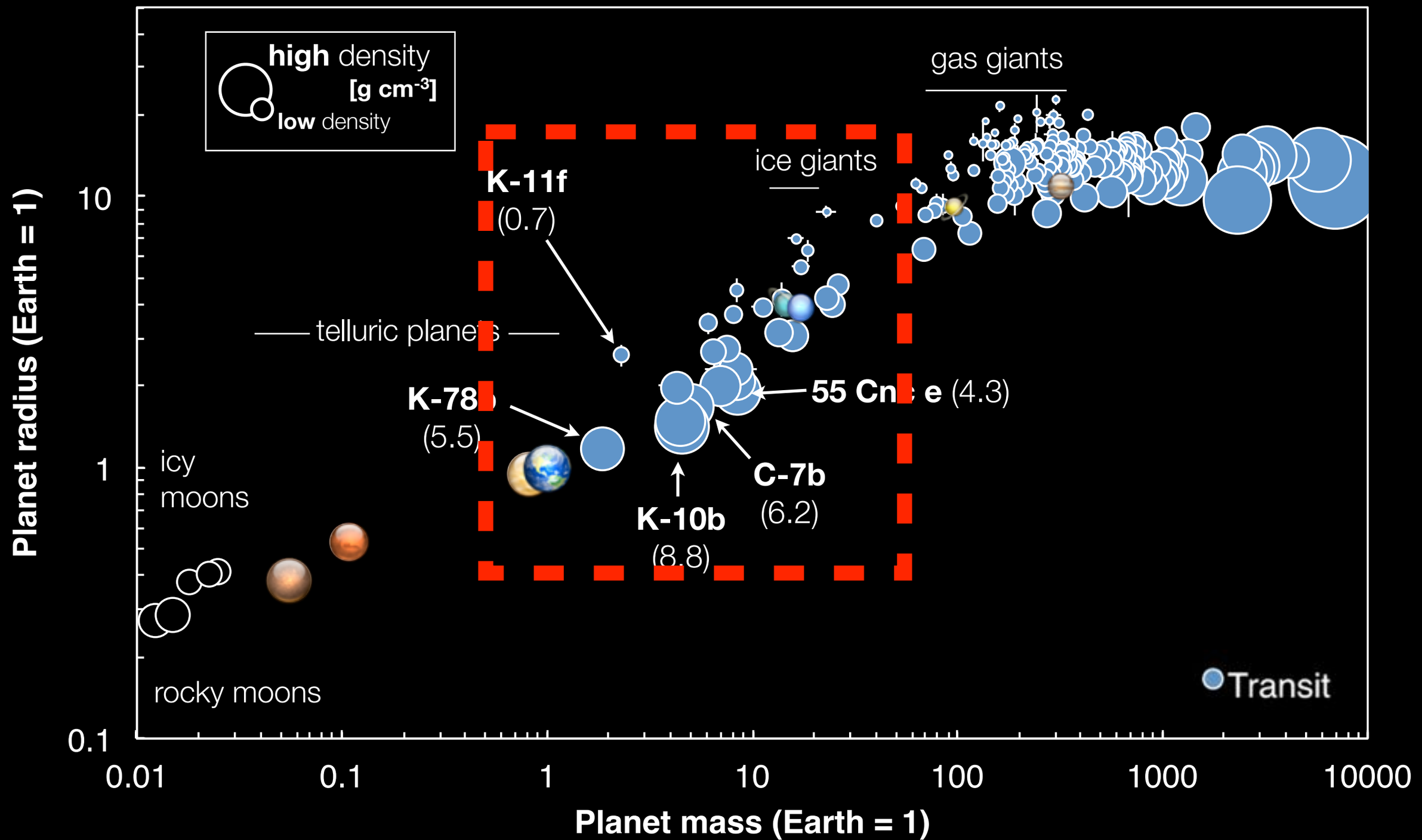
esa's first small-class mission

David Ehrenreich
CHEOPS Mission Scientist

UNIVERSITÉ DE GENÈVE

Mass-radius diagram

Apparent continuity of masses for exoplanets



What are exoplanets made of?

Corot-7b
Léger+ 2009

Kepler-78b
Pepe+, Howard+ 2013

Kepler-11f
Lissauer+ 2011

GJ 3470b
Bonfils+ 2012

HD 149026b
Sato+ 2005

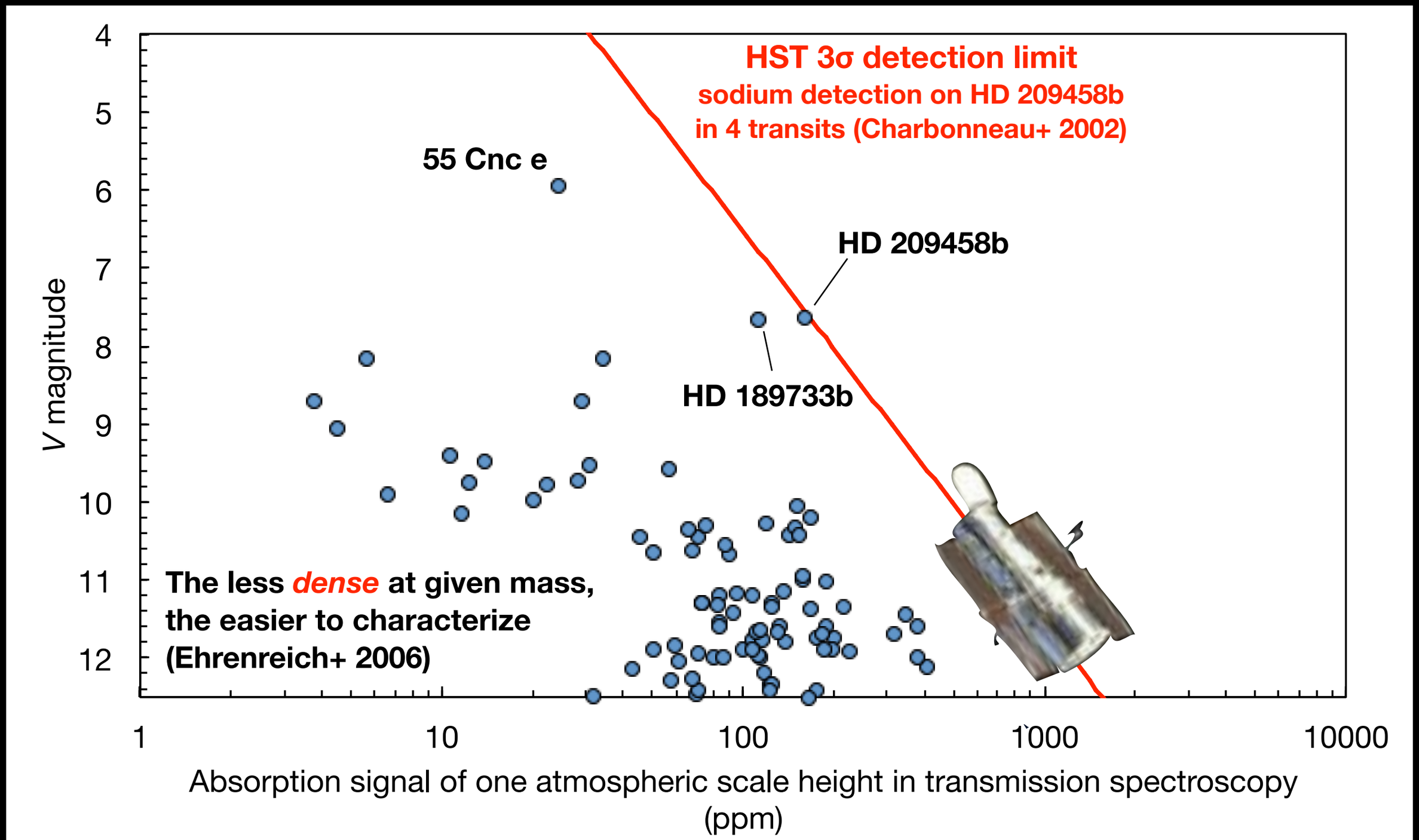
55 Cnc e
Winn+, Demory+ 2011

GJ 1214b
Charbonneau+ 2009

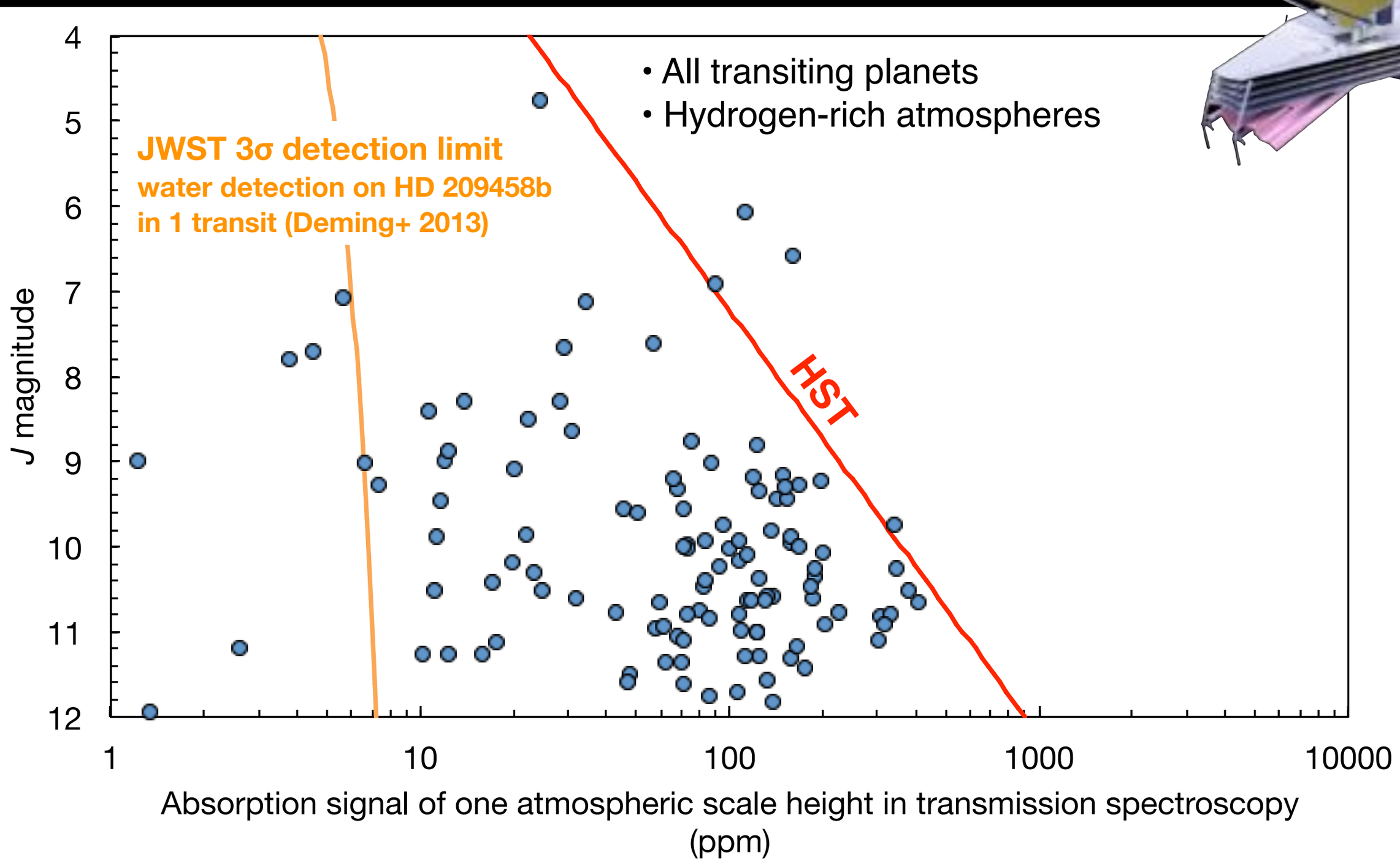
- hydrogen/helium envelope
- thin atmosphere
- ice mantle/volatile envelope
- solid core (rocks+metals)

Constraints based on bulk densities

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



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



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

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

JWST 3σ detection limit
water detection on HD 209458b in 1 transit (Deming+ 2013)

HST

J magnitude

4
5
6
7
8
9
10
11
12

1
10
100
1000
10000

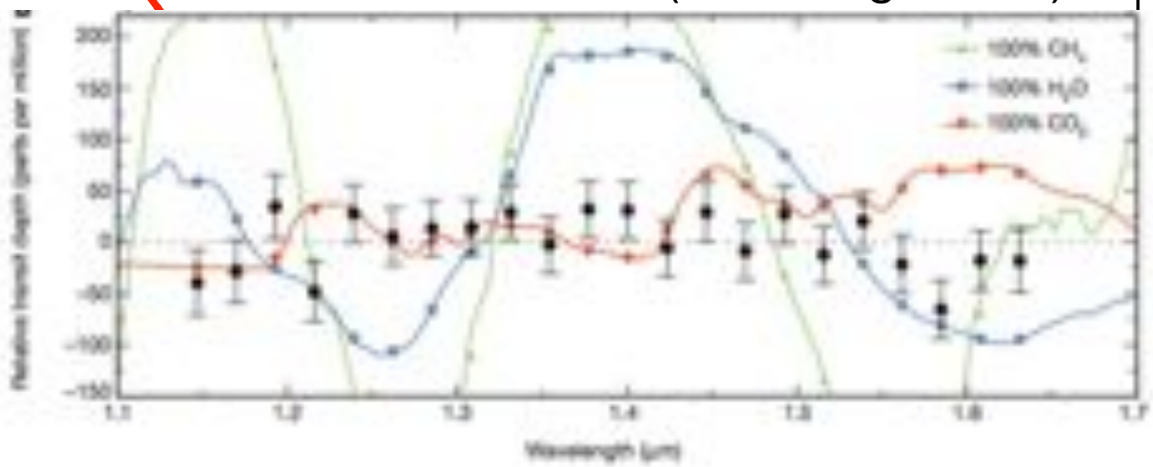
Absorption signal of one atmospheric scale height in transmission spectroscopy (ppm)

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

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

JWST 3σ detection limit
water detection on HD 209458b in 1 transit (Deming+ 2013)

Flat spectrum ➡ clouds!
12 HST transits (Kreidberg+ 2014)



GJ 1214b

J magnitude

4
5
6
7
8
9
10
11
12

1
10
100
1000
10000

Absorption signal of one atmospheric scale height in transmission spectroscopy (ppm)

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 1st-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)*

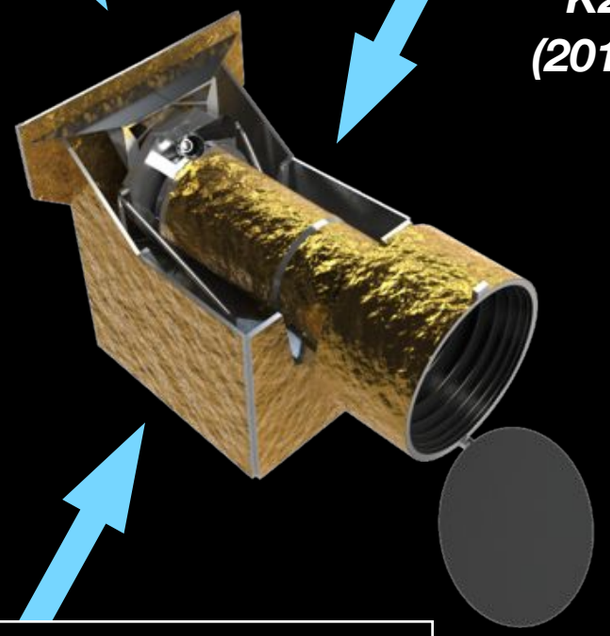
TESS
(2017)

Measure accurate light curves for Neptunes

K2
(2014)

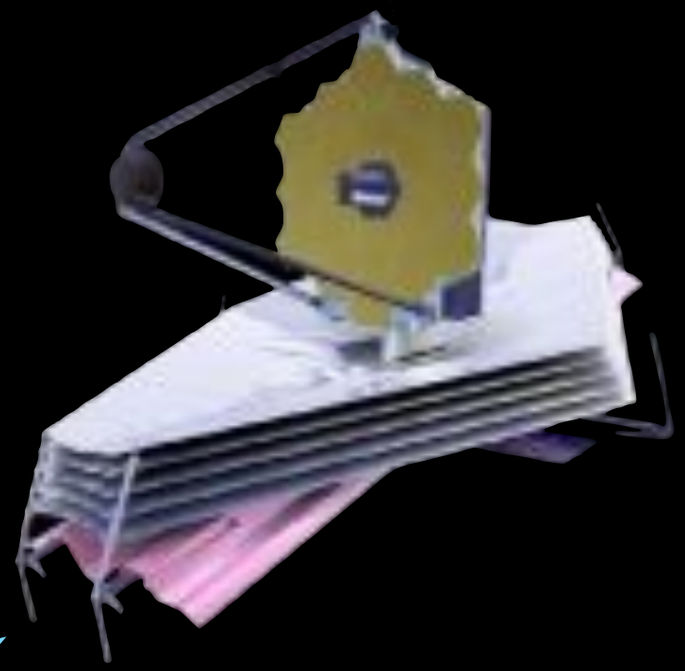
Ground-based RV surveys
HARPS, HARPS-N, HIRES, SOPHIE *(on going)*
ESPRESSO *(2017)*

Detect the transit of known super-Earths

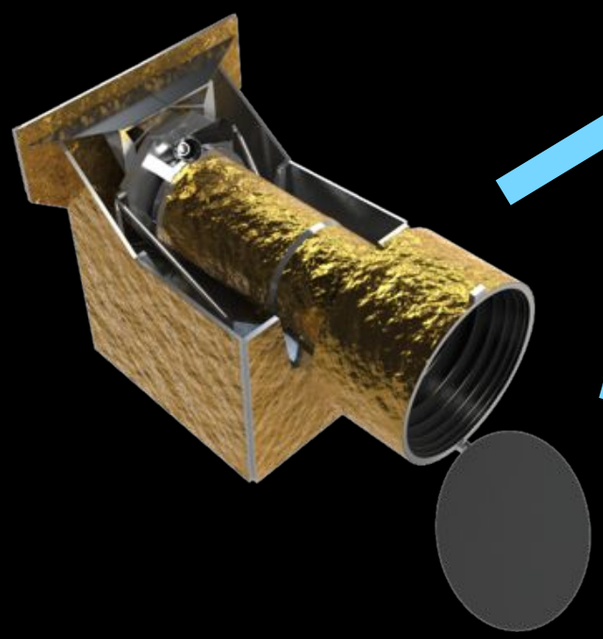


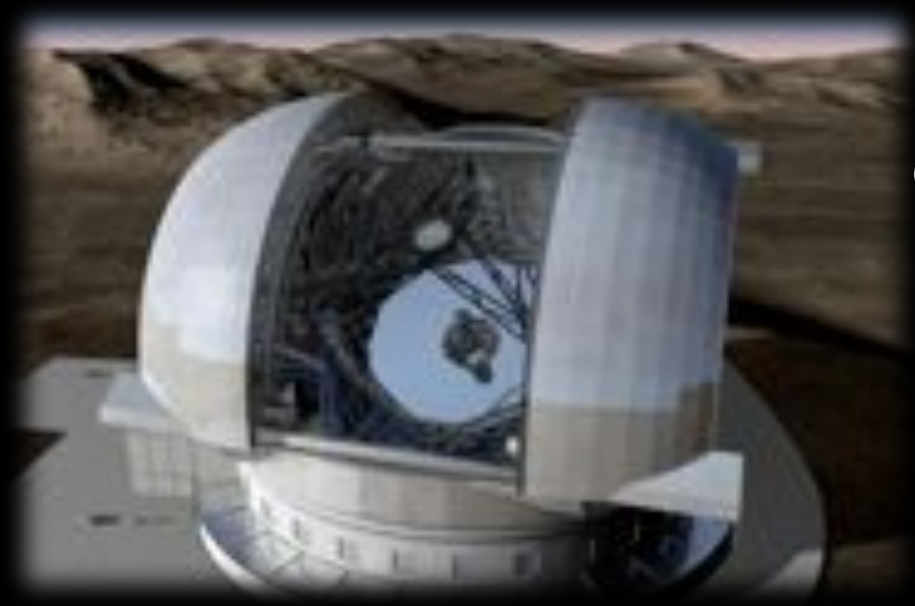
20% open time
(3.5-yr mission)

CHEOPS legacy



JWST
2018



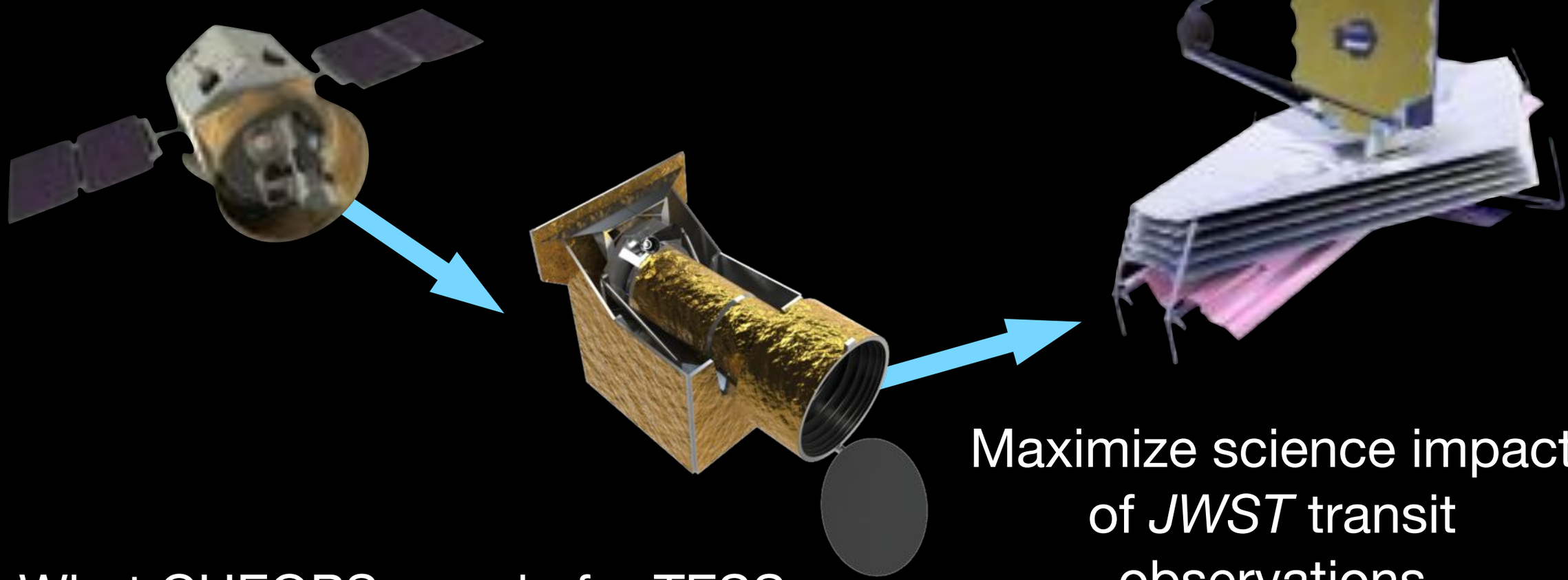


E-ELT,
GMT, TMT
~2020

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

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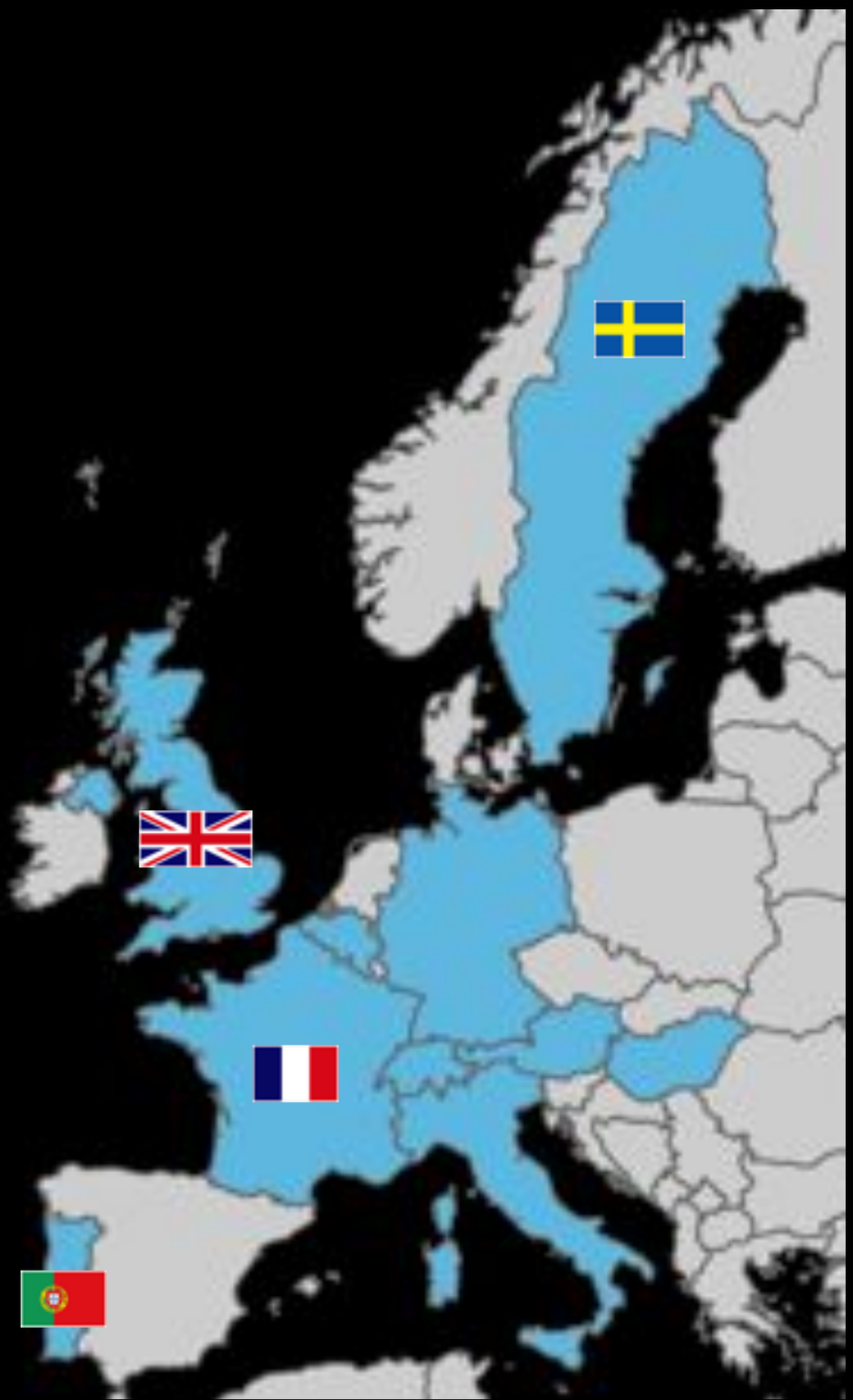


Germany
Focal Plane Assembly

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

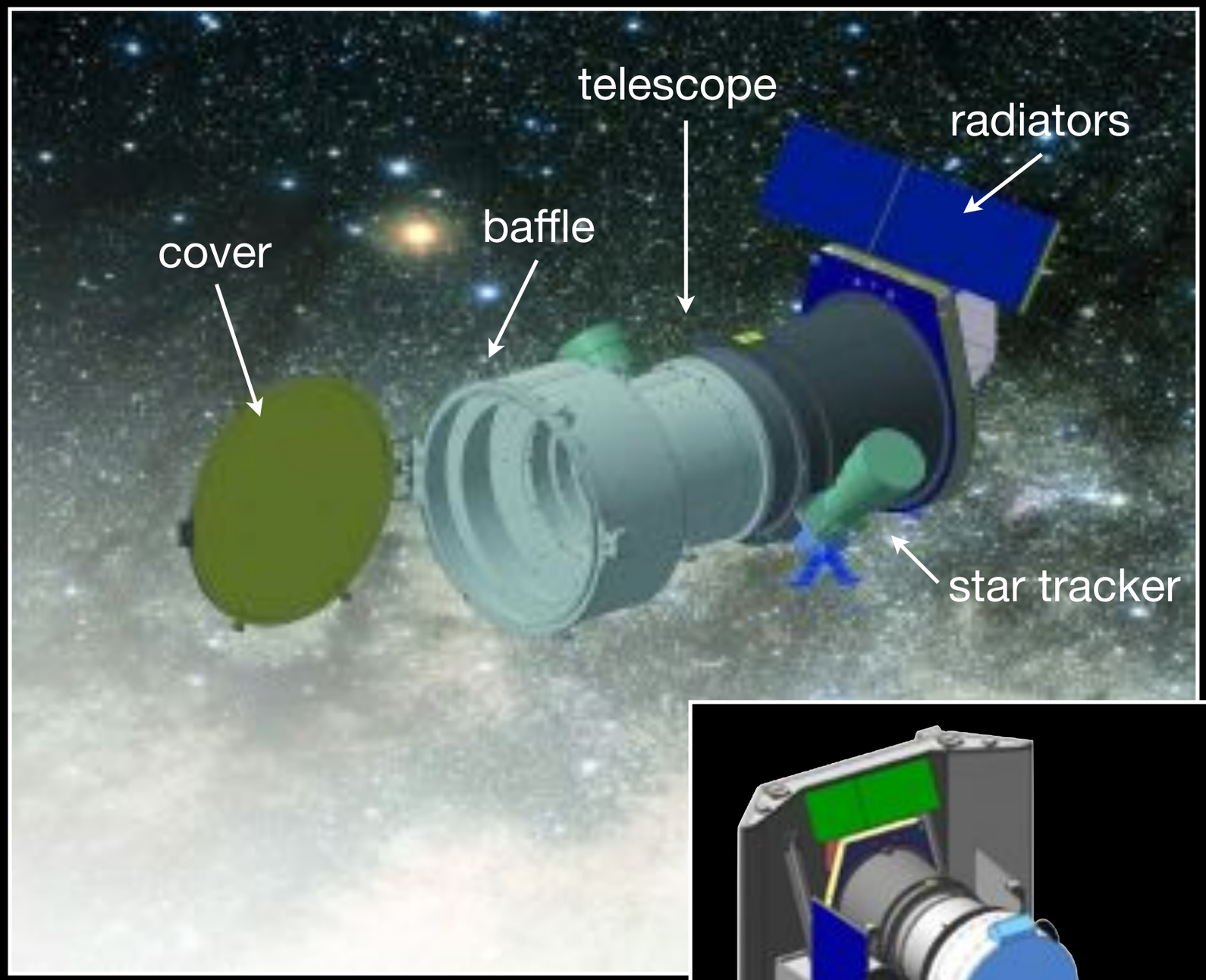
Hungary
Radiators

CHEOPS consortium

Small mission, large organization

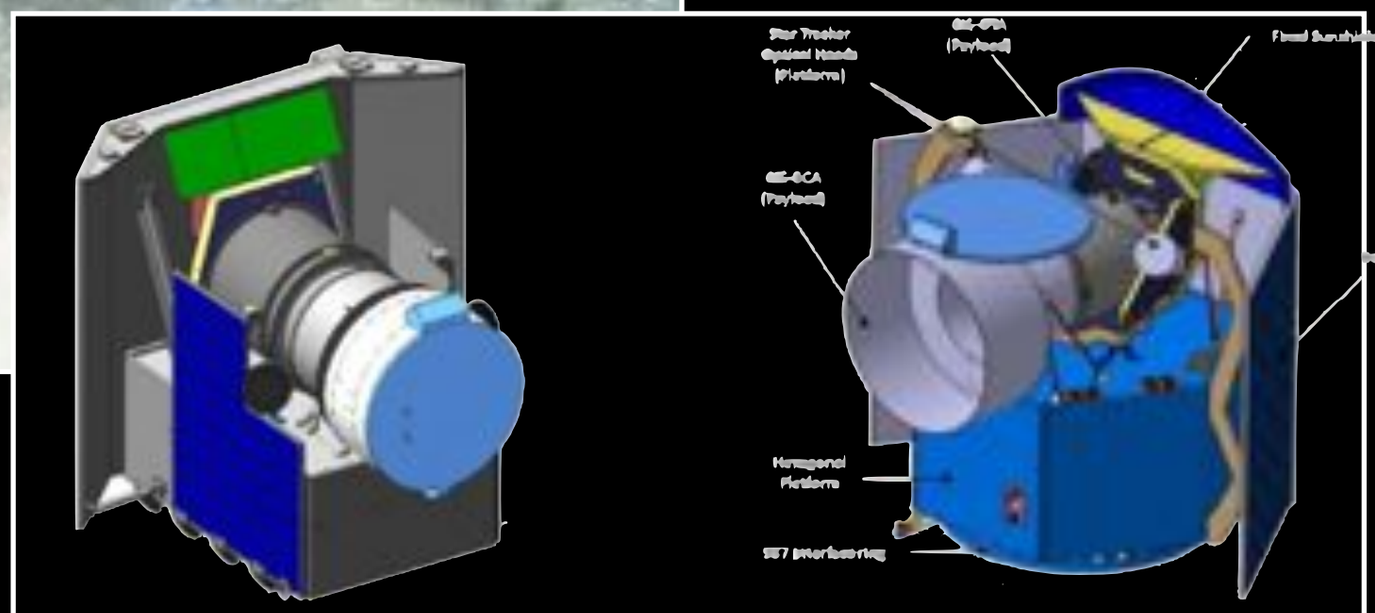
Switzerland	University of Bern (project lead) University of Geneva Swiss Space Center (EPFL) ETH Zürich
Austria	Institut für Weltraumforschung, Graz
Belgium	Centre Spatial de Liège Université de Liège
France	Laboratoire d'astrophysique de Marseille
Germany	DLR Institute for Planetary Research
Hungary	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

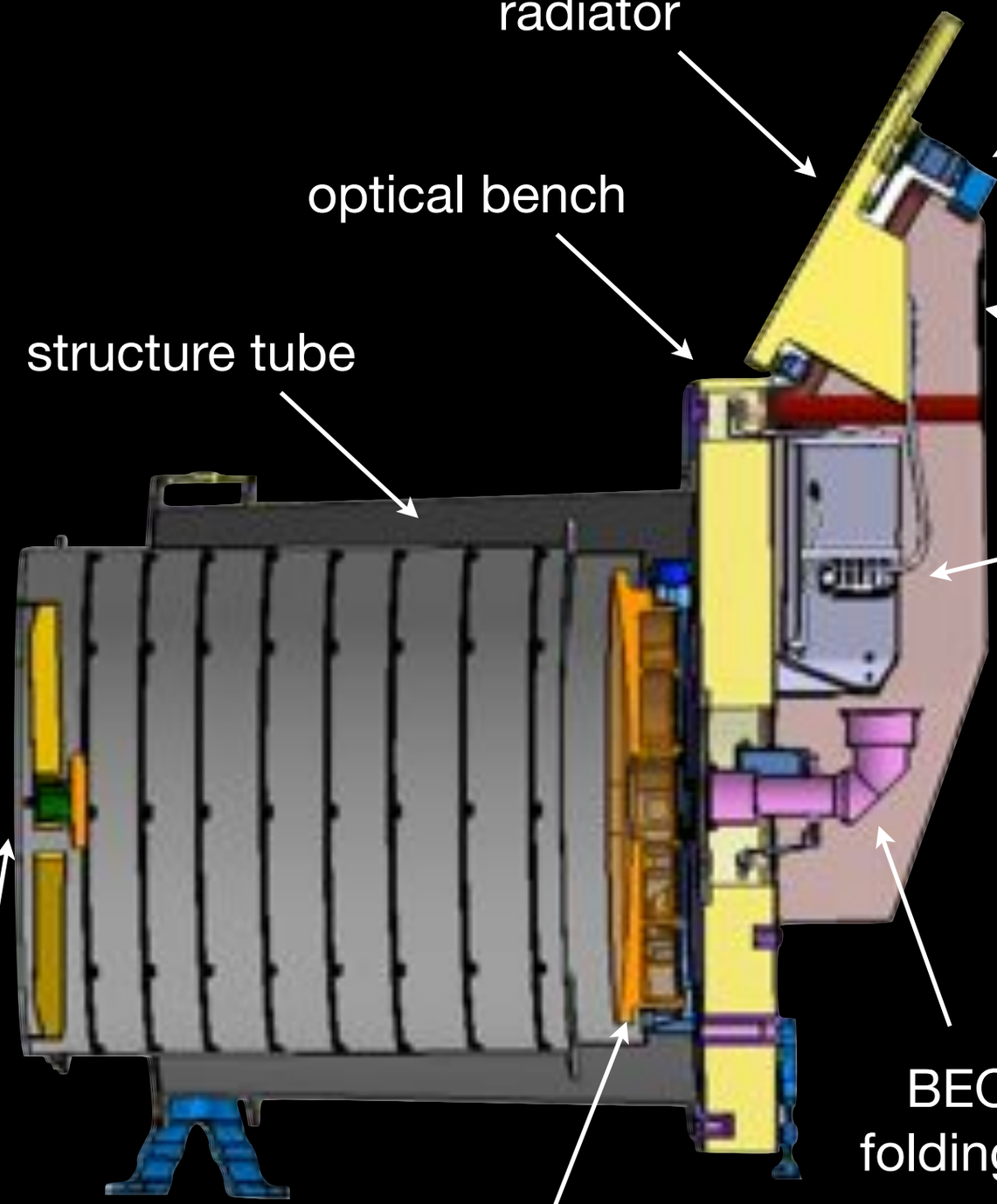
platform →



Two competing platform concepts

Total weight: 250 kg
Total length: 1.3 m

CHEOPS instrument system



Telescope ∅: 32 cm

Total weight: 60 kg

CHEOPS data acquisition

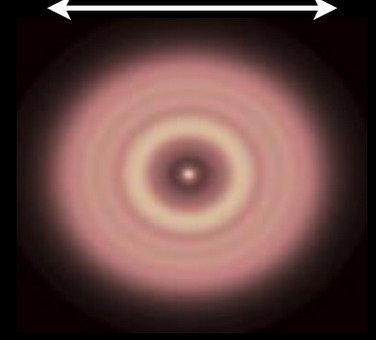
telescope
FoV: 20’

CCD 1k x 1k

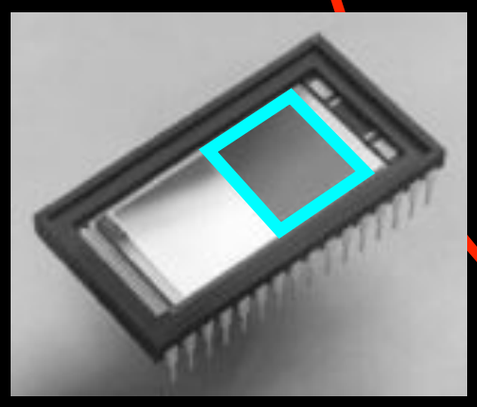
subarray image
200×200 pixels
(4 arcmin^2)

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

30 pixels (30”)



defocused PSF



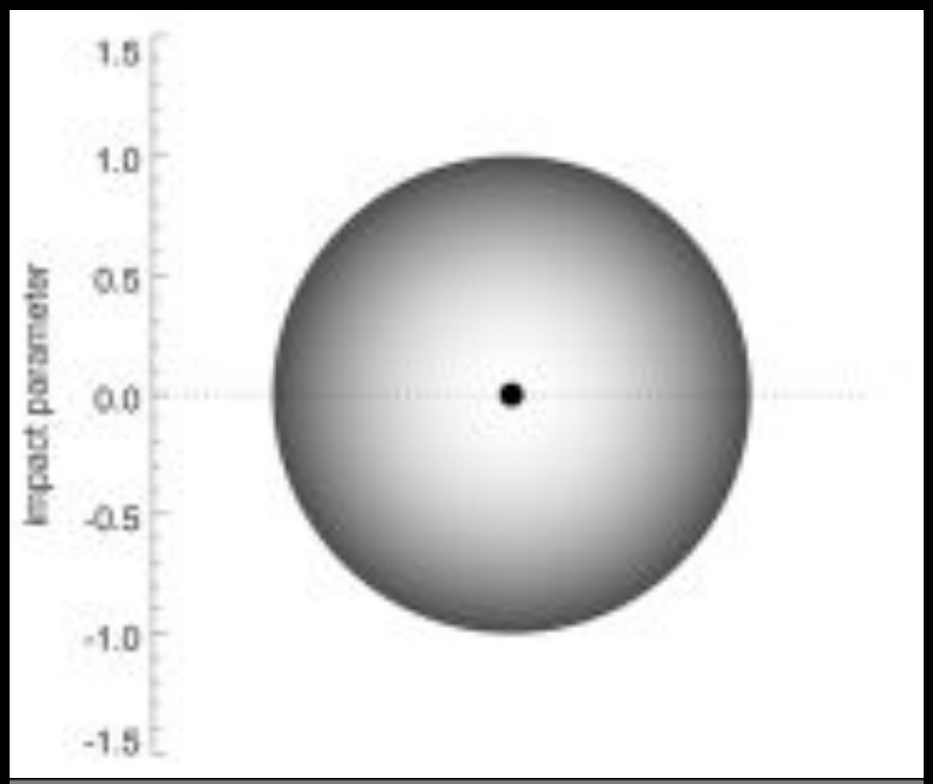
e2v

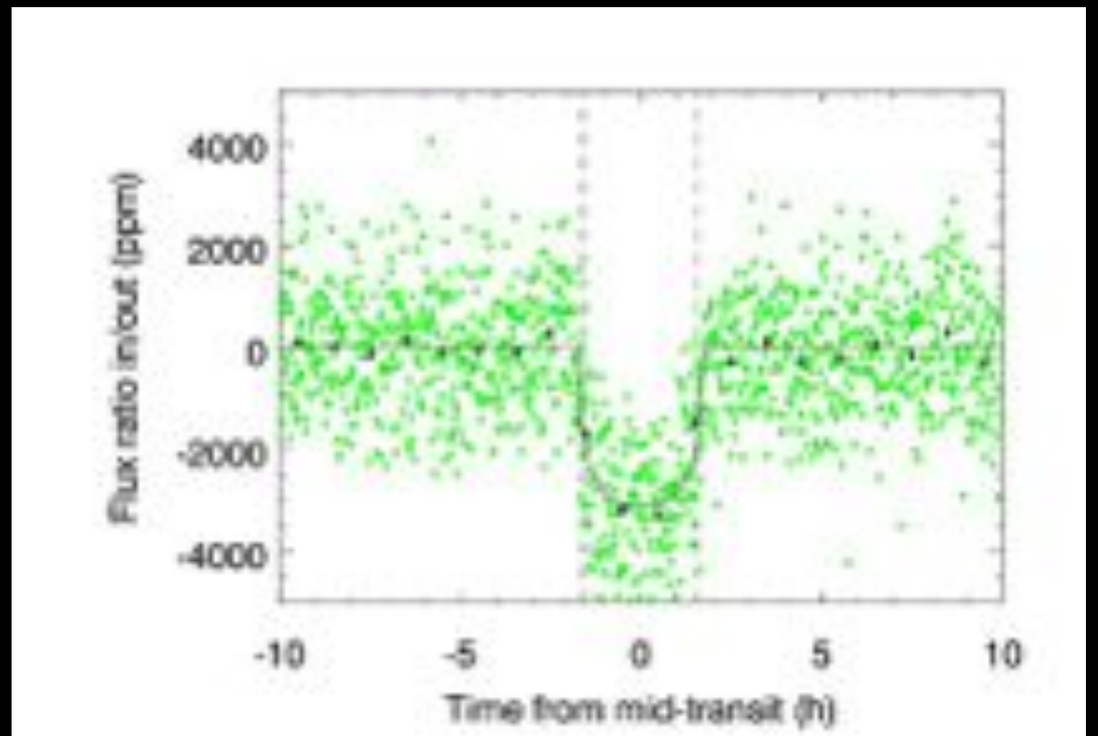
CHEOPS photometric precision

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

600—800 km

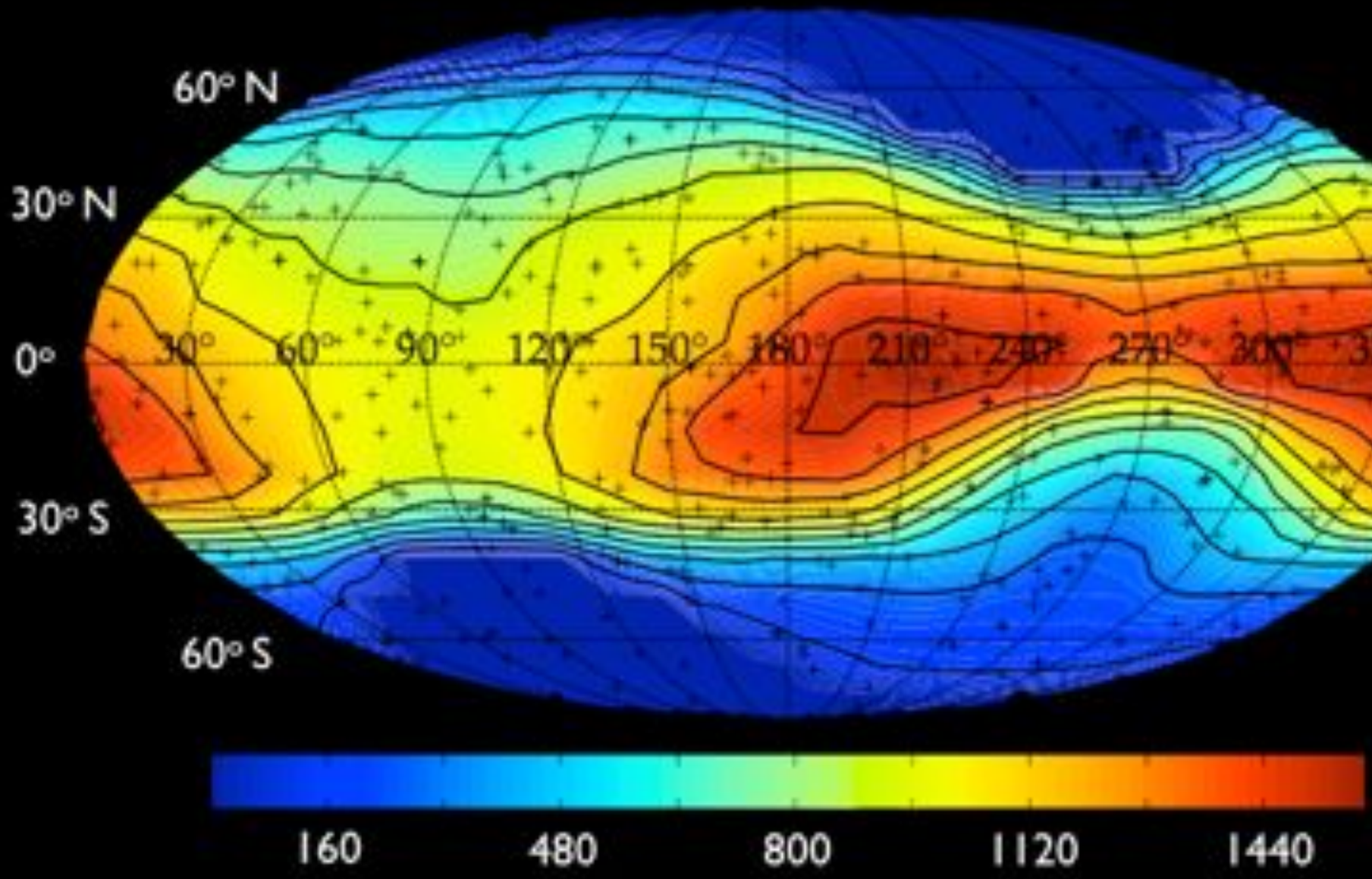
OBSERVATIONS

35°

120°

Sun

CHEOPS sky



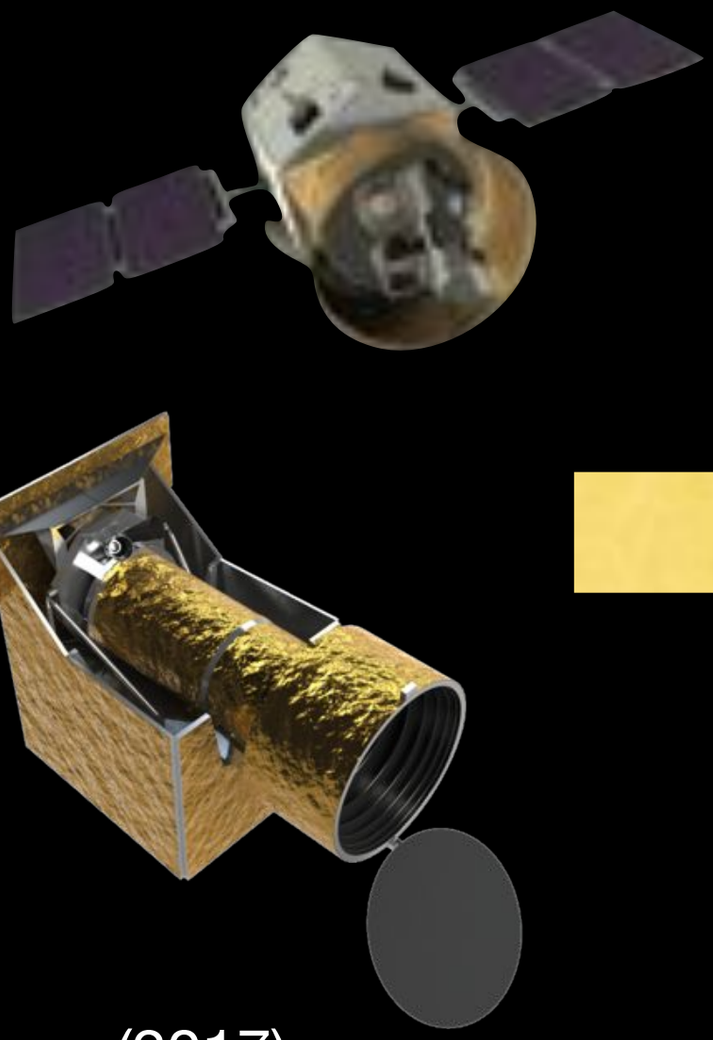
Observing time / year (hours)

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)