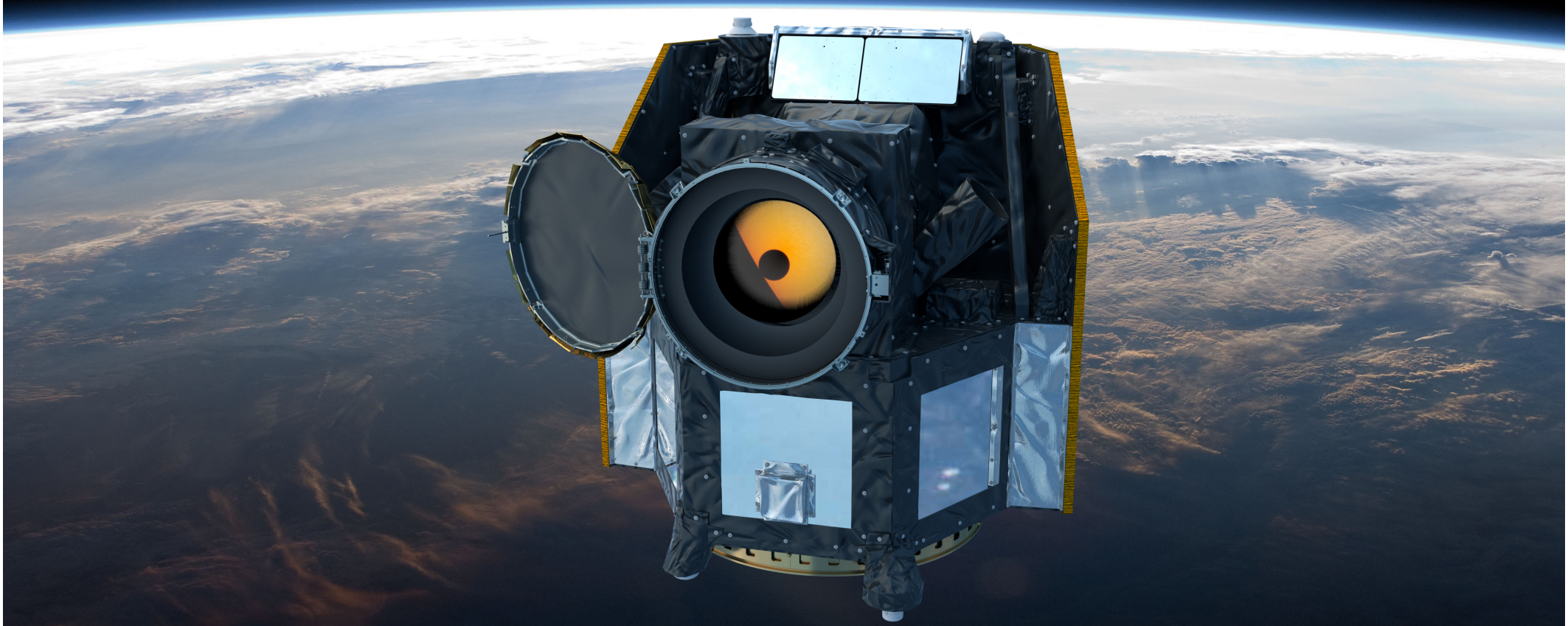
ExoPAG22 • 18 June 2020

CHEOPS

The Characterising Exoplanets Satellite

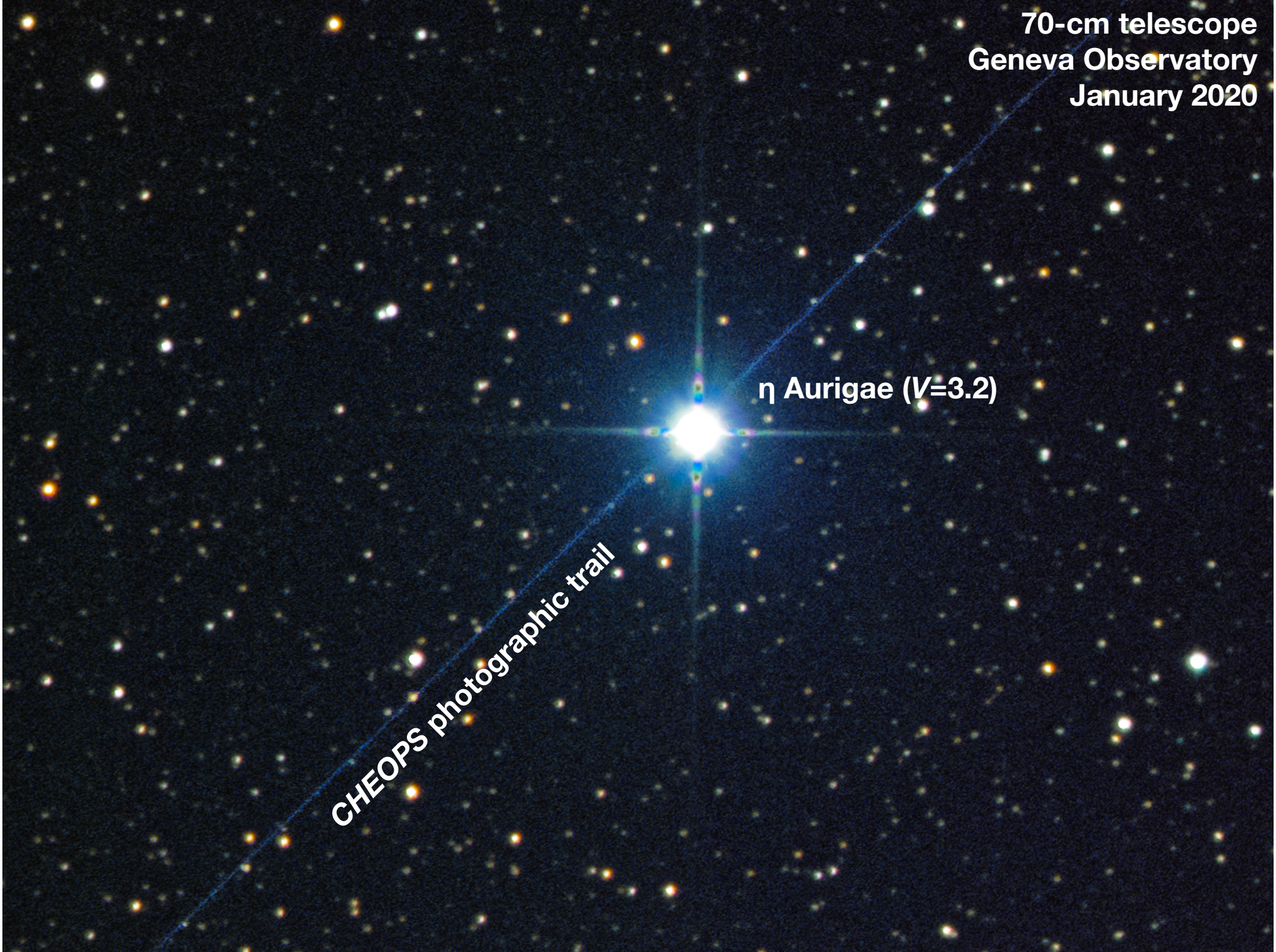
David Ehrenreich & the CHEOPS Mission Consortium



UNIVERSITÉ DE GENÈVE | PlanetS

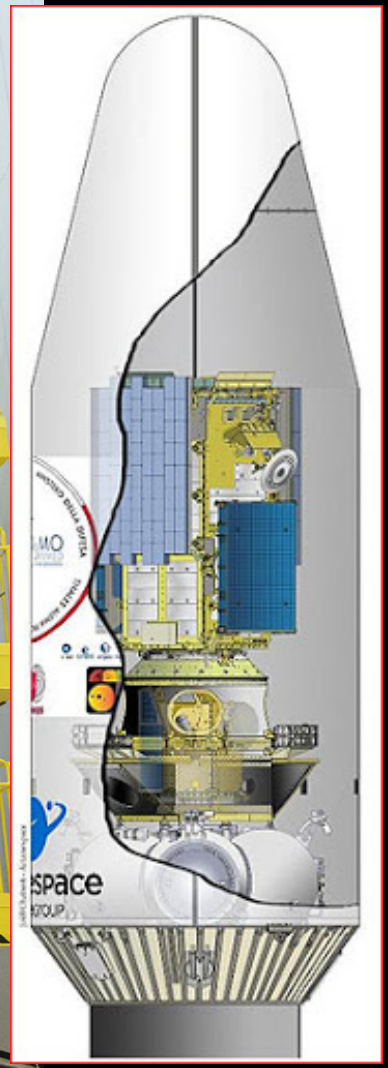
esa


70-cm telescope
Geneva Observatory
January 2020


70-cm telescope
Geneva Observatory
January 2020
η Aurigae (V=3.2)
CHEOPS photographic trail

Soyuz VS-23 fairing at French Guyana Space Center
December 2019

CHEOPS!



Credits: Arianespace

Soyuz launch VS-23 from French Guyana Space Center
18 December 2019

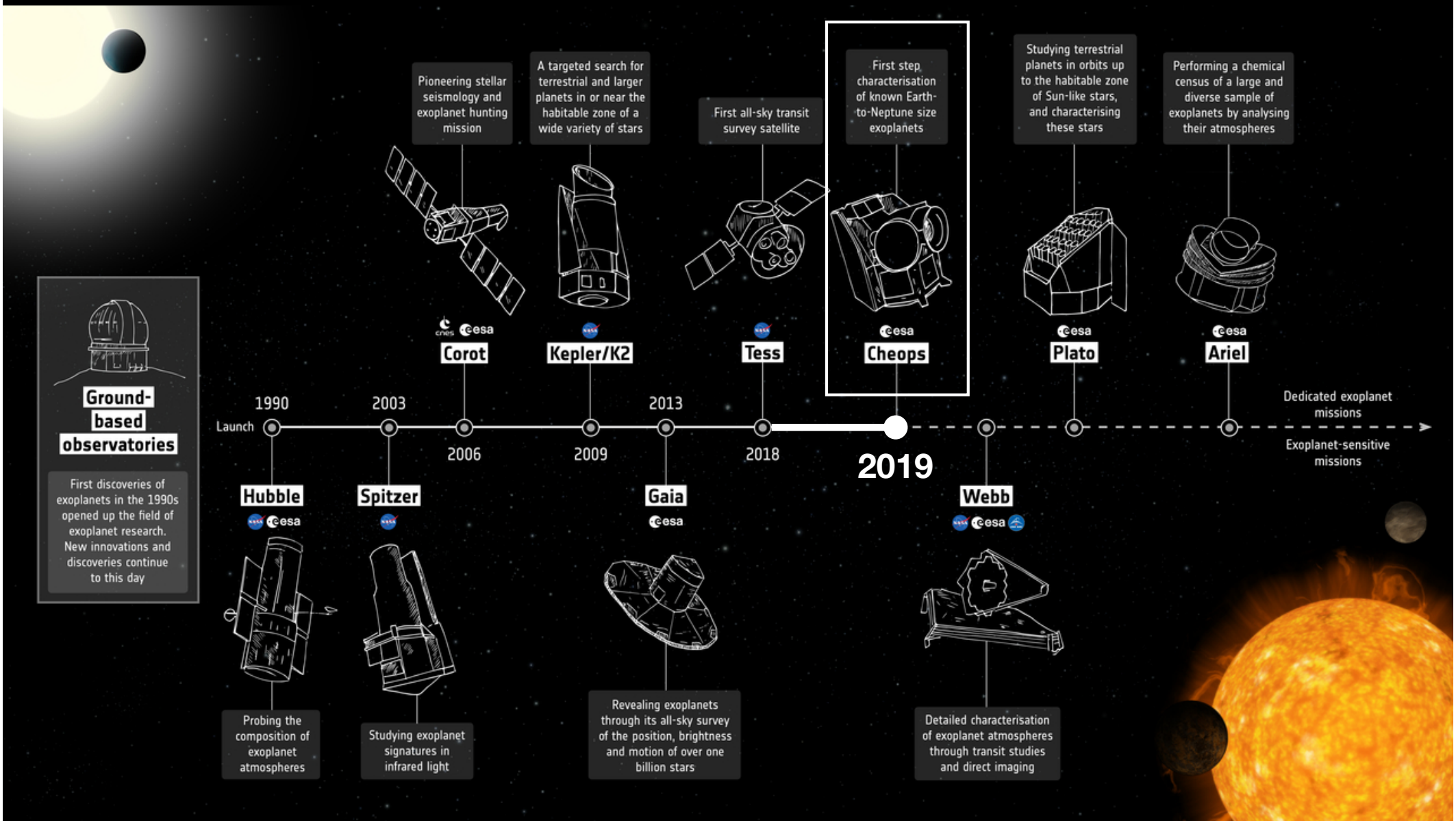
Credits: Arianespace

Insertion in low-Earth orbit at 700 km
18 December 2019

Credits: ESA

CHEOPS

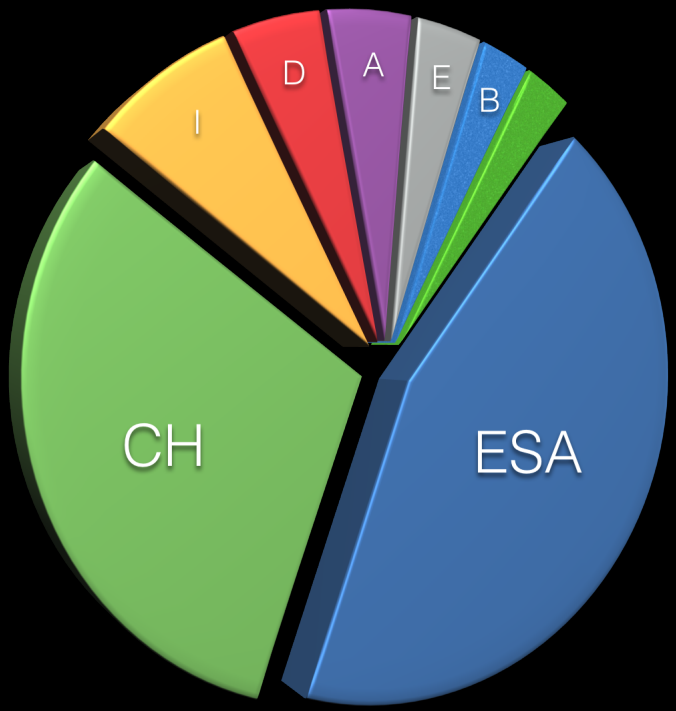
ESA's first S-class mission
First space mission dedicated to study known exoplanets



S-class mission:

S is not for “Simple”

“Small” Budget



- total budget: ~105 M€
- ESA: 50 M€

Short time

milestone	when
call issued	Mar 2012
call answered	Jun 2012
mission selected	Nov 2012
mission adopted	Feb 2014
instrument delivered	Feb 2019
launch	Dec 2019

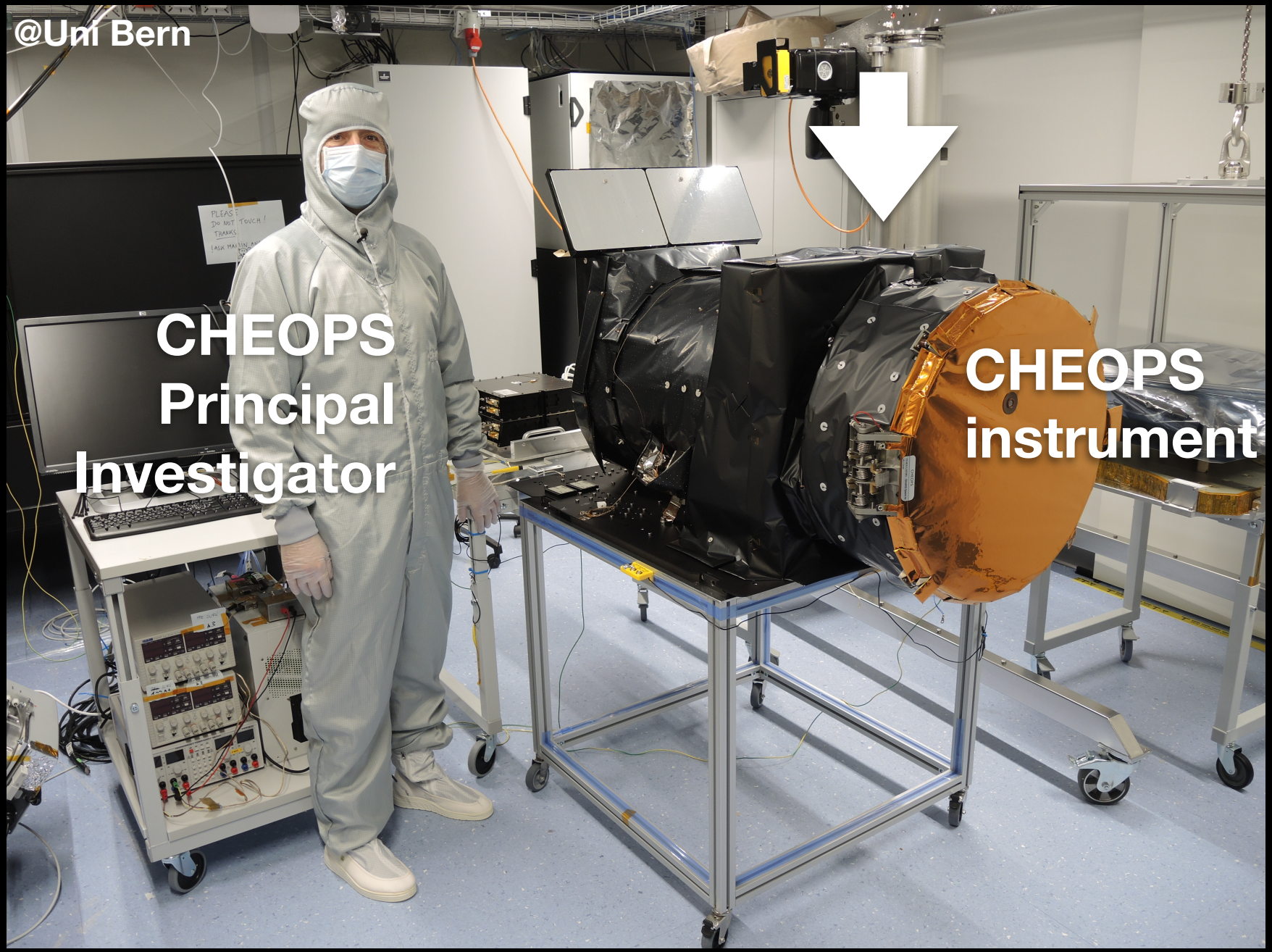
- 4–5 years development time

Several countries

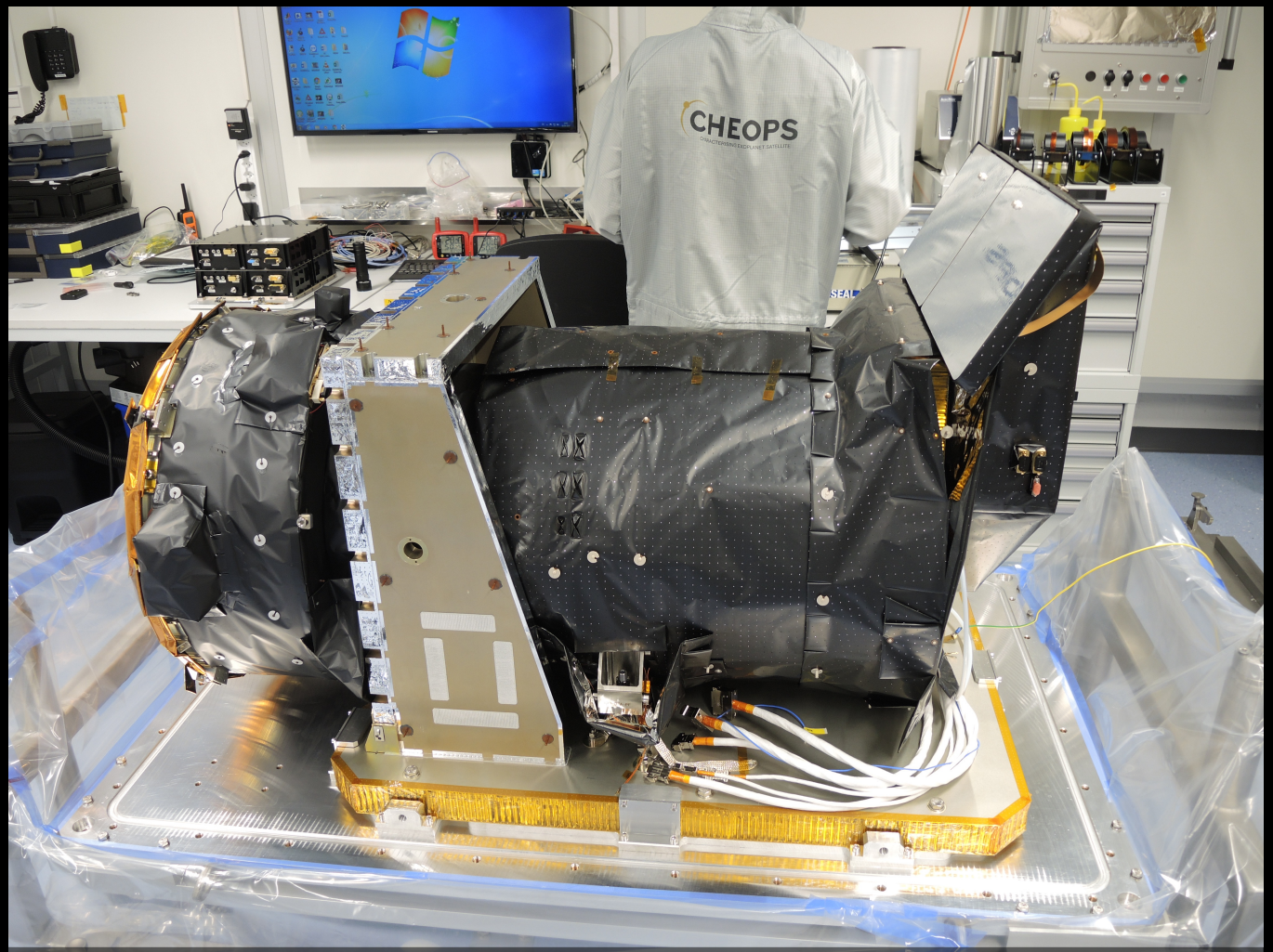
- 11 countries & ESA
- ~30 institutions

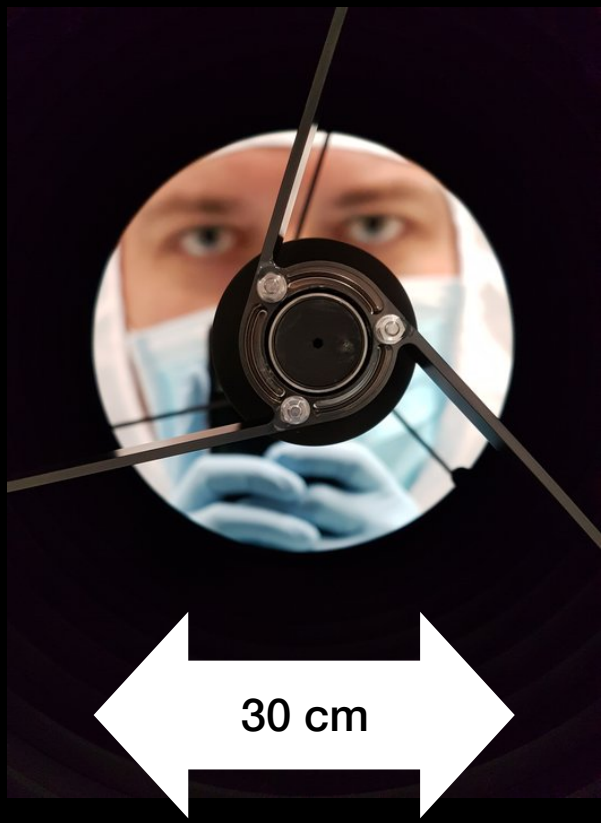
➡ Top Science is expected!

CHEOPS instrument



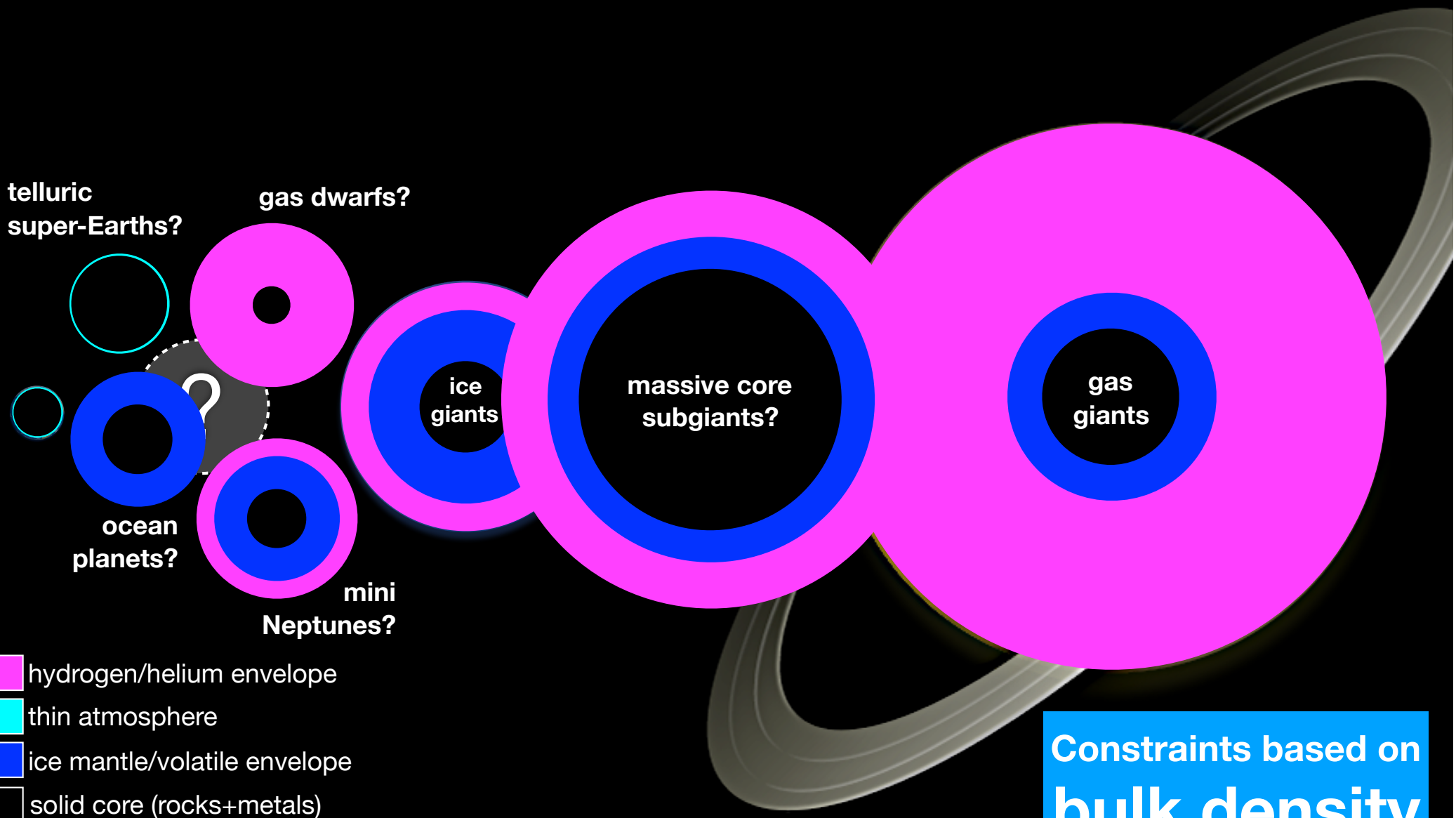
CHEOPS instrument





A 30-cm space telescope capable of ultra high-precision photometry

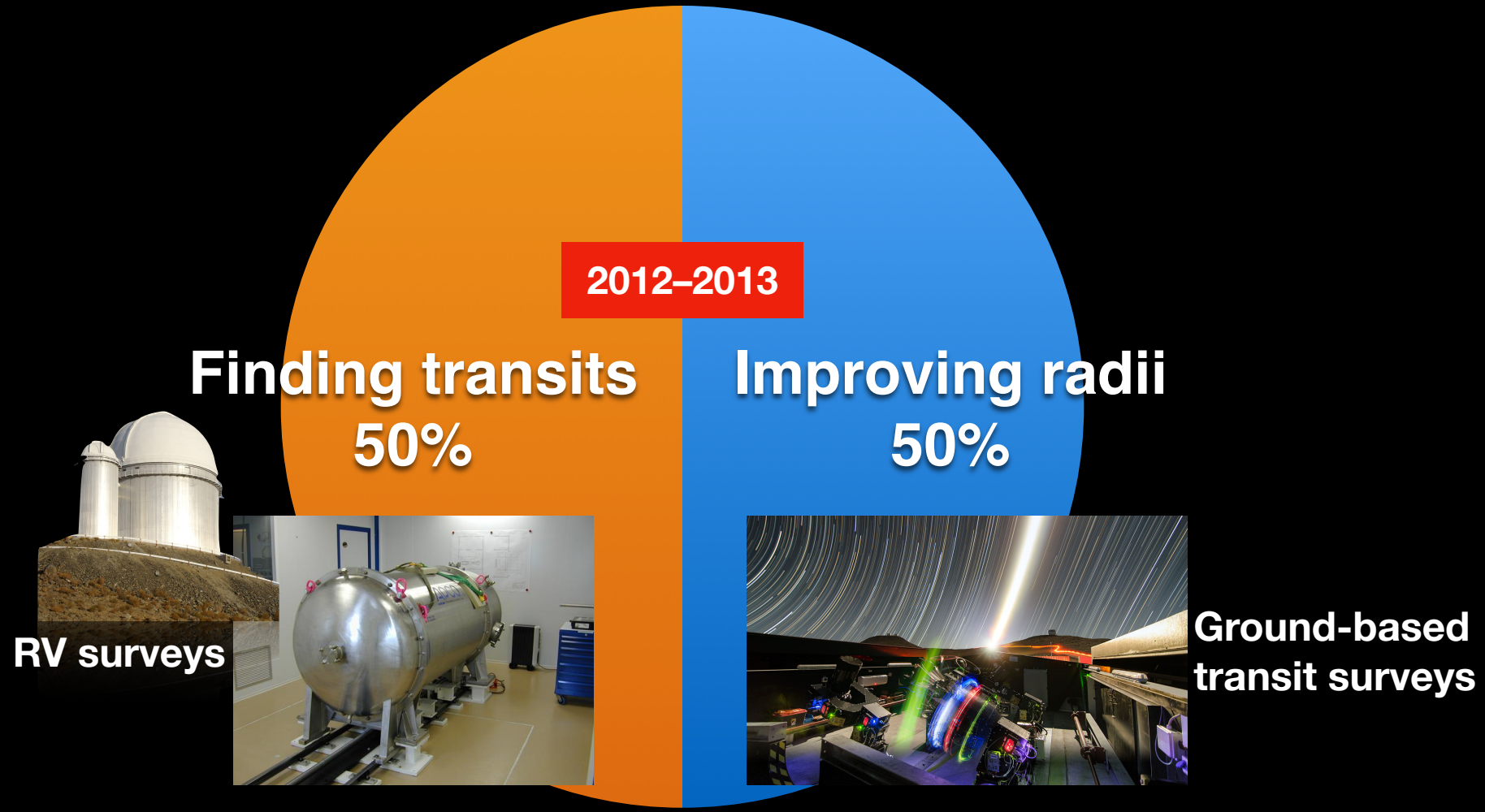
What are exoplanets made of?



Constraints based on
bulk density

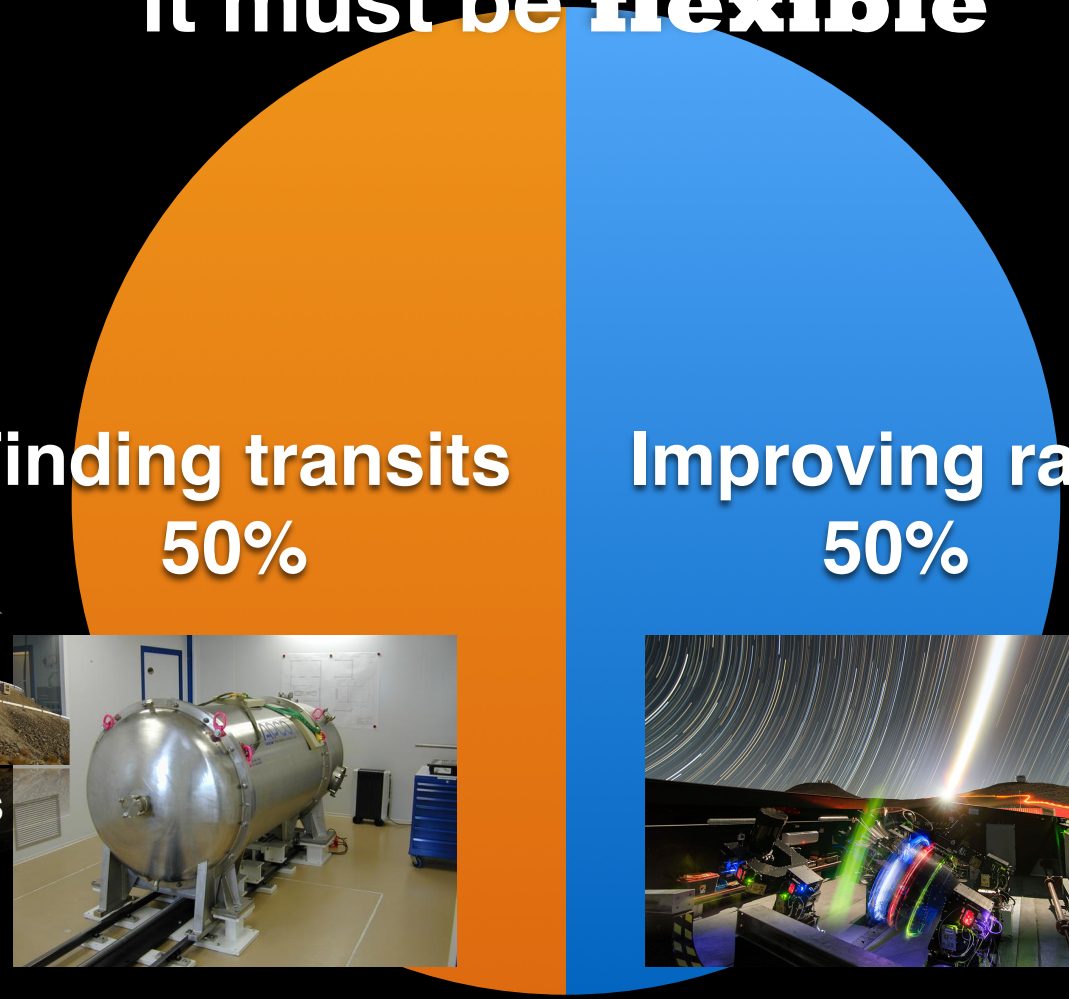
Science goals

1. Measure precise densities for super-earths and neptunes
2. Identify “golden targets” for atmospheric characterisation



Science strategy

CHEOPS is a follow-up mission
it must be flexible



RV surveys

Ground-based
transit surveys


2012
CHEOPS
selection
Gaia
MOST
CoRoT
Kepler
CHEOPS
Warm Spitzer
Hubble Space Telescope
JWST
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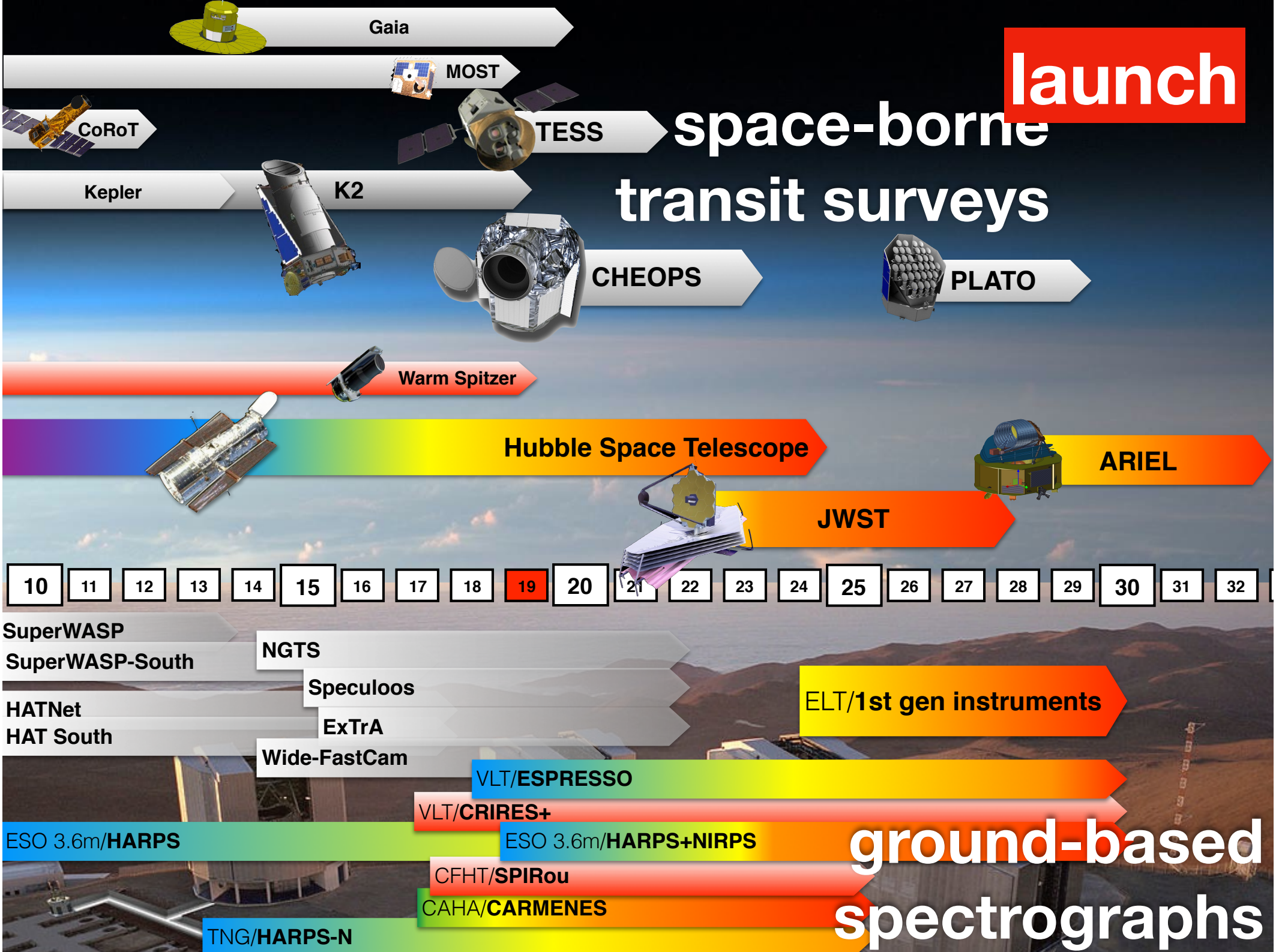
SuperWASP
SuperWASP-South
NGTS
Speculoos
HATNet
HAT South
Wide-FastCam
VLT/ESPRESSO
VLT/CRIRES+
ESO 3.6m/HARPS
CFHT/SPIRou
CAHA/CARMENES
TNG/HARPS-N


launch
space-borne
transit surveys
Gaia
MOST
CoRoT
TESS
Kepler
K2
CHEOPS
PLATO
Warm Spitzer
Hubble Space Telescope
ARIEL
JWST
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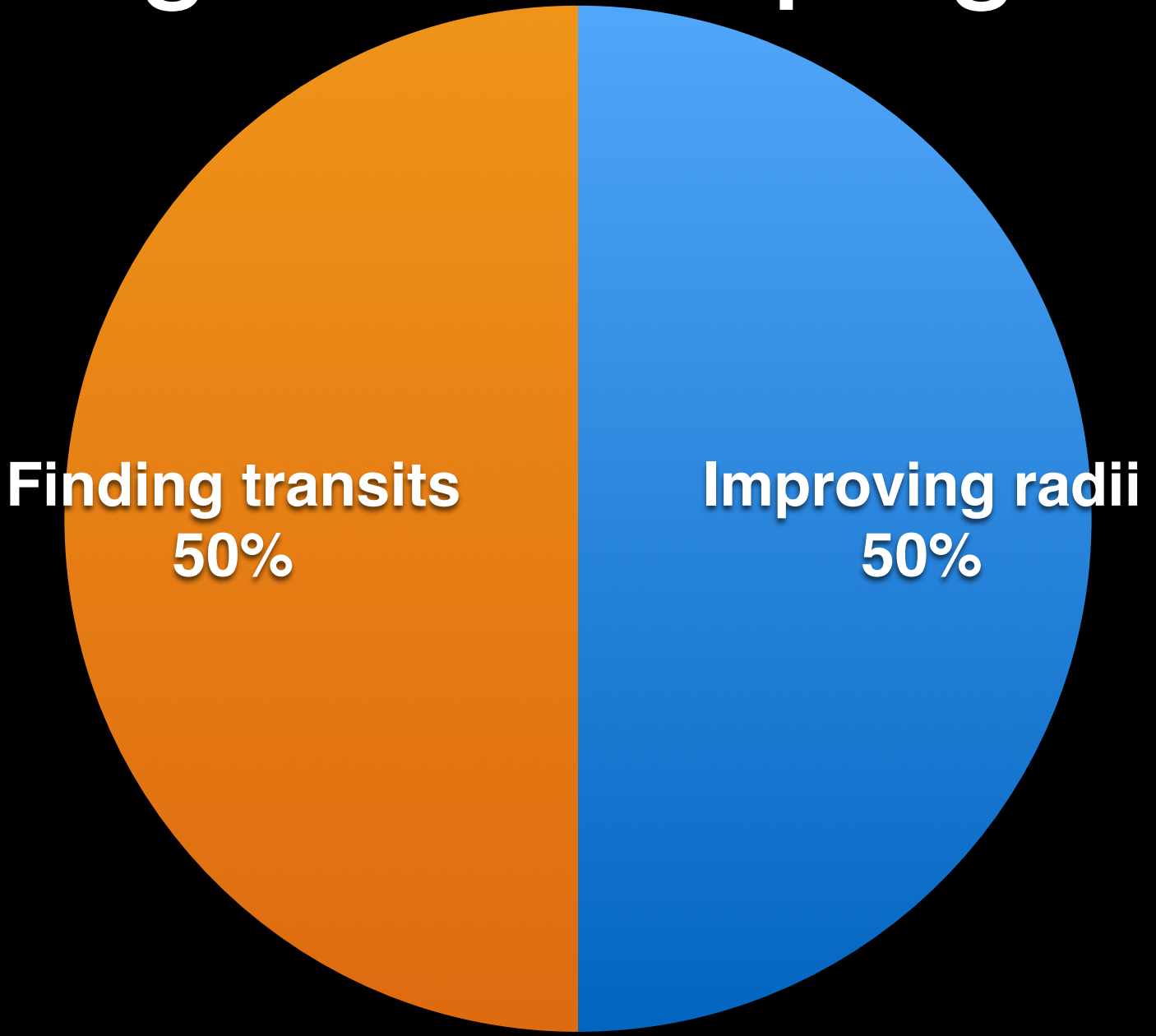
SuperWASP
SuperWASP-South
NGTS
Speculoos
HATNet
HAT South
ExTrA
Wide-FastCam
ELT/1st gen instruments
VLT/ESPRESSO
VLT/CRIRES+
ESO 3.6m/HARPS
ESO 3.6m/HARPS+NIRPS
CFHT/SPIRou
CAHA/CARMENES
TNG/HARPS-N
ground-based
spectrographs

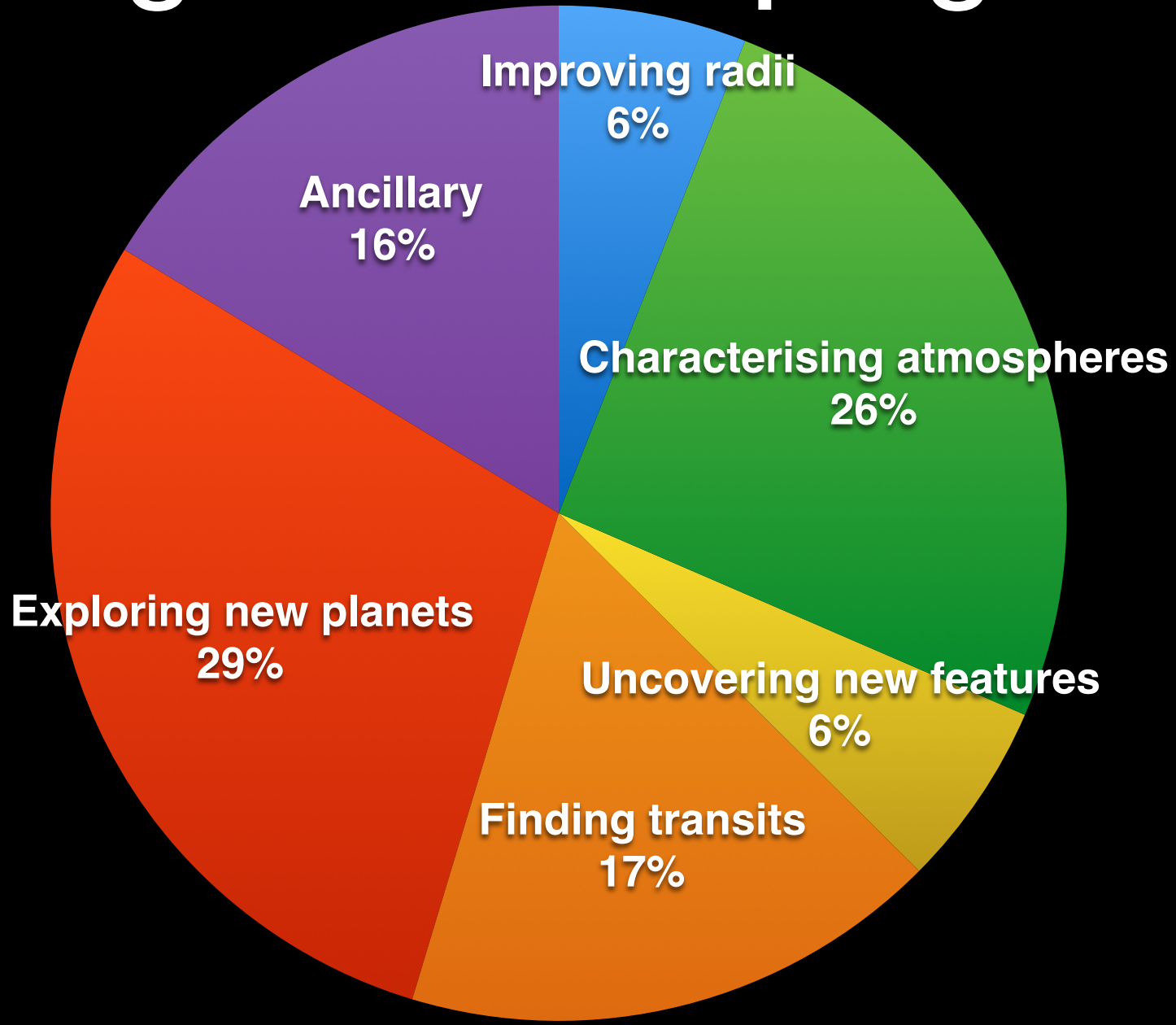
2012-2013

Building a science programme



2013-2018

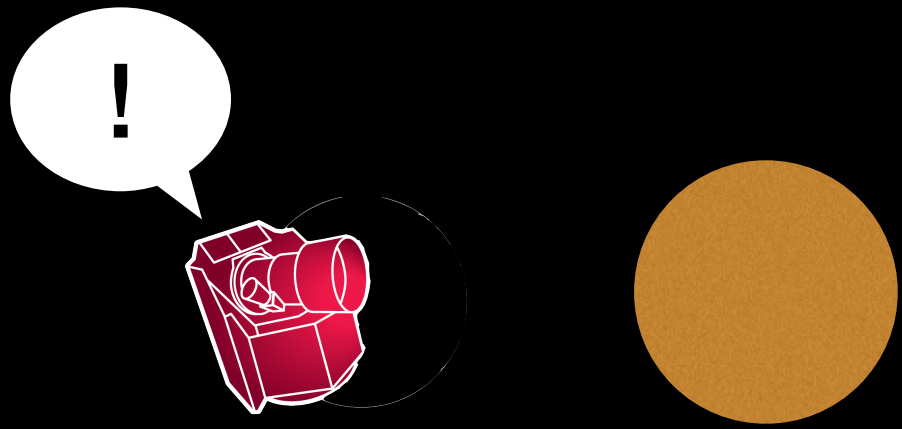
Building a science programme



Finding transits

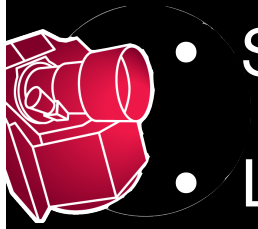
of known exoplanets

- Prioritise RV planets hard to detect with *TESS*
- **Warm & temperate super-earths & mini-neptunes** ($P > 9$ days) in Year 1
- Outer planets not known to transit in transiting systems
- ~60 exoplanets < $6M_\oplus$ (likely < $2R_\oplus$)



Improving radius

of known transiting exoplanets



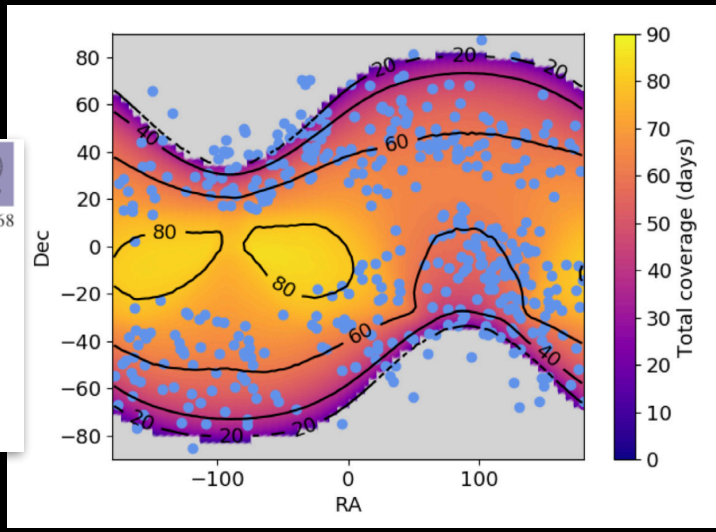
- Space-borne photometry ➡ higher photometric precision
- Larger collecting area ➡ higher photometric precision

- Follow-up of mono-transits
  ~70% of *TESS* primary mission mono-transits
  can be followed-up by CHEOPS
  (assuming their *P* can be determined)

Monthly Notices of the ROYAL ASTRONOMICAL SOCIETY
MNRAS **494,** 736–742 (2020) doi:10.1093/mnras/staa768
Advance Access publication 2020 March 18

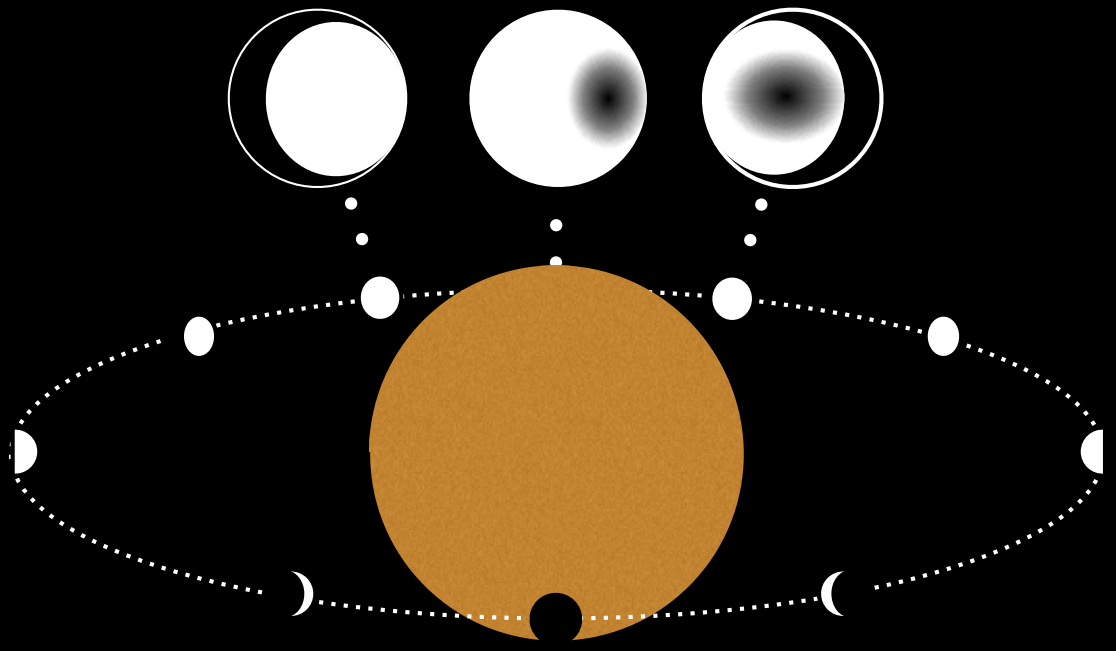
***CHEOPS* observations of *TESS* primary mission monotransits**

Benjamin F. Cooke [1,2]★ Don Pollacco,[1,2] Monika Lendl [3,4] Thibault Kuntzer [3] and Andrea Fortier[5]



Cooke et al. (2020)

Characterising atmospheres



- How common are very reflective hot Jupiters?
- **How reflective are ultrahot gas giants?**

Characterising atmospheres

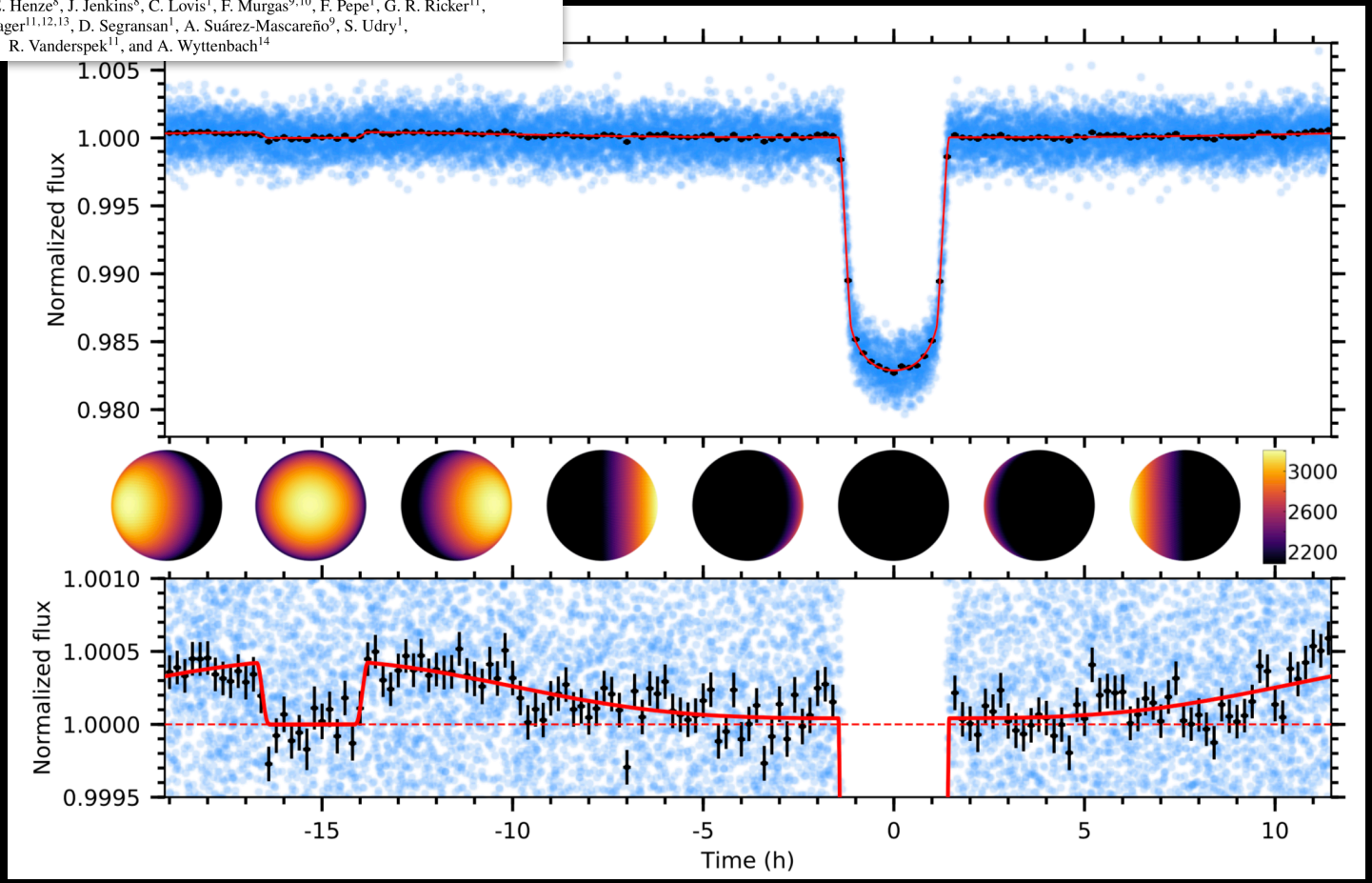
of ultrahot gas giants

A&A 637, A36 (2020)
https://doi.org/10.1051/0004-6361/201936647

Astronomy & Astrophysics

Optical phase curve of the ultra-hot Jupiter WASP-121b*

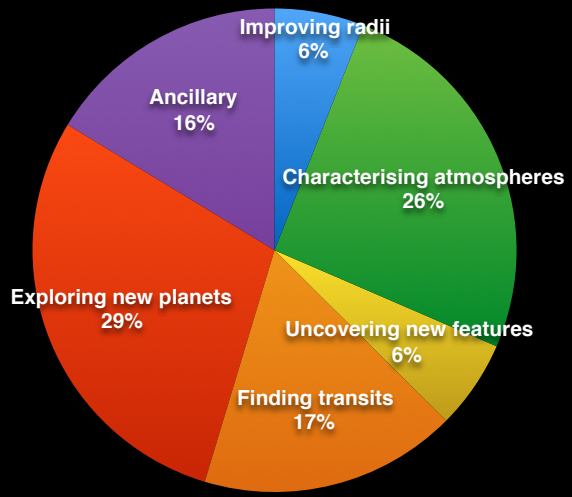
V. Bourrier[1], D. Kitzmann[2], T. Kuntzer[1], V. Nascimbeni[3], M. Lendl[1], B. Lavie[1], H. J. Hoeijmakers[1,2], L. Pino[4], D. Ehrenreich[1], K. Heng[2], R. Allart[1], H. M. Cegla[1], X. Dumusque[1], C. Melo[5], N. Astudillo-Defru[6], D. A. Caldwell[7,8], M. Cretignier[1], H. Giles[1], C. E. Henze[8], J. Jenkins[8], C. Lovis[1], F. Murgas[9,10], F. Pepe[1], G. R. Ricker[11], M. E. Rose[8], S. Seager[11,12,13], D. Segransan[1], A. Suárez-Mascareño[9], S. Udry[1], R. Vanderspek[11], and A. Wyttenbach[14]



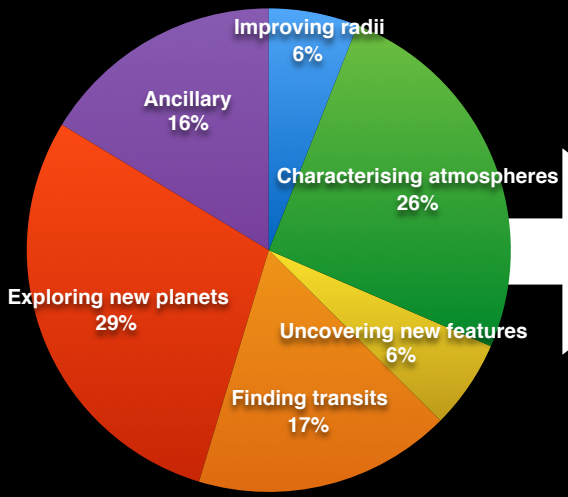
***TESS* lightcurve of WASP-121b • Bourrier et al. (2020)**

GTO programme summary

- 33 science programmes
- 350+ targets
- 13,500+ CHEOPS orbits = 2.5+ years



Is this science programme schedulable?



Mission Planning System

Automatised planning software optimising observation efficiency based on genetic algorithm

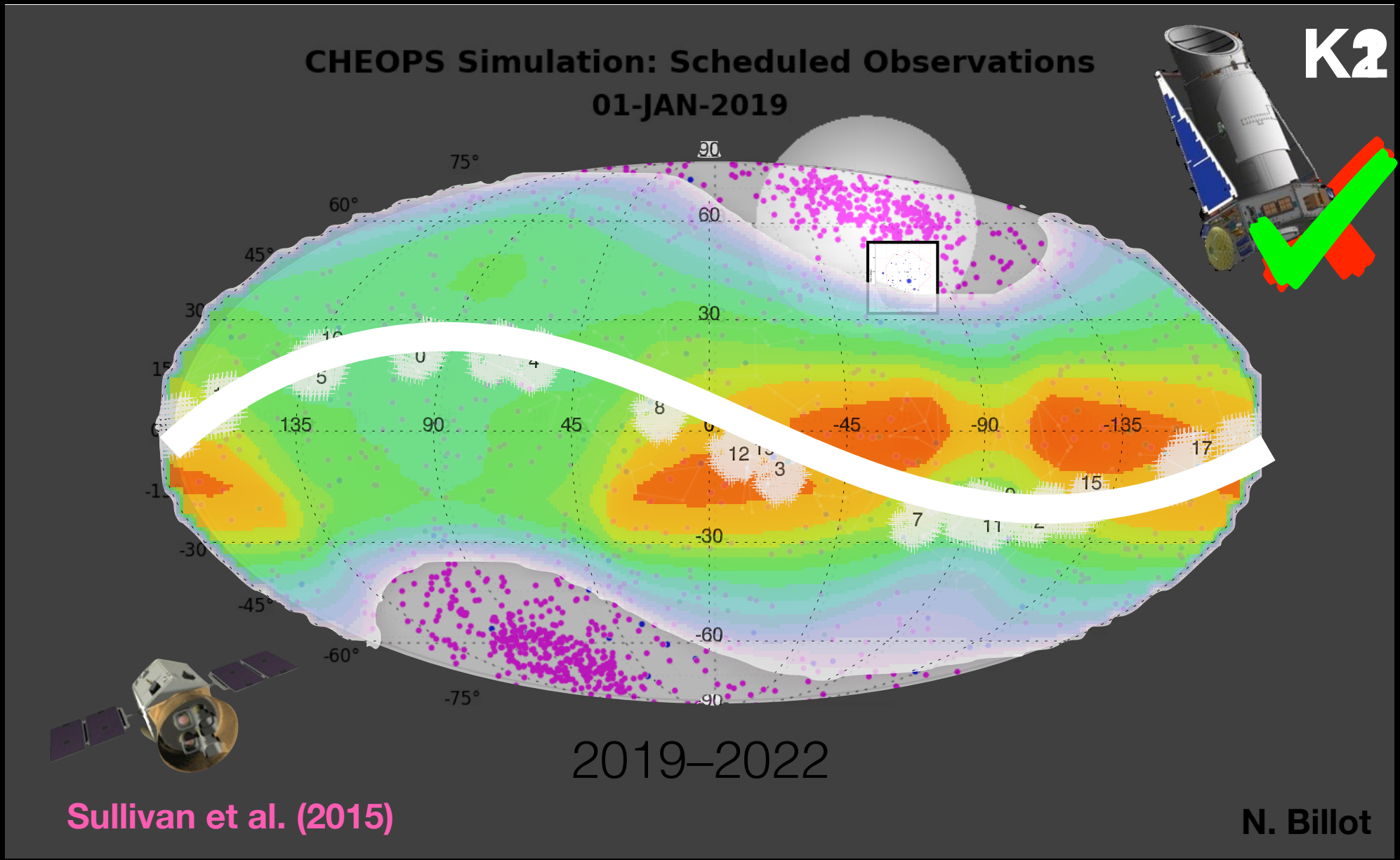
Data

End of commissioning & start of routine operations resistant to COVID-19 situation!

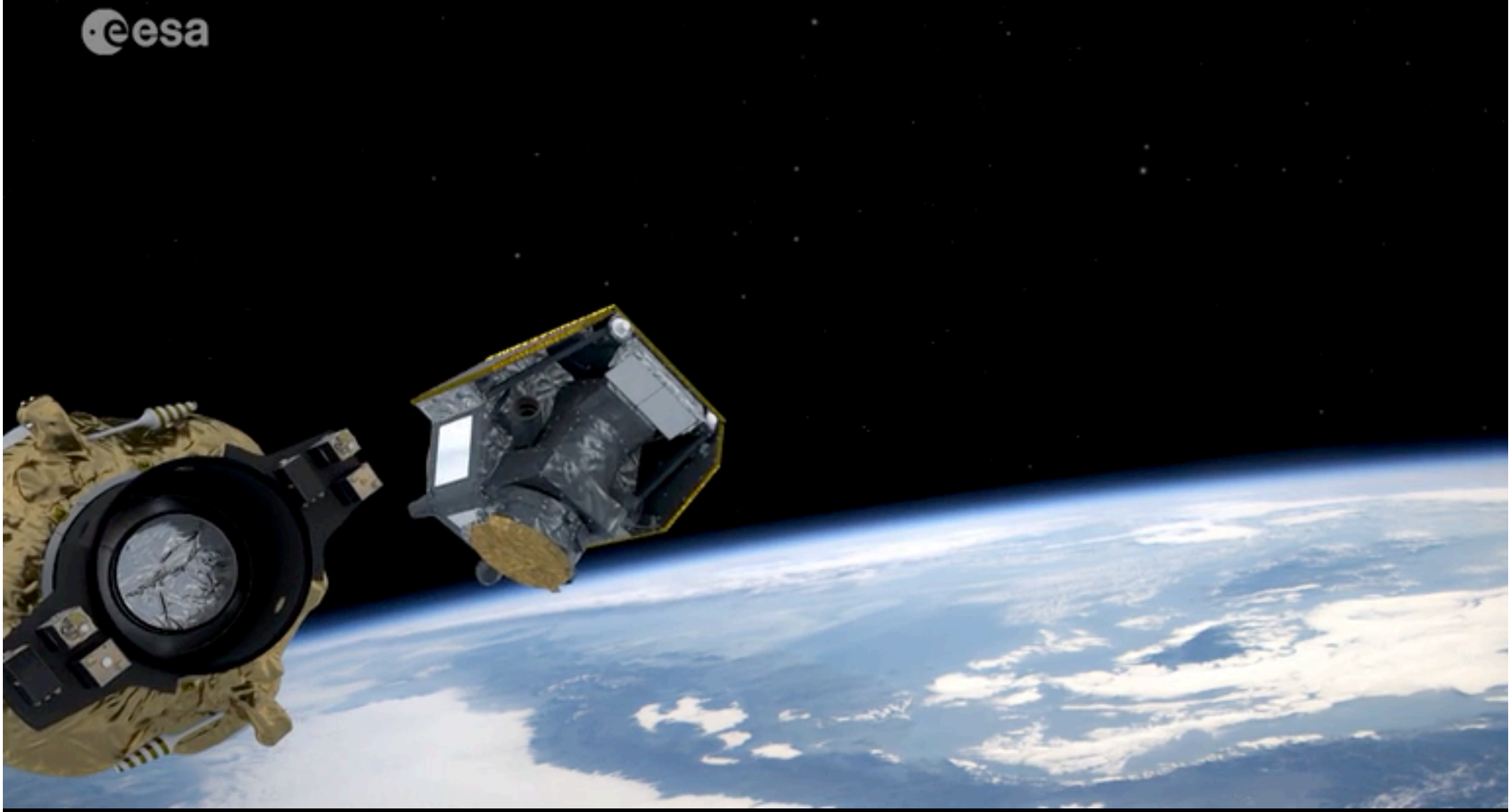
Science Operations Center at the University of Geneva

(Communication antena is in Spain)

Simulated CHEOPS mission



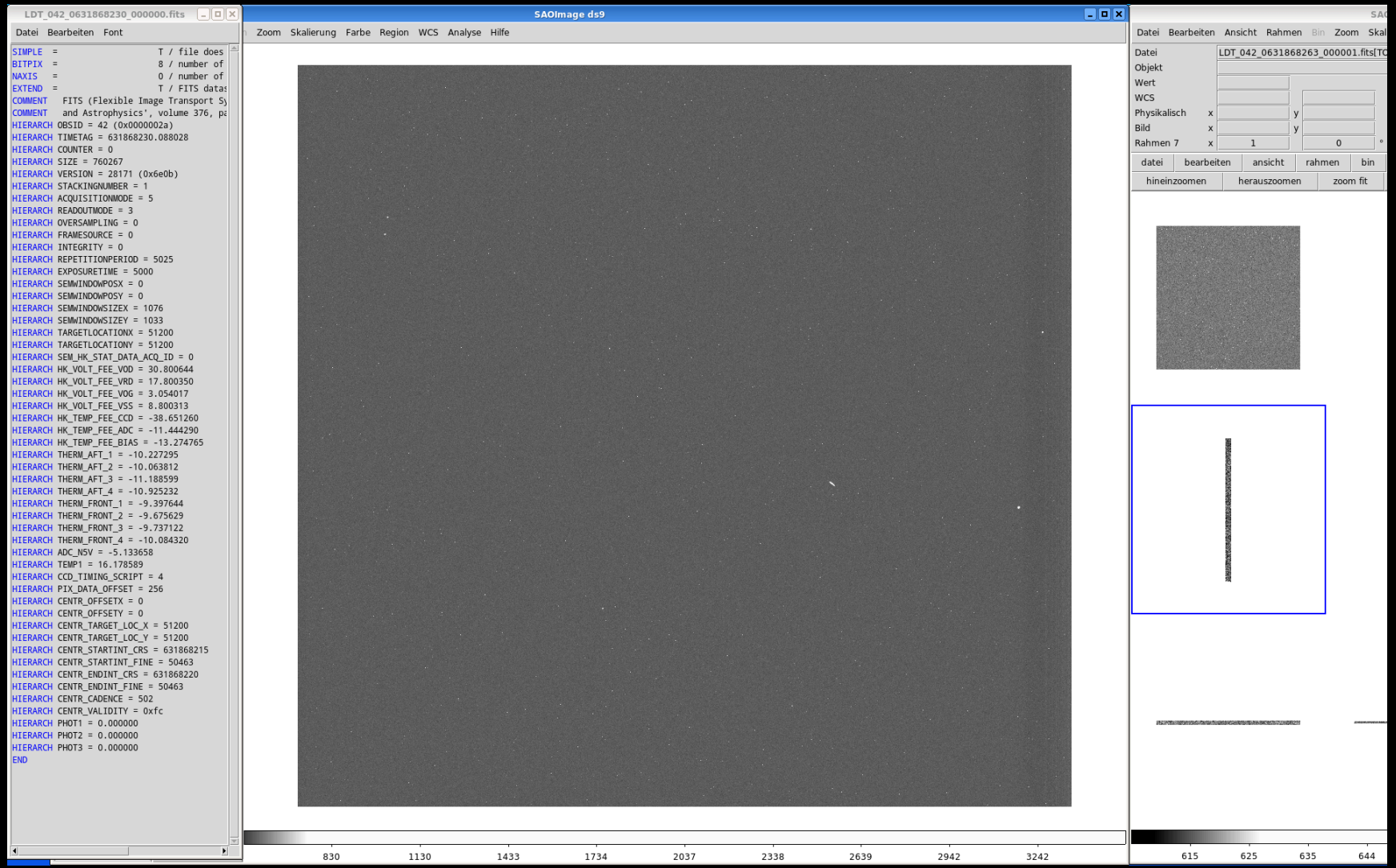
News since Dec 2019



Credits: ESA

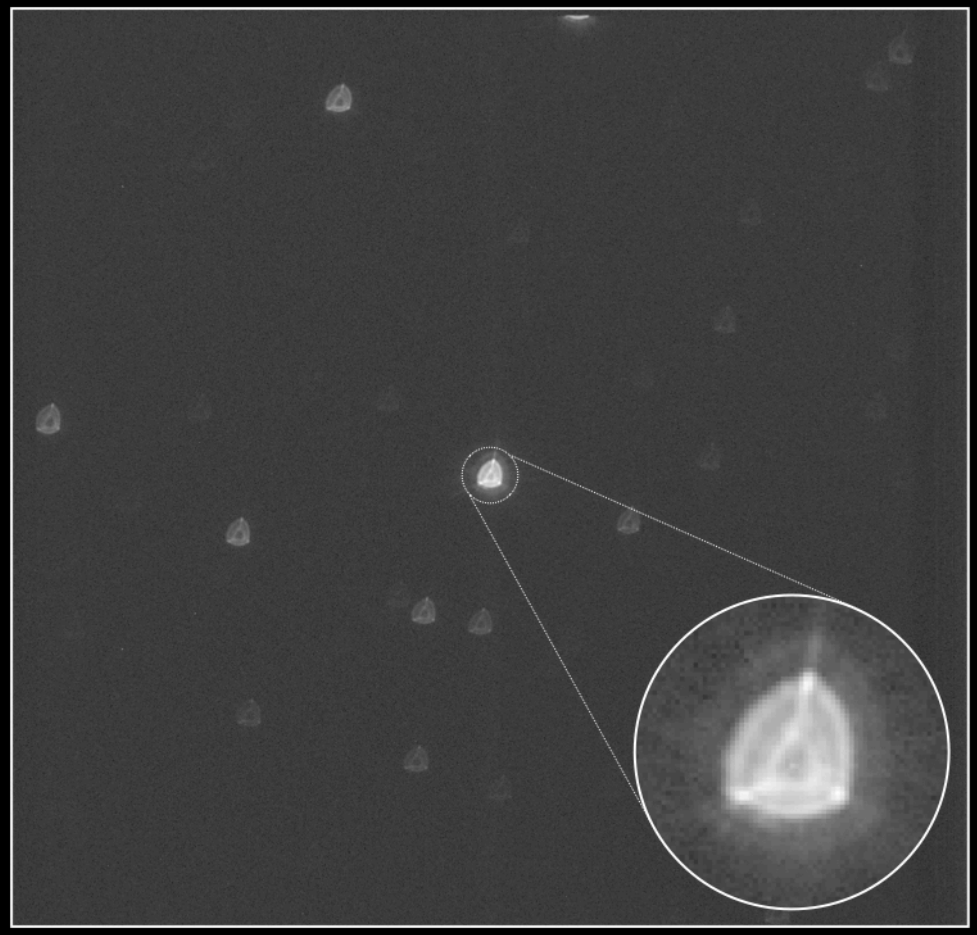
News since Dec 2019

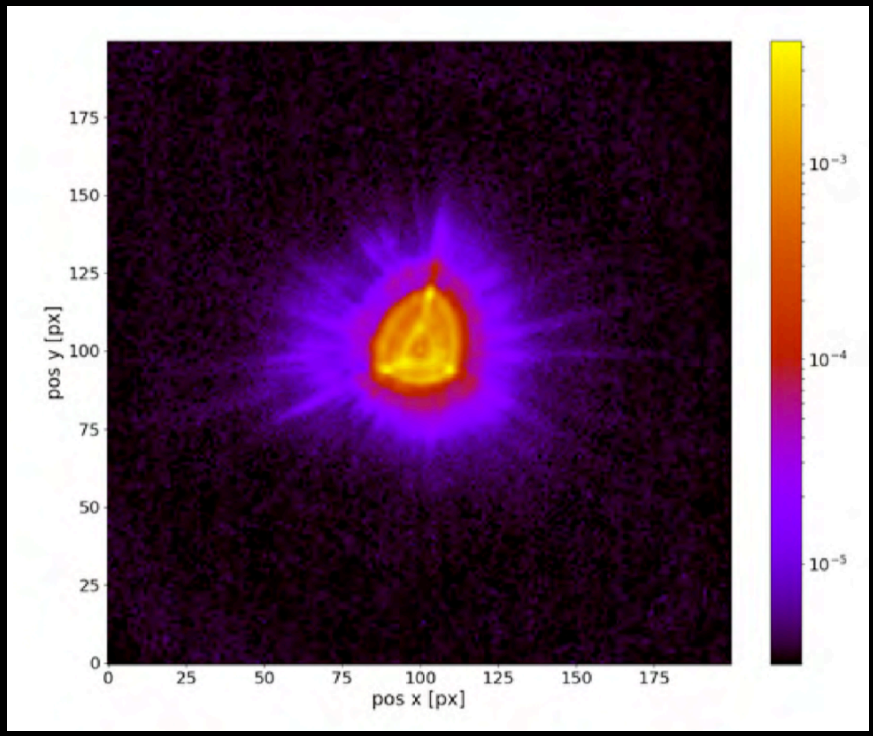
- 8 Jan 2020: CHEOPS switched on (darks!)



News since Dec 2019

- 8 Jan 2020: CHEOPS switched on (darks!)
- 29 Jan 2020: Cover opened!





Benz et al. (submitted)

News since Dec 2019

- 8 Jan 2020: CHEOPS switched on (darks!)
- 29 Jan 2020: Cover opened!

⋮

Lots of work by a wonderful & dedicated team

⋮

- 25 March 2020: In-orbit commissioning review

Successful!

CHEOPS
Pre-flight performances

A&A 635, A22 (2020)
https://doi.org/10.1051/0004-6361/201935977

Astronomy & Astrophysics

Expected performances of the Characterising Exoplanet Satellite (CHEOPS)

I. Photometric performances from ground-based calibration

A. Deline[1], D. Queloz[1,2], B. Chazelas[1], M. Sordet[1], F. Wildi[1], A. Fortier[3], C. Broeg[3], D. Futyan[1], and W. Benz[3]

Deline et al. (2020)

A&A 635, A23 (2020)
https://doi.org/10.1051/0004-6361/201936616

Astronomy & Astrophysics

Expected performances of the Characterising Exoplanet Satellite (CHEOPS)

II. The CHEOPS simulator

D. Futyan[1], A. Fortier[2], M. Beck[1], D. Ehrenreich[1], A. Bekkelien[1], W. Benz[2], N. Billot[1], V. Bourrier[1], C. Broeg[2], A. Collier Cameron[3], A. Deline[1], T. Kuntzer[1], M. Lendl[1,4], D. Queloz[1,5], R. Rohlfs[1], A. E. Simon[2], and F. Wildi[1]

Futyan et al. (2020)

A&A 635, A24 (2020)
https://doi.org/10.1051/0004-6361/201936325

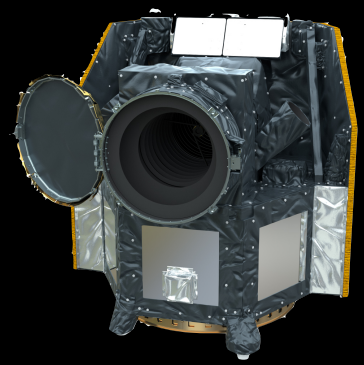
Astronomy & Astrophysics

Expected performances of the Characterising Exoplanet Satellite (CHEOPS)

III. Data reduction pipeline: architecture and simulated performances

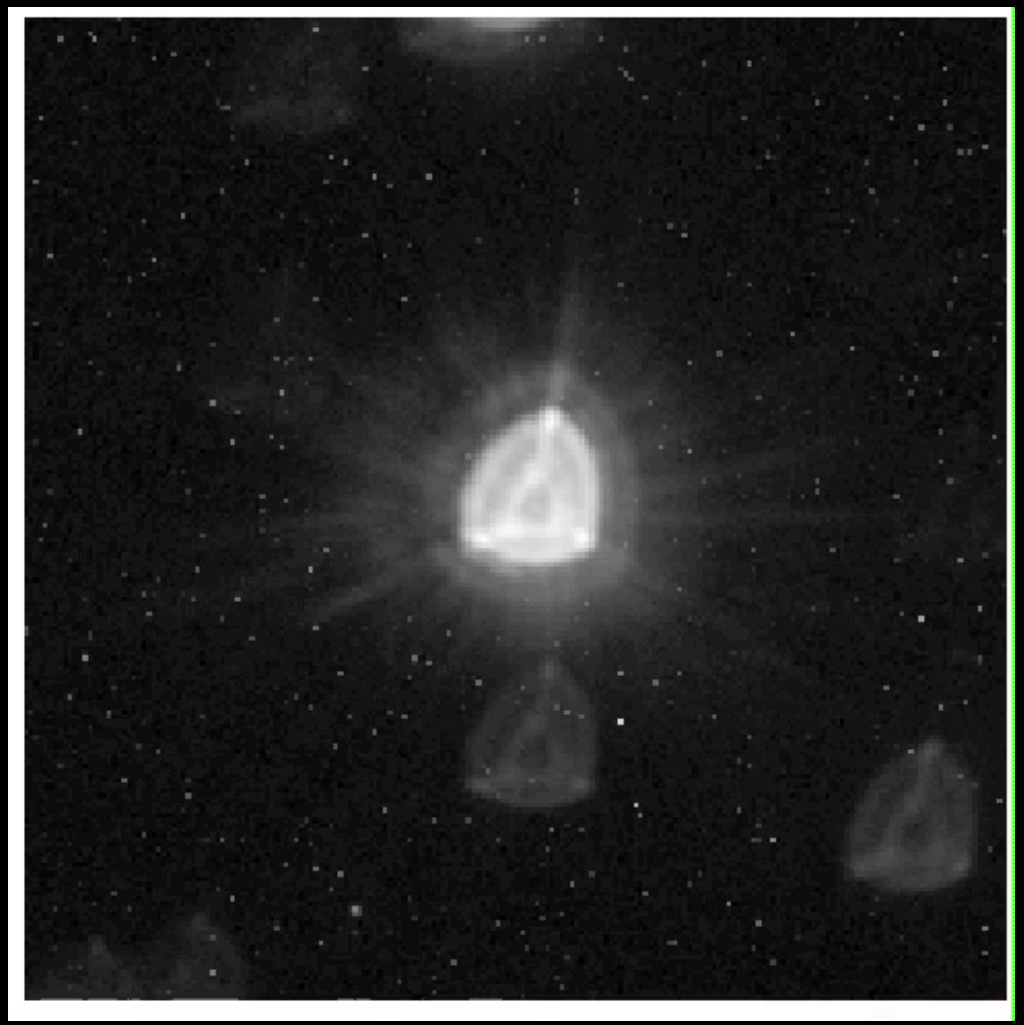
S. Hoyer[1], P. Guterman[1,2], O. Demangeon[1,3], S. G. Sousa[3], M. Deleuil[1], J. C. Meunier[1], and W. Benz[4]

Hoyer et al. (2020)



In-flight performances

- 47 hour sequence on *V*=9 star



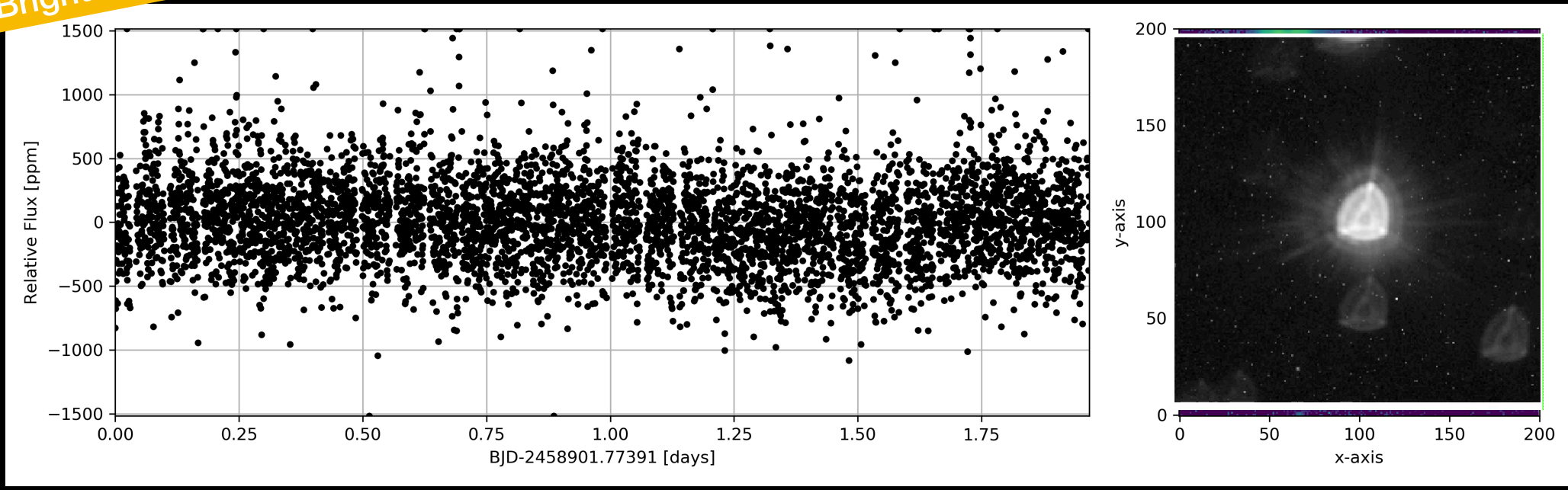
Credits: CHEOPS Project Science Office
Andrea Fortier (Instrument scientist), Christopher Broeg (project manager)

In-flight performances

- 47 hour “flat” sequence on ***V*=9** star

Bright stars

Benz et al. (submitted)

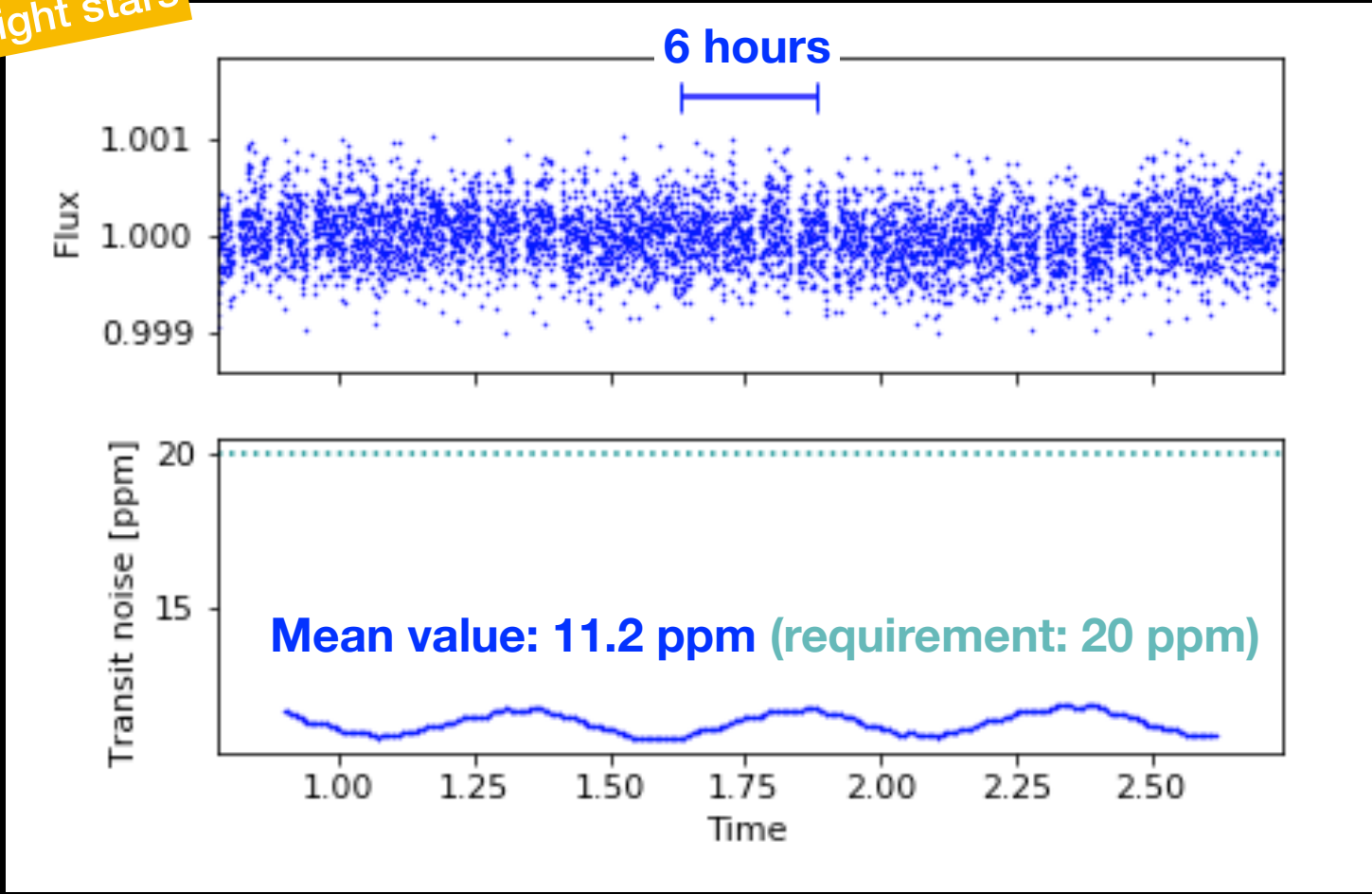


Credits: CHEOPS Project Science Office
Andrea Fortier (Instrument scientist), Christopher Broeg (project manager)

In-flight performances

Minimum transit depth that can be detected with SNR=1
(≈ Kepler's CDPP; Christiansen et al. 2012)

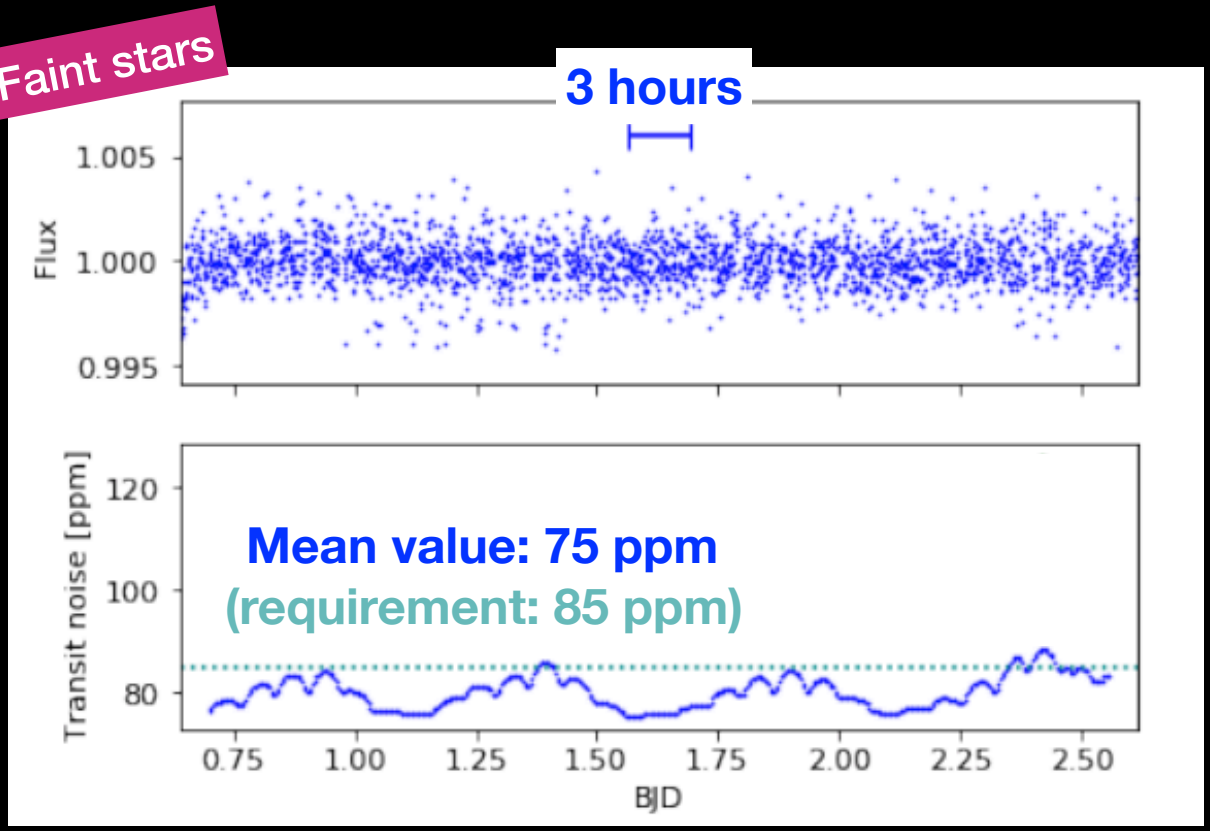
Bright stars

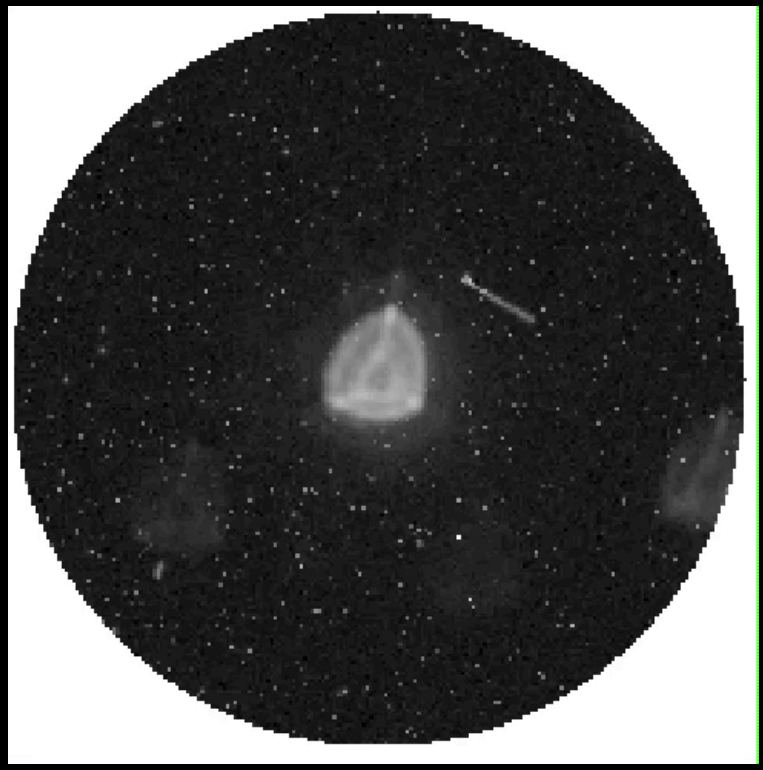


Credits: CHEOPS Project Science Office
Andrea Fortier (Instrument scientist), Christopher Broeg (project manager)

In-flight performances

- 47 hour “flat” sequence on ***V*=12** star





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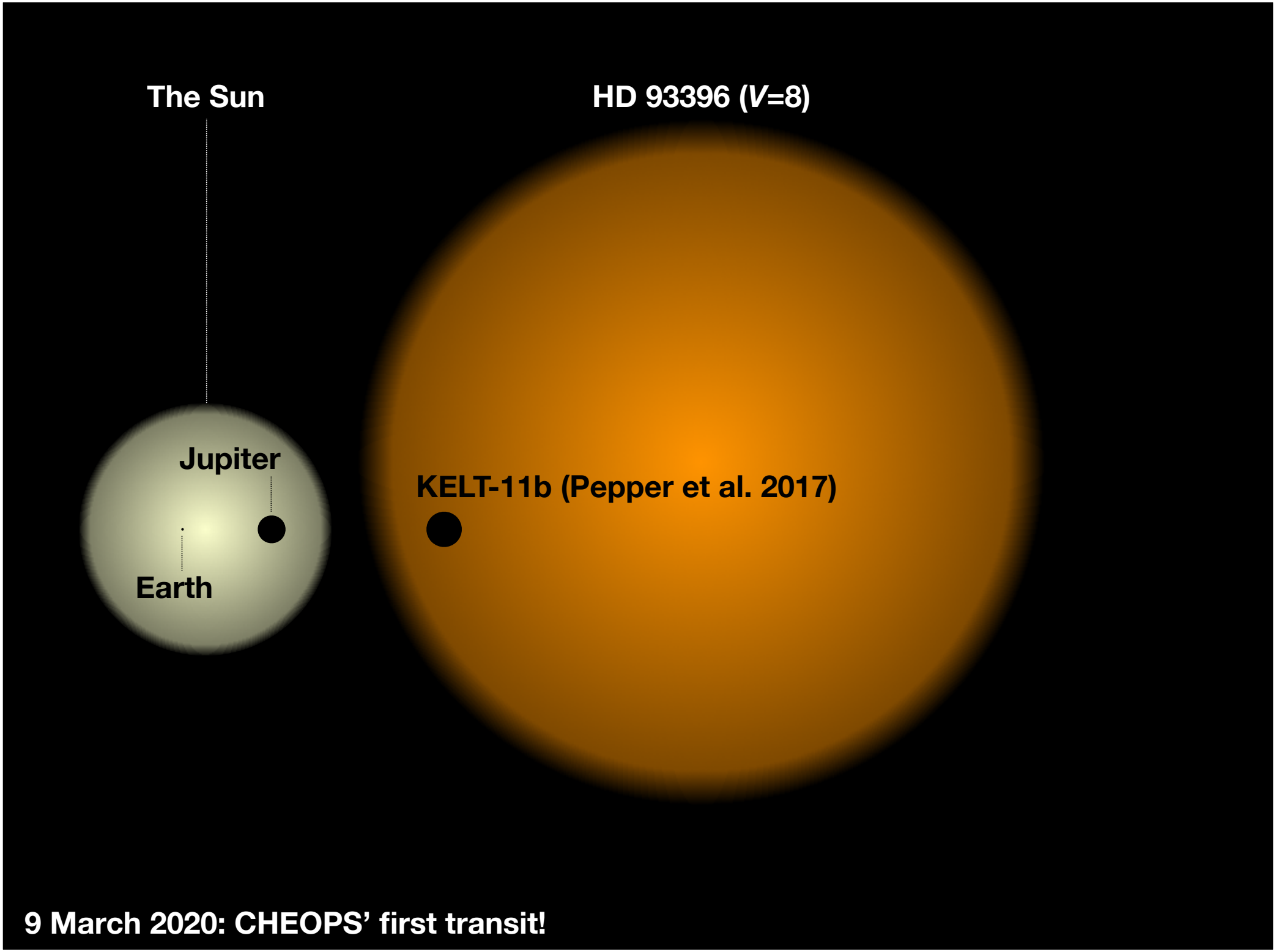
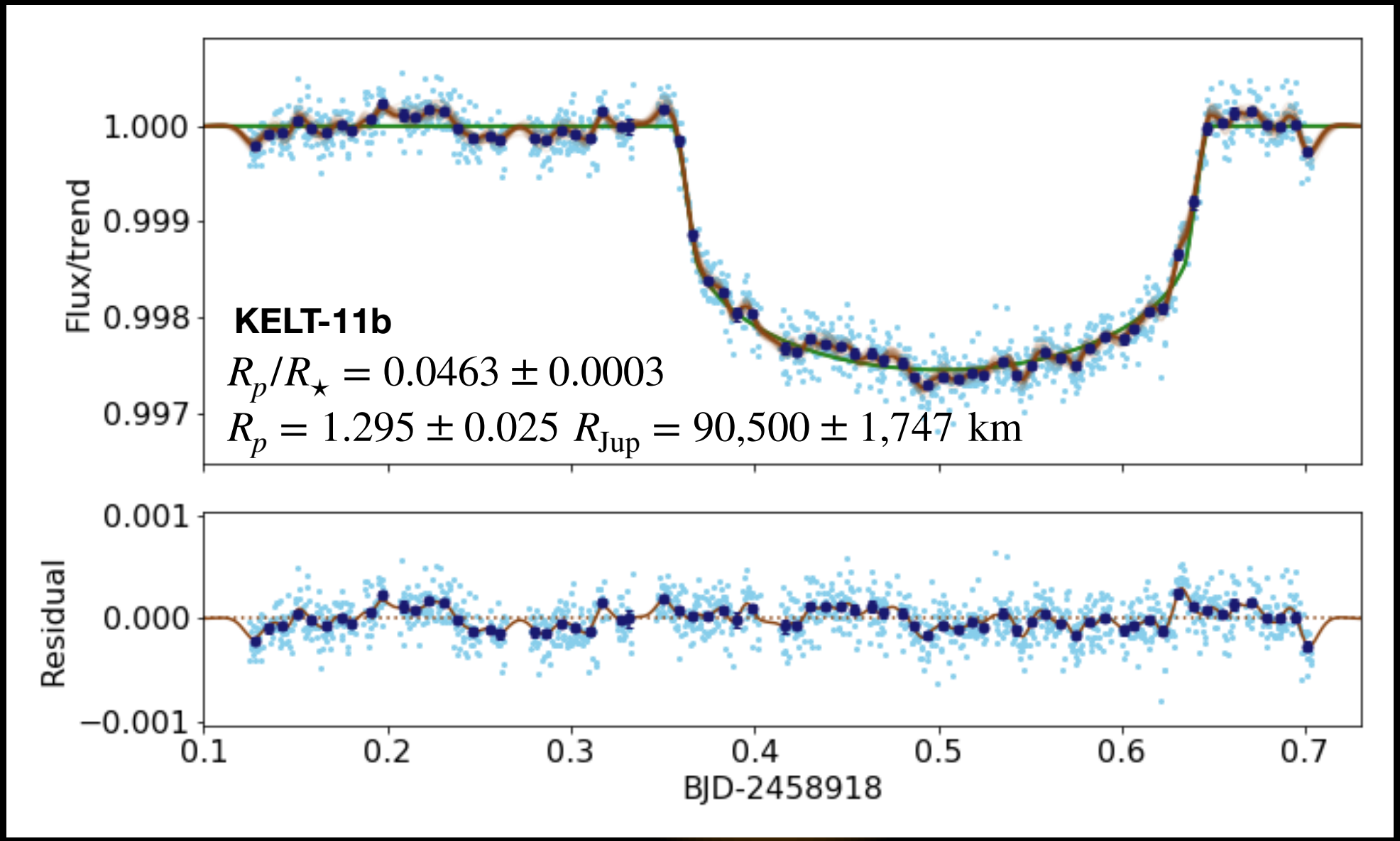
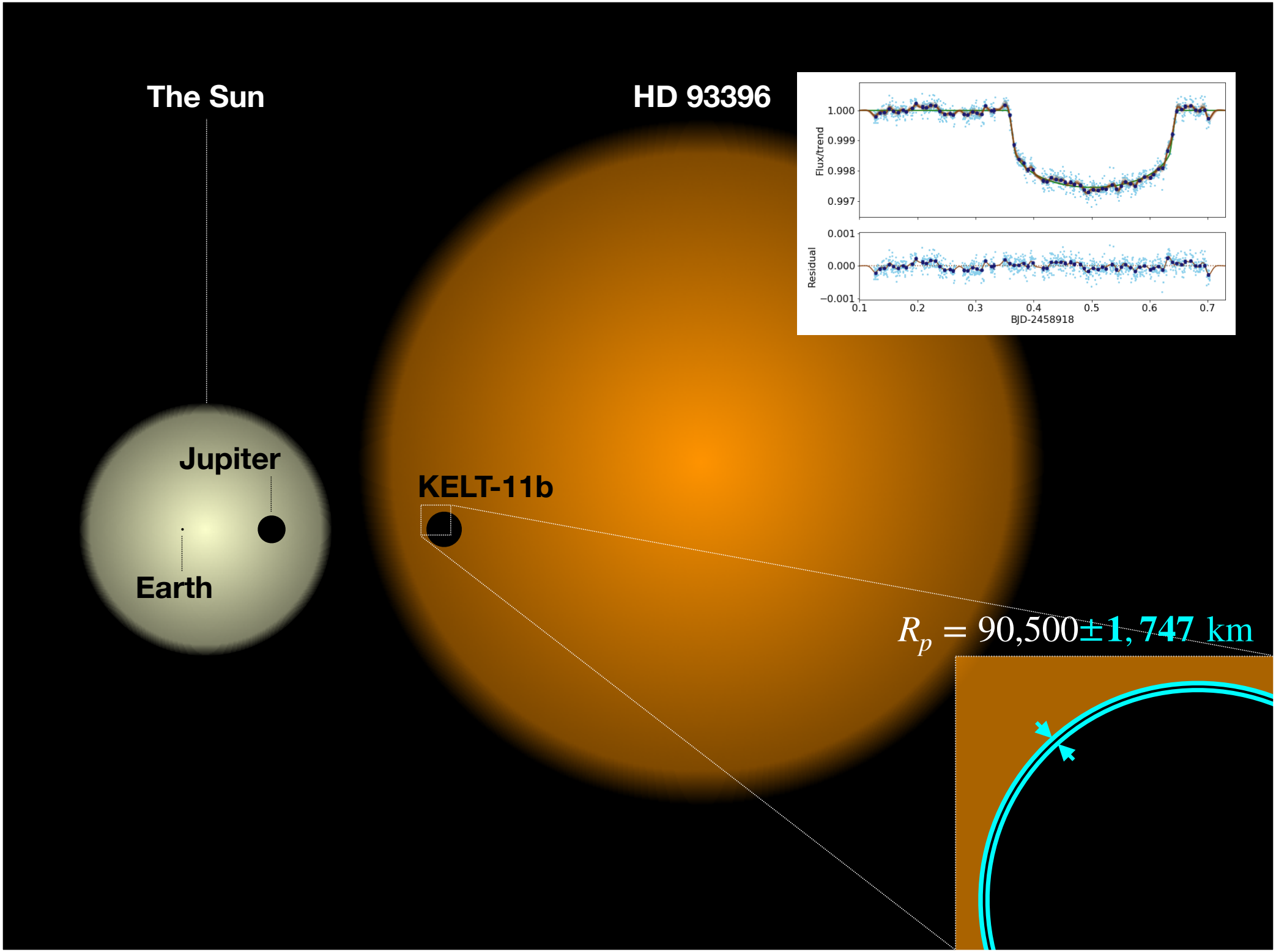

The Sun
HD 93396 (V=8)
Jupiter
KELT-11b (Pepper et al. 2017)
Earth
9 March 2020: CHEOPS' first transit!



Benz et al. (submitted)

9 March 2020: CHEOPS' first transit!


The Sun
HD 93396
Jupiter
Earth
KELT-11b
Flux/trend
1.000
0.999
0.998
0.997
Residual
0.001
0.000
−0.001
0.1
0.2
0.3
0.4
0.5
0.6
0.7
BJD-2458918
$R_p = 90{,}500 \pm 1{,}747$ km

ESA Guest Observer's programme

- 20% observing time to Community
- Proposals solicited through Annual Calls, open to ***all***
- Selected on scientific merit, by an ESA-appointed TAC
- Can be on ***any science topic***,
  using existing capabilities of CHEOPS
  * Targets on the Guaranteed Time Target List (Science Team) are ***blocked***
- Second Call/Announcement of Opportunity
  ➡ **Fall 2020** (for observations beginning in April 2021)

+ ESA DDT programme opening soon