ARIEL

Enabling planetary science across light-years

Ignasi Ribas

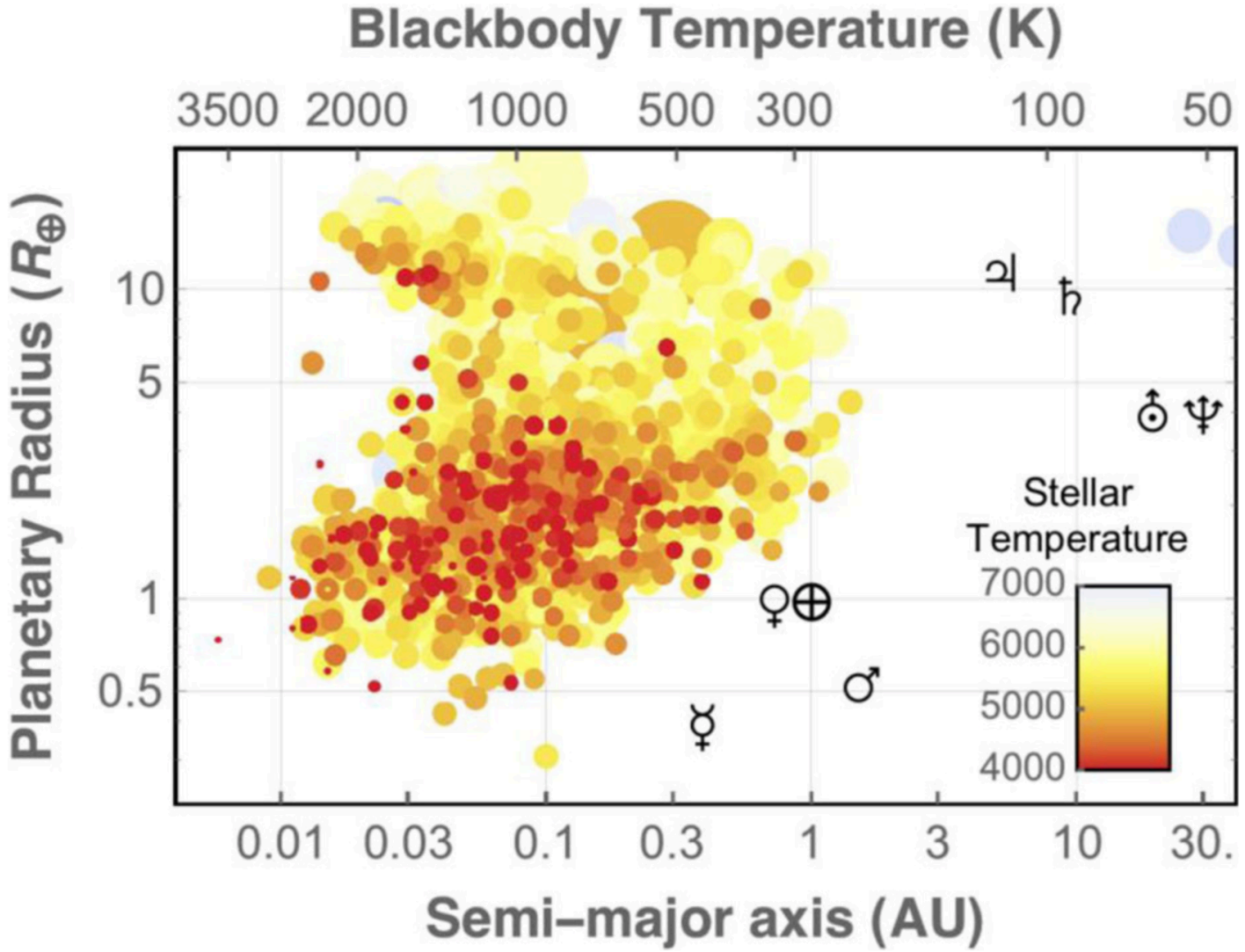
Institut d'Estudis Espacials de Catalunya (IEEC)

Institut de Ciències de l'Espai (ICE, CSIC)

1st meeting of ExoNet, Granada, 22/2/2019

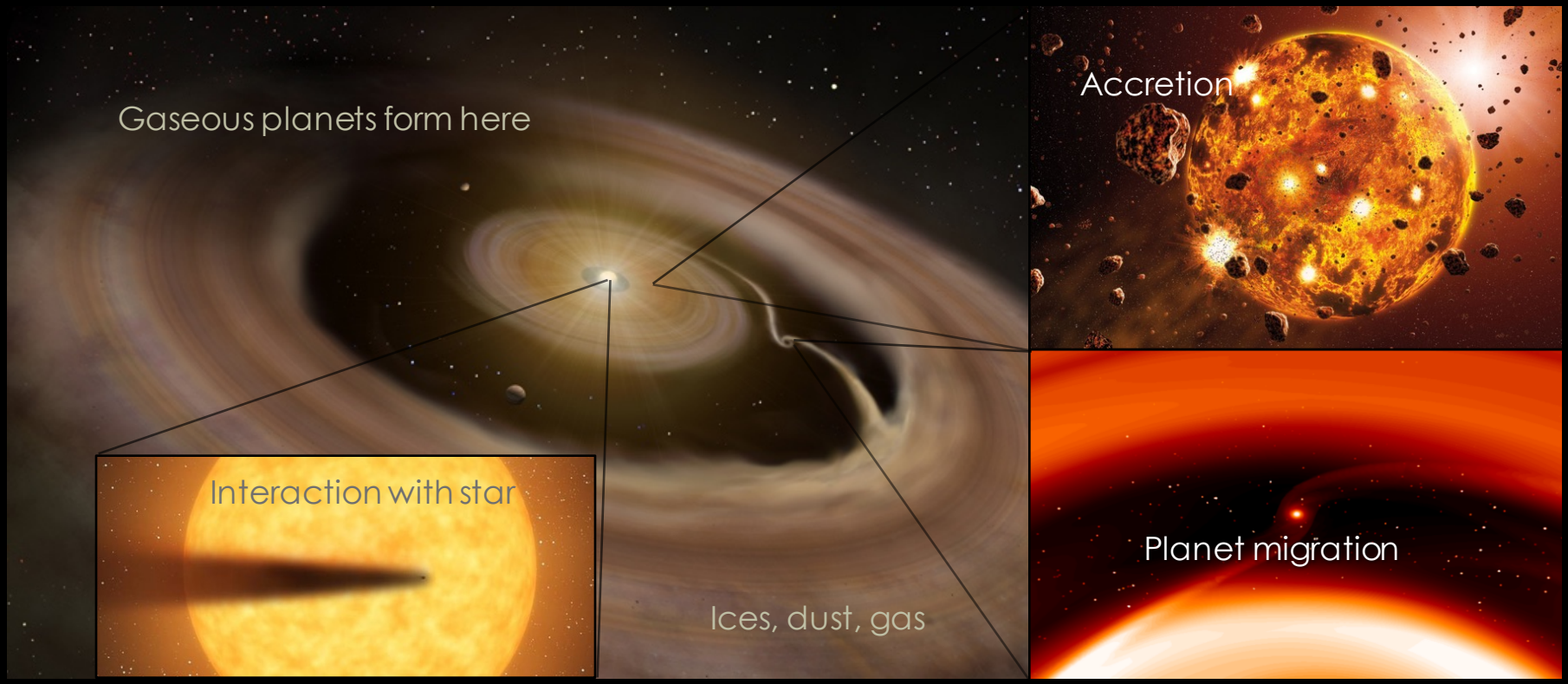
Exoplanets today: huge diversity

3800+ PLANETS, 2700 PLANETARY SYSTEMS KNOWN IN THE GALAXY



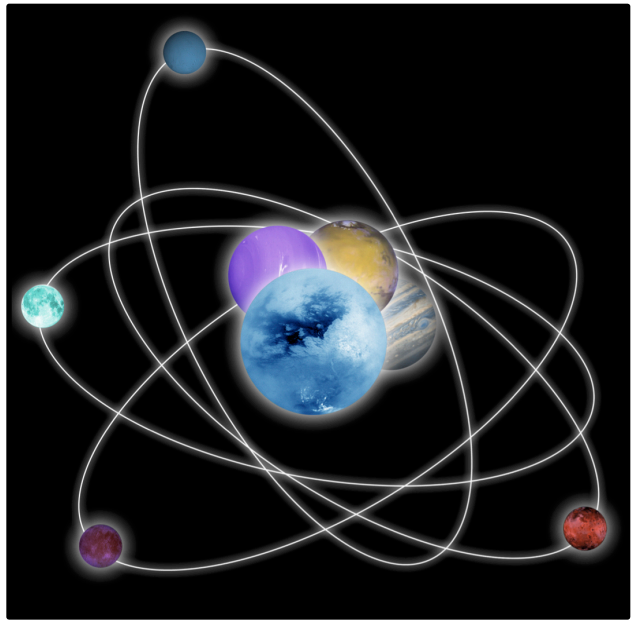
Huge diversity: why?

Formation & evolution processes?
Migration? Interaction with star?



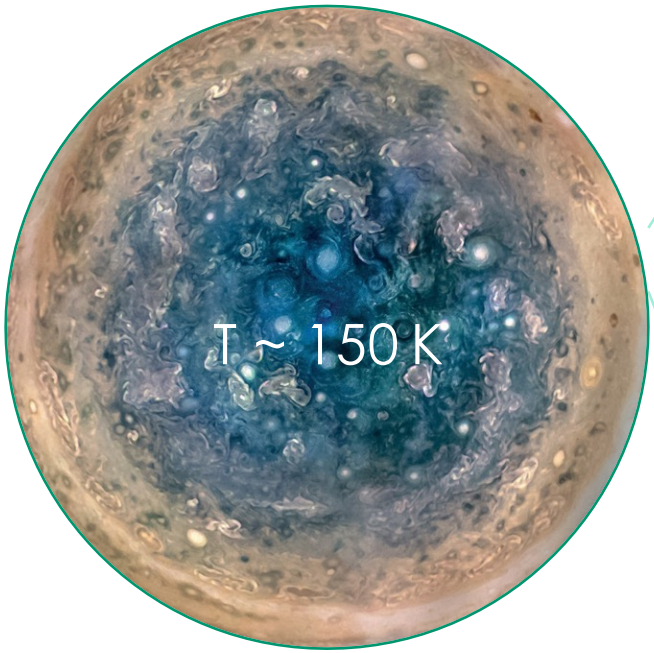
Key exoplanet questions

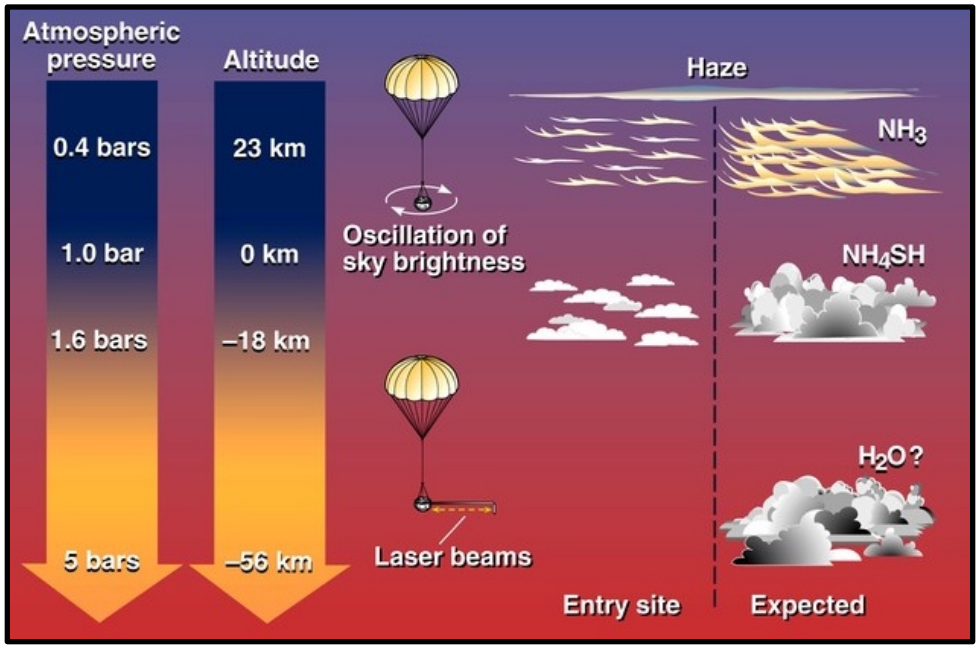
- How diverse are exoplanets chemically?
- Does chemical diversity correlate with other parameters?
  - How do planets form?
  - How do planets evolve?



The Sun's planets are cold

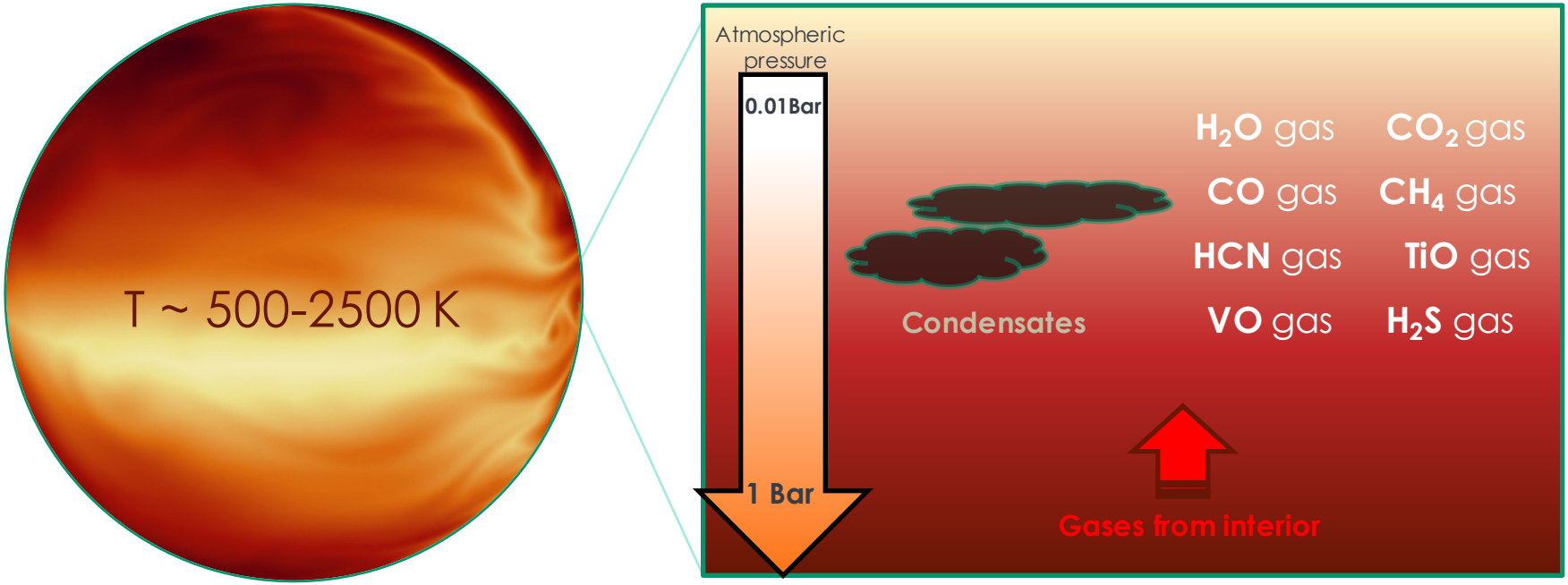
SOME KEY O, C, N, S MOLECULES ARE **NOT** IN GAS FORM





Warm/hot exoplanets

O, C, N, S (Ti, VO, Si) molecules are in gas form

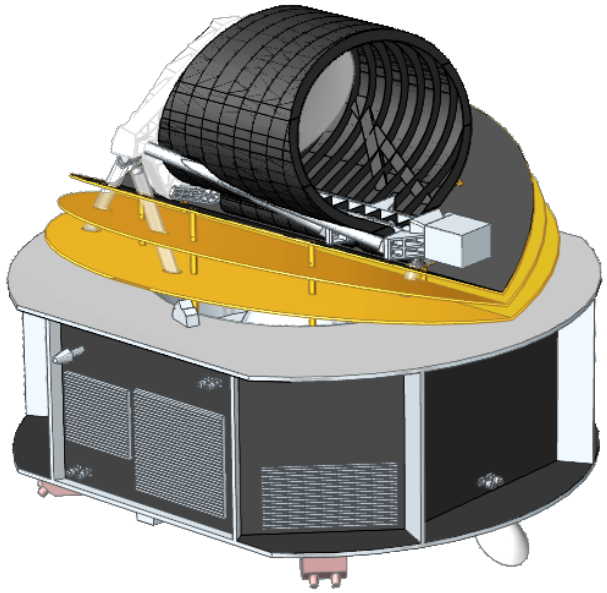


Issues with current data

- Low SNR & R observations
- Data are sparse, not enough wavelength coverage
- Broad wavelength coverage is not simultaneous
- Absolute calibration at the level of 10^{-4} is not guaranteed!
- Instrument systematics are difficult to disentangle from the signal
- Stellar activity is the largest source of astrophysical noise
- We need observations on a population of objects to draw conclusions

ARIEL – ESA M4 mission

- 1-m telescope, spectroscopy from VIS to IR
- Satellite in orbit around L2
- ~1000 exoplanets observed (rocky + gaseous)
- Launch in 2028 – 3.5-yr mission
- Simultaneous coverage 0.5-7.8 micron
- Payload consortium: 15 ESA countries + NASA under study



Channel Name	Wavelength (μm)	Spectral Resolution
VisPhot	0.5 – 0.55	Photometer
FGS-1	**0.6 – 0.8**	Photometer
FGS-2	**0.8 – 1.1**	Photometer
NIRSpec	**1.1 – 1.95**	R ~ 20
AIRS-Ch0	1.95 – 3.9	R = 102 – 180
AIRS-Ch1	3.9 – 7.8	R = 30 – 64

The exoplanet mission timeline

Ground-based observatories

First discoveries of exoplanets in the 1990s opened up the field of exoplanet research. New innovations and discoveries continue to this day

Launch

1990 — **Hubble**

Probing the composition of exoplanet atmospheres

2003 — **Spitzer**

Studying exoplanet signatures in infrared light

2006 — **Corot**

Pioneering stellar seismology and exoplanet hunting mission

2009 — **Kepler/K2**

A targeted search for terrestrial and larger planets in or near the habitable zone of a wide variety of stars

2013 — **Gaia**

Revealing exoplanets through its all-sky survey of the position, brightness and motion of over one billion stars

2018 — **Tess**

First all-sky transit survey satellite

Cheops

First step characterisation of known Earth-to-Neptune size exoplanets

Webb

Detailed characterisation of exoplanet atmospheres through transit studies and direct imaging

Plato

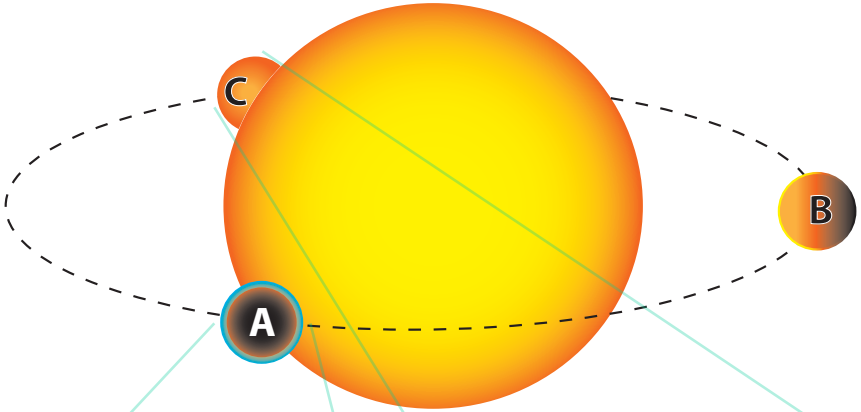
Studying terrestrial planets in orbits up to the habitable zone of Sun-like stars, and characterising these stars

Ariel

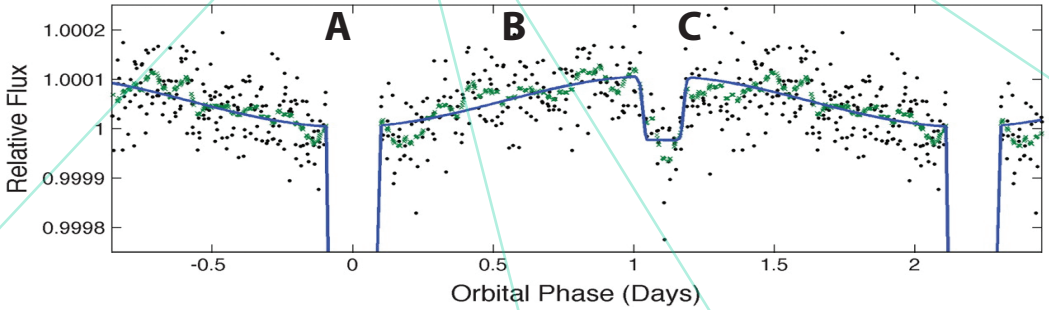
Performing a chemical census of a large and diverse sample of exoplanets by analysing their atmospheres

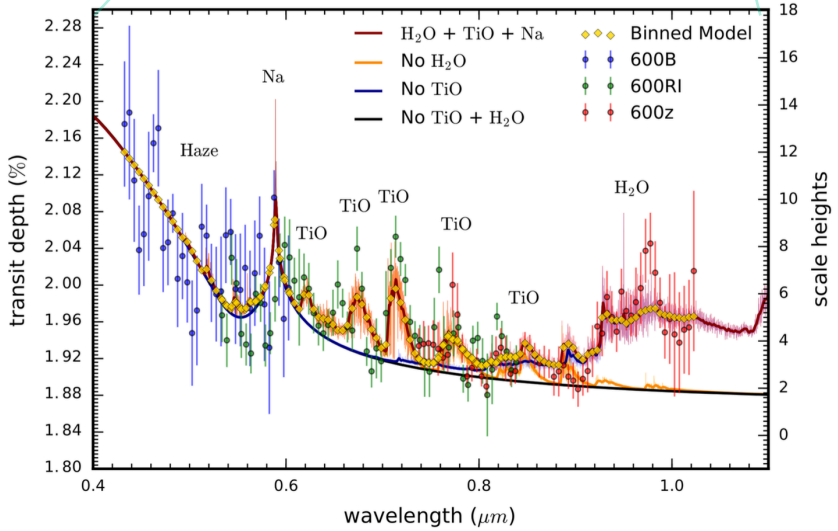
Dedicated exoplanet missions

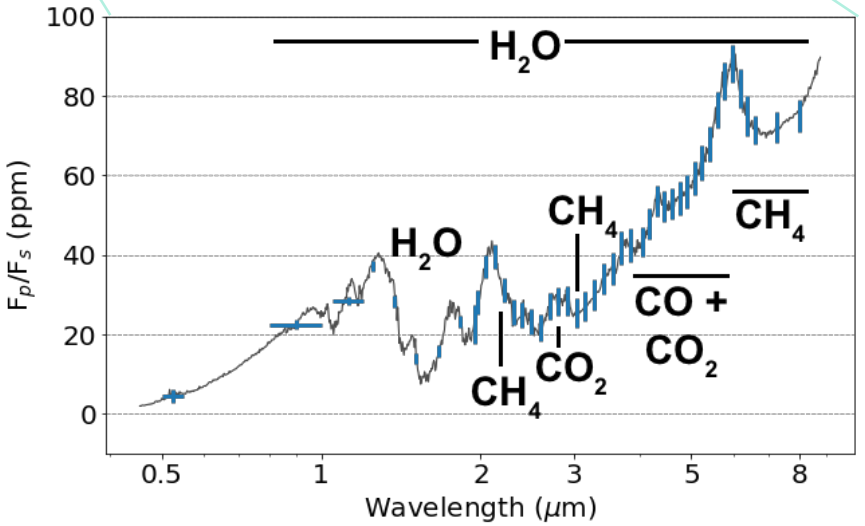
Exoplanet-sensitive missions



10^{-4} – 10^{-5} relative precision



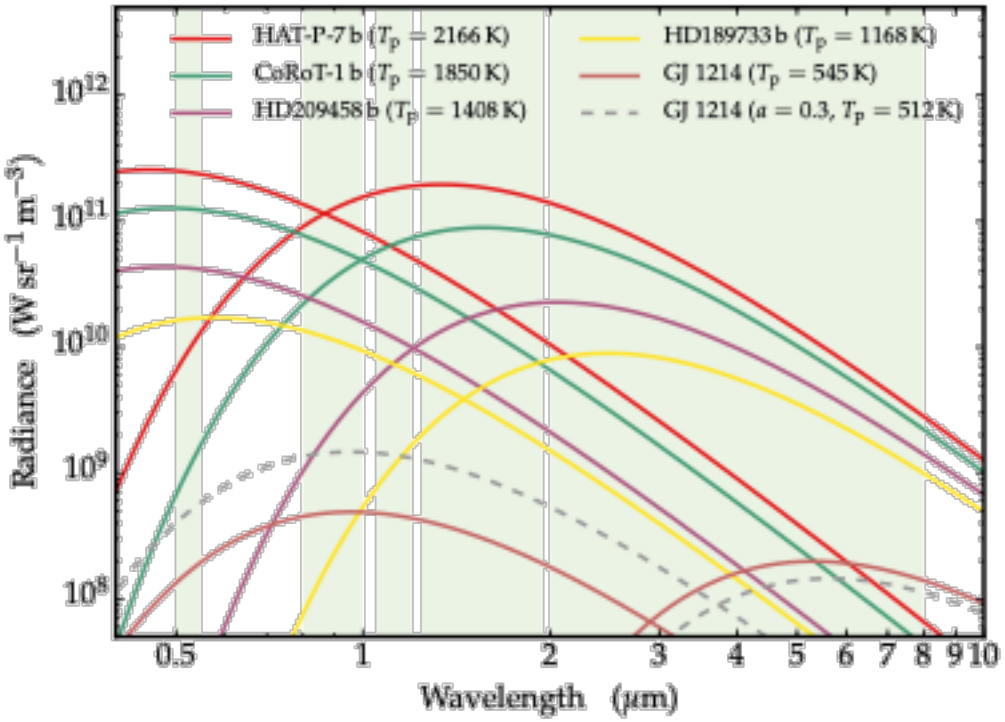


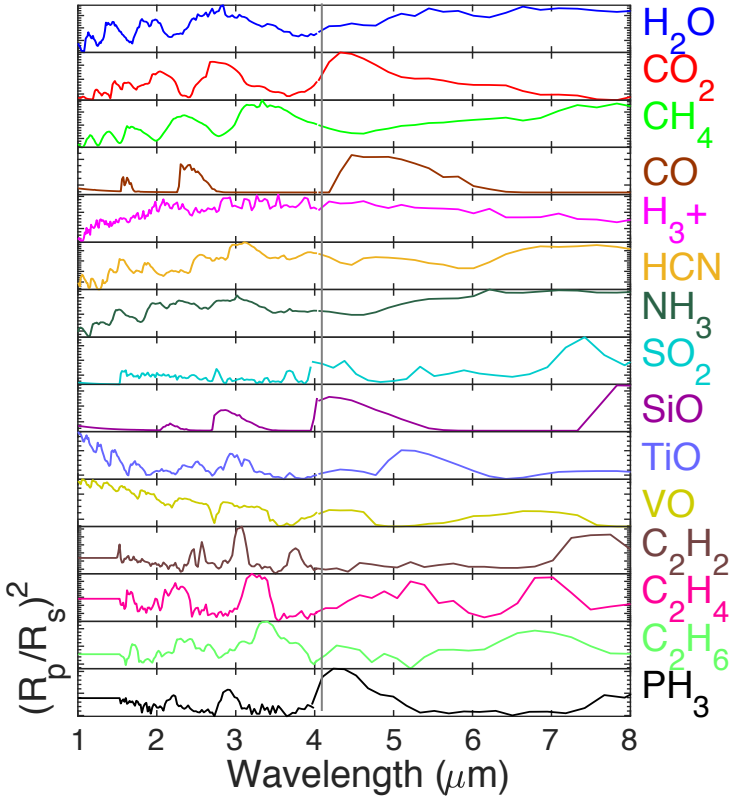


Sedaghati et al. 2017

A chemical survey of a large population

SCIENCE REQUIREMENTS: **EXOPLANET RADIATION, MOLECULAR** & CLOUD SIGNATURES, STELLAR ACTIVITY

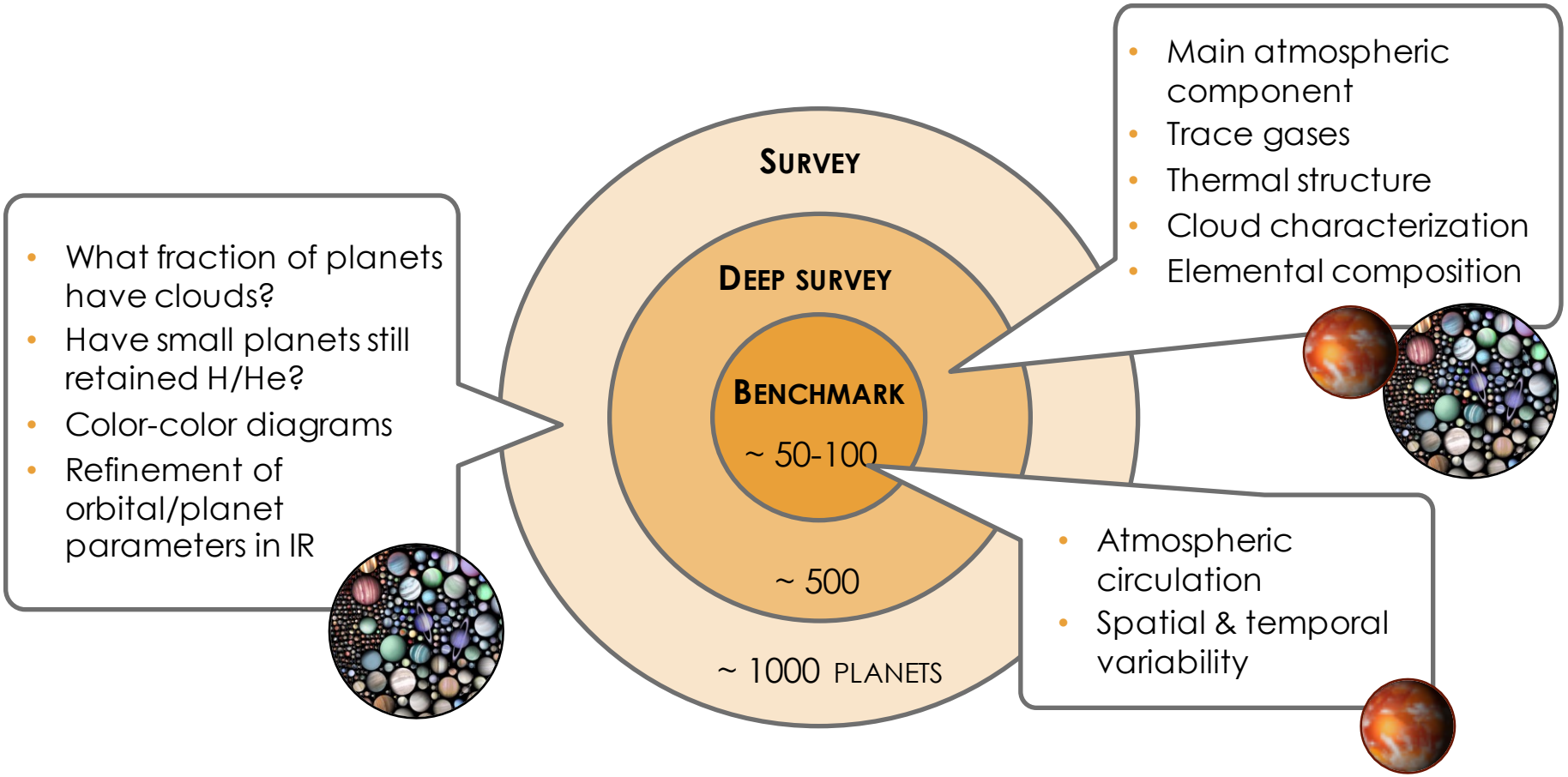




Simultaneous observations in the VIS and IR are needed

ARIEL 3-tier approach

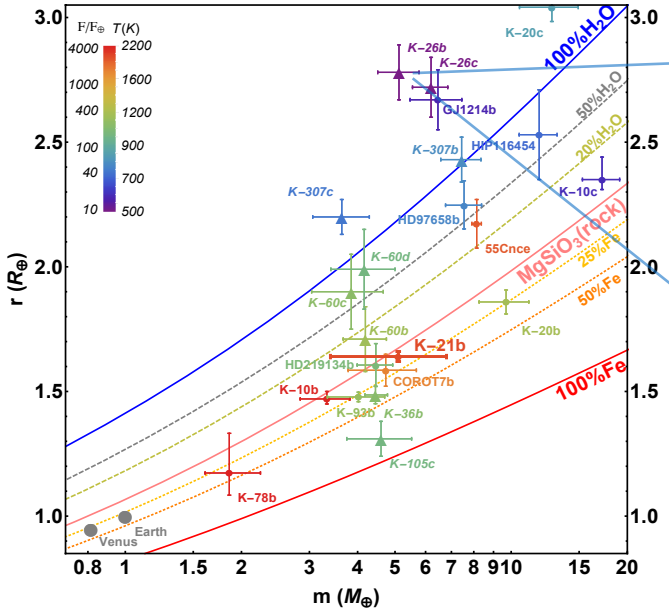
INDIVIDUAL PLANETS & POPULATION ANALYSIS



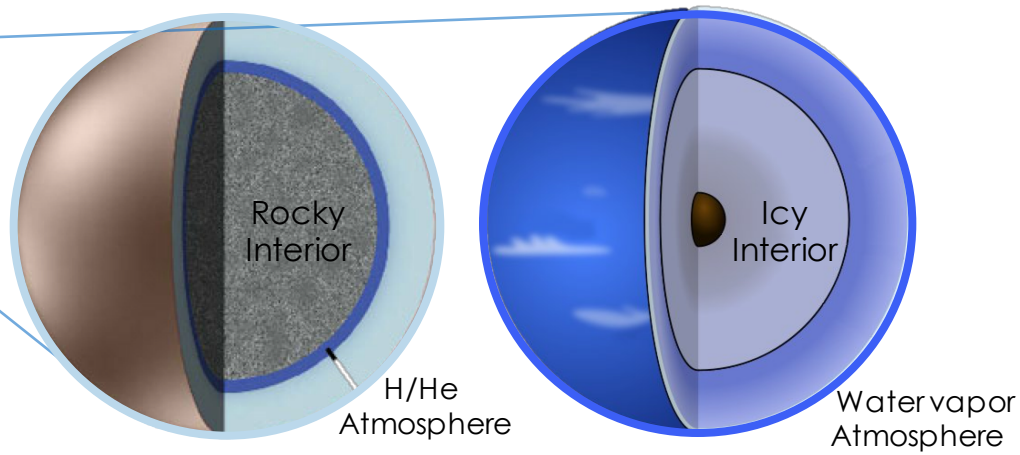
Chemical diversity

ARIEL WILL CLARIFY CORRELATION WITH THE DENSITY

Density observations



Atmospheric composition through ARIEL will clarify the degeneracy

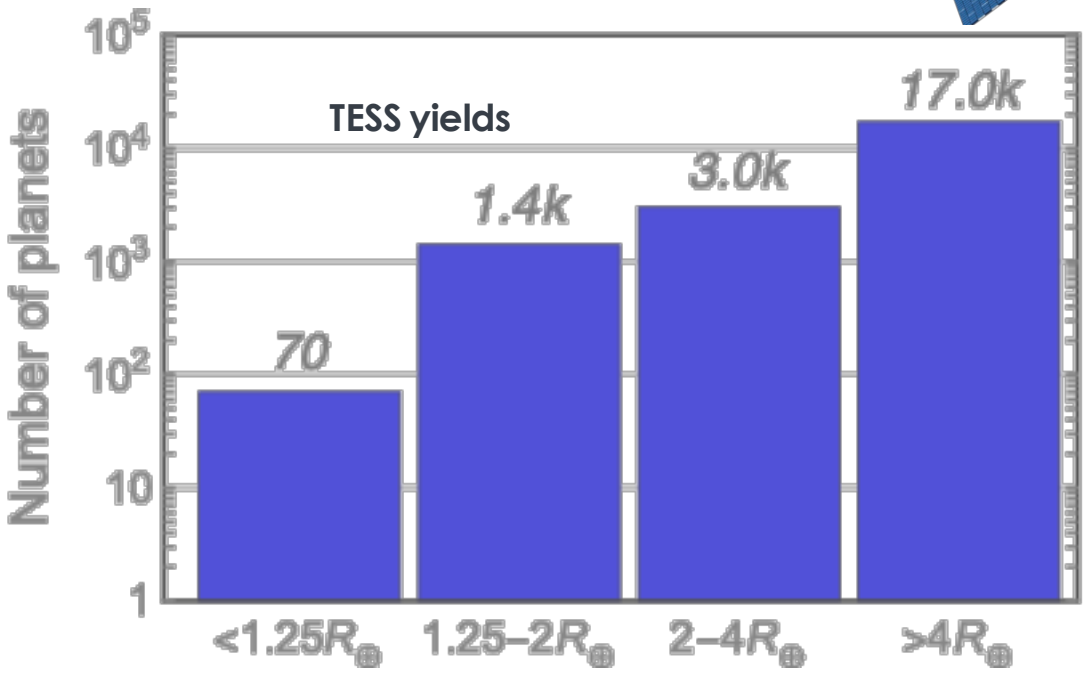


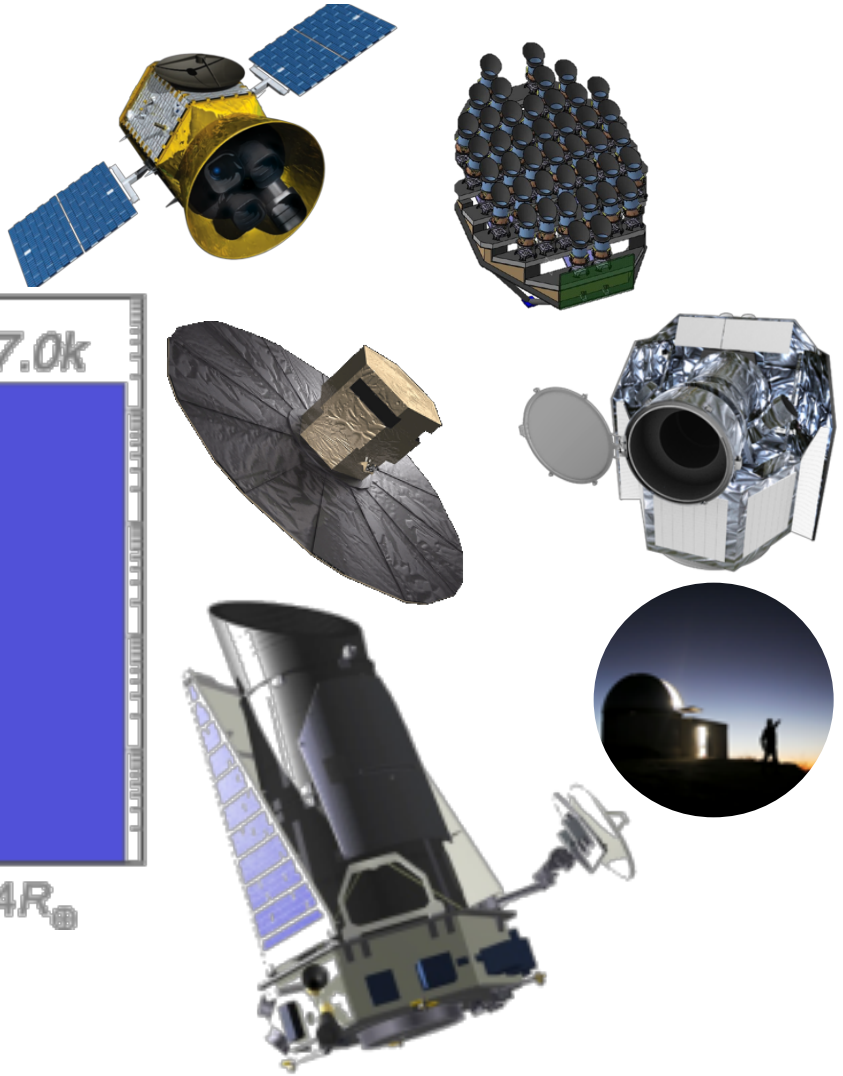
<u>Same</u> mean density – <u>Different</u> atmospheric signatures

López-Morales et al. 2016; Valencia et al. 2013

Large population of warm/hot planets

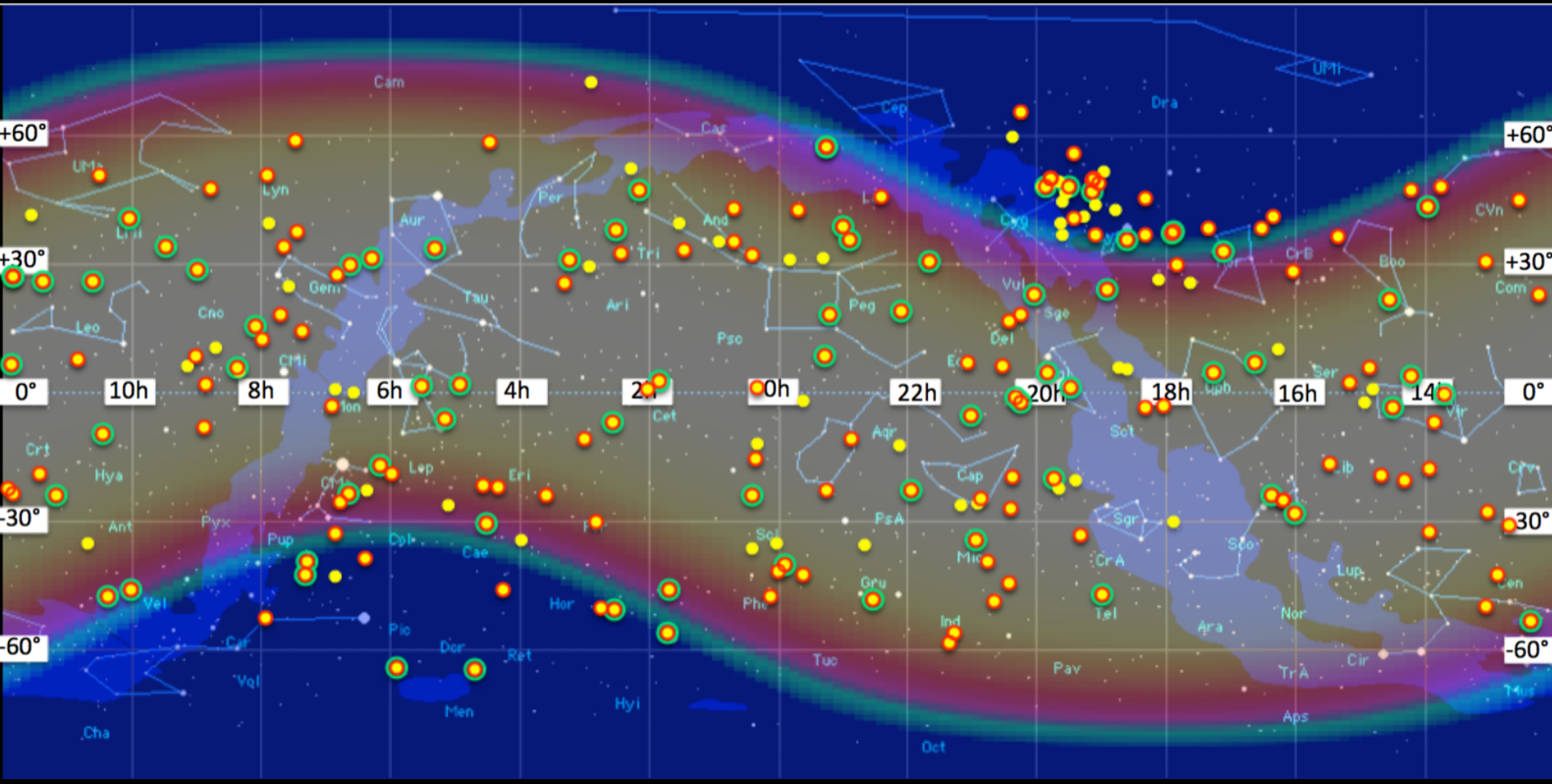
TODAY AND IN THE NEXT DECADE





Sullivan et al. 2015

ARIEL sky visibility



Instantaneous Sky Visibility

100% 80% 60% 40%

- Survey
- Deep
- Benchmark

ARIEL science working groups

Spectral retrieval:

Michiel Min (SRON), Joanna Barstow (UCL), Ingo Waldmann (UCL)

Planet interior:

Ravit Helled (Un. Zurich), Stephanie Werner (Un. Oslo)

Planet formation:

Diego Turrini (INAF)

Disks:

Mihkel Kama (Cambridge), Olja Panic (Leeds)

Atmospheric chemistry:

Olivia Venot (LISA), Yamila Miguel (Un. Leiden), Franck Selsis (Un. Bordeaux)

Mass measurement with RV:

Lars A. Buchhave (DTU), Olivier Demangeon (Un. Porto)

Stellar characterisation:

Camilla Danielski (CEA)

Data challenges:

Subi Sarkar (Un. Cardiff) and Theresa Leuftinger (Un. Vienna) (Stellar activity)

Nikos Nikolaou (UCL) (Data reduction), Michel Min (SRON) (Retrievals)

Stellar activity:

Bart Vandenbussche (Un. Leuven), Ignasi Ribas (IEEC-CSIC), Giusi Micela (INAF)

Data analysis:

Ingo Waldmann (UCL), Angelos Tsiaras (UCL)

ARIEL science working groups

Upper atmosphere/star-planet interaction:

Antonio Garcia Muñoz (TU Berlin), Manuel Guedel (U. Vienna), Luca Fossati (U. Graz)

High-cadence photometry:

Davis Waltham (RH), Gyula Szabo (Un. Eötvös Loránd), Luca Borsato (Un. Padova)

Ephemerides:

Vincent Coudé du Foresto (Obs. Paris)

Phase-curves:

Benjamin Charnay (Obs. Paris), João Mendonça (DTU)

Albedo and reflected light (+ synergy with other instruments):

Olivier Demangeon (Un. Porto)

Synergy with ELT & ground-based obs.:

Enric Palle (IAC)

Synergy with JWST:

Pierre-Olivier Lagage (CEA)

Synergy with Solar System science:

Gabriella Gilli (Obs. Lisboa), Pedro Machado (Obs. Lisboa)

Synergy with PLATO and CHEOPS:

Isabella Pagano (INAF), Giampaolo Piotto (Un. Padova)

ARIEL science working groups

Scheduling:

Juan Carlos Morales (ICEE-CSIC), Andrea Moneti (IAP)

Performance simulations:

Enzo Pascale (La Sapienza/Cardiff), Subi Sarkar (Cardiff), Billy Edwards (UCL), Lorenzo Mugnai (La Sapienza)

Spectroscopic database:

Clara Sousa-Silva (MIT), Svatopluk Civiš (Heyrovsky Institute)

Other science: brown dwarfs:

Sarah Casewell (Un. Leicester)

Other science: young stellar objects:

Csaba Kiss (Konkoly Obs.), Krisztián Vida (Konkoly Obs.)

Novel methods to handle high-volume, high-dimensional data:

James Cho (QMUL)

Synergy with NGTS, HAT:

Matt Burleigh (Leicester Un.), Gaspar Bakos (Princeton)

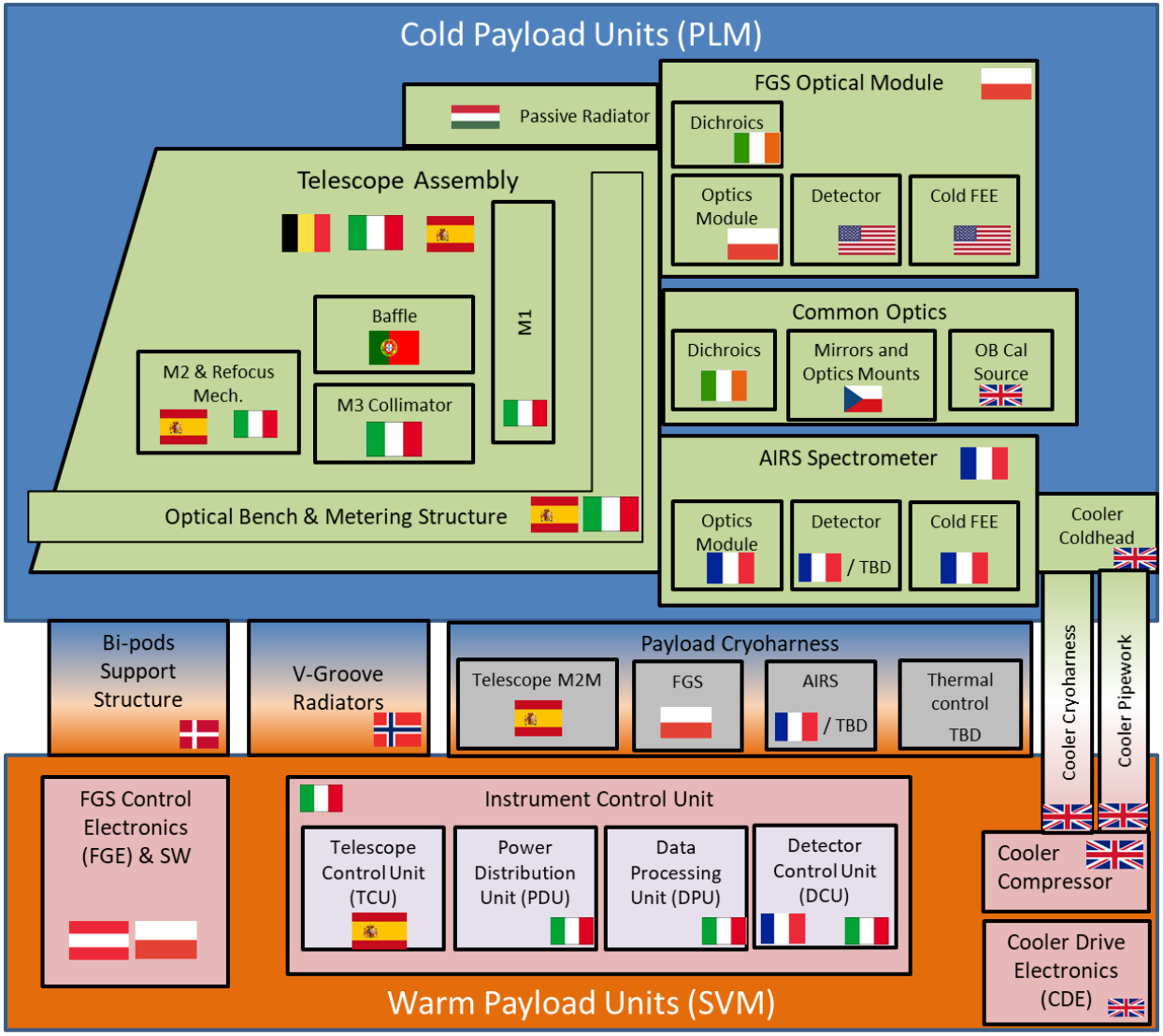
Synergy with TESS:

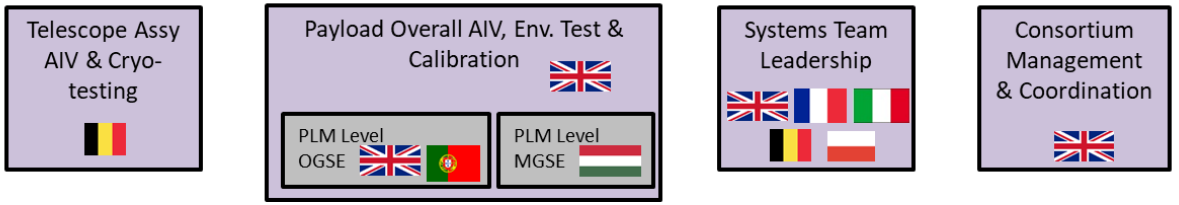
TBA from US

Synergy with amateur astronomers:

Anastasia Konkori (Royal Museums Greenwich), Marco Rocchetto (Konica Minolta)

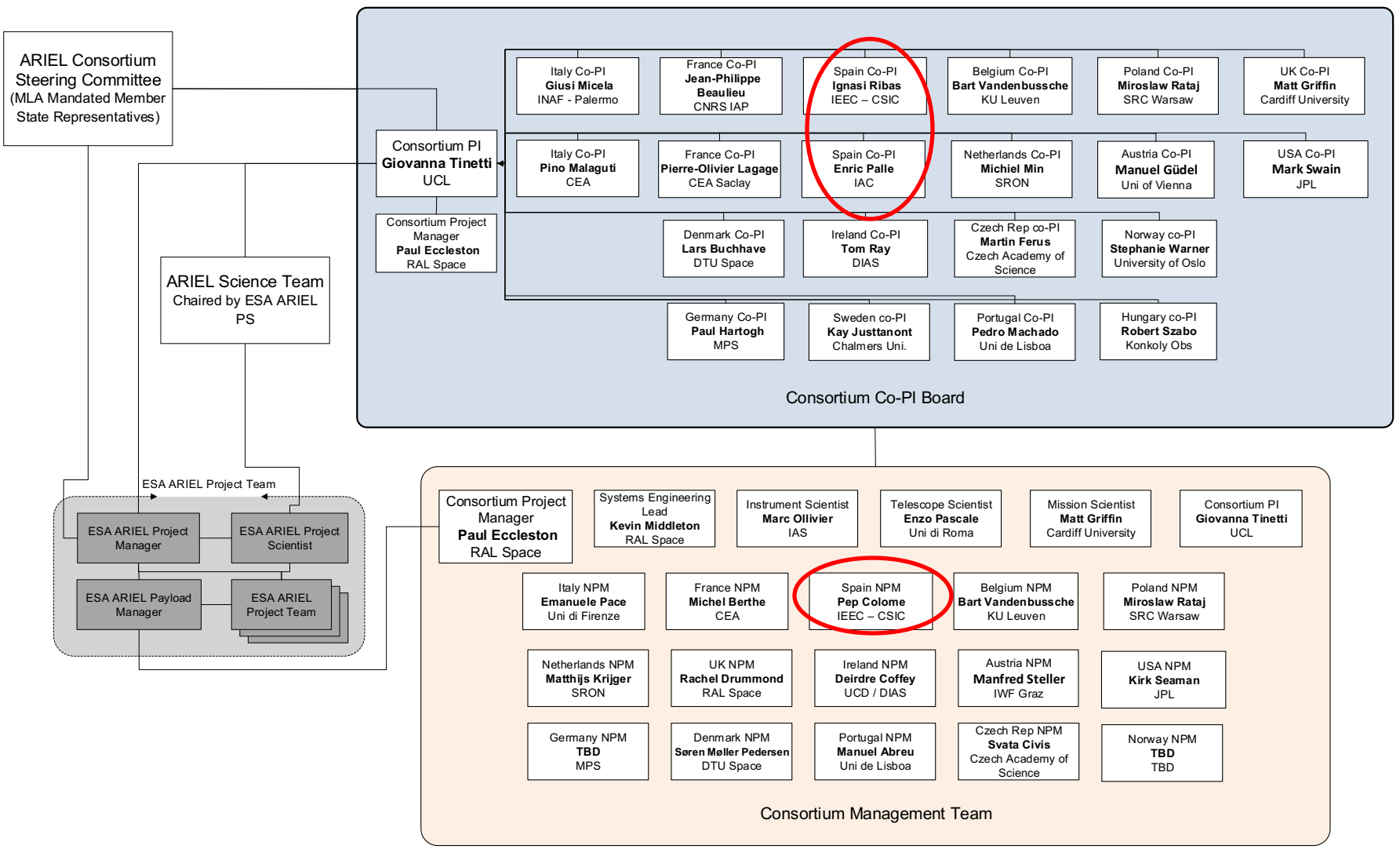
ARIEL payload



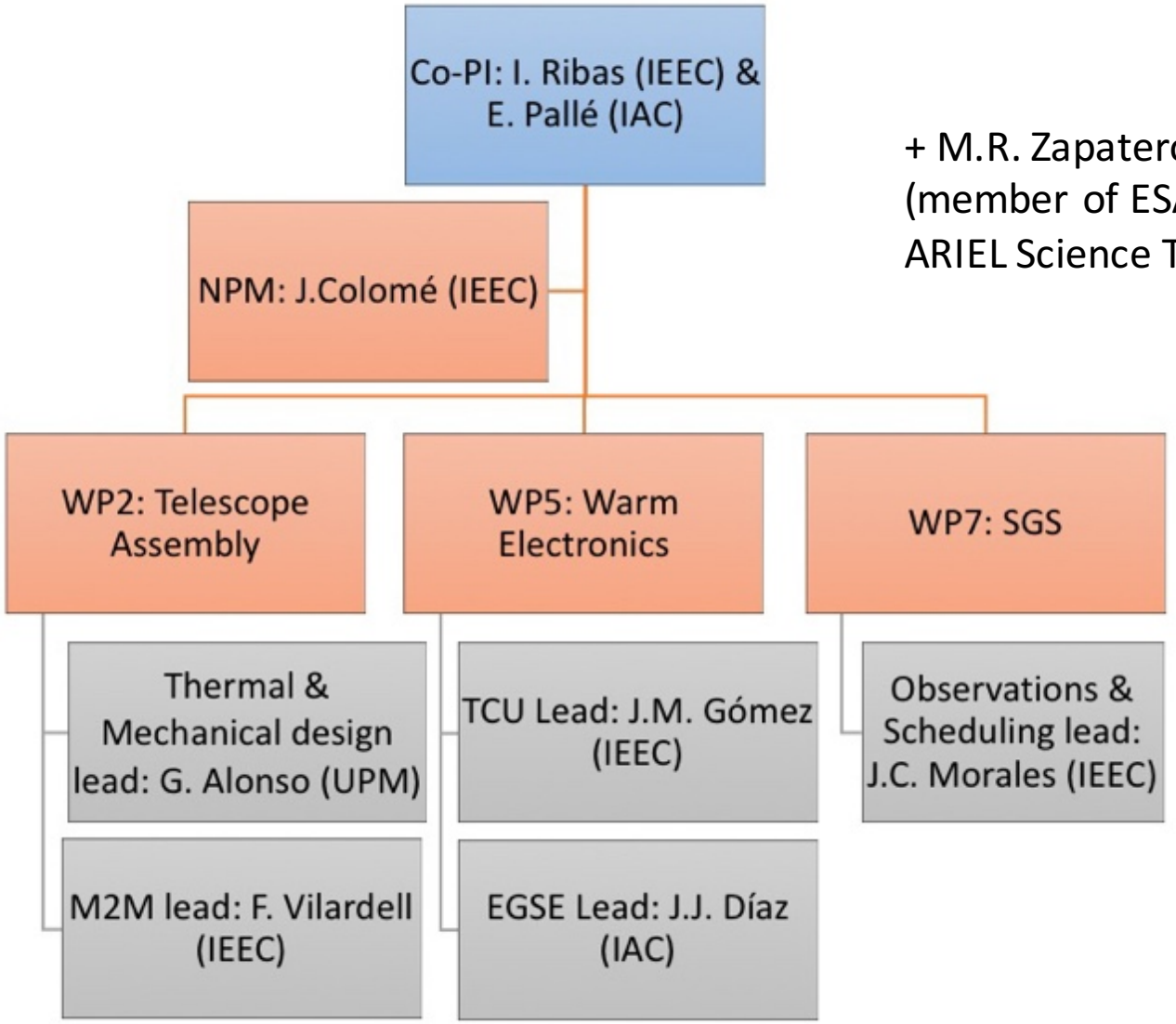


+ EGSE
+ mission planning

Our role in the ARIEL consortium



Spanish consortium organization



+ M.R. Zapatero Osorio (member of ESA's ARIEL Science Team)

Conclusions

- ARIEL has been conceived to deliver the first chemical survey of ~1000 exoplanets, probing uniformly the gamut of planet and stellar parameters
- The Spanish participation in the ARIEL mission science consortium and payload development is very significant
- Timeline: Phase B1 (2019-2020), mission adoption (Nov 2020), phase B2 (2021-2022)
- Think abut joining the science WGs!