ARIEL –

Atmospheric Remote-sensing Infrared Exoplanet Large-survey

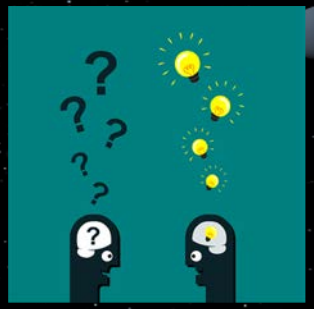
ARIEL: Mission Overview & Community Participation

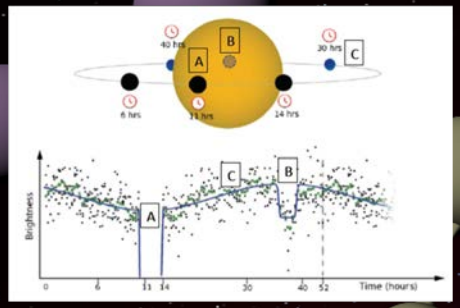
Göran Pilbratt, ESA ARIEL Study Scientist

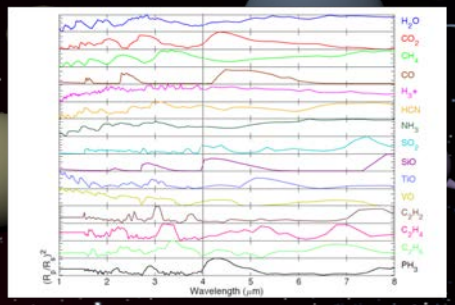
ARIEL: Science, Mission & Community 2020, ESTEC, Noordwijk, 14-16 January 2020

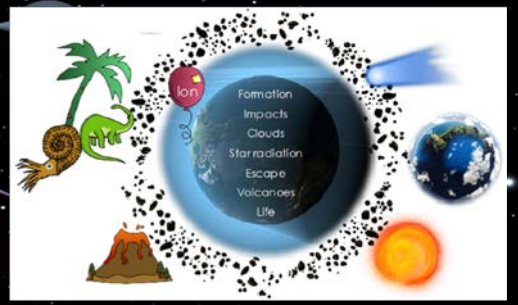
ARIEL – In a nutshell

Atmospheric Remote-sensing Infrared Exoplanet Large-survey









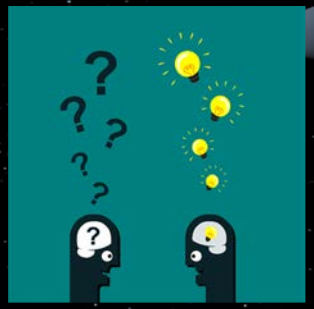
ARIEL will enable transformative science:

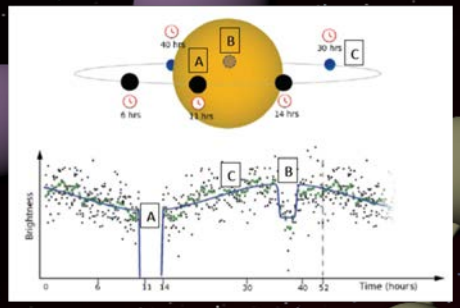
The first dedicated chemical census of a large diverse sample of exoplanets in diverse systems

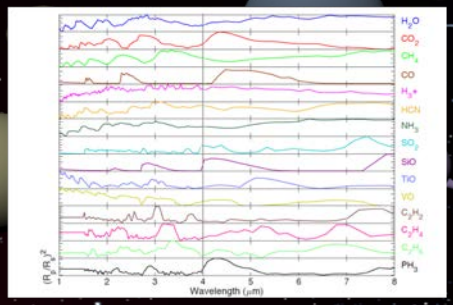
ARIEL selected as Cosmic Vision M4 mission

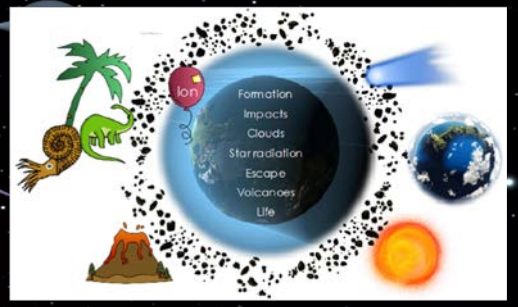
Conference – In a nutshell

ARIEL: Science, Mission & Community 2020



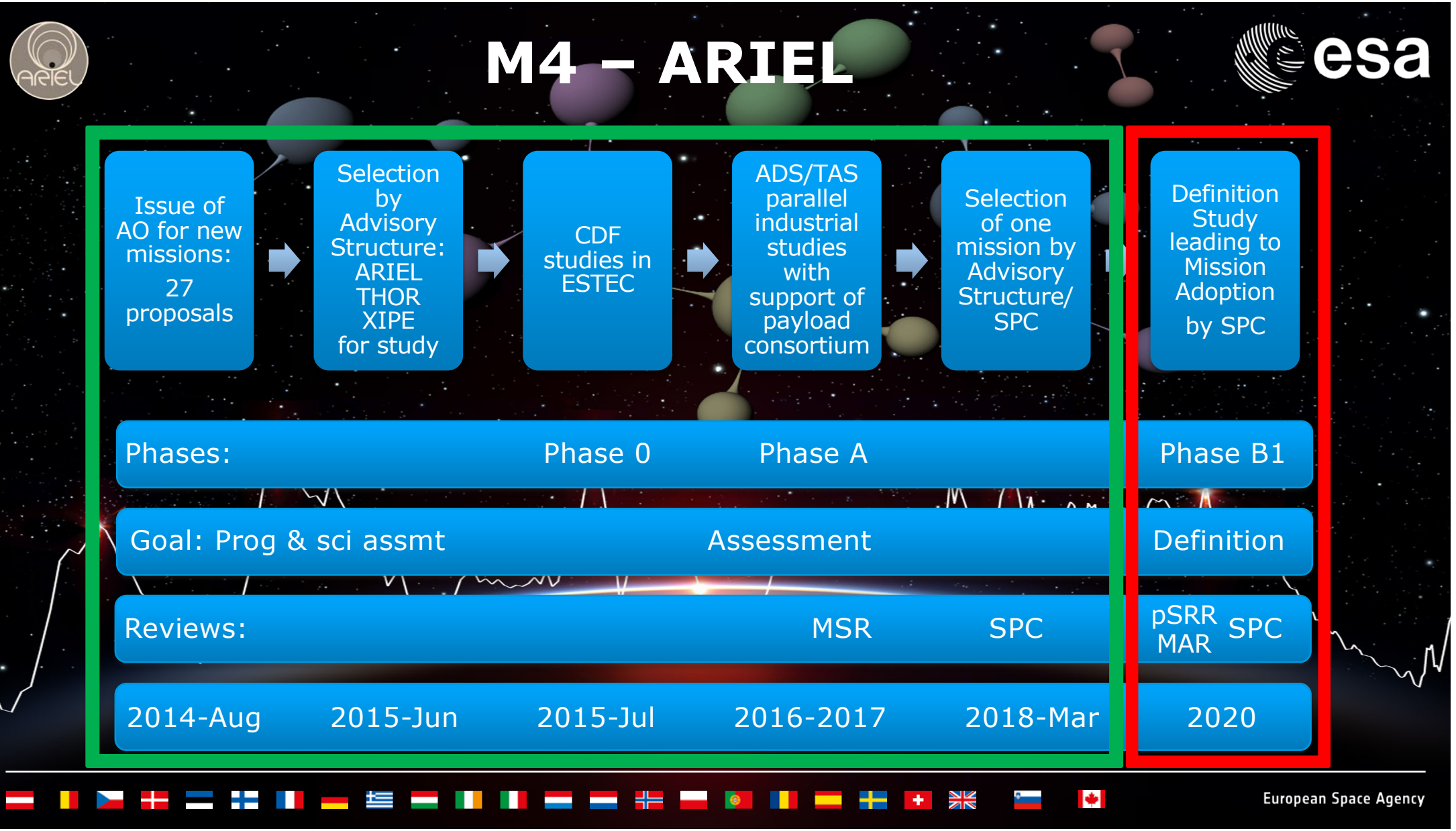






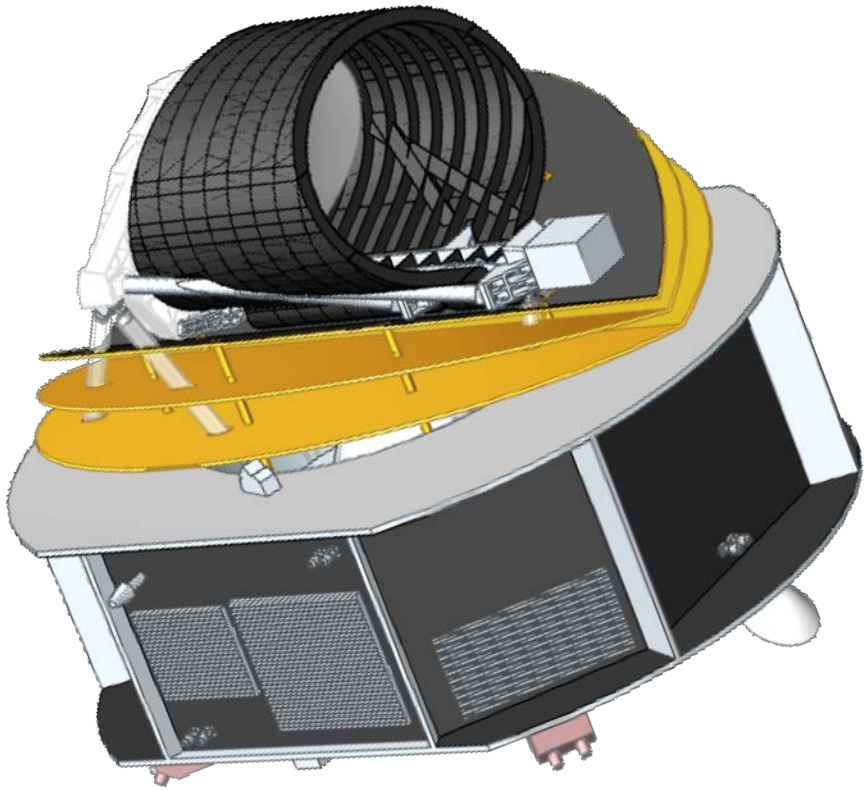
- Involve the exoplanet community at large in ARIEL
- Present ARIEL and its science as proposed for adoption
- Put ARIEL into context of other missions and observatories
- Discuss, plan, & promote long term community involvement

M4 – ARIEL


Issue of AO for new missions: 27 proposals
Selection by Advisory Structure: ARIEL THOR XIPE for study
CDF studies in ESTEC
ADS/TAS parallel industrial studies with support of payload consortium
Selection of one mission by Advisory Structure/ SPC
Definition Study leading to Mission Adoption by SPC
Phases:
Phase 0
Phase A
Phase B1
Goal: Prog & sci assmt
Assessment
Definition
Reviews:
MSR
SPC
pSRR MAR
SPC
2014-Aug
2015-Jun
2015-Jul
2016-2017
2018-Mar
2020

Spacecraft & mission

S/c under study by industry (x2) and ARIEL Consortium (PLM)



Instruments

- Spectrometers
  - NIRSpec: 1.1-1.95 μm R~15
  - AIRS0: 1.95-3.9 μm R~100
  - AIRS1: 3.9-7.8 μm R~30
- Photometer
  - VNIR channels: 0.5-0.6, 0.6-0.8, 0.8-1.1 μm

Telescope

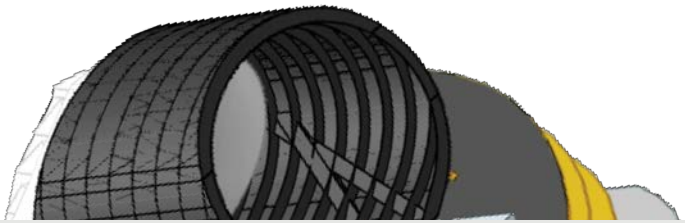
- Off-axis Cassegrain (all aluminium)
- 1.1 x 0.7 m aperture (0.64 m^2 collecting area)

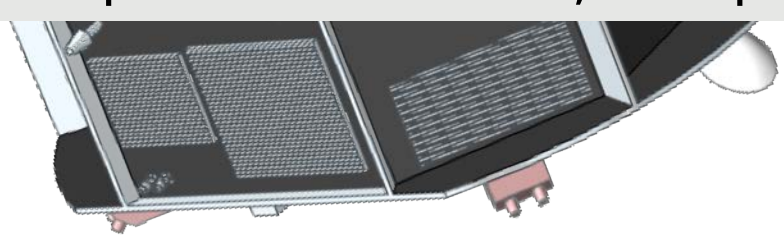
Spacecraft & mission

- Payload module (PLM) passively cooled
- Some detectors actively cooled
- Dual A62 launch, max launch mass 1335 kg
- Large halo-orbit around L2
- Nominal lifetime 4 years, extended 6 years

Spacecraft & mission

S/c under study by industry (x2) and ARIEL Consortium (PLM)





Instruments

- Spectrometers
  - NIRSpec: 1.1-1.95 μm R~15
  - AIRS0: 1.95-3.9 μm R~100
  - AIRS1: 3.9-7.8 μm R~30

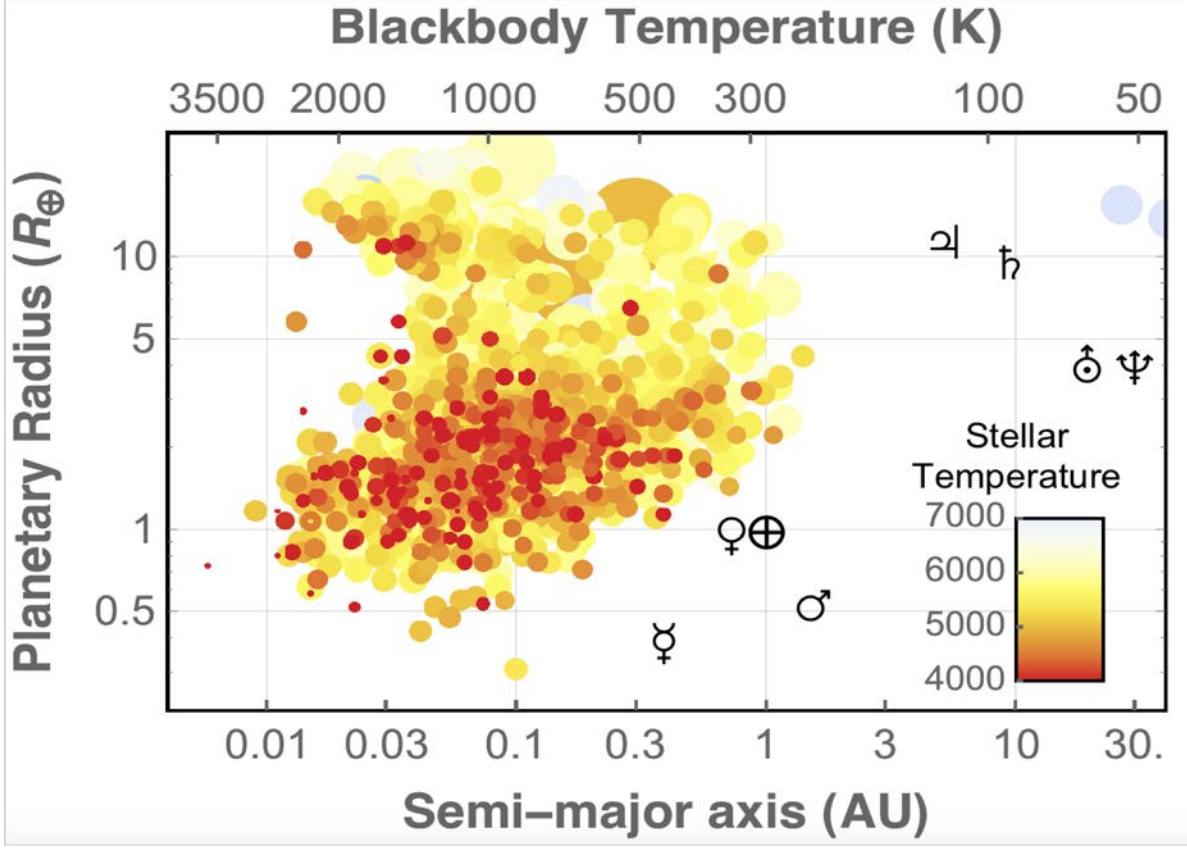
ARIEL is realized by ESA and the ARIEL Mission Consortium (AMC)

- ESA has overall responsibility for the mission
- ESA provides the SVM, launch services, mission operations (MOC), and part of the science operations (SOC)
- AMC provides the PLM, and part of the science operations (IOSDC)

- Payload module (PLM) passively cooled
- Some detectors actively cooled
- Dual A62 launch, max launch mass 1.4 ton
- Large halo-orbit around L2
- Nominal lifetime 4 years, extended 6 years

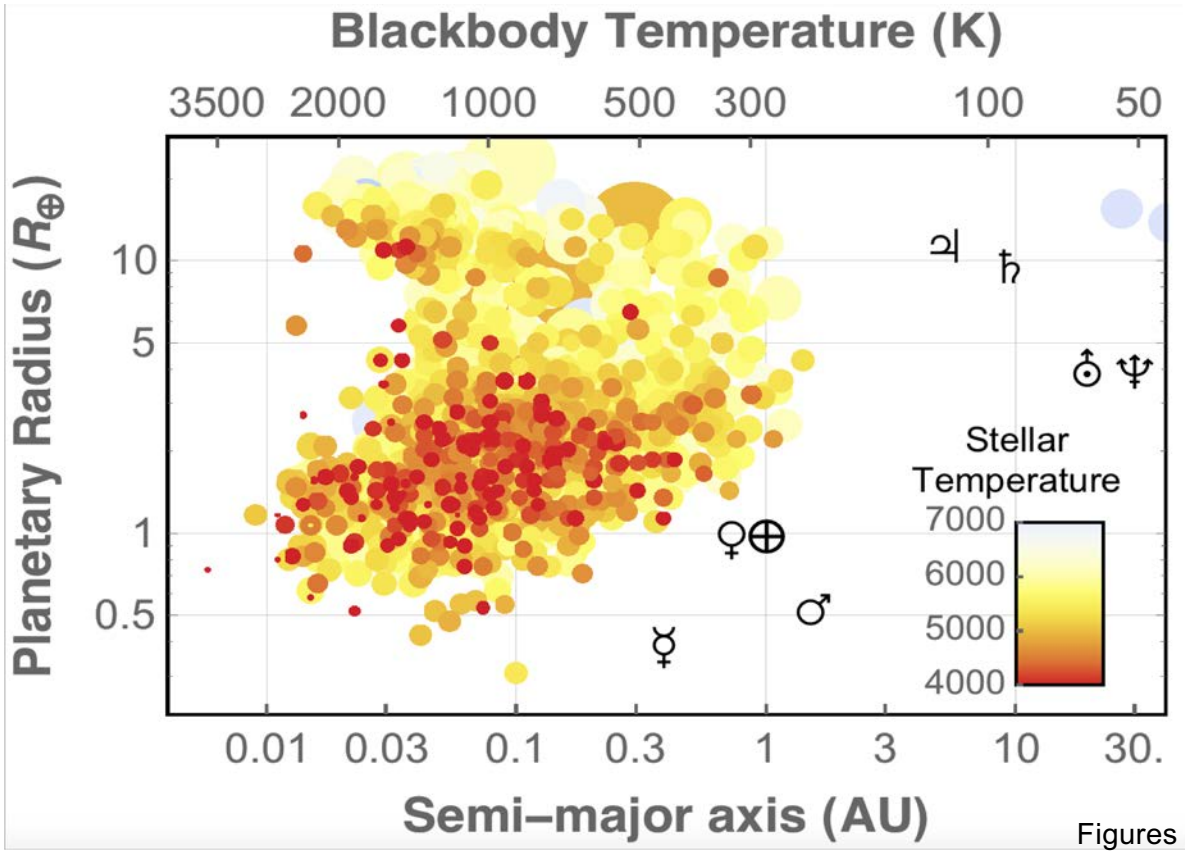
Exoplanets: they abound

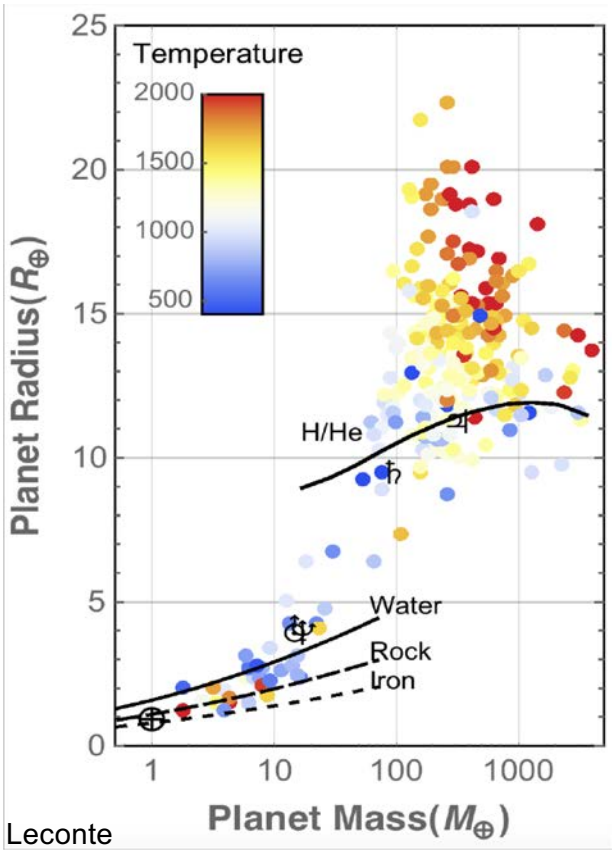
4104 confirmed exoplanets in 3047 systems (as of 12 Jan 2020)



Exoplanets: but limited knowledge

4104 confirmed exoplanets in 3047 systems (as of 12 Jan 2020)





Figures courtesy of Leconte

ARIEL: the next step

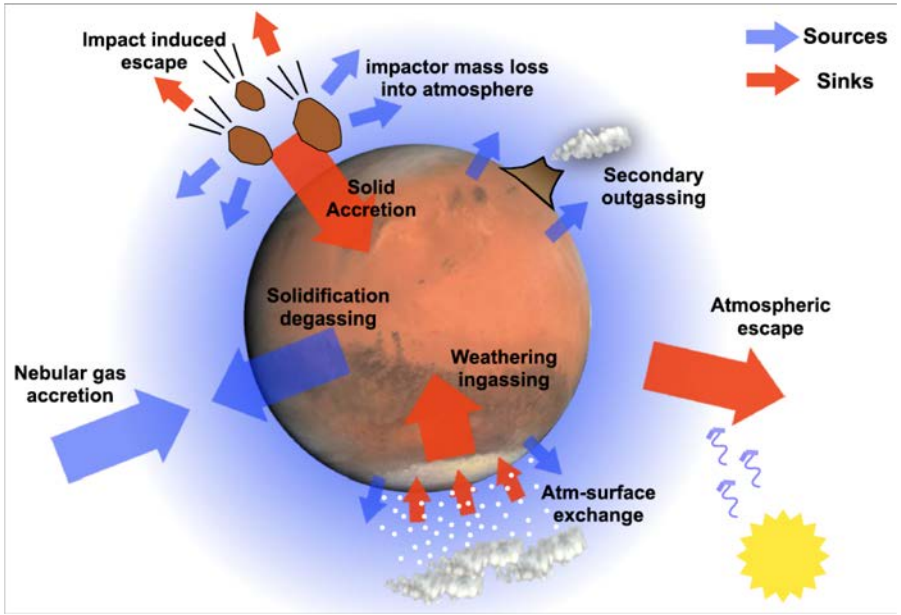
Chemical census of a LARGE sample of DIVERSE exoplanets

Key top level questions

- What are exoplanets made of?
- How do planets & planetary systems form?
- How do planets & their atmospheres evolve?

Observations

- Probe atmospheric chemistry & dynamics
- IR transit & eclipse spectroscopy (1.1-7.8 μm)
- VNIR multiband photometry (0.5-1.1 μm)



Leconte et al. 2014

Targets

- ~1000 known exoplanets, transiting stars brighter than K=9.5
- Diverse sample from gas giants to super-earths (possibly reaching earth-sized)
- Focus on warm & hot planets, T >500 K, to limit sequestration

ARIEL: the next step

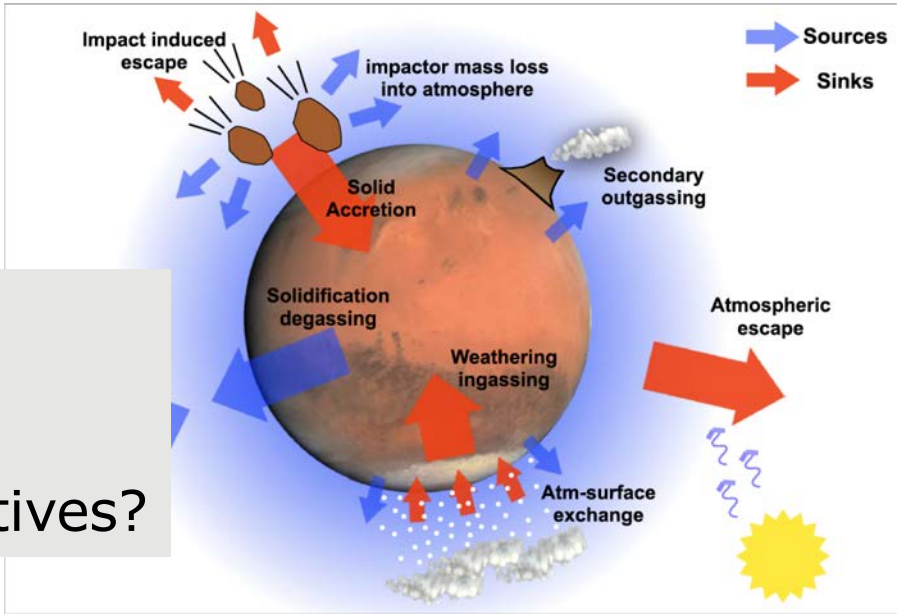
Chemical census of a LARGE sample of DIVERSE exoplanets

Key top level questions

- What are exoplanets made of?
- How do planets & planetary systems form?
- How do planets & their atmospheres evolve?

Questions and priorities

- Which targets are to be observed?
- What observations are to be carried out?
- Providing answers to what science objectives?



Leconte et al. 2014

Targets

- ~1000 known exoplanets, transiting stars brighter than K=9.5
- Diverse sample from gas giants to super-earths (possibly reaching earth-sized)
- Focus on warm & hot planets, T >500 K, to limit sequestration

ARIEL: planetary diversity

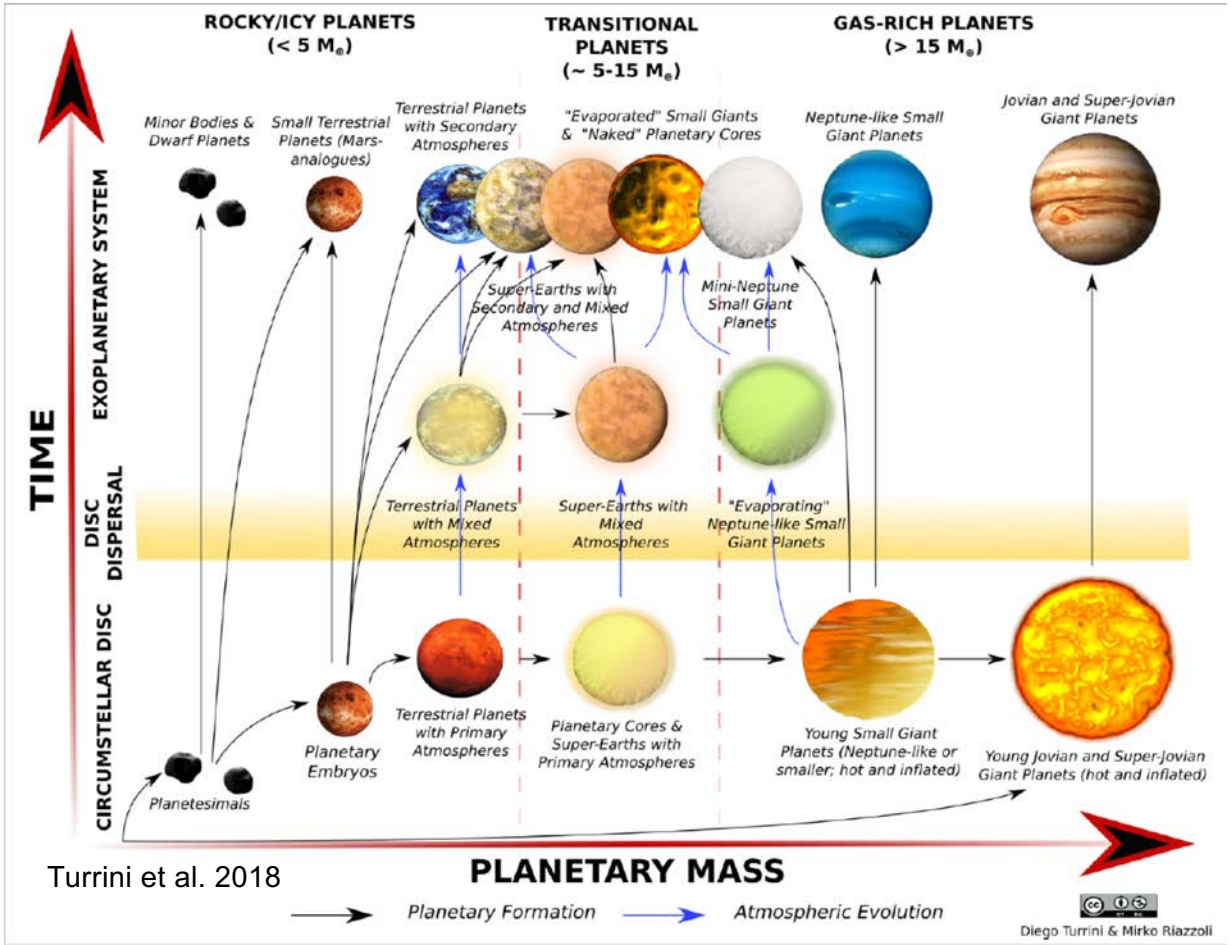
(Exo)planetary systems

- Solar system is one outcome of planetary system formation
- Many other possible outcomes

(Exo)planets

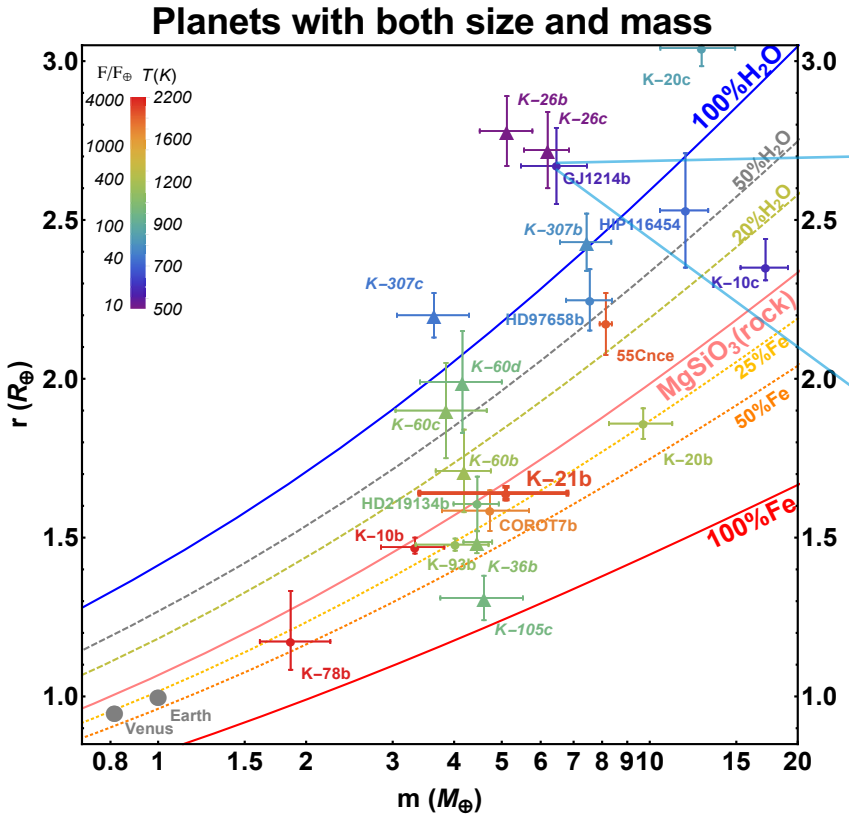
- Solar System has
  - Temperate rocky planets
  - Cold gas rich planets
- Exoplanetary systems have
  - Extreme diversity of planets
  - Types of planets missing in SS
  - More to come (and biases)

Observe large and statistically representative sample!



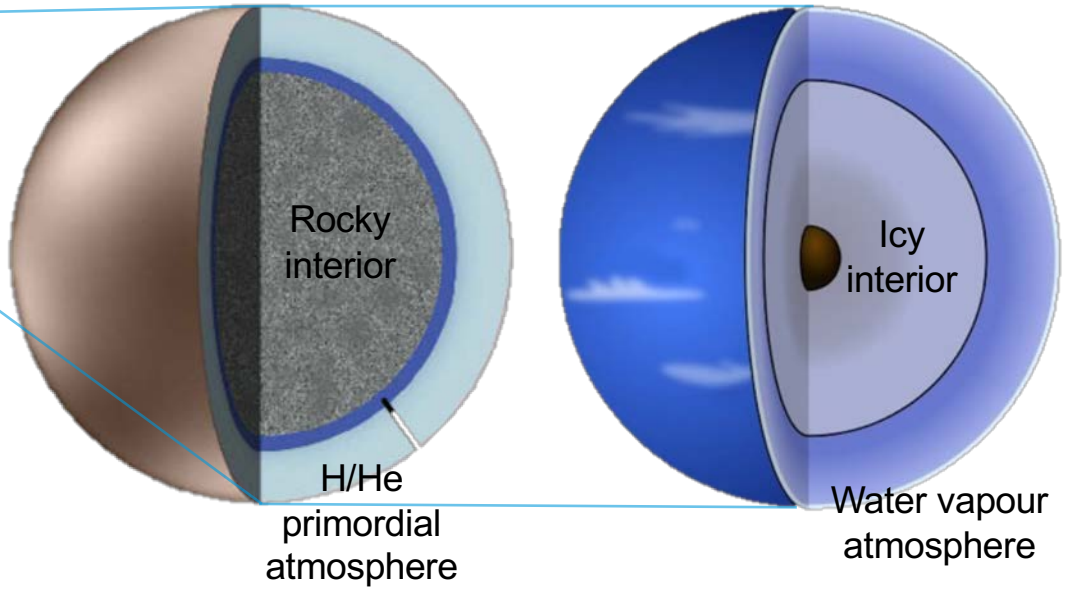
Turrini et al. 2018

ARIEL: beyond 'bulk' density



López-Morales et al. 2016

Atmospheric composition can clarify degeneracy

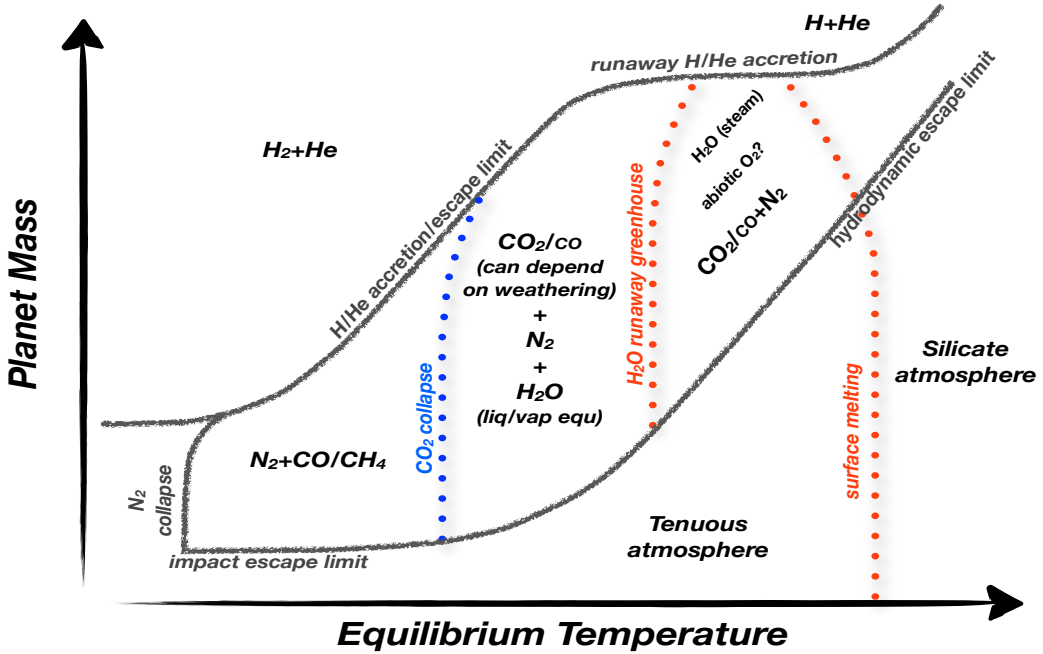


Same bulk density – different atmospheric signatures

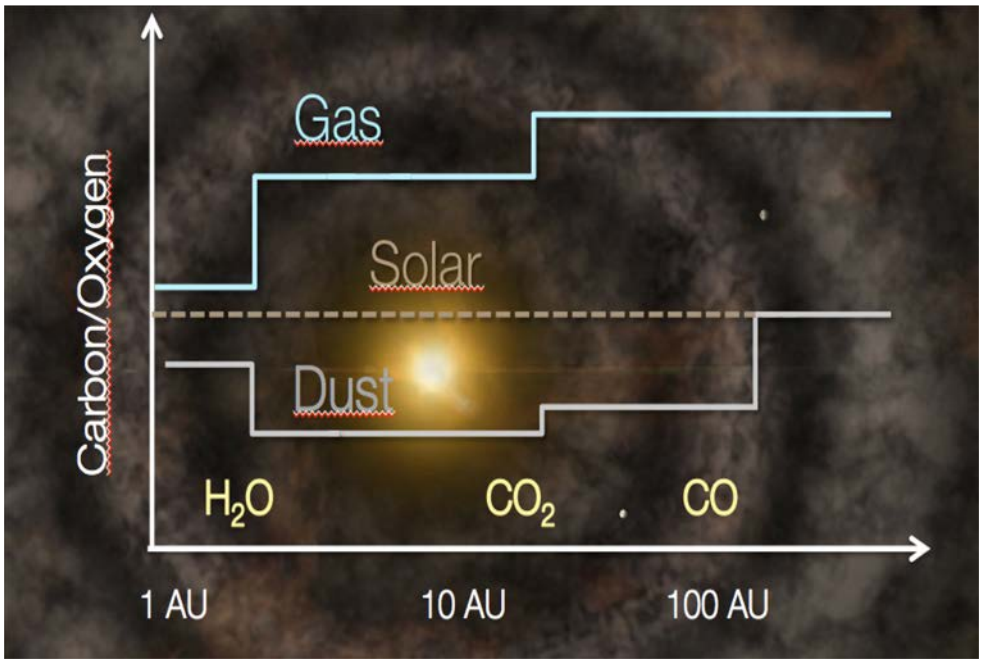
See Valencia et al. 2013

ARIEL: 'trends' & populations?

Does chemical diversity correlate with other (stellar? disk?) parameters?



Forget & Leconte 2014
Leconte et al. 2014



Öberg et al. 2011
Turrini et al. 2015

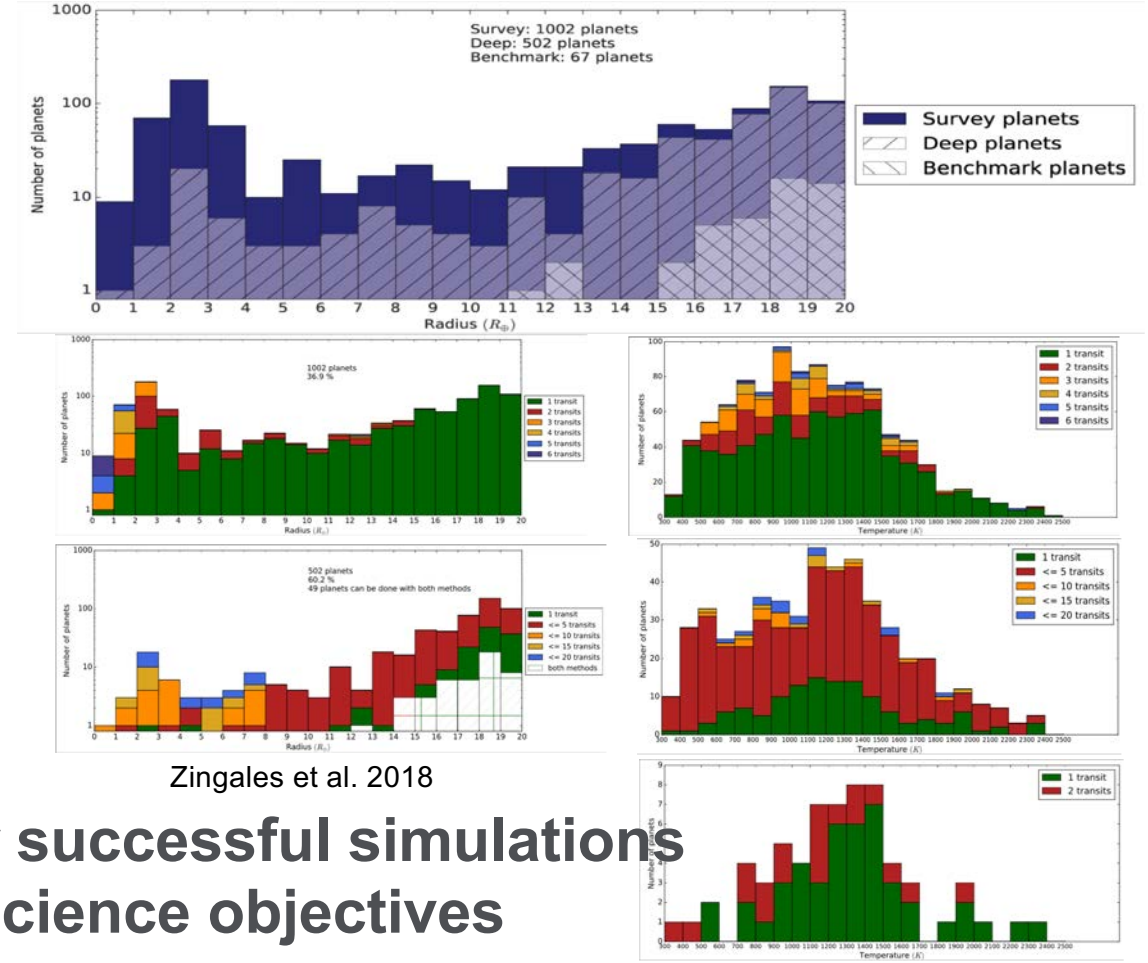
Targets: Yellow Book sample

Potential ARIEL targets

- Hundreds available then, more now
- Thousands expected by 2028
  - Most from TESS (CHEOPS, PLATO)
  - Groundbased also contributing

Mission Reference Sample

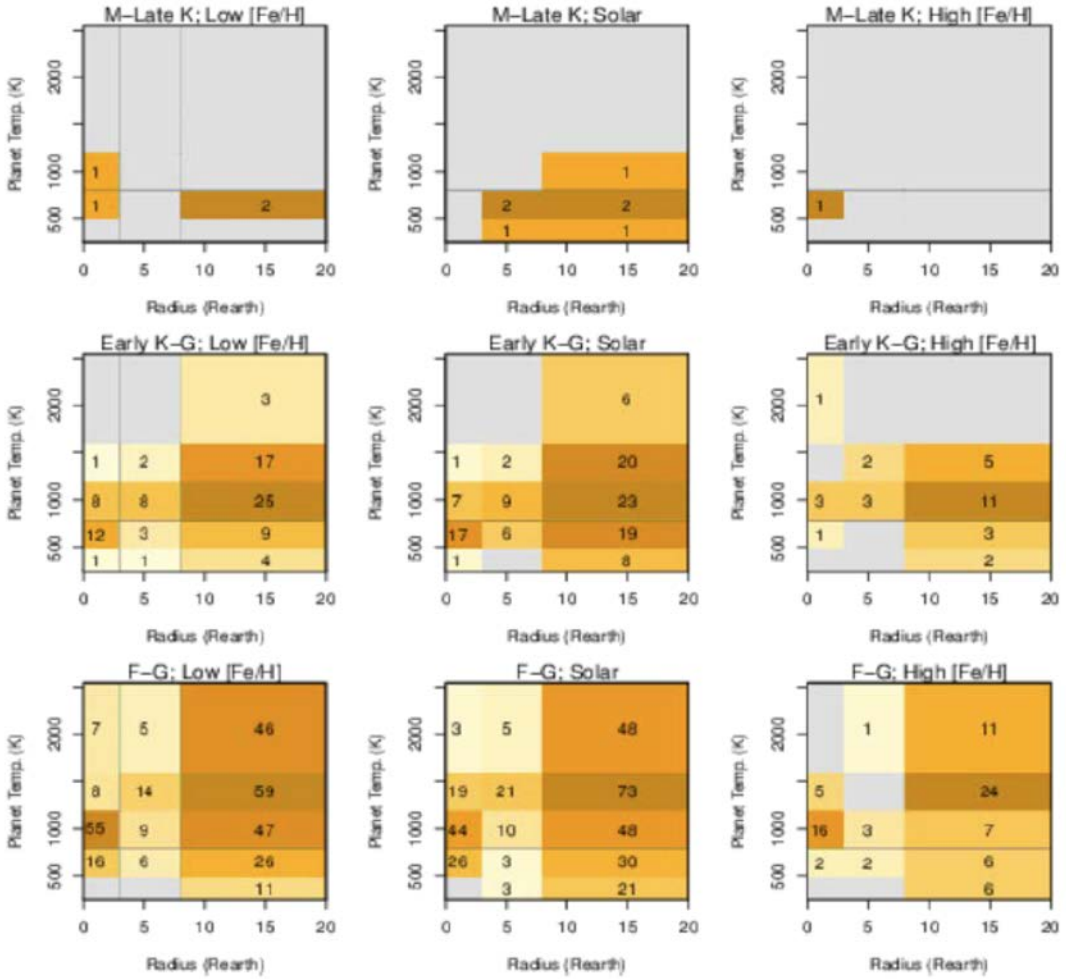
- Will continuously evolve
- New targets
- New science questions/priorities
- New observations
- Yellow Book example illustrated



Zingales et al. 2018

Yellow Book (2017) MRS used for successful simulations to verify the feasibility of ARIEL science objectives

Targets: constructing MRS



Introduce 4D space: T_{eff}, [Fe/H], R_{pl}, T_{pl}

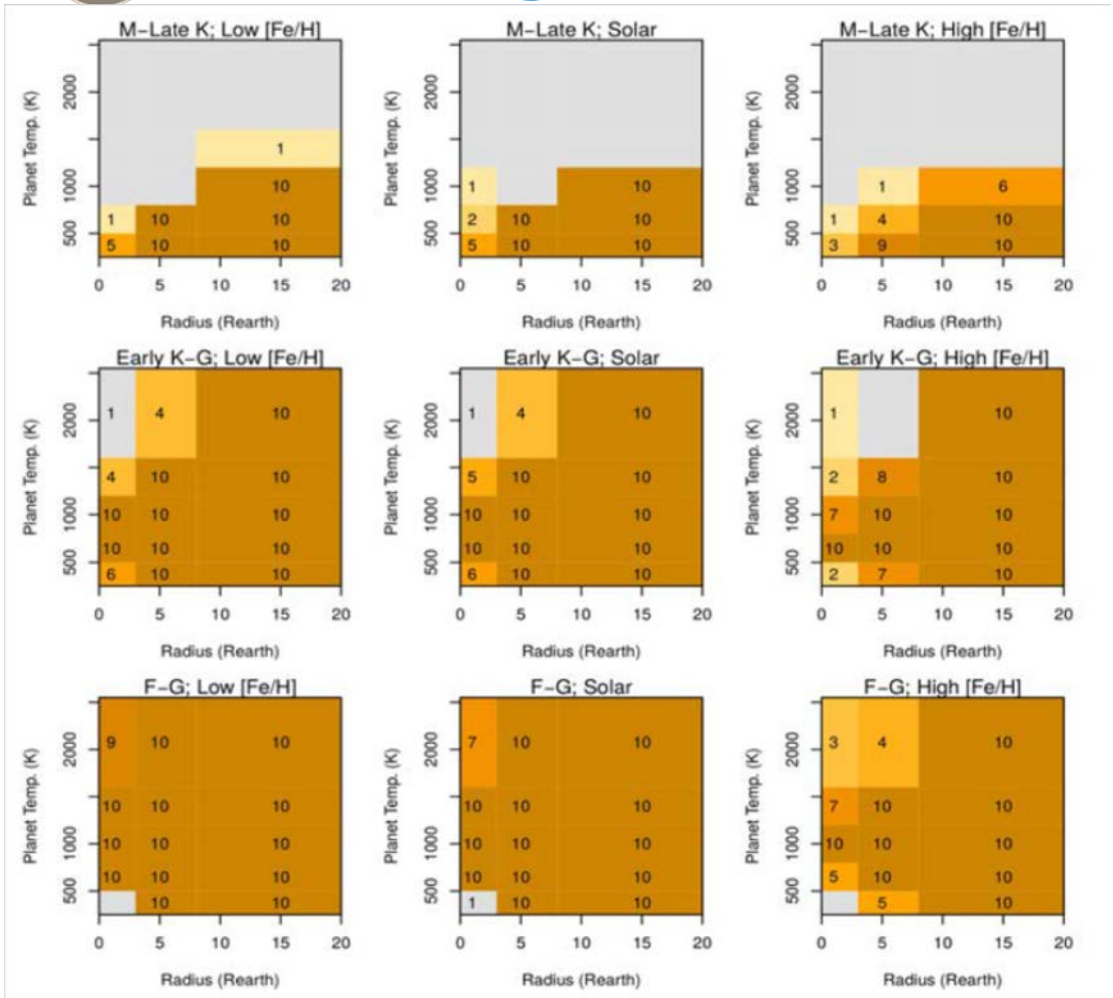
Stellar Temp.: T_{eff}	$3000 < T(K) < 4100$	$4100 < T(K) < 5800$	$T > 5800K$
Labels	M-Late K	Early K-G	F-G
Metallicity: [Fe/H]	[Fe/H] < -0.15	$-0.15 <$[Fe/H]< 0.15	[Fe/H]> 0.15
Labels	Low [Fe/H]	Solar	High [Fe/H]
Planet Radius: R_{pl}	$R_{pl} < 3R_{\oplus}$	$3 < R_{\oplus} < 8$	$R_{pl} > 8R_{\oplus}$
Labels	Earths/ Super Earths	Neptunes	Jupiters
Planet Temp.: T_{pl}	contiguous bins: [250, 500, 800, 1200, 1600, 2600] K		

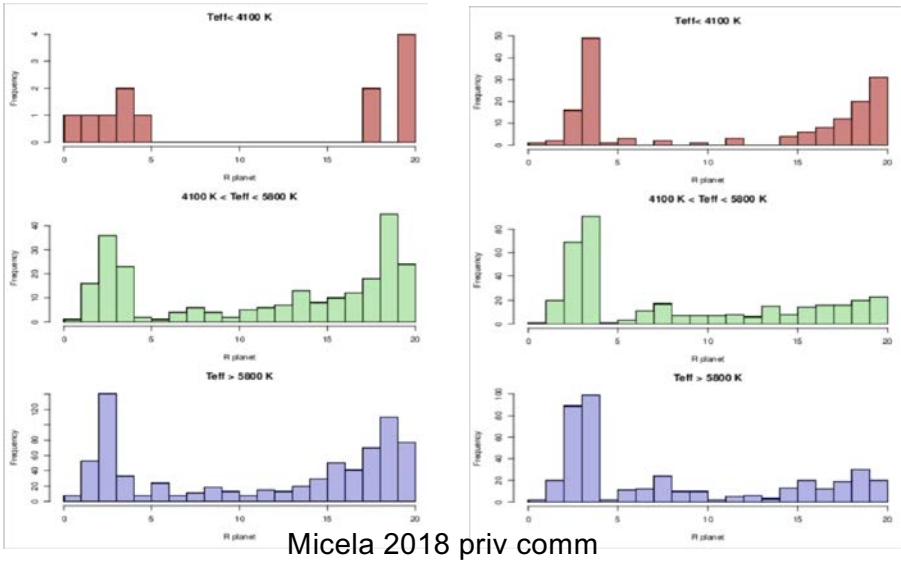
Micela 2018 priv comm

‘Optimal’ sample definition

- (Down-)Selection of potential targets to ‘optimal’ MRS currently discussed
- Here the YB sample (1002 targets)
- What is a/the ‘optimal’ sample?
- Depends on scientific priorities!
- Expect changes from now => launch!

Targets: constructing MRS





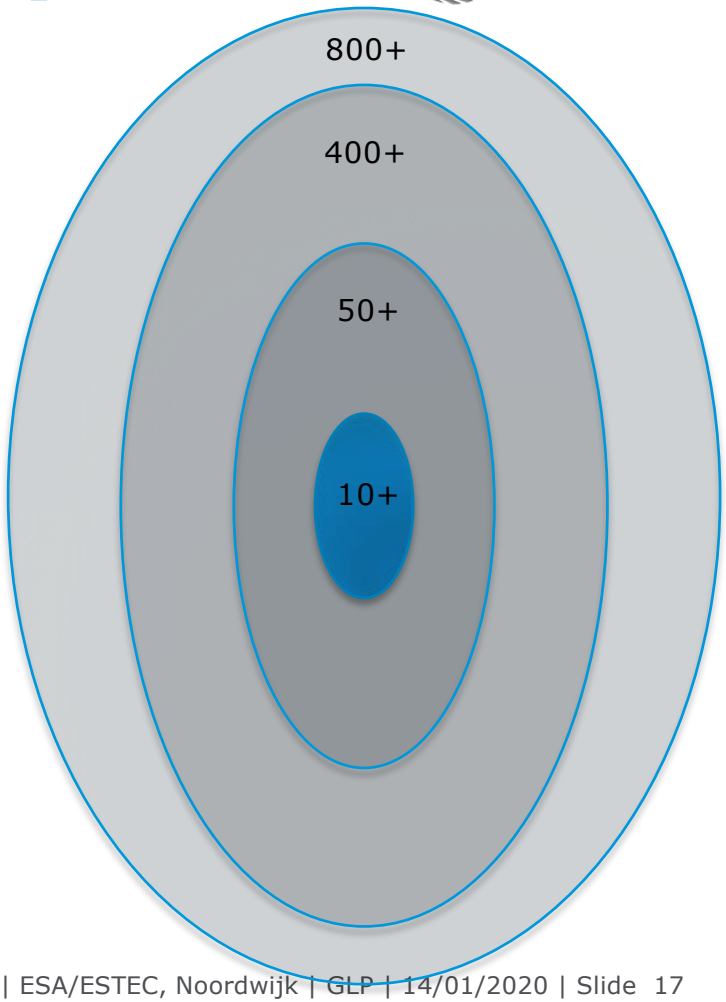
Micela 2018 priv comm

‘Optimal’ sample definition

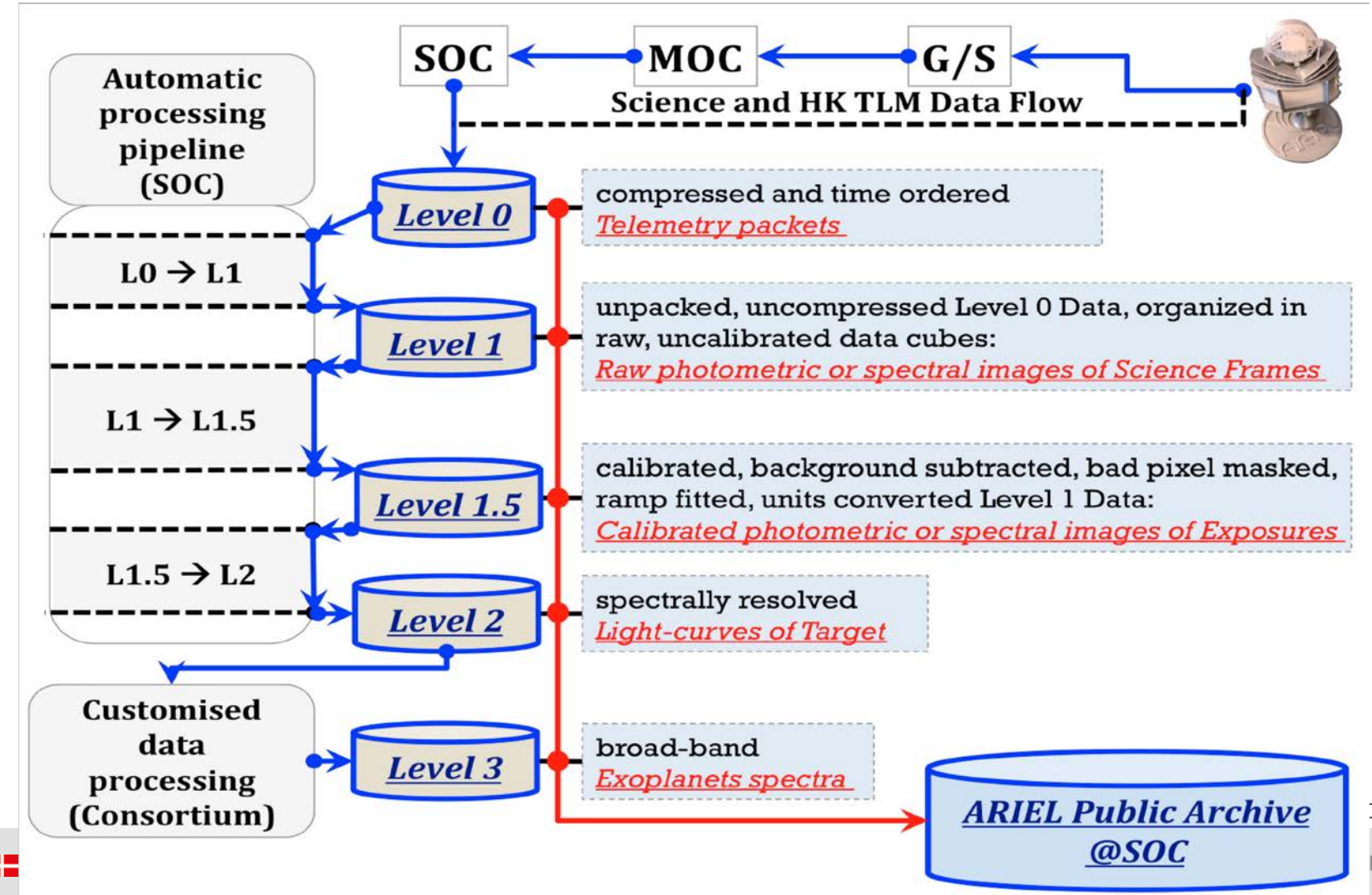
- Maximise to 10 planets per bin – slightly lower number of targets 1002 => 908 (left)
- Ongoing work – will continue!

Science: 4-tier strategy

Observational strategy	Science outcome	Expected No. of planets
TIER 1: RECONNAISSANCE SURVEY		
• Low resolution spectroscopy (5-10 spectral resolution elements covering the 1.10 – 7.80 μm range) measurements with average SNR ≥ 7 • All planets in the sample • Transit or eclipse	• What fraction of planets are covered by clouds? • What fraction of small planets have still retained H_2? • Colour-colour diagrams • Constraining/removing degeneracies in the interpretation of mass-radius diagrams • Albedo, bulk temperature & energy balance for a subsample	800+
TIER 2: DEEP SURVEY		
• Spectroscopic measurements for a subsample (e.g., 50% of sample) • R~10 for 1.10< λ<1.90 μm; R~50 for 1.95<λ<3.90 μm; R~15 for 3.90<λ<7.80 μm, with average SNR ≥ 7 • Transit and/or eclipse	• Main atmospheric components for small planets • Chemical abundances of trace gases • Atmospheric thermal structure (vertical/horizontal) • Cloud characterisation • Elemental composition	400+
TIER 3: BENCHMARK/REFERENCE PLANETS		
• Spectroscopic measurements • R~15 for 1.10< λ<1.90 μm; R~100 for 1.95<λ<3.90 μm; R~30 for 3.90<λ<7.80 μm, with average SNR ≥ 7 achievable in 1-2 observations • Transit and/or eclipse, repeated in time	• Detailed knowledge of the planetary chemistry and dynamics • Weather, temporal variability • Elemental composition	50+
TIER 4: BESPOKE OBSERVATIONS & PHASE-CURVES		
• Phase-curves, eclipse mapping, bespoke observations • Multiple-band photometry/spectroscopy with SNR ≥ 7	• Detailed knowledge of the planetary chemistry and dynamics • Spatial variability	10+



Data products



ARIEL and the Community

ARIEL wants to embrace and have a dialogue with the Community

Attend ARIEL conferences

- Like this one – there will be more at a TBD frequency

Join the ARIEL Mission Consortium (AMC)

- Talk to the AMC

Use public ARIEL data

- ARIEL survey data and complementary science data – *rules under discussion/definition*

Data releases

Timely deliveries of high quality data products (core science)

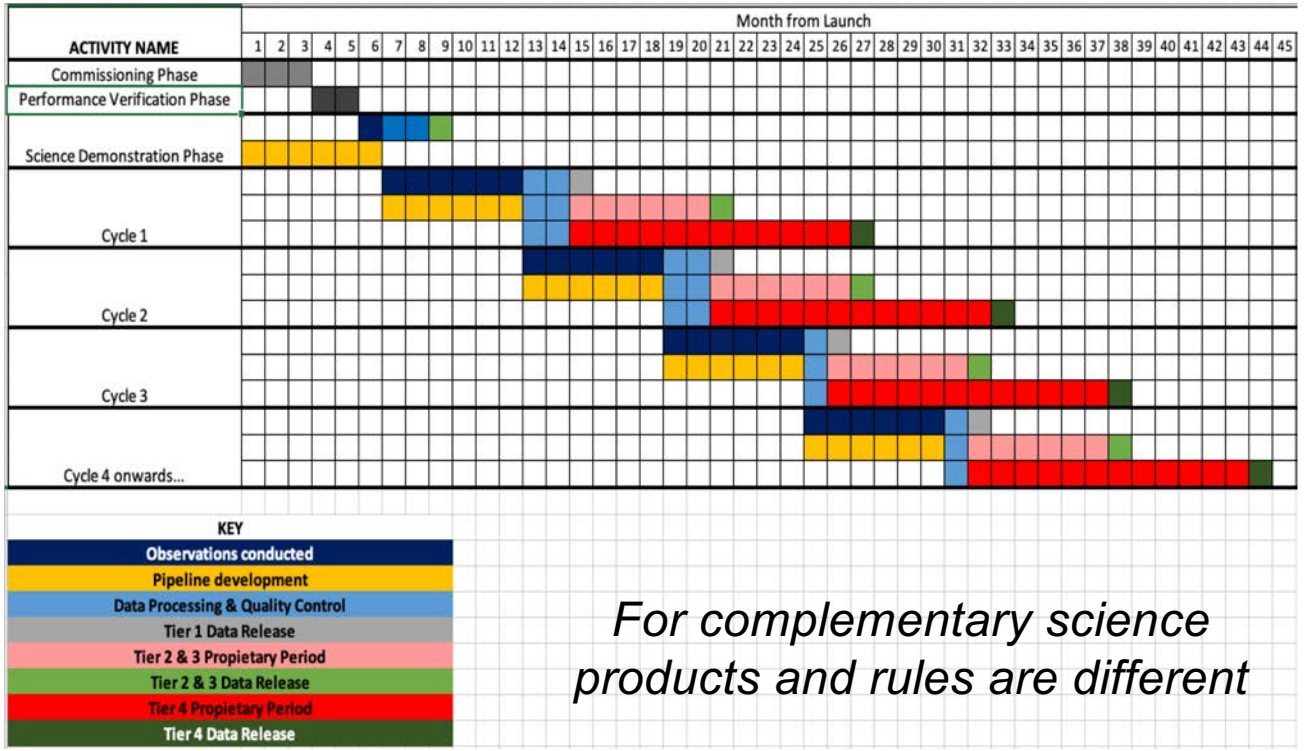
currently under discussion/definition

Data products Level ≤ 2

- **SDP:** data public **immediately** after quality control is completed
- **Tier 1**: data public **immediately** after quality control is completed
- **Tiers 2 & 3**: data public **6 months** after quality control is completed
- **Tier 4**: data public **12 months** after quality control is completed

Data products Level 3

- Will be made public **after publication** in journal



For complementary science products and rules are different

ARIEL and the Community

ARIEL wants to embrace and have a dialogue with the Community

Attend ARIEL conferences

- Like this one – there will be more at a TBD frequency

Join the ARIEL Mission Consortium (AMC)

- Talk to the AMC

Use public ARIEL data

- ARIEL survey data and complementary science data – *rules under discussion/definition*

'Formal' Community participation – *under discussion/definition*

- Community Scientist in the ARIEL Science Team (AST)
- Participation in the definition of the target lists
- Complementary science programme

Community participation

Currently under discussion/definition

Community Scientist in the ARIEL Science Team (AST)

- (Selected) **AST responsibilities**:
  - Maximising the **scientific return** of ARIEL within programmatic constraints, … while ensuring that the development and operations of the mission remain compatible with its main scientific objectives
  - Optimising the **scientific performance** of the payload and spacecraft, calibration, data products, scientific exploitation, …
  - Supervising and being closely involved in the preparation and periodic update of the **Mission Candidate Sample** (MCS) list and being responsible for defining the scientific priorities for the generation of the **Mission Reference Sample** (MRS) list(s)
  - **Promoting** the mission
- A **TBC number of Community Scientists** will be recruited through an Announcement of Opportunity (AO) issued by ESA, and **appointed by ESA** (as all AST members are)
- **Timescale**: (shortly) **after mission adoption**

Community participation

Currently under discussion/definition

Participation in the definition of target lists

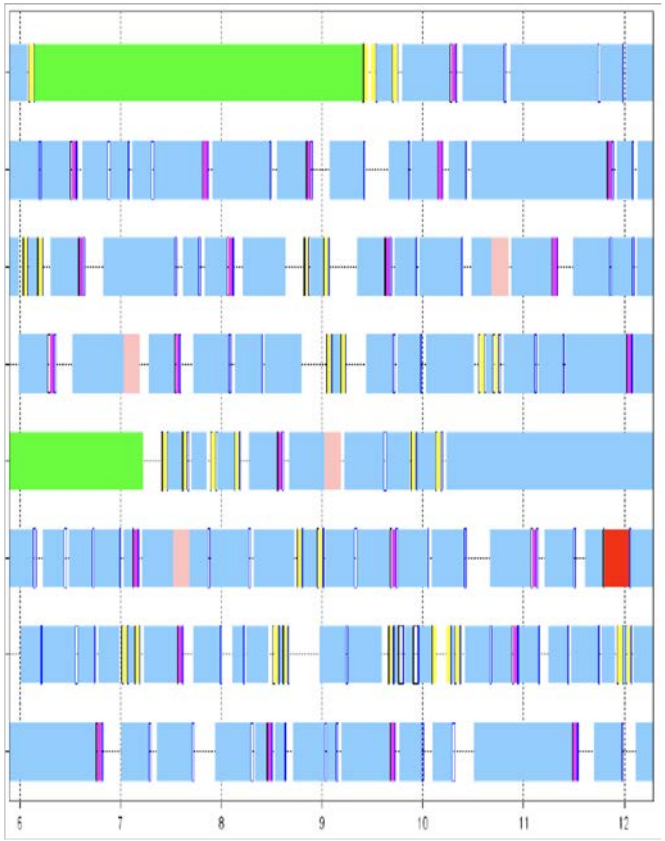
- Mission Candidate Sample (MCS) and Mission Reference Sample (MRS) lists
  - **MCS**: 'all potential' ARIEL targets
    - Today most are 'virtual' sources, but in the future need to become real targets
  - **MRS**: a list of targets that could be observed in the nominal ARIEL mission
    - Multiple MRSs can/will be produced from the MCS with different scientific priorities, provided by the AST, as part of science optimization before and during the mission
- These lists will be made **publicly available** online through a dedicated website
- **Complementary processes** for participation are currently being **considered**:
  - 'Continuous' processes consisting of input provision through a dedicated website, and public regular workshops
  - Other 'dedicated' processes are also being considered

Community participation

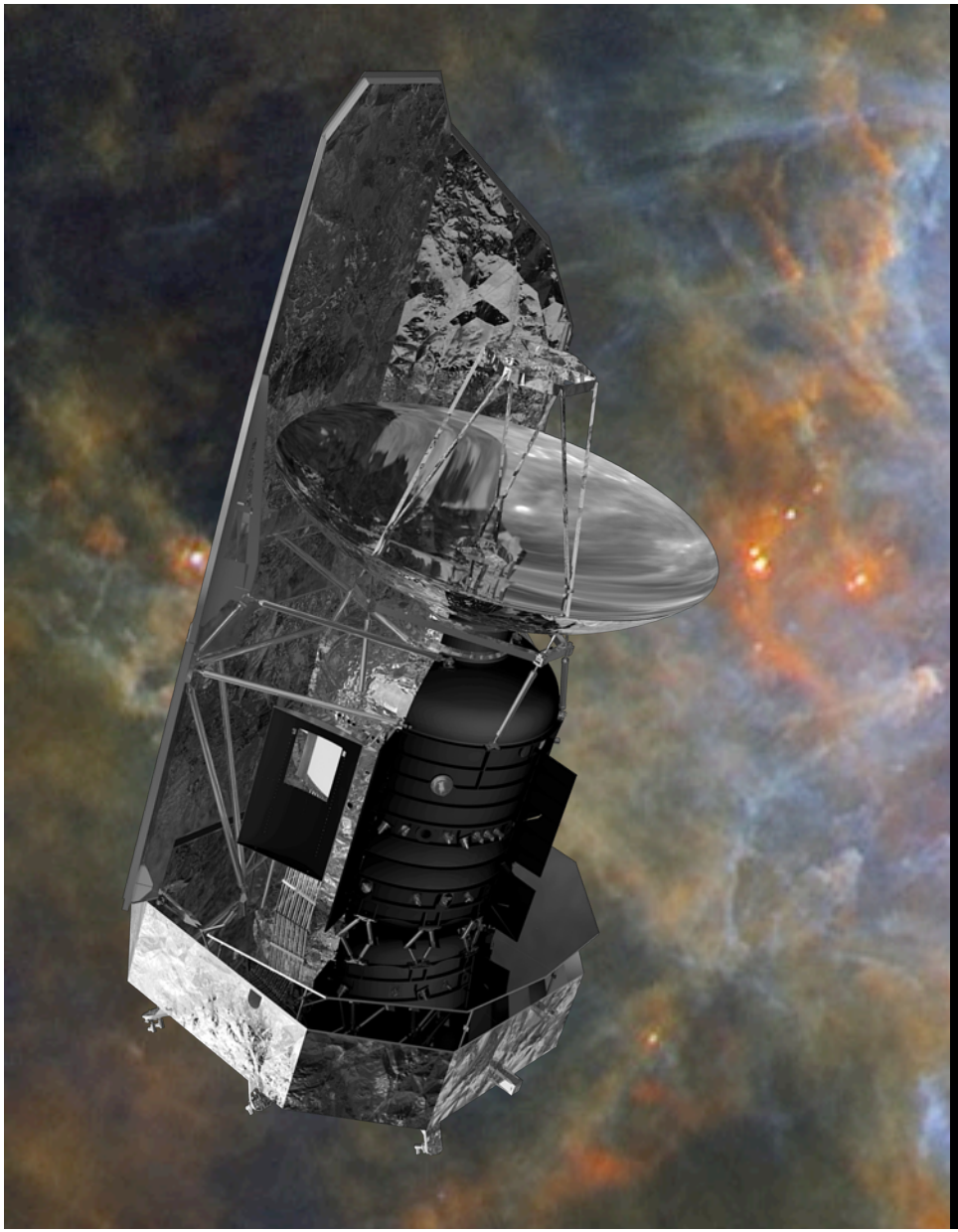
Currently under discussion/definition

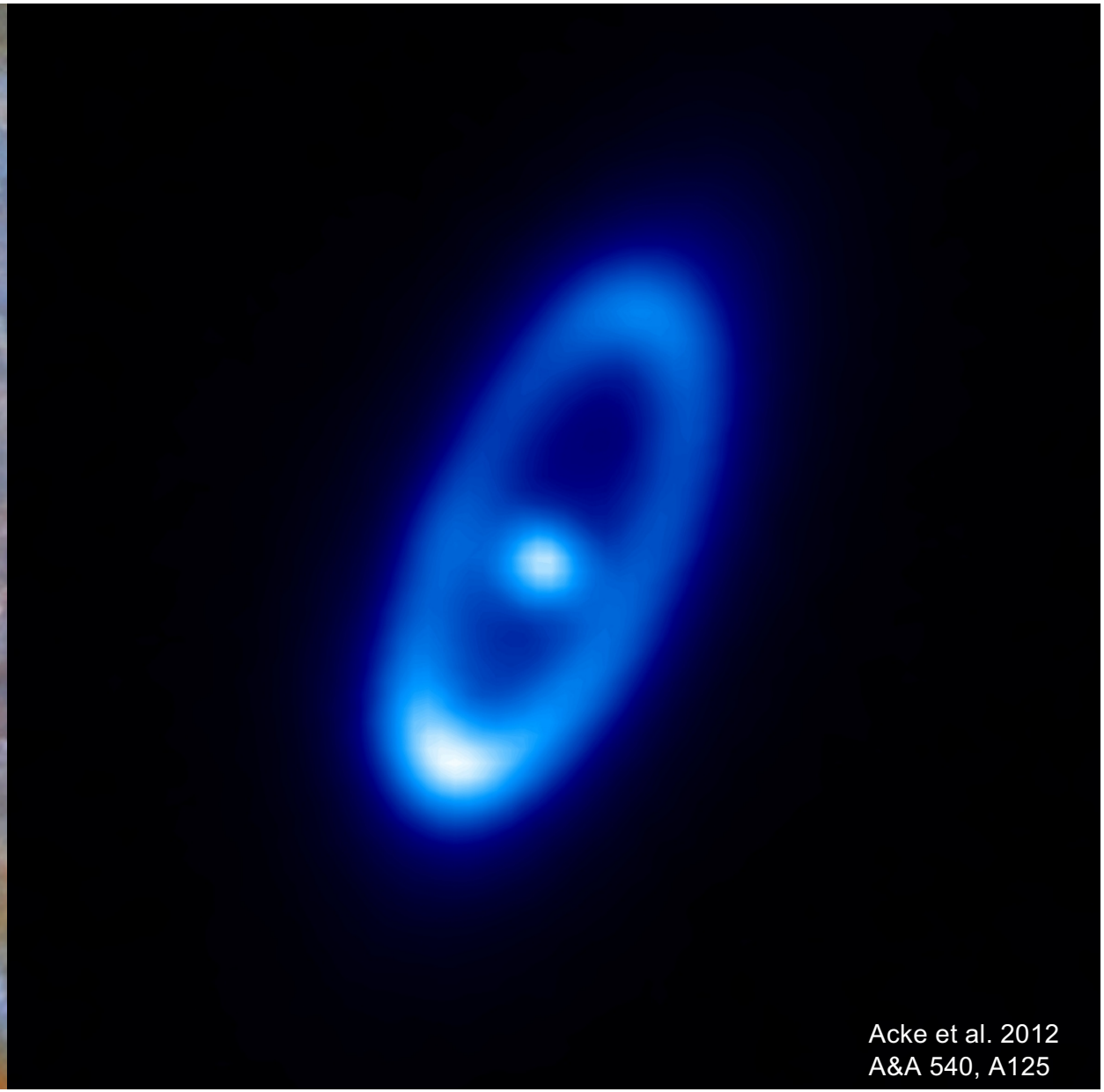
Complementary science programme

- Due to the **nature of the ARIEL exoplanetary observations** there will be a fraction (~10% TBC) of the total available observing time which cannot be used for these
- The bulk of these **non-schedulable slots will be short**, ~75% ≲2 hours, a few x1000 ≲4 hours, some longer
- This time can be used for complementary science observing
  - Must be **schedulable as 'fillers'** – not time critical
  - **Cannot drive** the mission/payload in any way
- An **ESA-led AO is foreseen** for such observation proposals
  - Data products up to level 1.5 (for some 2) are foreseen
  - Proprietary time of 6 months after receiving the data.




ESA/Herschel/Hi-GAL/
G. Li Causi, IAPS/INAF

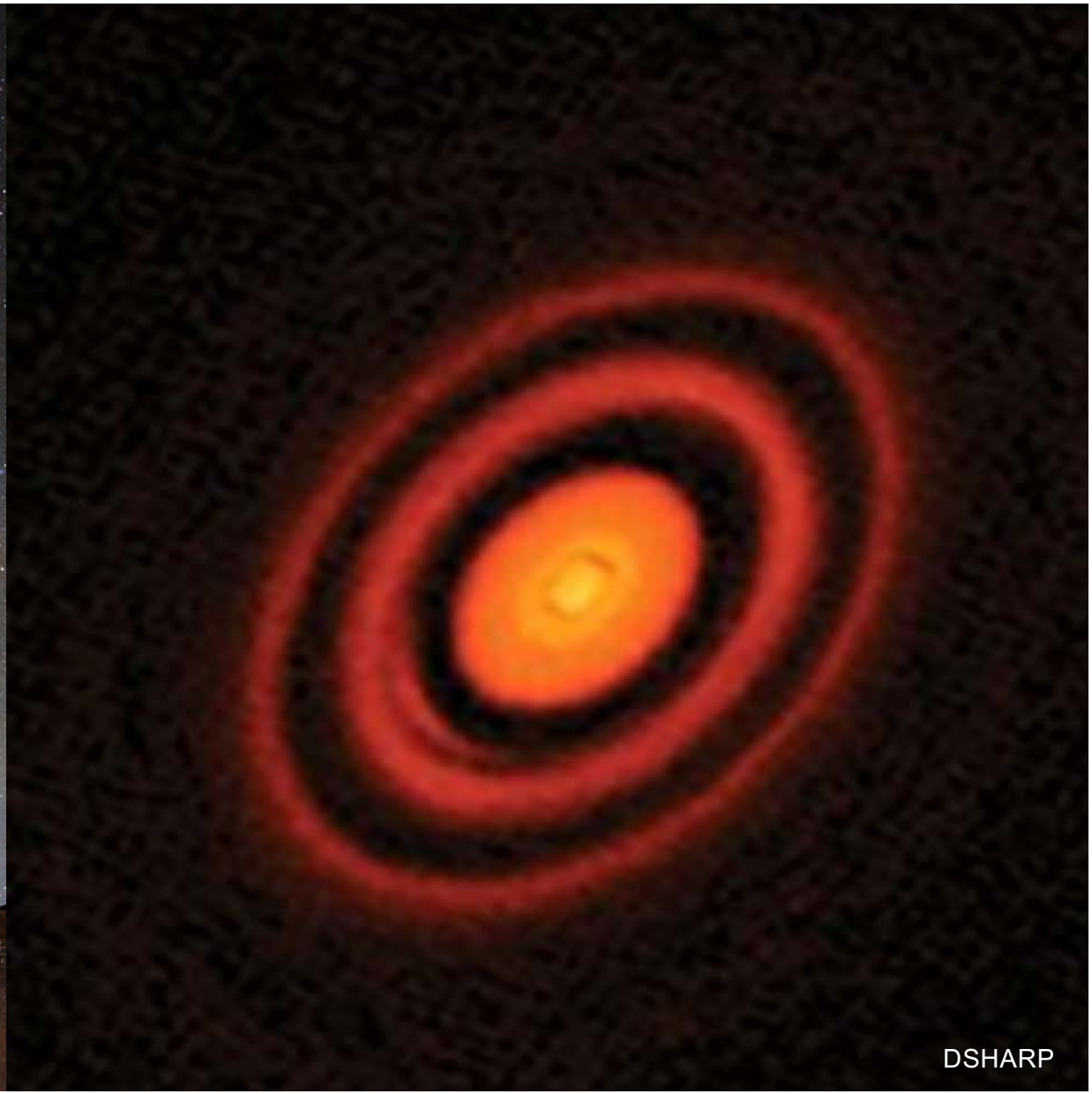


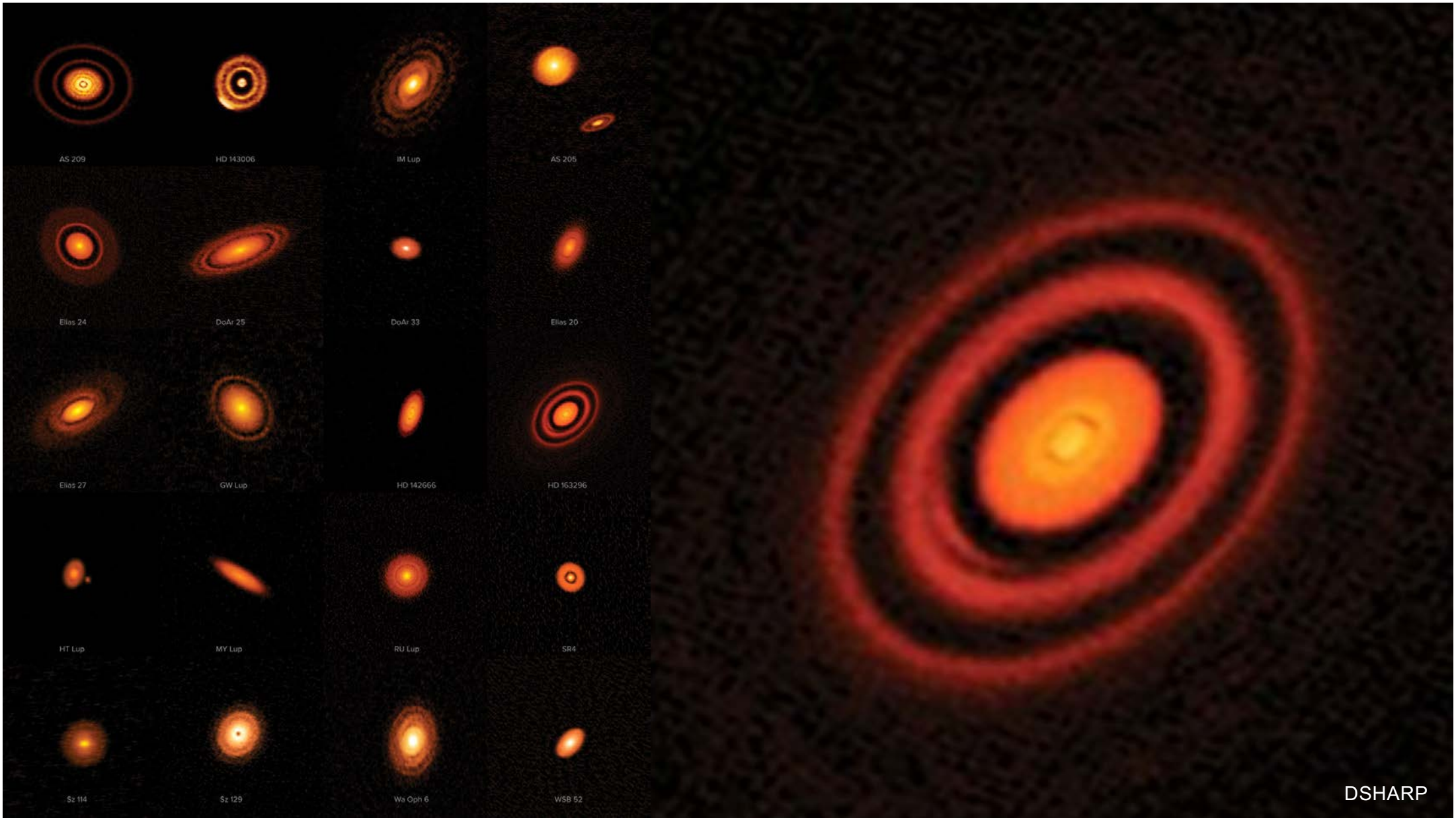


Acke et al. 2012
A&A 540, A125


ESO

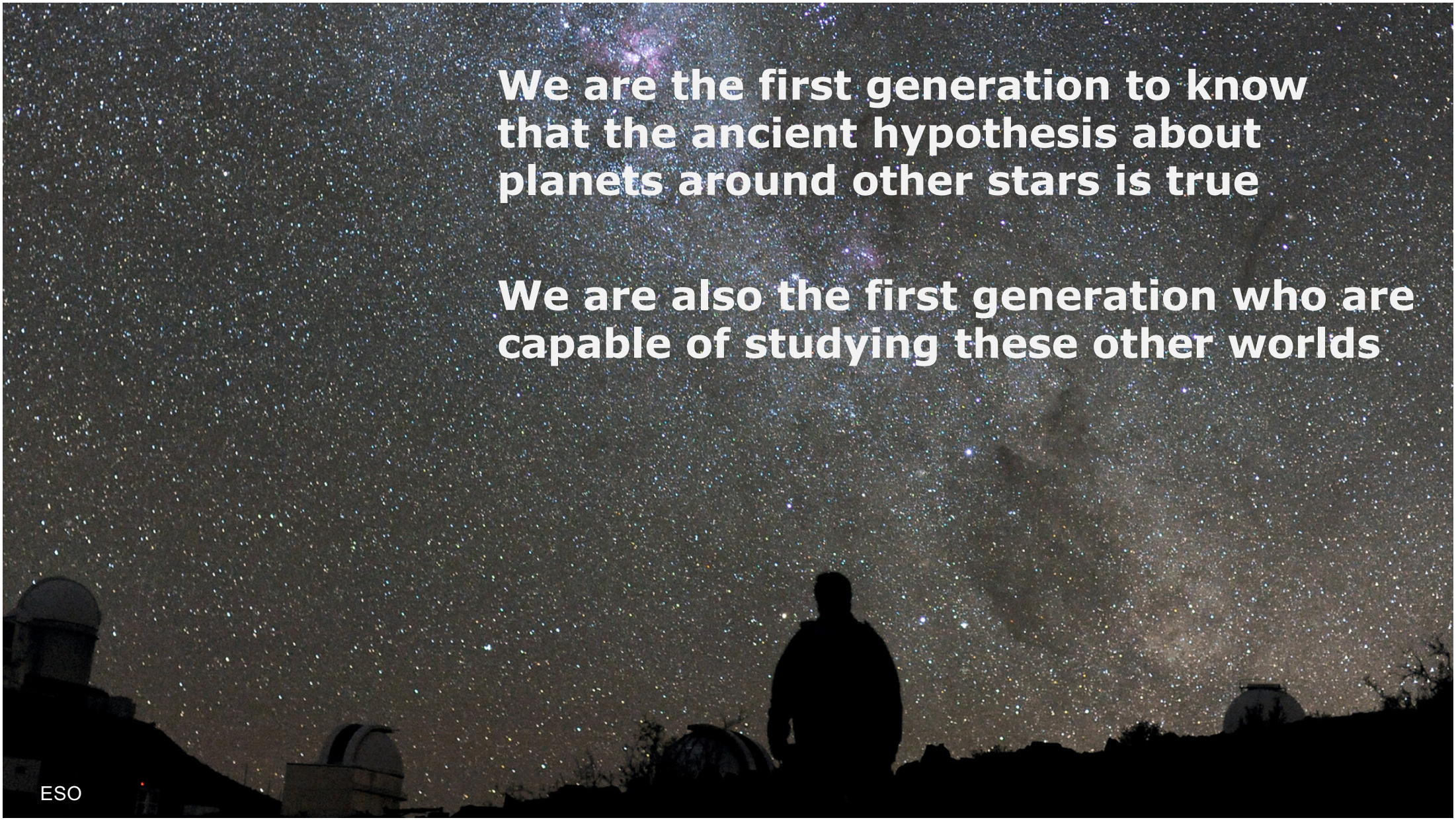

ESO


DSHARP


AS 209
HD 143006
IM Lup
AS 205
Elias 24
DoAr 25
DoAr 33
Elias 20
Elias 27
GW Lup
HD 142666
HD 163296
HT Lup
MY Lup
RU Lup
SR4
Sz 114
Sz 129
Wa Oph 6
WSB 52
DSHARP


We are the first generation to know that the ancient hypothesis about planets around other stars is true
ESO


We are the first generation to know that the ancient hypothesis about planets around other stars is true
ESO


We are the first generation to know that the ancient hypothesis about planets around other stars is true
We are also the first generation who are capable of studying these other worlds
ESO


Thank you!
ESO