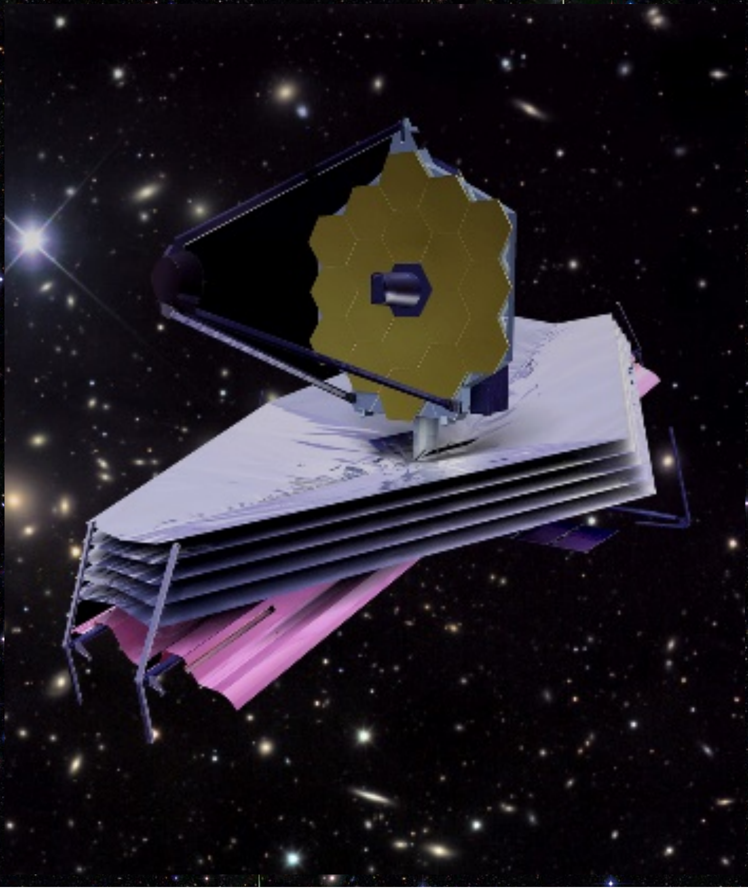
Complementarities and Synergies between Ariel and JWST



P.-O. Lagage

CEA Saclay

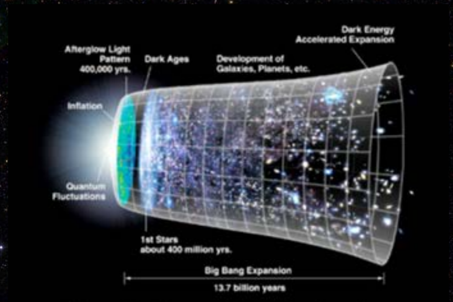
Differences between JWST and Ariel

	JWST	Ariel
Telescope size :	D = 6.5 m	D ∼ 1 m
Wavelength coverage :	0.6 – 12 (→ 28) μm	0.6 – 7.8 μm
Instrumentation :	Four instruments	Two instruments simultaneously
Spectral resolution :	From 100 to a few 1000	From 15 to 100
Type of mission :	Observatory	Survey dedicated o exoplanets
Launch date :	2021	2028
Operation duration :	5 + 5 years	4 + 2 years

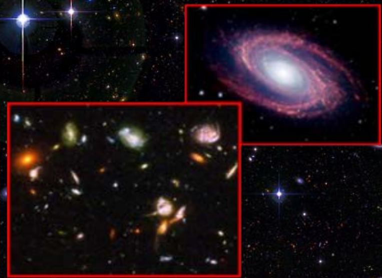
Type of mission :

Observatory of interest for a broad community

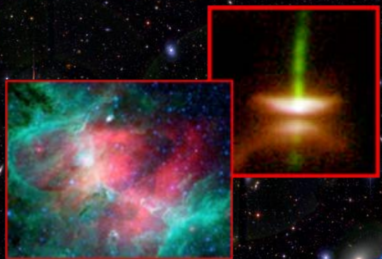
4 scientific themes for JWST



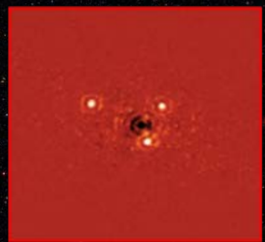
First Light and Re-Ionization



Assembly of Galaxies



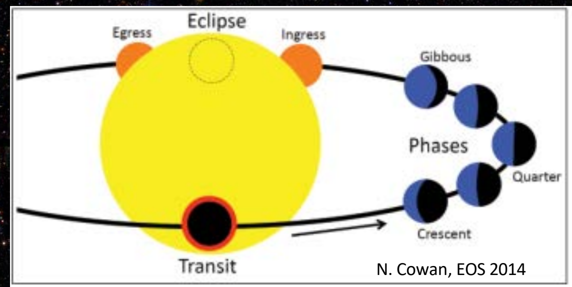
Birth of stars and proto-planetary systems



Planetary systems and the origin of life

25% dedicated to exoplanets?
From GTO and ERS this is about right

Survey dedicated o exoplanets



Full time (except scheduling gaps) dedicated to exoplanets

Telescope size :

D = 6.5 m

D ~ 1 m

For transit

S/N depends on f(planet, H)*D*$(F_{star}*t_{obs})^{1/2}$

$t_{obs} = N_{transit}\, t_{transit}$

brighter the star is, better the S/N is

→ higher S/N

High S/N can be very good, for example monitoring egress ingress

Which S/N needed to retrieve molecular content ?

Retrieval simulations : typically 7 (UCL group)

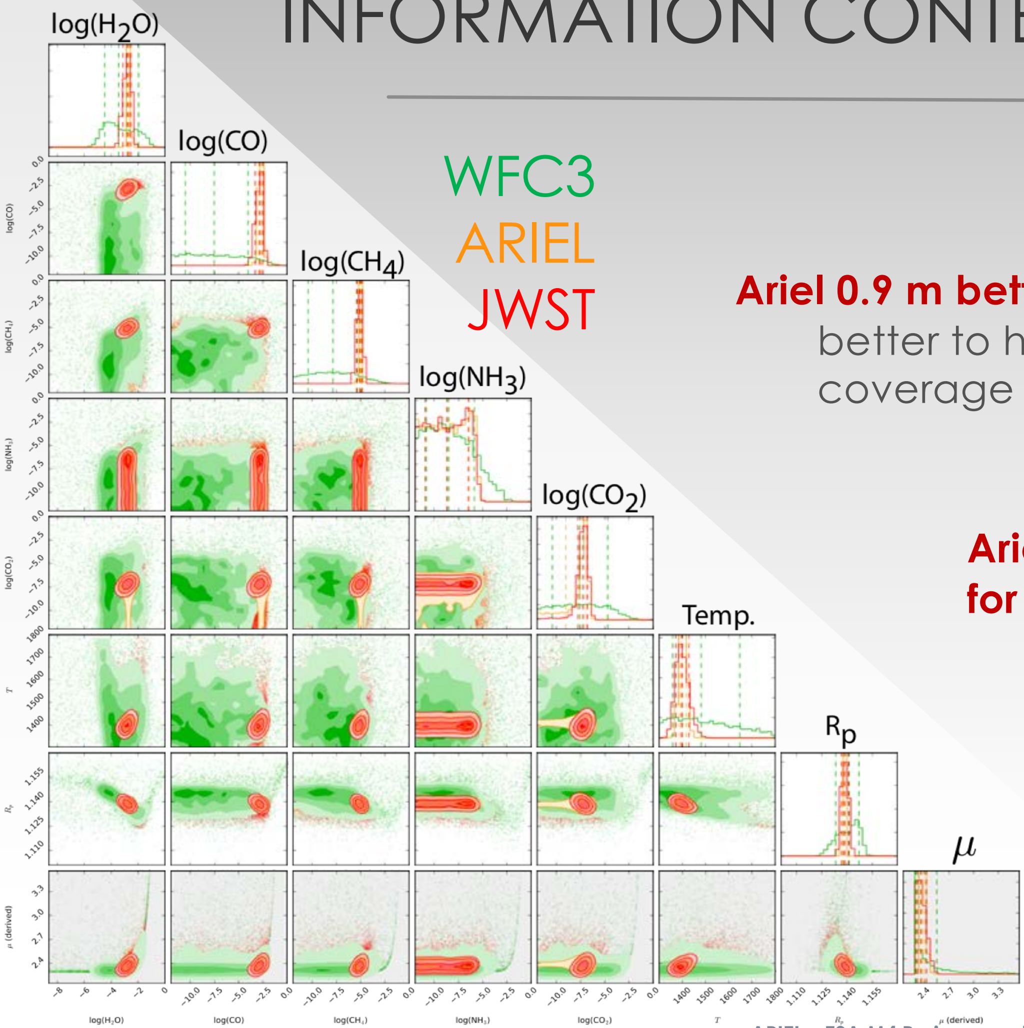
Is it possible to have such a S/N with 1 m telescope ?

Yes : see Spitzer cold have shown it

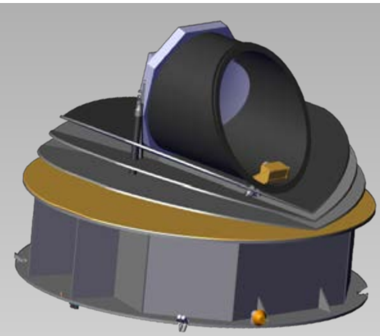
The key: going to bright stars

Thanks TESS

ARIEL HAS BEEN OPTIMIZED GIVEN THE INFORMATION CONTENT TO RETRIEVE

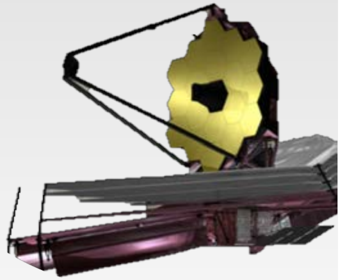


ARIEL – ESA M4 Paris presentation



Ariel 0.9 m better than HST 2.5 m

better to have large wavelength coverage than high S/N



Ariel 0.9 m as good as JWST 6.5 m for such sources

JWST ‘overkilling‘ the S/N in this case

S/N depends on f(planet, H)*D*$(F_{star}*t_{obs})^{1/2}$

longer the wavelenth is in the IR, lower the S/N is

Longer wavelengths more for JWST

Telescope size :

D = 6.5 m

D ~ 1 m

For Eclipse and the detection of planet emission

S/N depends on f(planet(r, T, d))*D*$t_{obs})^{1/2}$ / $(F_{star})^{1/2}$

faintest the star is, better the S/N is

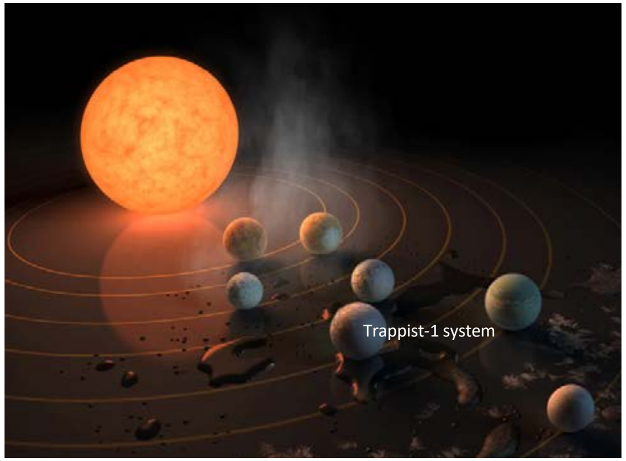
$t_{obs} = N_{transit}\, t_{transit}$

→ higher S/N

Higher S/N means detecting smaller planets or at a lower temperature

Trappist 1 b JWST MIRI GO observations

MIRI European Consortium



Guillon et al. 2017, Nature

Imaging
Search for thermal emission of Trappist b

(400 K; ~ Earth size) by combining 5 eclipses (25 hours)
with the 12.80 μm filter
S/B of 5 expected
Paving the way to higher number of eclipses

Program P.O. Lagage et al., in collaboration with
T. Greene similar observations at 15 microns (CO_2 feature)

Not feasible with ARIEL

Better target than Trappist 1b ? Probably not

For eclipse, we want the star temperature as low as possible ; TRAPPIST 2550 K → peak in the IR → Not TESS but Ground-based such as Speculos; Finding at a distance less than 12 pc (Trappist) would be very valuable? But South hemisphere observations already done. North hemisphere

Overheads :

Large Overheads

Slew : 30 minutes

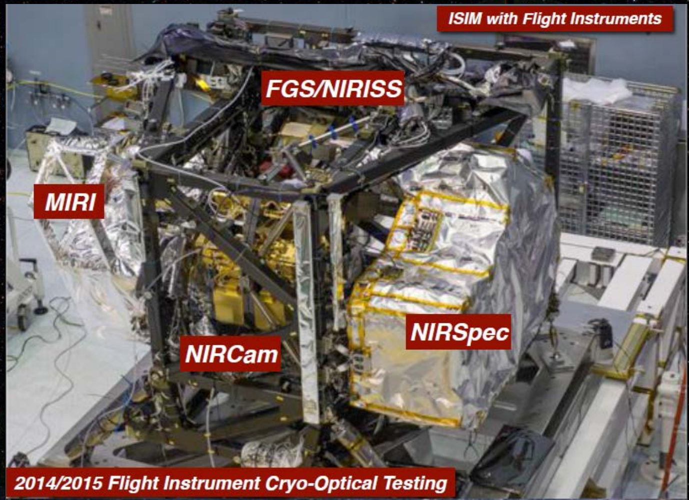
Precise timing of the observations →1 hour tax

Observatory overheads : 16% of the time

Next APT version: probably an increase of overheads

Overheads minimized

Type of Instrumentation

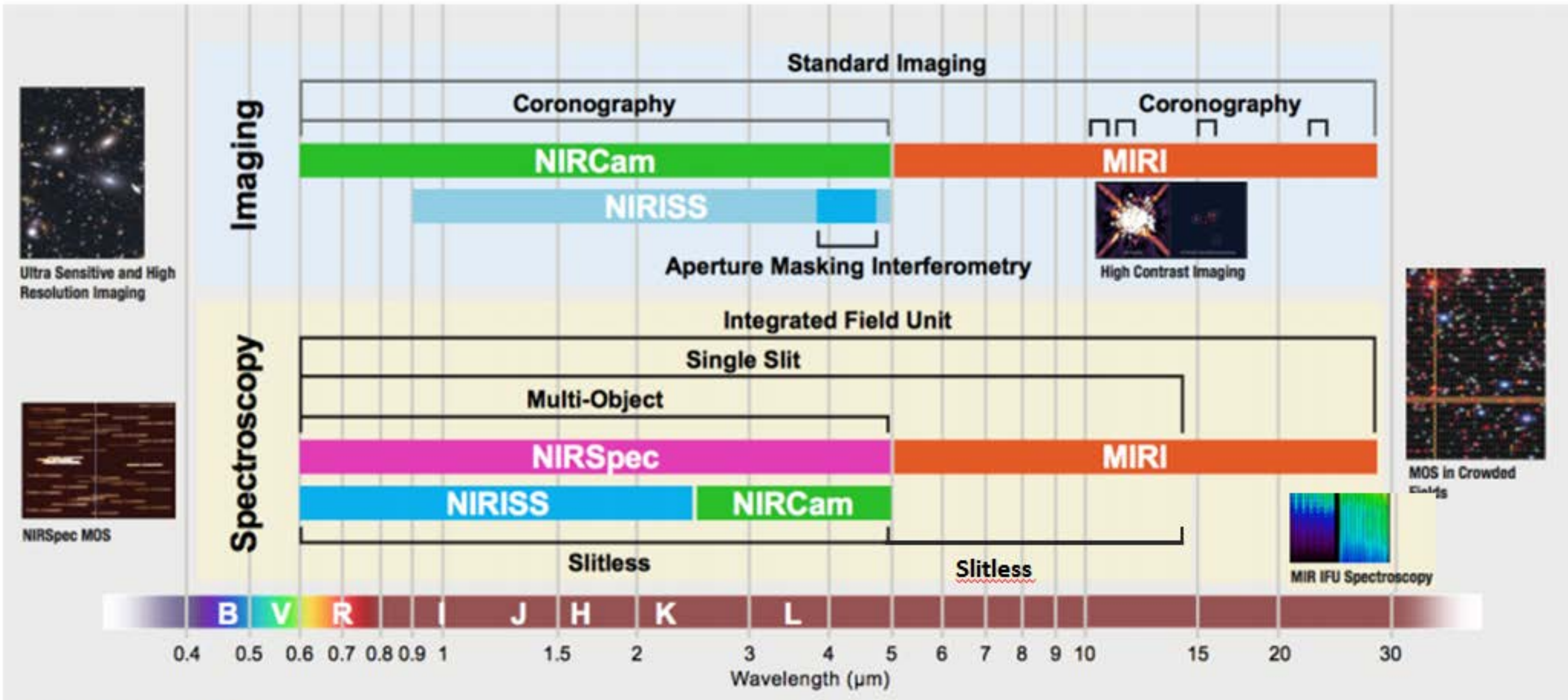


4 instruments

2 instruments

FGS and AIRS

JWST Instrumentation

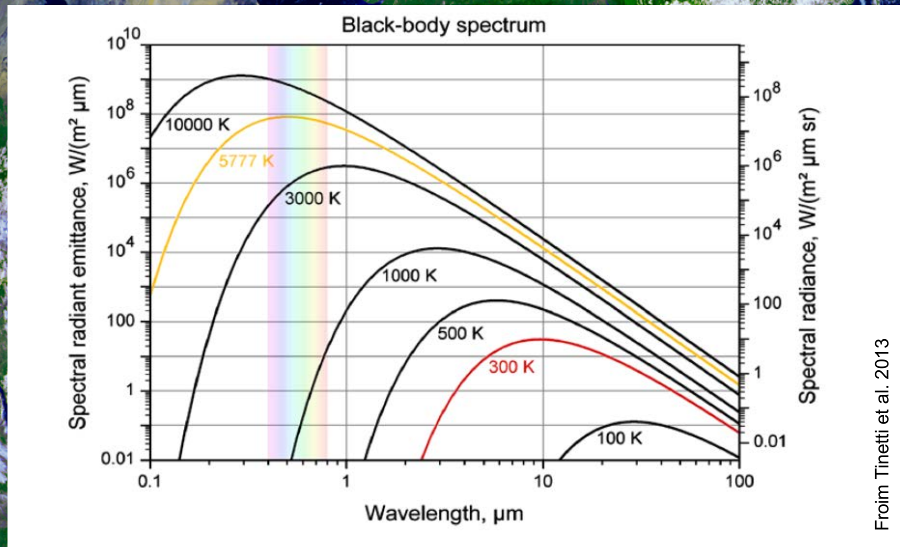


Adapted from STScI

Complex instruments : numerous observing modes
Modes added for exoplanets observations (for example slitless LRS for MIRI)
Allowing the possibility to observe bright stars
At least 2 transits to cover the full wavelength ; 3- for bright stars using high spectral resolution
To avoid saturation

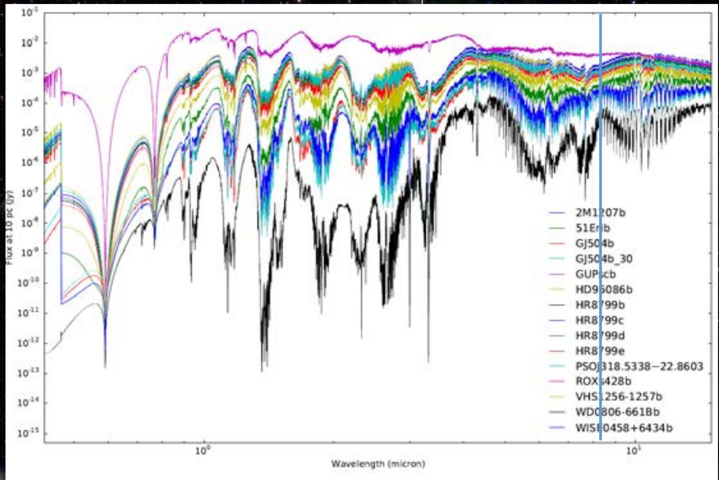
ERS to determine what is the best way to observe exoplanets at short wavelength

5 – 27 microns → BB peak emission with T 600 K - 165 K.
MIRI best suited to detect the emission of “cool” objects.



Froim Tinetti et al. 2013

Beyond 7.8 microns : strong NH3 line

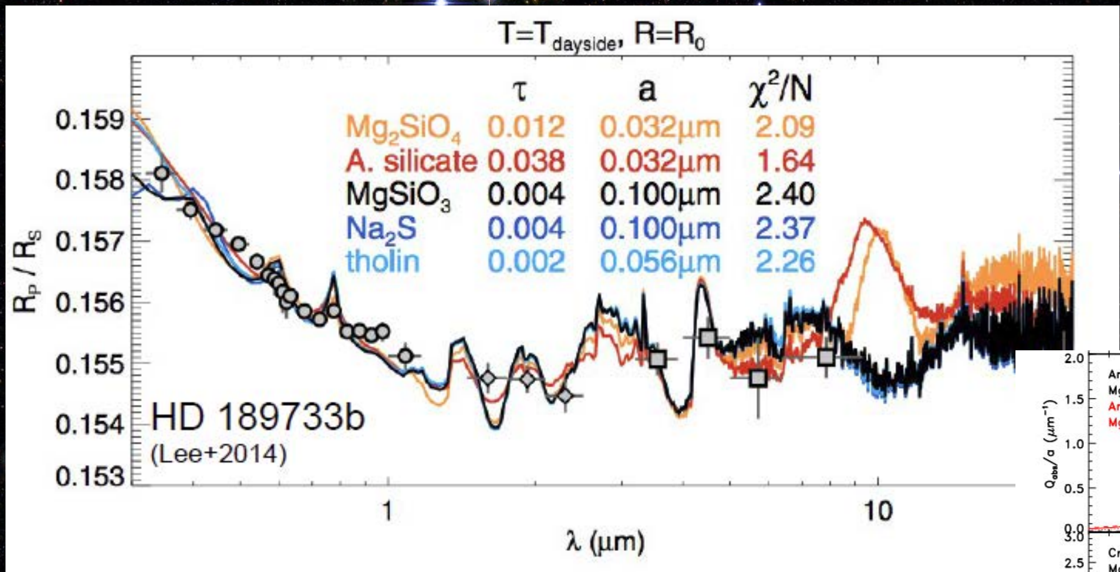


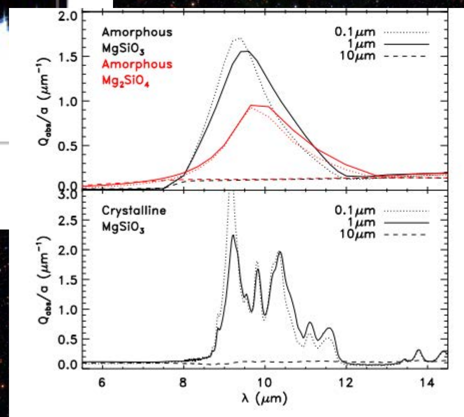
Molecule	$\Delta\nu = 2B_0$ cm^{-1}	λ (S_{max}) 2–5 μm	S_{max} cm^{-2} am^{-1}	R 2–5 μm	λ (S_{max}) 5–16 μm	S_{max} cm^{-2} am^{-1}	R 5–16 μm
H_2O	29.0	2.69 (ν_1, ν_3)	200	130	6.27 (ν_2)	250	55
HDO	18.2	3.67 ($\nu_1, 2\nu_2$)	270	150	7.13 (ν_2)		77
CH_4	10.0	3.31 (ν_3)	300	300	7.66 (ν_4)	140	130
CH_3D	7.8	4.54 (ν_2)	25	280	8.66 (ν_6)	119	150
NH_3	20.0	2.90 (ν_3)	13	170	10.33	600	50
		3.00 (ν_1)	20		10.72 (ν_2)		
PH_3	8.9	4.30 (ν_1, ν_3)	520	260	8.94 (ν_4)	102	126
					10.08 (ν_2)	82	110
CO	3.8	4.67 (1-0)	241	565			
CO_2	1.6	4.25 (ν_1)	4100	1470	14.99 (ν_2)	220	420
HCN	3.0	3.02 (ν_3)	240	1100	14.04 (ν_2)	204	240
C_2H_2	2.3	3.03 (ν_3)	105	1435	13.7 (ν_5)	582	320
C_2H_6	1.3	3.35 (ν_7)	538	2300	12.16 (ν_{12})	36	635
O_3	0.9				9.60 (ν_3)	348	1160

Table 5 Main molecular signatures and constraints on the spectral resolving power. $\Delta\nu$ is the spectral interval between two adjacent J-components of a band. S_{max} is the intensity of the strongest band available in the spectral interval. R is the spectral resolving power required to separate two adjacent J-components

Beyond 7.8 microns

Prominent Dust features in the mid-IR





Beyond 7.8 microns

SuperEarth with mineral atmosphere : SiO band at 10 μm

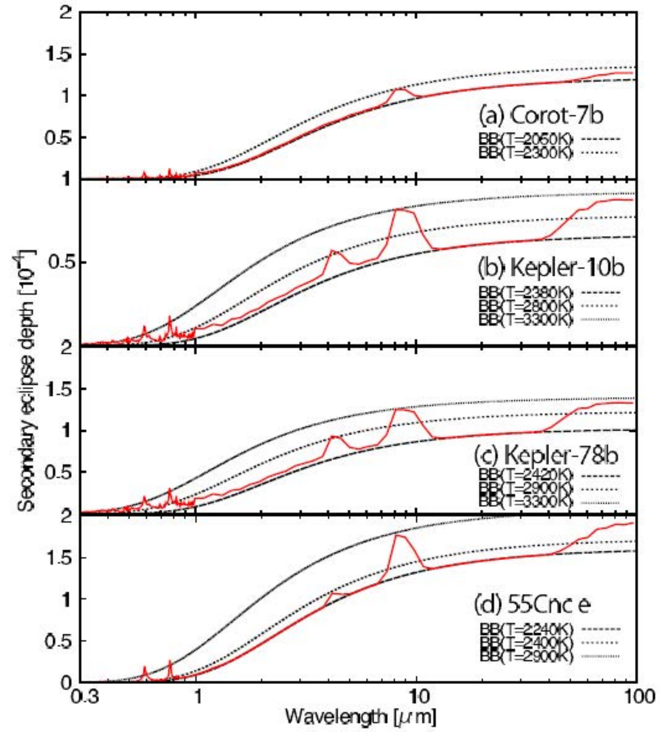


Figure 10. The secondary eclipse depths theoretically predicted for (a) Corot-7 b, (b) Kepler-10 b, (c) Kepler-78 b and (d) 55 Cnc e, shown as a function of wavelength, assuming that they have the mineral atmosphere. The solid lines show the predicted secondary eclipse depth. The black dotted lines show the secondary eclipse depths of the blackbody, temperatures of which are indicated by "BB(T)". We have assumed $\Re = 100$ in 0.3-1 μm and 10 in 1-100

Conclusions

JWST will be an excellent preparation to ARIEL to many respects

Science, Data reduction (see e.g. talk by Jeroen, see poster by Giouseppe)), Retrieval, Modelisation, ….

(ARIEL is flexible enough to take into account those evolutions)

It is a NASA led mission with participation of ESA and CSA with a minimum of 15% of time to scientist from ESA countries (similar to HST)

Open time cycle 1 call imminent (One step process; not two as for HST proposals)
I encourage you to answer ; complex Instrumentation → Early Release Science ;
ESA master class

From cycle 2 on, there will probably be legacy program

With our US colleagues on board of ARIEL, we can think of what would be the best for ARIEL preparation

Exciting perspective to have both JWST and ARIEL in operation during the 2029 – 2031

Ariel TIER 1 → good targets to be observed with JWST especially with MIRI