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Exosim’s simulations for ARIEL

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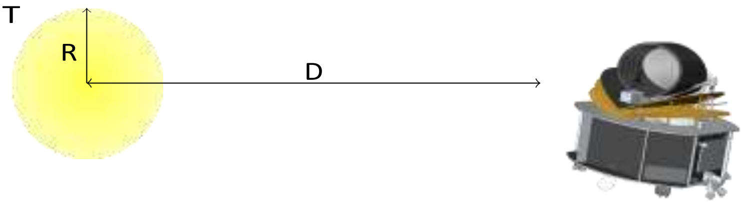
[redacted]

For the AIRS iCDR, we needed the expected light flux on the AIRS detectors across a representative range of operational observation conditions



Context and motivation

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What was needed to perform this survey :

1. A representative list of known potential targets (stars) for Ariel, in terms of radius R, distance D and temperature T
2. A tool that let us transform a target input, in terms of (R,T,D), into a prediction of the focal plane seen by AIRS detector in terms of $e^{-} \times s^{-1} \times \text{pixel}^{-1}$

Ariel’s Mission Candidate Sample

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Ariel's Mission Candidate Sample

Our targets list comes from the so-called Ariel's Mission Candidate Sample (MCS)

- Under Git versioning and publicly available on Github
- Latest version used at the time of performing the analysis (2025-08-18, Commit ID #40a3fb6)

```
Star Name,Star Mass [Ms],Star Mass Error Lower [Ms],Star Mass Error Upper [Ms],Star Temperature [K],Star Temperature Error Lower [K],
K2-232,1.039,-0.065,0.071,5888,-77,71,1.233,-0.025,0.026,4.273,-0.035,0.035,0.051,-0.056,0.058,[Fe/H],7.1,-2.7,3.1,,4.16,-0.282,0.282,,,
Qatar-10,1.156,-0.068,0.068,6124,-40,40,1.254,-0.026,0.026,4.303,-0.027,0.027,0.016,-0.009,0.009,[Fe/H],3.2,-1.9,1.9,F7 V,3.9,-0.5,0.5,,,
WASP-60,1.078,-0.035,0.035,5900,-100,100,1.14,-0.13,0.13,4.35,-0.09,0.09,-0.04,-0.09,0.09,[Fe/H],3.6,-2.1,4.3,G1 V,3.4,-0.8,0.8,,,,431
WASP-20,1.2,-0.041,0.041,5940,-100,100,1.392,-0.044,0.044,4.231,-0.02,0.02,-0.008,-0.06,0.06,[Fe/H],7,-1,2,F9,4.75,-0.51,0.51,,,,211
HATS-52,1.111,-0.054,0.054,6010,-150,150,1.046,-0.058,0.058,4.445,-0.034,0.034,,,,,1.2,-1.1,1.5,,4.59,-0.64,0.64,,,,555,134,-6.057,
TOI-1820,1.04,-0.13,0.13,5734,-50,50,1.51,-0.06,0.06,4.24,-0.05,0.05,0.14,-0.15,0.15,[Fe/H],11,-2,2,,4.5,-0.8,0.8,25,-6,6,248.504,
TOI-2202,0.841,-0.032,0.034,5169,-78,80,0.806,-0.022,0.024,4.548,-0.031,0.03,0.059,-0.043,0.043,[Fe/H],6.4,-3.9,4.4,,2.14,-0.25,0.28,
```

- More than 800 exoplanets orbiting around 754 host stars
- Each of them defined by roughly 200 parameters, among which our (R, T, D) host star parameters

Ariel’s Mission Candidate Sample

More information : Edwards, B., & Tinetti, G. (2022). *The Ariel target list : the impact of TESS and the potential for characterizing multiple planets within a system.* The Astronomical Journal, 164(1), 15.

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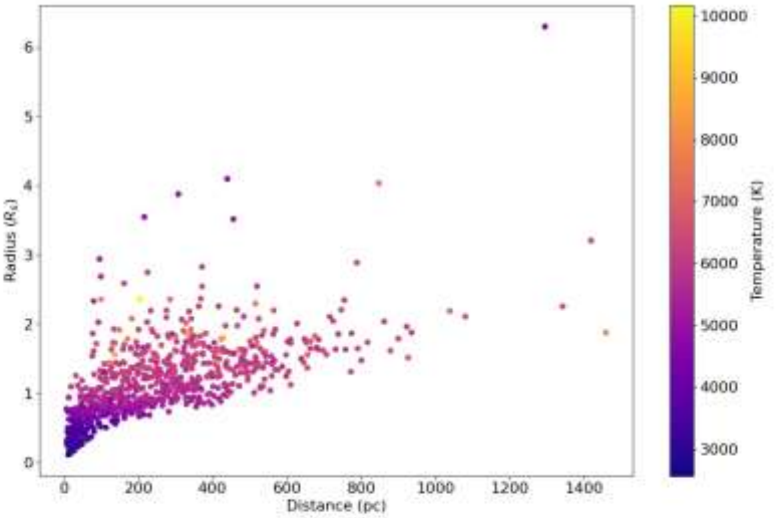
Ariel’s Mission Candidate Sample



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Ariel’s Mission Candidate Sample

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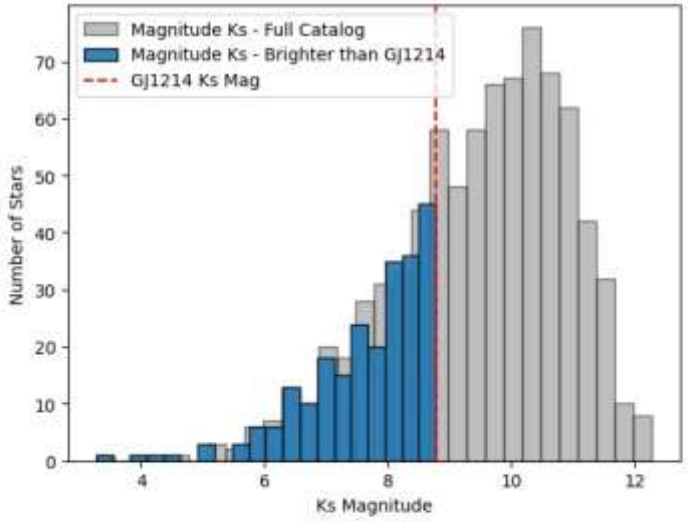
Ariel’s Mission Candidate Sample



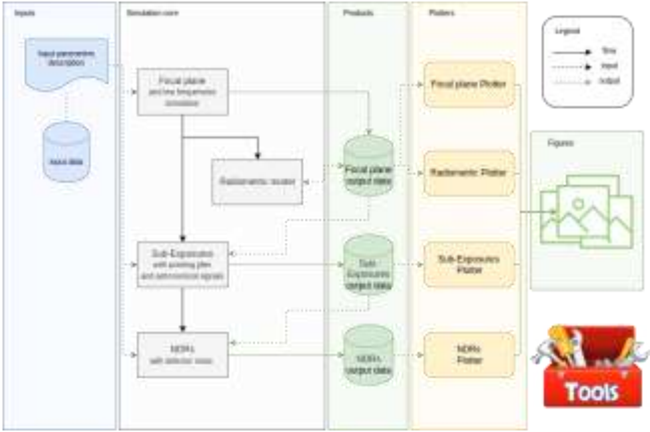
Ariel's Mission Candidate Sample

K_S band $\approx 2.2\mu$m

Exosim2[7]

Exosim2 is a time domain simulator exoplanet observations that was used to convert those (*R*,*T*,*D*) star parameters into flux predictions at the AIRS detectors

CH0 optical path



Exosim2 inputs :

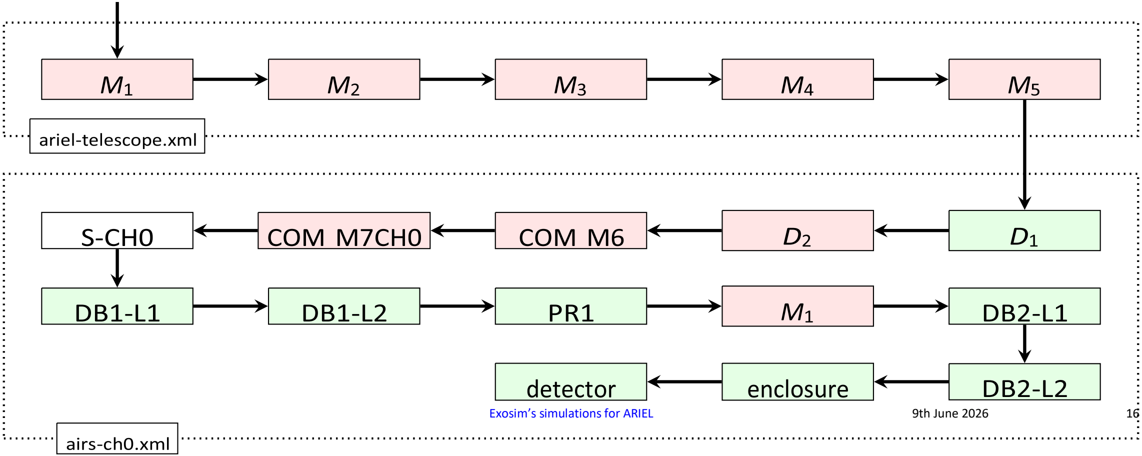
- [redacted] target
- [redacted] optical path
- [redacted] dispersion law
- [redacted] QE curve
- [redacted] Point Spread Function (PSF) [redacted] etc.

More information : Mugnai et al., 2025, *ExoSim 2 : new exoplanet observation simulator applied*
the

CH0 optical path

to the Ariel space mission, Exp. Astron, 59, 9. DOI :10.1007/s10686-024-09976-2.

CH0 optical path



CH0 optical path

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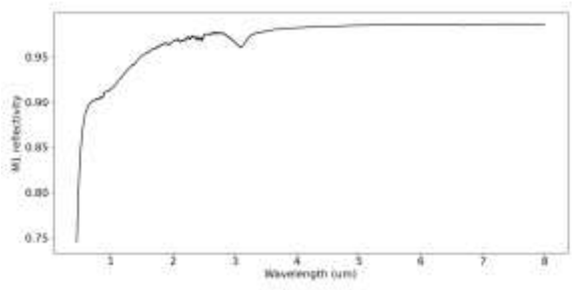
Each object of the optical path is defined by its temperature and its wavelength-dependant efficiency

CH0 optical path

```xml
<opticalElement>M1
   <type>surface</type>
   <task_model>LoadOpticalElementHDF5</task_model>
   <temperature unit='K'>60</temperature>
   <hdf5_file>__MPDBdata__</hdf5_file>
   <group_key>ta/m1</group_key>
   <wavelength_key>wavelength</wavelength_key>
   <efficiency_key>reflectivity.eol</efficiency_key> </opticalElement>
```



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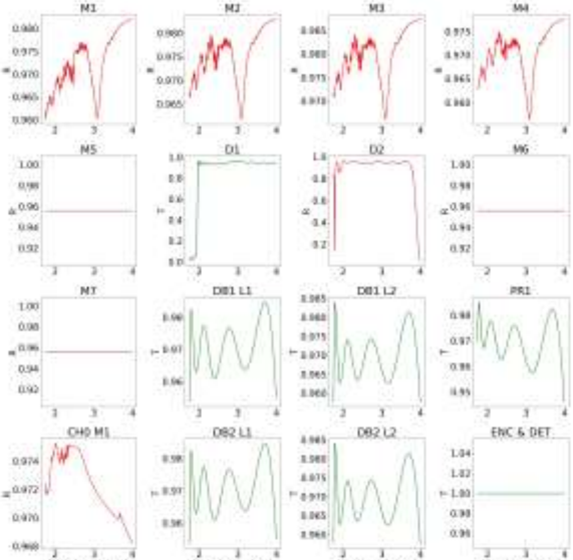
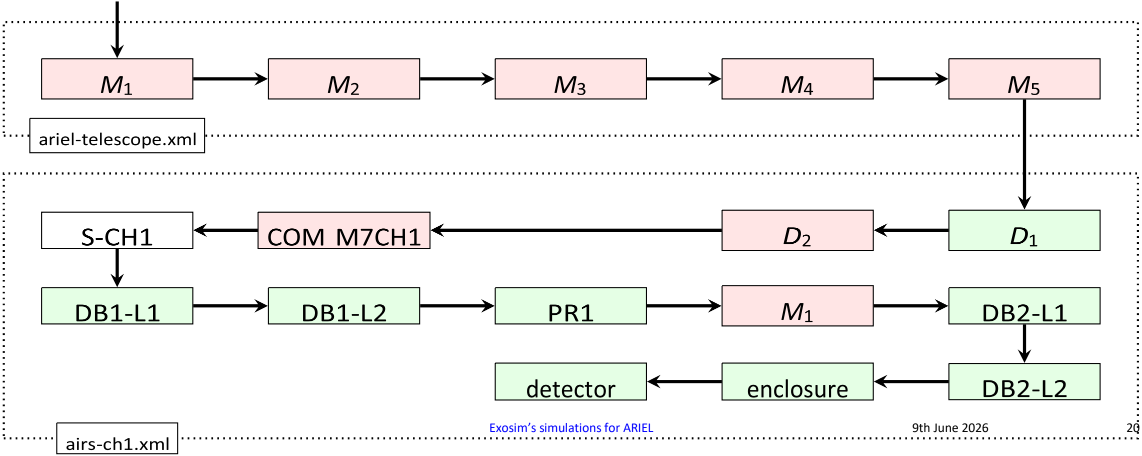
CH0 optical path



CH1 optical path



CH1 optical path

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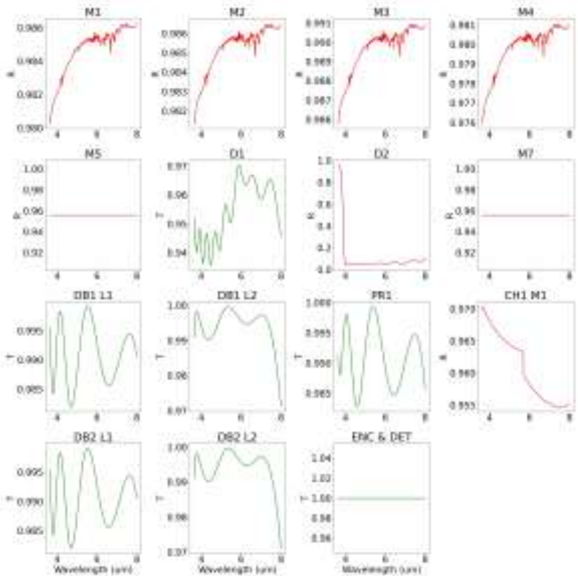
M1
M2
M3
M4
M5
D1
D2
M7
DB1 L1
DB1 L2
FR1
CH1 M1
DB2 L1
DB2 L2
ENC & DET
Wavelength (μm)

Total efficiency

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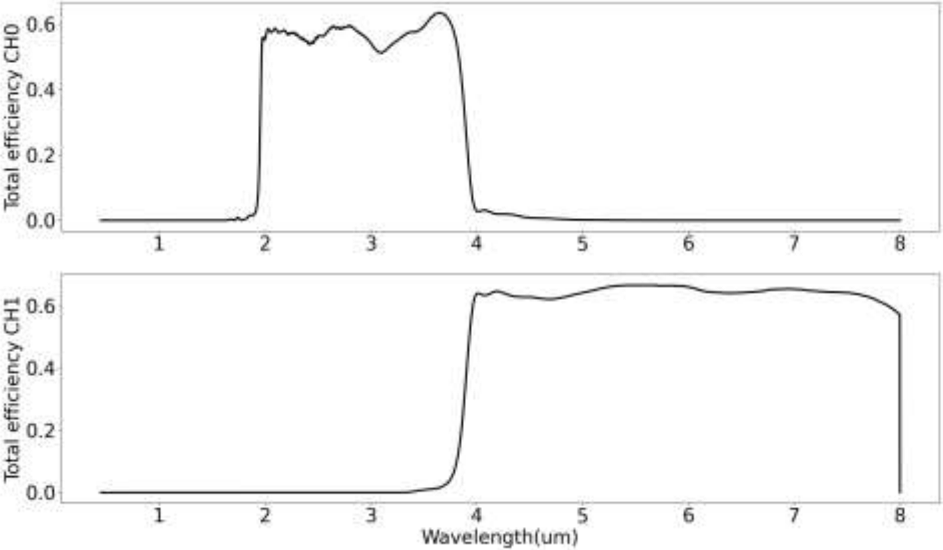
Total efficiency CH0
0.0
0.2
0.4
0.6
Total efficiency CH1
0.0
0.2
0.4
0.6
1
2
3
4
5
6
7
8
Wavelength(um)

Dispersion law

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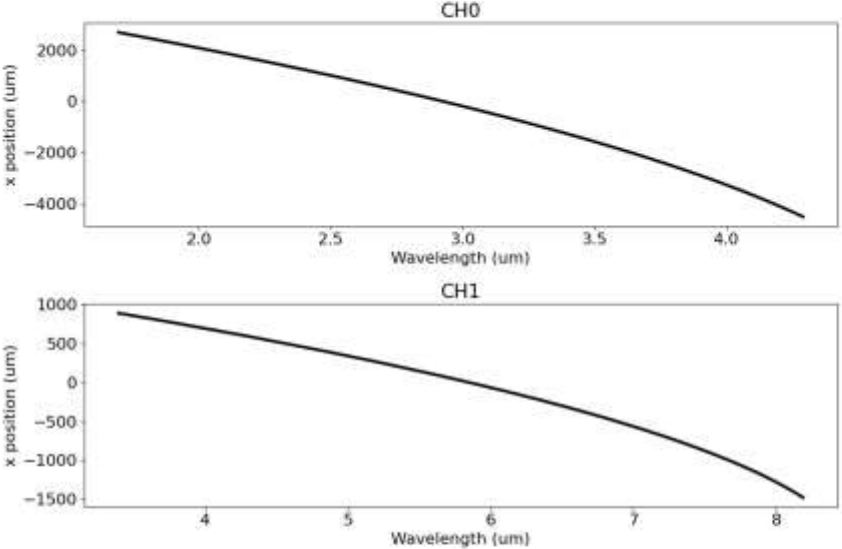
CH0
2000
0
−2000
−4000
x position (um)
2.0
2.5
3.0
3.5
4.0
Wavelength (um)
CH1
1000
500
0
−500
−1000
−1500
x position (um)
4
5
6
7
8
Wavelength (um)

QE curves

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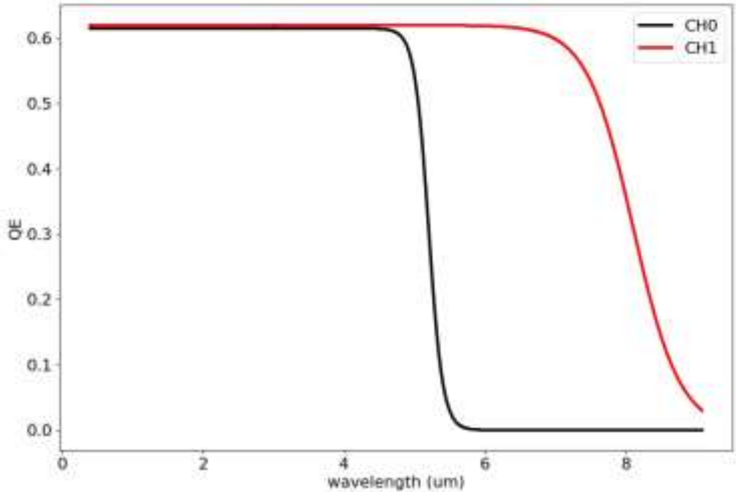
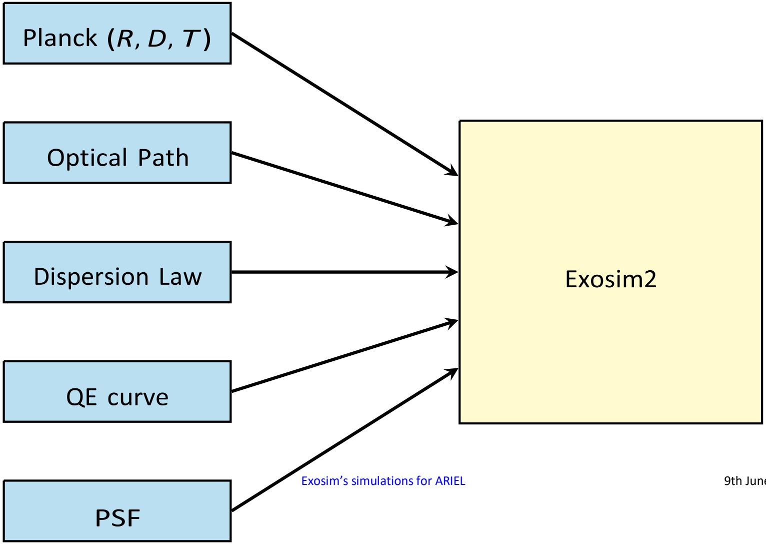
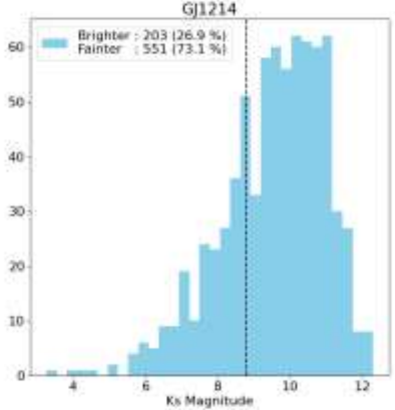
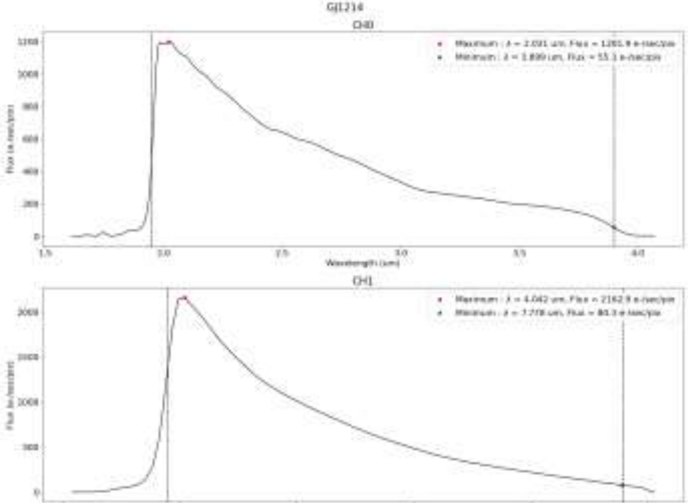

CH0
CH1
0.6
0.5
0.4
QE
0.3
0.2
0.1
0.0
0
2
4
6
8
wavelength (um)

16

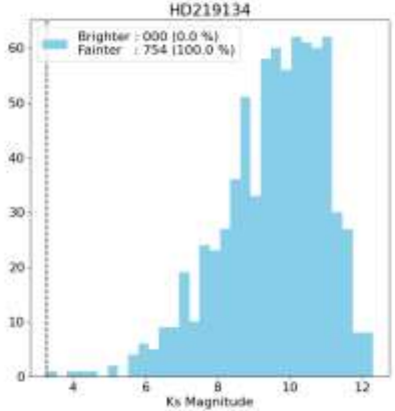

Planck (R, D, T)
Optical Path
Dispersion Law
QE curve
PSF
Exosim2

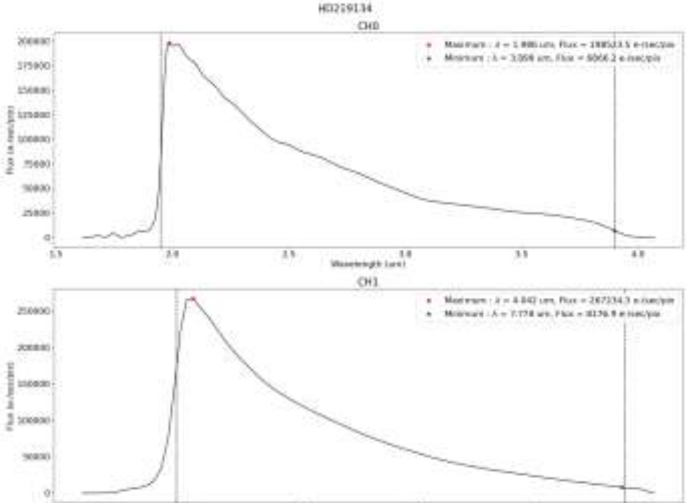
Diffraction limited simulations

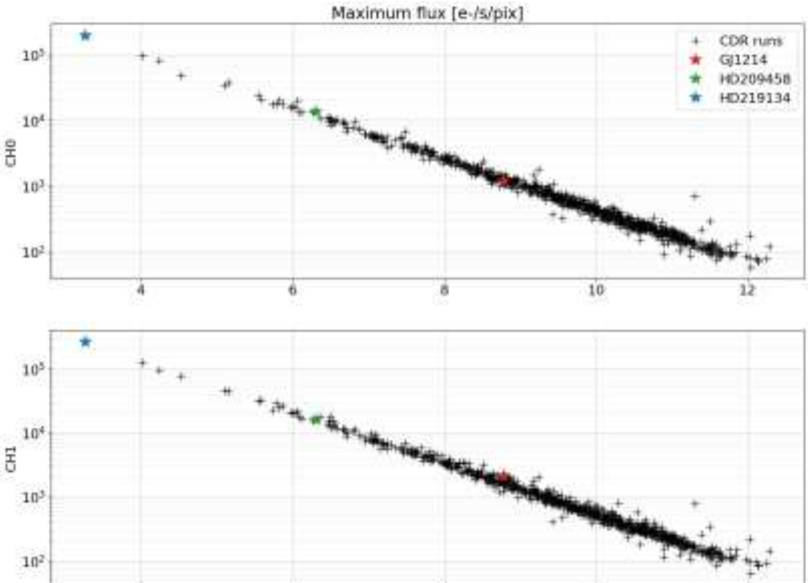




Diffraction limited simulations







Maximum flux [e-/s/pix]
CDR runs
GJ1214
HD209458
HD219134
CH0
CH1

Wave front error simulations

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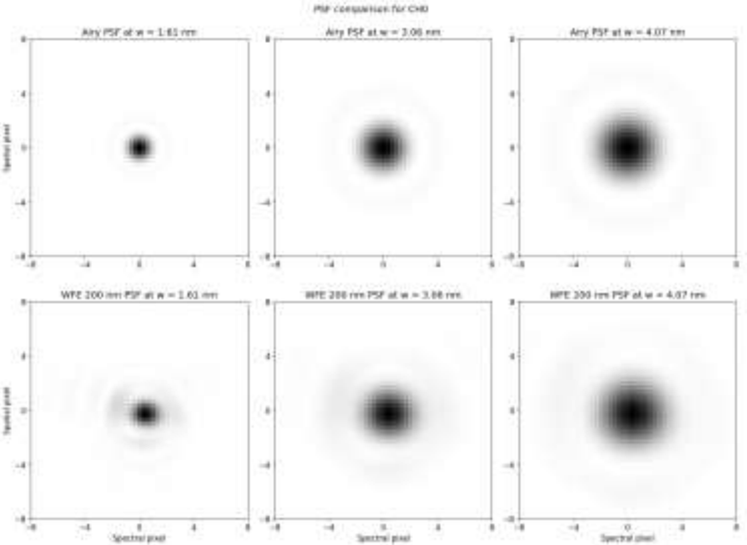
Wave front error simulations



Wave front error simulations

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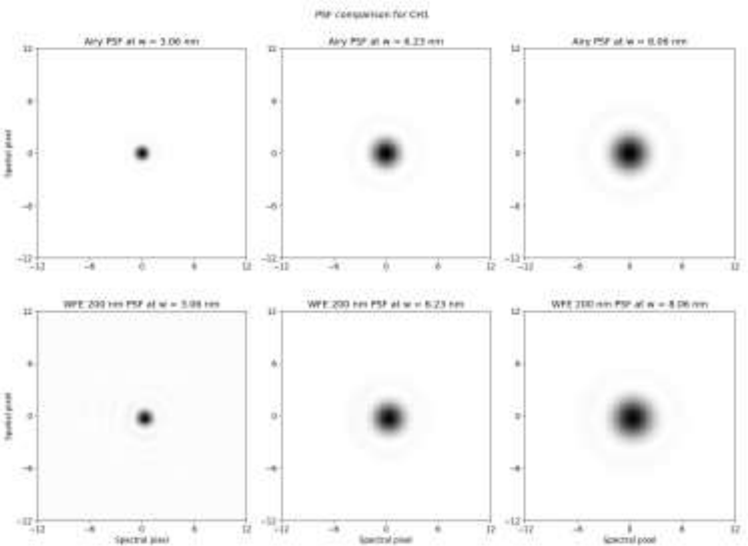
Wave front error simulations



Wave front error simulations

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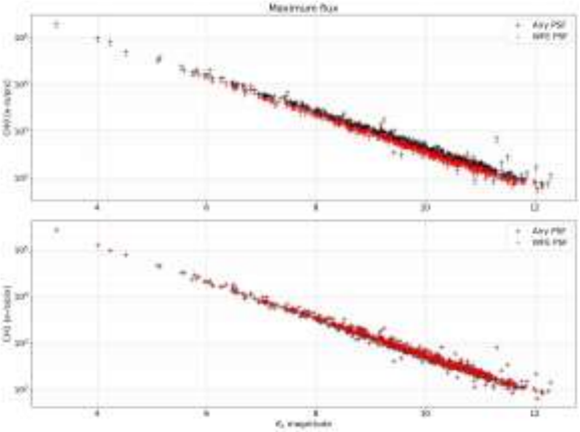
Wave front error simulations

- ≈−15 % on total flux on CH0

Roughly similar on CH1



Foreground analysis[23]

We finally analysed the foreground contamination when no stars are visible. Such foreground consists in :

1. Zodiacal light
2. Thermal radiation from every element of the optical path

$$I_{\text{Zodi}}(\lambda) = A\left(3.5 \times 10^{-14}\,\mathrm{BB}(\lambda, 5500\,\mathrm{K}) + 3.58 \times 10^{-8}\,\mathrm{BB}(\lambda, 270\,\mathrm{K})\right)$$

Our simulations explored various amplitude factors of the zodiacal light (0.0, 1.0 and 2.5) and two different enclosure temperatures (55 K and 60 K)

Foreground analysis[24]

Run	A (Zodiacal light)	$T_{enclosure}$ (K)	Max flux CH0 ($e^{-}s^{-1}pix^{-1}$)	Max flux CH1 ($e^{-}s^{-1}pix^{-1}$)
1	0.0	55	1.2×10^{-14}	1.1×10^{-1}
2	0.0	60	2.5×10^{-12}	1.9×10^{0}

3	1.0	55	7.2×10^{-2}	3.5×10^{0}
4	1.0	60	7.2×10^{-2}	5.2×10^{0}
5	2.5	55	1.8×10^{-1}	8.5×10^{0}
6	2.5	60	1.8×10^{-1}	1.0×10^{1}

Conclusion

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The Exosim's simulations for AIRS iCDR consisted in

1. 754 runs with an Airy shaped PSF
2. 754 runs with a more realistic PSF
3. 6 runs that explored the foreground contamination

All the results presented here are detailed in ARIEL-IAP-INST-TN-002 document

Thank you for your attention