Auxiliary science with ARIEL

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Abstract

Due to the fixed times of the ARIEL exoplanet transit observations waiting periods remain between the actual active periods. Scheduling simulations estimate that a significant fraction, 19%-27% of the total mission duration will be waiting time. The simulations also predict that these gaps are short, typically 0.5-2.0 h, much shorter than the typically ~7 h-long target measurements. With efficient scheduling and target selection these waiting times could be filled with valuable observations of ancillary targets and could maximise ARIEL's scientific impact. Our proposed ancillary targets include a selected sample of young stars, specifically newborn Sun-like stars, relatively young normal main-sequence stars, and brown dwarfs. In the youngest subsample ARIEL can study the composition of the circumstellar discs and envelopes and characterise the impact of stellar variability on disc properties. In the main-sequence stellar sample and in brown dwarfs the focus of research is debris discs, stellar activity and magnetism. For all these target groups mid-infrared spectroscopy is an extremely valuable tool, but currently observations are available for a very limited sample only.

Proposal for auxiliary observations

- Simulations indicate that, depending on the target sample and observing strategy, 19%-27% of the total mission duration will be 'waiting time', i.e. gaps between scheduled exoplanet transit observations (Morales et al., 2017).
- The typical length of these gaps are 0.5-2 h, much shorter than the average ~7 h duration of the exoplanet transit observations.
- Waiting times can be filled with observations of ancillary targets to maximise ARIEL's scientific outcome. These targets should (i) be scientifically interesting, (ii) show clear signatures in the near- and mid-infrared to be covered by ARIEL, (iii) be bright enough to reach good signal-to-noise in the 0.5-2 h observations, and (iv) numerous and distributed evenly in the sky to be reachable in a short time considering the observational overheads (e.g. slewing time).
- **Variability of young stellar objects**: Young stellar objects (YSOs) are variable. This phenomenon has long been known in the visible wavelength range, but observations in the last decades show that this is also the case in the infrared (Eiroa et al. 2002, Cody et al. 2014, Kóspál et al. 2012). While variability in the visible range is mainly due to hot/cold stellar spots or extinction changes in the line of sight, in the mid-infrared the dominant source is the variation in the thermal emission of the circumstellar disc. Measurement covering this phenomenon are currently rare, however, they are essential in understanding eruptive young stars (FU Ori-s and EX Lupi-s).
- **Dust, molecules and ices as building blocks of planets**: Protoplanetary discs around pre-main sequence stars are mainly build of gas and contain about 1% of dust that changes dramatically as planet formation progresses. In the central plane of the disc ice mantle forms on the surface of the silicate grains. These grain surfaces are the places of complex chemical reactions, leading to more complex molecules which are excellent tracers of the physical conditions, and are very important in understanding the initial conditions of planet formation. Spectral features of these molecules and dust grains can be observed in the mid-infrared. Such spectra of young stars were observed with the PHT-S instrument of ISO and with the IRS instrument of the Spitzer Space Telescope (Kessler-Silacci et al. 2006, Ábrahám et al. 2009, Kóspál et al. 2012).
- **Magnetic activity** is a characteristic phenomenon of young stars. The related UV radiation may modify and ionise the exoplanet atmospheres, e.g. through the photodissociation of water and ozone. Stellar flares may also have significant impact on exoplanet atmospheres, but their long term effect has not been studied in details (Segura et al., 2010). ARIEL observations will open the way to monitor fast changes during stellar flares, detect microflares, and estimate the energy of these events.
- **Brown dwarfs:** While the general consensus is that brown dwarfs are non-magnetic, H-alpha, X-ray and radio emission indicate the presence of magnetic activity among these objects in some cases (Morales et al., 2017; Rutledge et al., 2000). Mid-infrared monitoring of brown dwarfs by ARIEL could find the signatures of magnetic activity, and help to extend the current models (based mainly on solar data) to M-stars and also to brown dwarfs, to the bottom of the stellar mass scale.
- **Extreme debris discs**: Extreme debris discs are rare systems with large amount of warm dust surrounding a young Sun-like star. This dust is believed to stem from a recent giant collision of planetary embryos in the terrestrial zone (<1-2au); such events likely happened in the past of our own solar system (e.g Wyatt & Jackson 2016). These discs show strong mid-infrared variability on month to year-long timescales as the result of the orbital and collisional evolution of the new dust and vapour produced in the impact event (Su et al. 2019). Monitoring these discs by the ARIEL thus offers a unique opportunity to study the immediate aftermath of rocky-planet-forming giant collisions.

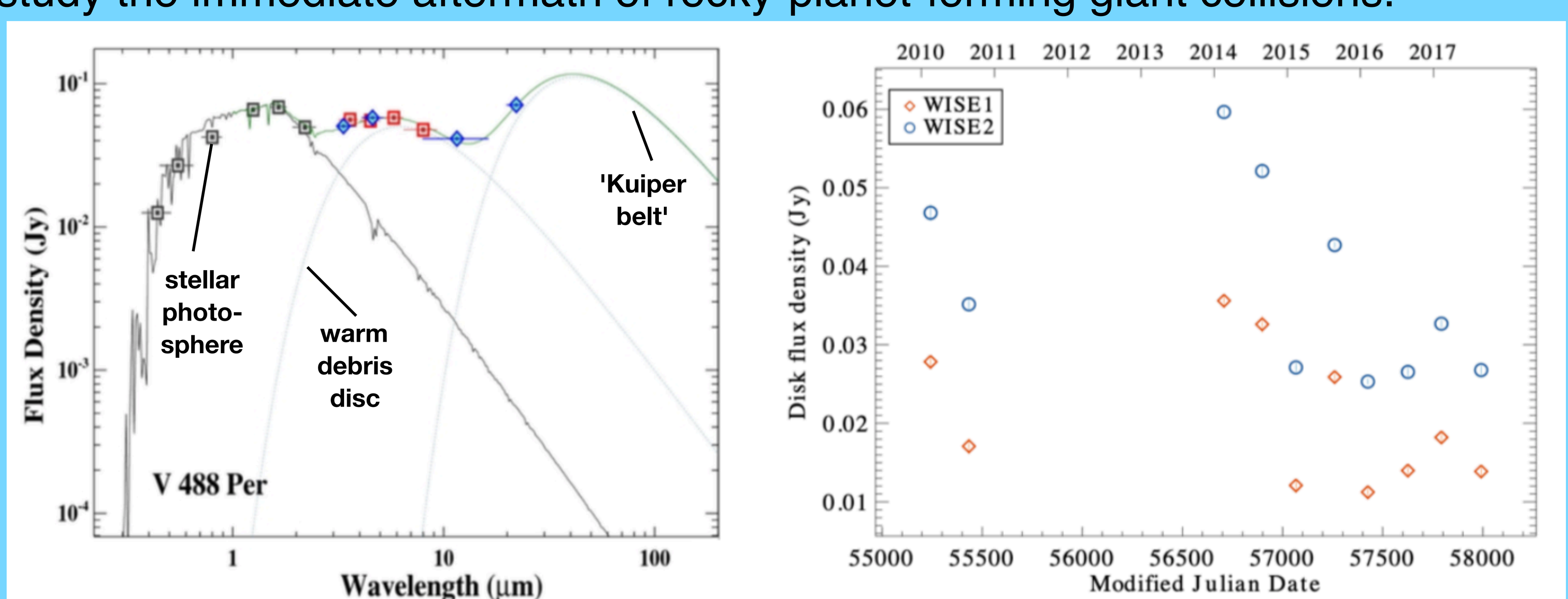

Fig. 1: Spectral energy distribution of the variable star V448 Per (left, , from Zuckerman et al., 2012), and its brightness variation (right) in the WISE W1 (red diamonds, 3.4μm) and W2 (blue circles, 4.6μm) bands. At mid-infrared wavelength the warm debris disc component has the dominant contribution.

FU Ori-type stars

- We started with a sample of 22 known FUors (from Audard et al., 2014) and investigated their observability considering (i) slewing time and (ii) single-to-noise ratios for the ARIEL instruments
- Preliminary results show that majority of FUors can be reached within 10 min from any exoplanet target and all FUors can be reached within 20 min
- 95% of the known FUors are at least partly observable with a good signal-to-noise ratio, at least with the AIRS-1 instrument (3.9-7.8μm).

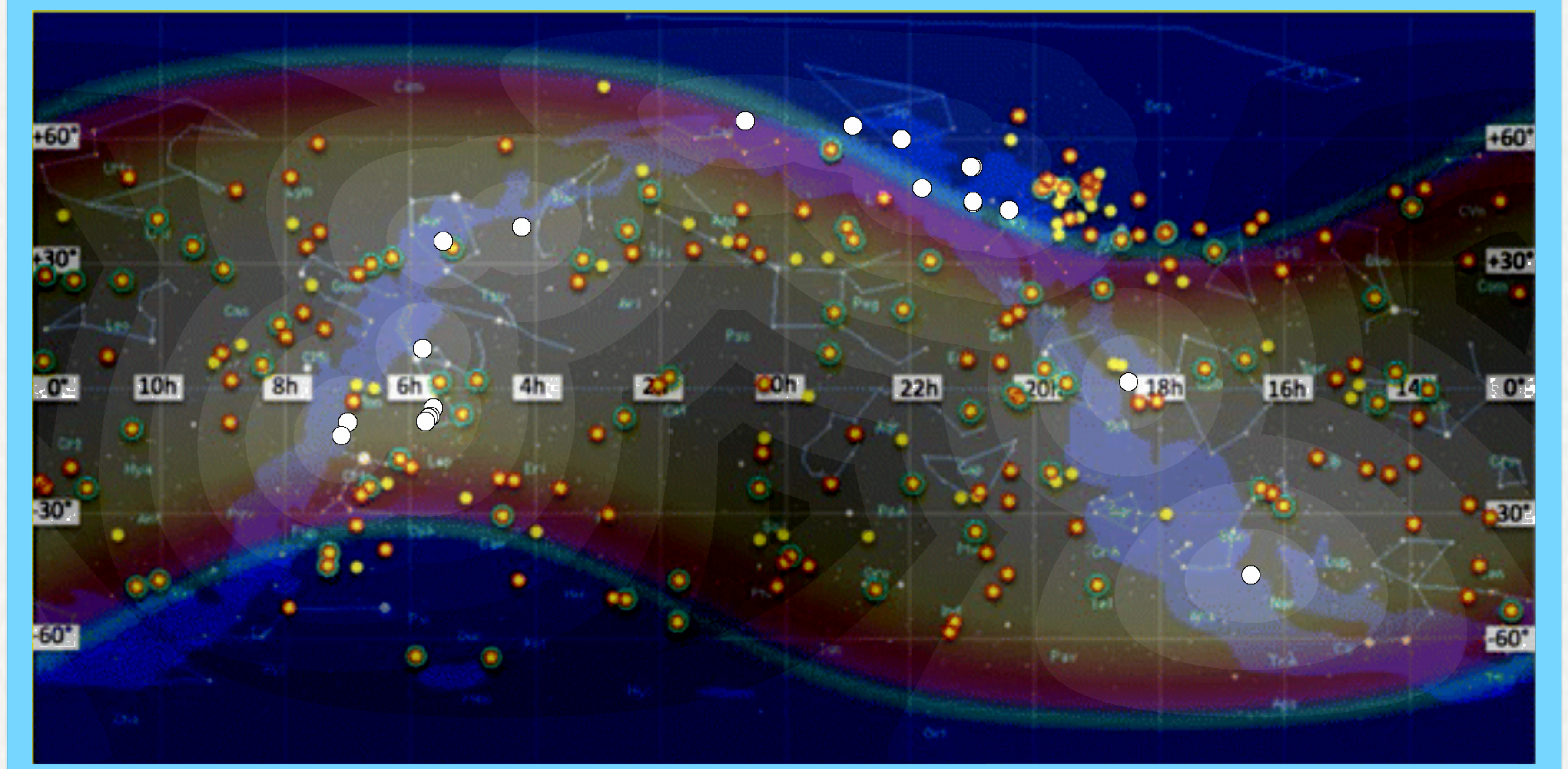

Fig. 2: Location of FU Orionis stars (white filled circles) used in our sample plotted over the map presenting the location of ARIEL exoplanet transit targets

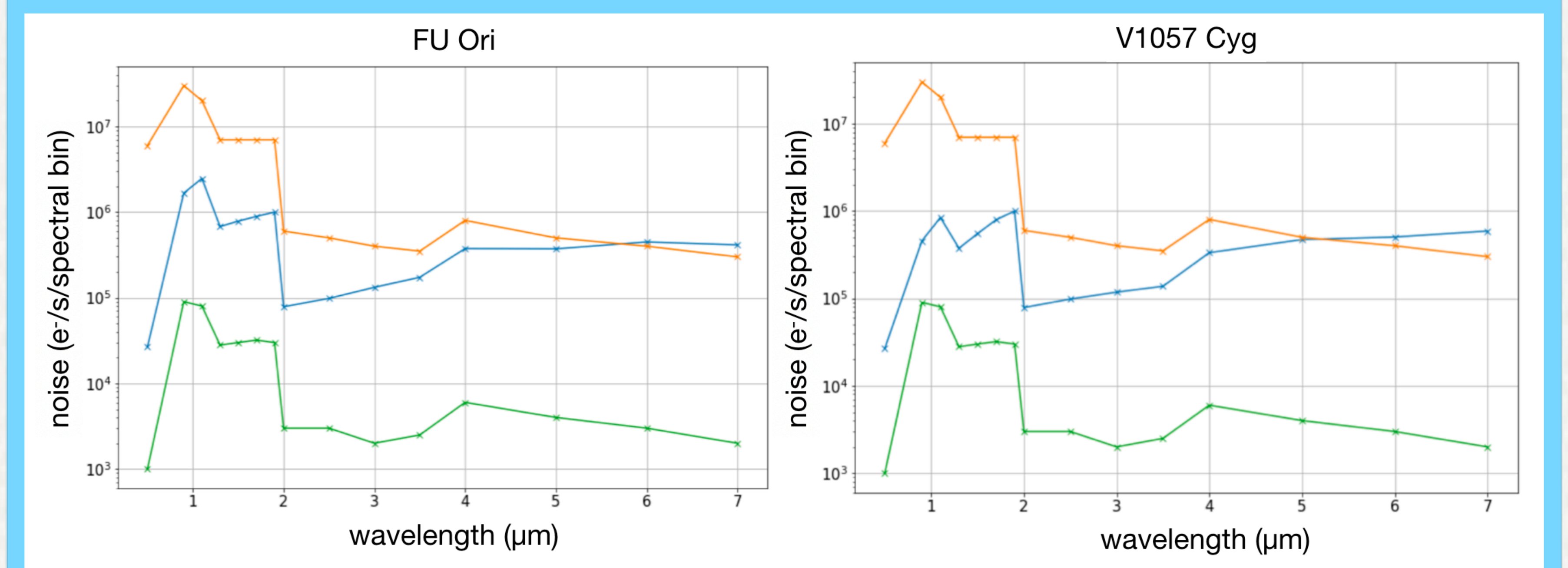

Fig. 3: Noise estimates for FU Ori and another FUor, V1057 Cyg (blue curves). Orange and green curves correspond to the reference stars HD 219134 and GJ 1214, respectively.

Slew time (min)	Fraction
2.5	10.7%
5	31.6%
7.5	54.0%
10	69.8%
12.5	82.8%
15	92.1%
17.5	98.6%
20	100.0%

Instrument	λ (μm)	Partly observable	Fully observable
VPhot	0.50-0.55	27.3%	18.2%
FGS1	0.80-1.00	9.1%	9.1%
FGS2	1.05-1.20	27.3%	18.2%
NIRSpec	1.20-1.95	40.9%	18.3%
AIRS-0	1.95-3.90	63.6%	40.9%
AIRS-1	3.90-7.80	72.7%	36.4%

Table 1: Left: Slewing time from a randomly selected exoplanet transit target to the closest FUor from our sample. Right: Observability of the FUors with the ARIEL instruments, using the current sensitivity estimates.

Related papers

● Ábrahám, P., et al, 2009, Nature, 459, 224 ● Audard et al., 2014, Protostars and Planets VI, pp. 387-410● Cody et al., 2014, AJ, 147, 82 ● Eiroa et al. 2002, A&A, 384, 1038 ● Kessler-Silacci et al., 2006, ApJ 639, 275 ● Kóspál, Á., et al, 2012, ApJS, 201, 11 ● McLean, M., Berger, E., Reiners, A., 2012, ApJ, 746, 23 ● Morales, J.C., et al, 2017, „ARIEL Long Term planning", ARIEL-ICE-GS-TN-001 Issue 1.0, 2017.02.15. ● Rutledge, R.E., et al, 2000, ApJS, 131, 335 ● Segura, A., et al, 2010, AsBio, 10, 751 ● Su, K. et al., 2019, AJ, 157, 202 ● Tinetti, G., et al, 2018, Experimental Astronomy, 46, 135 ● Venot, O., et al, 2018, Experimental Astronomy, 46, 101 ● Wyatt, M.C. & Jackson, A.P., 2016, SSRv, 205, 231 ● Zuckerman et al. , 2012, ApJ, 752, 58

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