1. Science aim/goal:

1) Understand the origin and evolution of gas in planetary systems around mature stars 2) Probe the composition of exo-comets 3) Study the inner parts of planetary systems to find planets.

2. (i) Scientific Importance:

Finding gas in planetary systems around main sequence stars is becoming more and more frequent. Molecular gas (CO) and atomic species (such as CI, CII, OI and some metals) are detected. Most of the observed gas is interpreted as secondary rather than primordial as its lifetime is short compared to the age of systems. This secondary gas is thought to be released in collisions between comets in debris belts. Being able to clearly understand the origin of gas and its evolution will be critical to further our understanding of planetary systems and eventually improve our knowledge of planet formation.

Gas observations with FIRS would represent a new avenue to studying debris discs, which is complementary to dust observations. The dust in these systems is generally cool and resides at tens of au where terrestrial planets are not expected to form. With many detections, the origin and evolution of molecular and atomic species (which can be complicated, see Kral & Latter 2016) can be understood in detail. The OI to CII ratio yields a measurement of the composition of exo-comets (see Kral et al. 2016, KRA16), and thus information about the disc mid-plane conditions during planet formation. As atomic gas in debris disc systems is expected to extend all the way to the star (KRA16), studying the gas disc structure created by planets in the habitable zone could be possible.

(ii) Measurements Required:

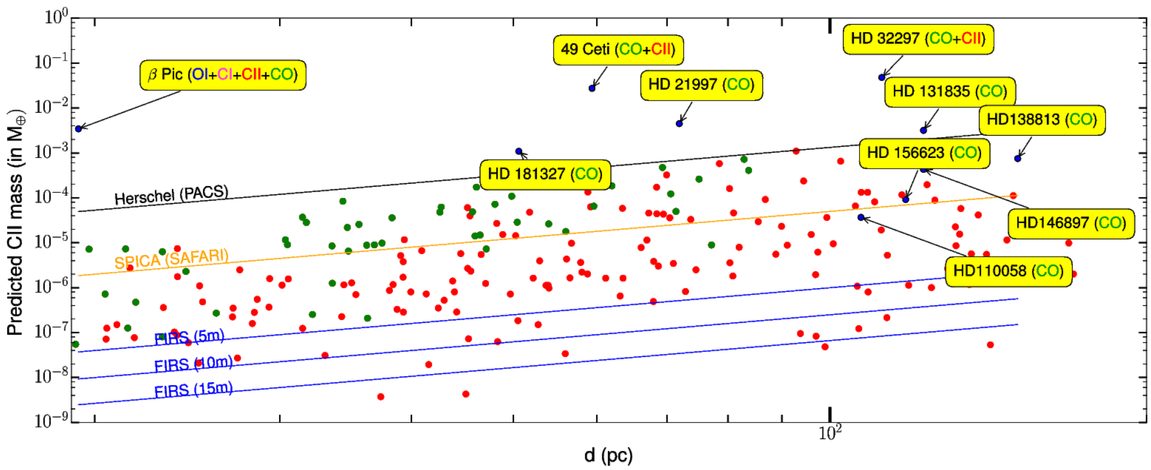
The aim of the proposed spectroscopic measurements is to detect the CII (157μm) and OI (63μm and 145μm) fine structure lines with a much higher sensitivity and resolution than was possible with Herschel. Based on the model presented in KRA16, which predicts the mass in atomic species produced by comet collisions in a debris disc, we can detect all atomic gas discs in systems with CO detections and many more whose CO has not been detected yet (see Figure). This amounts to at least 130 targets from our sample comprised of a selection of nearby stars with discs detected. A 5σ detection in one hour for these 130 targets requires a sensitivity of at least 5×10^{-21} W/m^2, which is reachable with FIRS with a 5m aperture. Not many stars lay below the FIRS 5m detection limit, not because these discs do not exist but because their fractional luminosity is too low to be detected with current facilities. The FIR surveyor will definitely populate this lower envelope in the future. Approximately 70 of these gas discs can be spatially resolved with a resolution of 1", and this is needed to infer the radial profile of these discs, which tells us about the physics of the evolution of gas (Kral & Latter 2016). To infer structures (and thus planets) within a few au, we desire $R=10^6$ (0.3km/s, which is close to the highest resolution attained with Herschel/HIFI) but we could still tackle science goals 1) and 2) with $R=10^4$ (30km/s or 1au spectral resolution). We checked that even for $R=10^4$ the line-to-continuum ratio is much greater than 1 for all our targets and the CII fine structure lines will be easily detected.

(iii) Uniqueness to 10μm to few mm wavelength facility:

Far-IR is needed to detect the CII and OI fine structure lines. SPICA, if launched, could detect the targeted lines for the brightest targets, but will only be able to resolve a few. Only the FIRS can address the three science goals proposed above.

(iv) Longevity/Durability:

The actual and future CO detections by ALMA must be accompanied by FIRS spectral data in order to be able to infer the composition of exo-comets.



3. Figure: CII mass predicted from Kral et al. (2016) versus distance to Earth for systems having CO gas detected (yellow boxes) and a debris disc sample (red+green points, 150 stars). The systems that can be resolved with a 1" resolution within the sample are the green points. The different lines show the detection limits for Herschel (in black), SPICA (in orange) and FIRS (in blue) for three different aperture sizes (5m, 10m and 15m).

4. Table:

Parameter	Unit	Required value	Desired Value	Comments
Wavelength/band	μm	60-160	60-160	Or only CII and OI lines
Number of targets		100	300	
Survey area	deg.^{2}	n/a		
Angular resolution	arcsec	1	0.3	The higher the better to observe structures in gas discs and infer planets
Spectral resolution	Δλ/λ	10^4	10^6	R=10^4 resolve the lines but R=10^6 would enable to track structures in gas discs
Spectral line sensitivity (1 σ)	W m^{-2}	5x10^{-21}	10^{-21}	
Signal-to-noise		5	10	Per beam

5. Key references:

Kral et al. 2016, in press (arXiv:1606.01247)

Kral & Latter 2016, in press (arXiv:1606.04509)

* Gas modelling in debris discs is a rather new field, so no review article is available.