DUST ENTRAINMENT IN EXTERNALLY PHOTO-EVAPORATED DISC MODELS

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THE ROYAL SOCIETY

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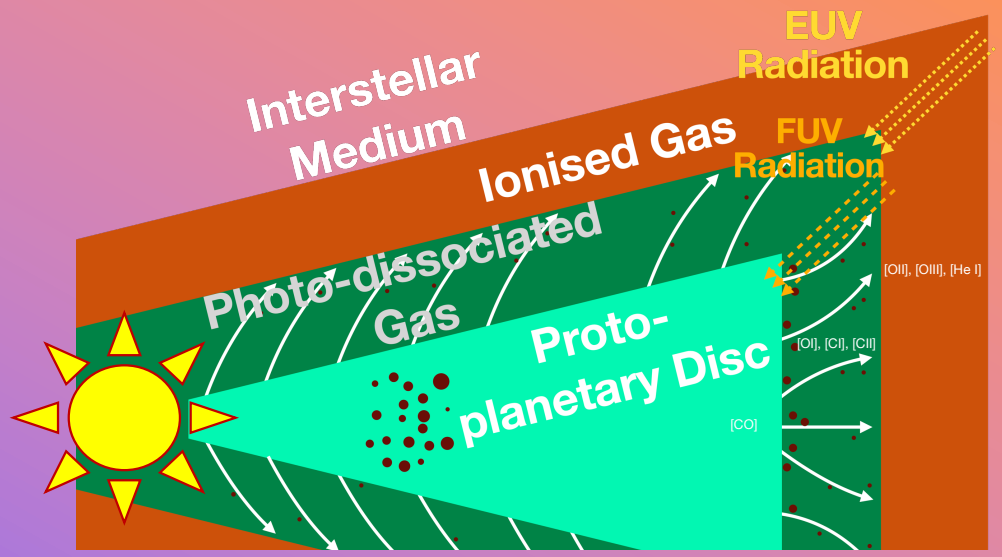
Talk Outline

- Motivation
- External photoevaporation
- 2D dust simulations in disc winds
- Synthetic images of dust in disc winds
- Far-infrared SEDs of dust in disc winds
- Brief discussion on water lines in external winds

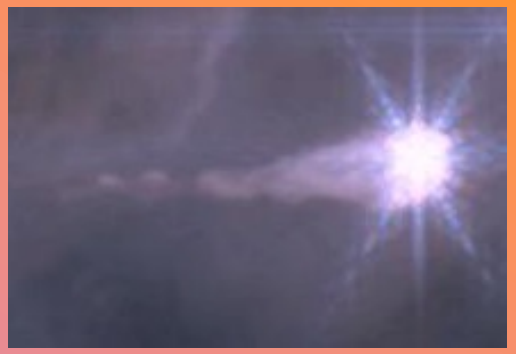
Externally Photoevaporated Discs

- Radiation heats and evaporates gas in disc
- Some dust is dragged out with the gas
- This removes mass from the disc and shrinks its size
- Entrained dust blocks radiation, shielding disc from further radiation
- Over 1~10 Myrs all the mass in a disc will be evaporated



Motivation

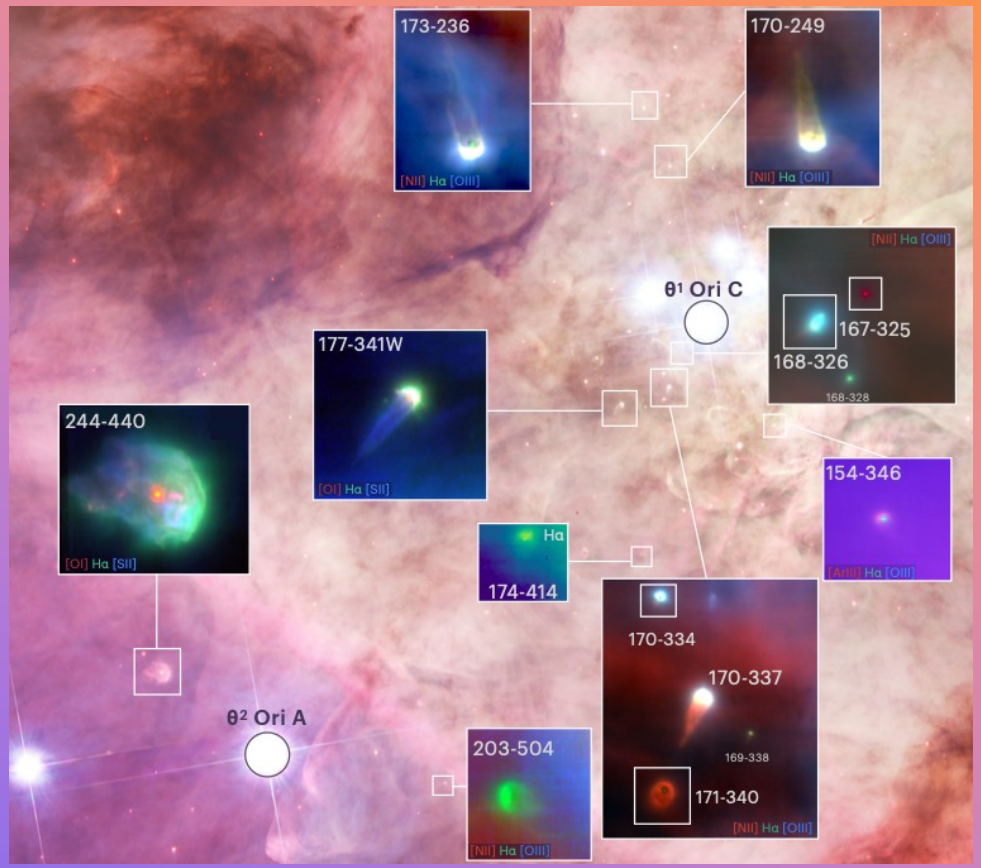
- Dust in internal winds has been well studied [e.g. Hutchison 2016], but dust in external winds not as much
- External winds are important in star forming regions with nearby large stars [e.g. Haworth 2016a]
- Lifetime and distribution of dust determine whether and where planets can form [Qiao et al. 2023]
- Analytic predictions from literature on what the maximum entrained grain size should be in 1D [Facchini et al. 2016]
- Observations of grain sizes at specific distances in the disc/wind [e.g. Miotello & Robberto 2012]



[NASA/ESA]

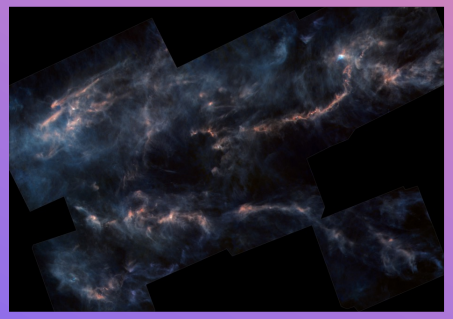
External Photoevaporation

- Stars form in clusters and affect their neighbours
- Radiation from neighbouring stars -> external photoevaporation
- Biggest contributions from massive O and B type stars
  - Sum contributions from smaller A stars [Anania et al. 2025]
- ‘teardrop’ shaped ionisation front
- “Proplyd”: irradiated proto-planetary disc



[Aru et al. 2024]

Where is external photo-evaporation?



Taurus/Lupus

Orion Nebular Cluster

The arches cluster/
Westerlund 1/Tarantula

10^2 10^3 10^4 10^5

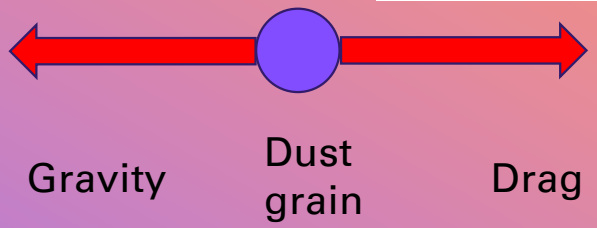
Number of stars

Dust Dynamics in irradiated winds

- Dust is acted upon by gravity and aerodynamic drag
- Small dust ($\lesssim$1μm) is 'coupled' and will follow the gas, larger dust is 'decoupled' and won't
- For external winds, there is negligible back reaction from dust on the gas (low density gas and dust)

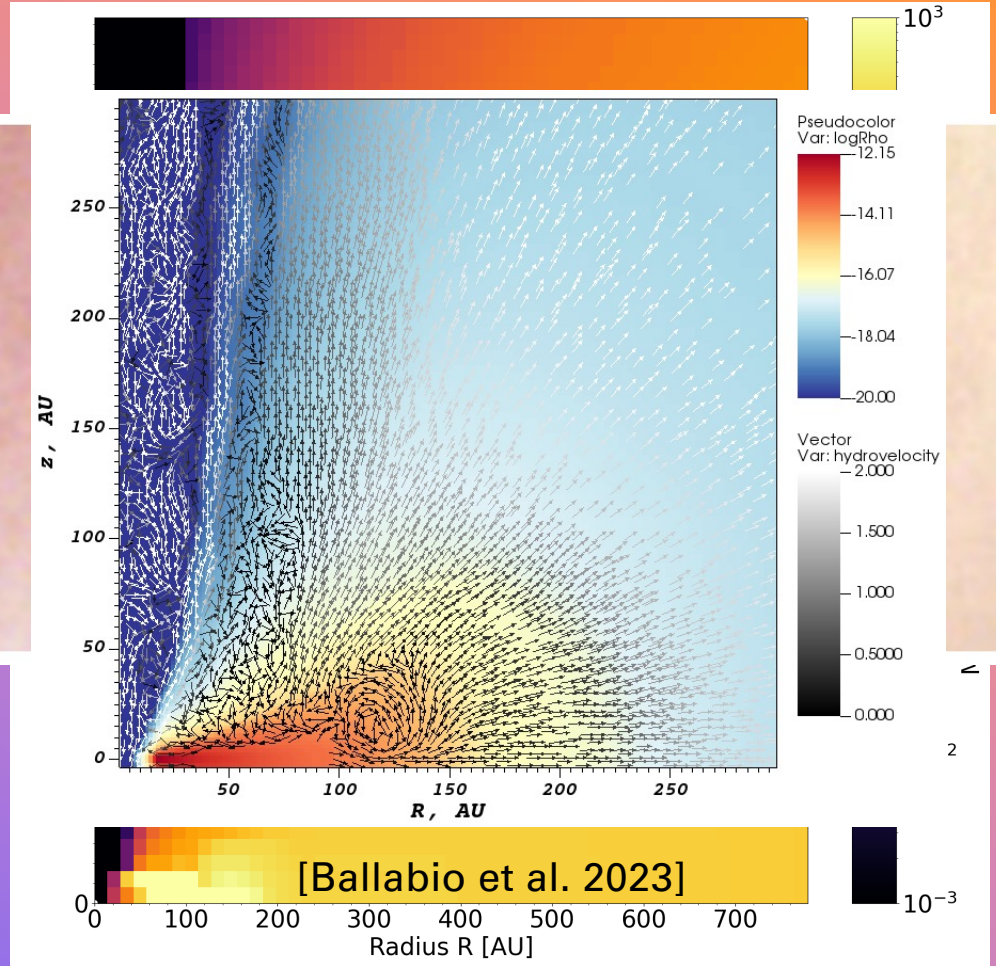
$$a_g = -\frac{GMR}{(R^2+z^2)^{3/2}} + \frac{h^2}{R^3}$$

$$\vec{a}_D = \frac{\rho}{s\rho_s}\bar{v}\Delta\vec{v}$$



2D Dust Map

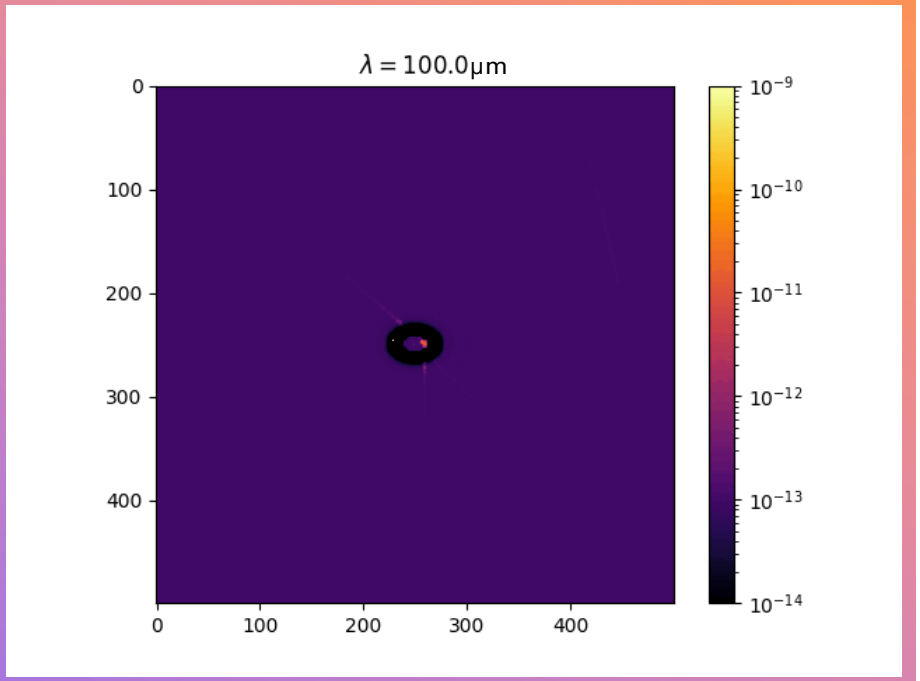
- Placed tracer dust of varying size in a steady-state radiation hydronamics disc model
- Upper bound on entrained dust sizes
- Dust size decreases with polar angle: largest dust at midplane, smallest dust above disc surface
- Radial variation occurs only at the midplane



[Paine et al., in review]

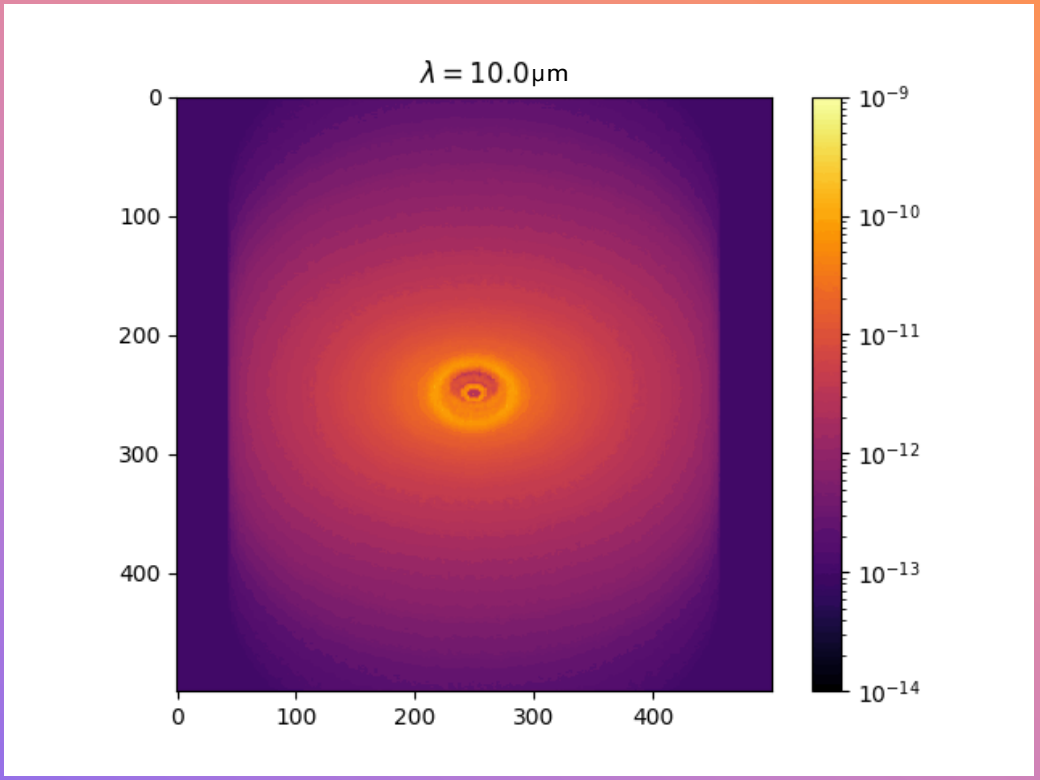
Synthetic Observations Methods

- RADMC3D to compute dust temperatures, spectra and images via Monte Carlo methods [Dullemond et al.]
- OpTool to compute dust scattering matrices [Dominik et al., 2021]
- Still early work-in-progre



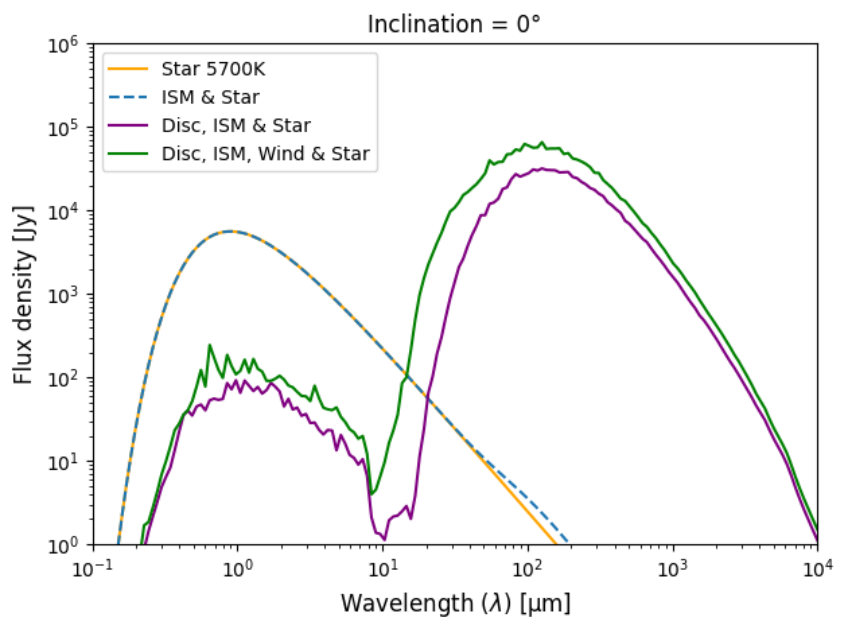
Synthetic Dust Observations

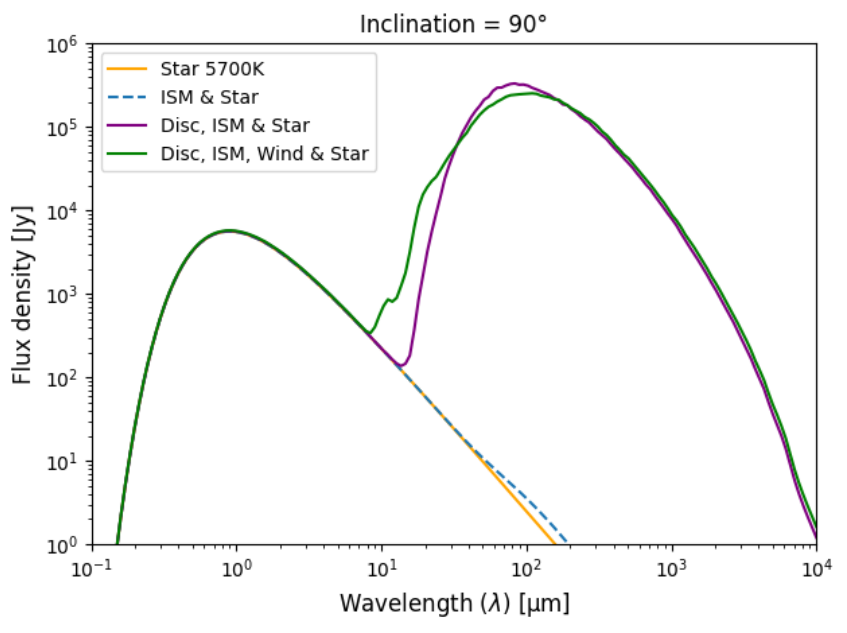
- Modeled dust entrainment for a 50AU disc in a 5000G0 radiation environment
- ~10μm dust in the wind midplane
- Sub-micron ~ few micron dust in wind above surface



Disc SEDs

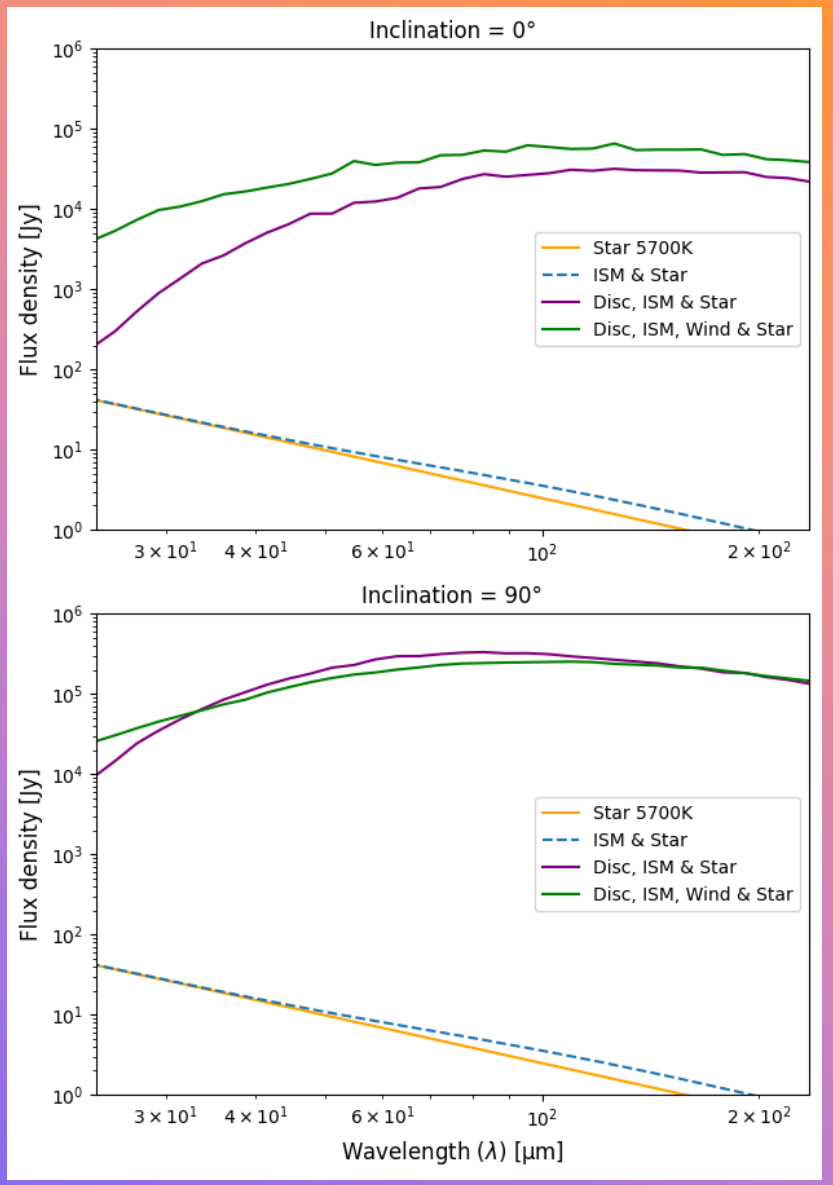
- Flux density normalised at 1pc
- Small overall contribution from the wind
- Excess emissions due to wind in the IR and FIR





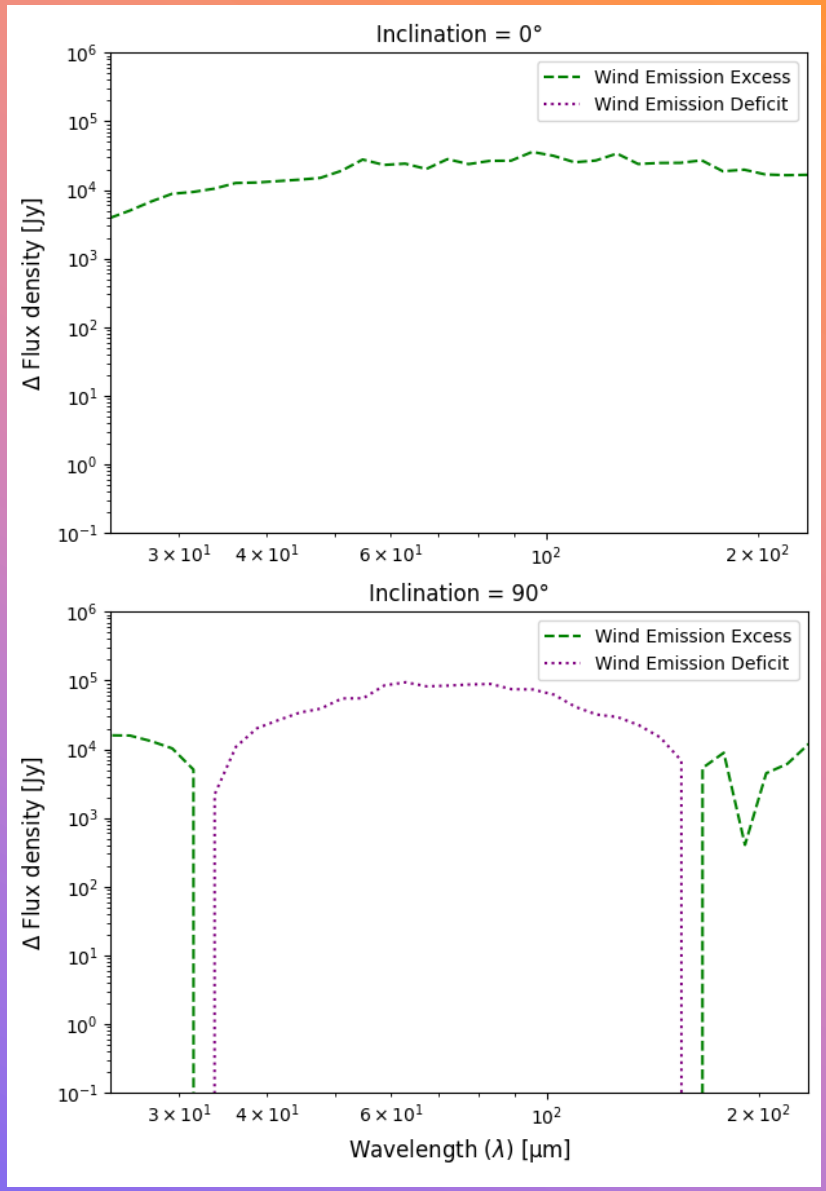
Disc SEDs in FIR

- Potential excess emission in FIR due to wind in the 20~50μm range (FIRESS Band 1&2) for all inclinations
- For low inclinations: excess emissions across entire FIR than would be expected from just disc
- For high inclinations: similar deficit emissions across entire FIR



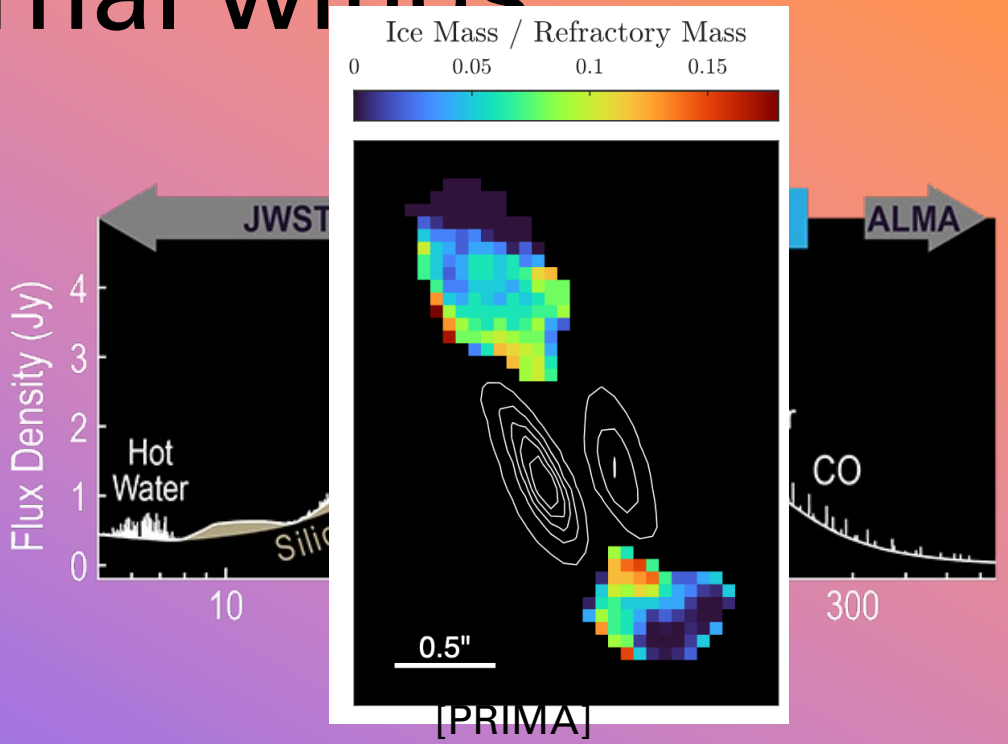
Disc SEDs in FIR

- Emission excess/deficits when an externally photoevaporated wind is present
  - Subtracted star, ISM and disc spectra from overall SED
- Potential regions of interest:
  - Taurus (D=136pc)
  - Orion Nebula Cluster (D=412pc)



Brief discussion of icy dust and water lines in external winds

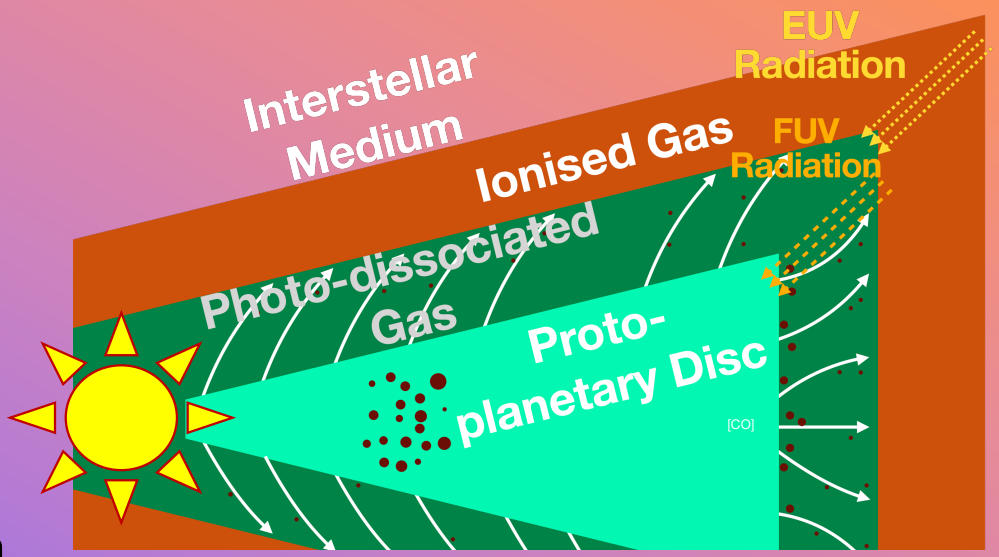
- Icy grains are expected to be dragged out by the wind
- These will be photo-desorbed in the wind by the UV
  - As opposed to thermally desorbed grains in the inner disc
- This could create a water halo with different emission line ratios
- This could be used as a diagnostic for the impact of external photoevaporation



[Ballering et al. 2025]

Conclusions

- External photoevaporation is an important effect on the evolution of protoplanetary discs in clusters
- 2D dust size decreases above midplane, and gradually along midplane
  - But, UV dust shielding is uniform
- Preliminary results indicate potentially interesting FIR signatures from dust in external winds



QUESTIONS?

THANKS FOR LISTENING!