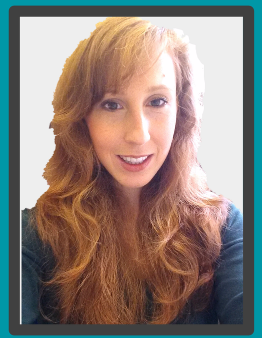

Optical and infrared radiation pressure on dust and gas around AGN as drivers of dusty winds

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Motivation

- The **"dusty torus"** is a cornerstone of the standard unification picture of AGN. It successfully in explains the type 1/type 2 dichotomy via angle-dependent obscuration (Antonucci & Miller 1985).
- Infrared interferometry is able to **spatially resolve the dust emission from the torus at parsec-scale distances** from the central supermassive black hole (e.g. Jaffe et al. 2004, Burtscher et al. 2013).
- Surprisingly, the bulk of the infrared emission is oriented **perpendicular to the disk in polar direction** and cospatial with outflowing gas (e.g. Hönig et al. 2012, 2013, Tristram et al. 2014).
- It has been proposed that this elongated polar structure is produced by **radiatively accelerated dusty winds** (e.g. Hönig et al 2012, Wada 2012, Dorodnitsyn & Kallman 2012, Gallagher et al. 2015, Hönig & Kishimoto 2017).

The model

- To test this hypothesis we build an **semi-analytical model** that considers
  - ➔ radiation pressure from the AGN (UV/optical), and
  - ➔ radiation pressure from the dust emission (infrared)

  as the main drivers of radiatively accelerated dusty outflows on parsec scales.
- We assume a disk+wind model (Hönig & Kishimoto 2017) consisting of a **geometrically thin, dense dusty gas disk** and consider **radiation onto a dusty gas cloud** above the disk (see Figure 1).
- We then consider the **radiative force terms** acting on this cloud, accounting for both the AGN radiation and the radiation from the dusty disk.

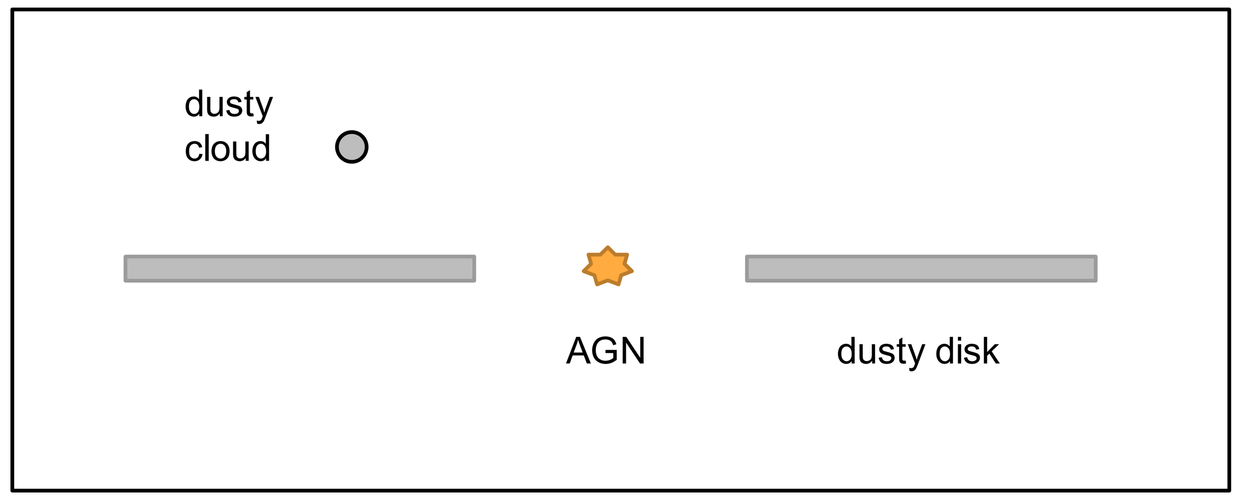

Fig 1. Schematic setup of the model. The main two components are the AGN and the dusty disk, both generating a radiation pressure on a dusty cloud.

Method

- The analytic model uses the **photoionization code CLOUDY** developed by Gary J. Ferland to compute the **gas and dust opacities Q_ν of the cloud** as a function of frequency.
- For our purposes, we model the disk as a sequence of infinitesimal small rings of length dr radiating as a blackbody. **The dusty disk will exert a net total force on the cloud** at a distance d from the AGN

$$F_{ir} = \frac{\int Q_\nu \pi B_\nu(T) \pi r \; dr \; d\nu}{4\pi c d^2}$$

- The **temperature profile of the disk** is assumed to vary radially according to

$$T(r) = T_{sub} \left(\frac{r}{r_{sub}}\right)^{\beta}$$

  where the exponent $\beta = -0.358$ for astronomical dust. All physical parameters are scaled with respect to their value at the sublimation radius.
- After deriving the components of the force in cylindrical coordinates, we compute the disk radiation field by **summing up the vector contributions** of all infinitesimal rings of the disk, extended up to 10 sublimation radius. The resulting spatial distribution is shown in Figure 2.

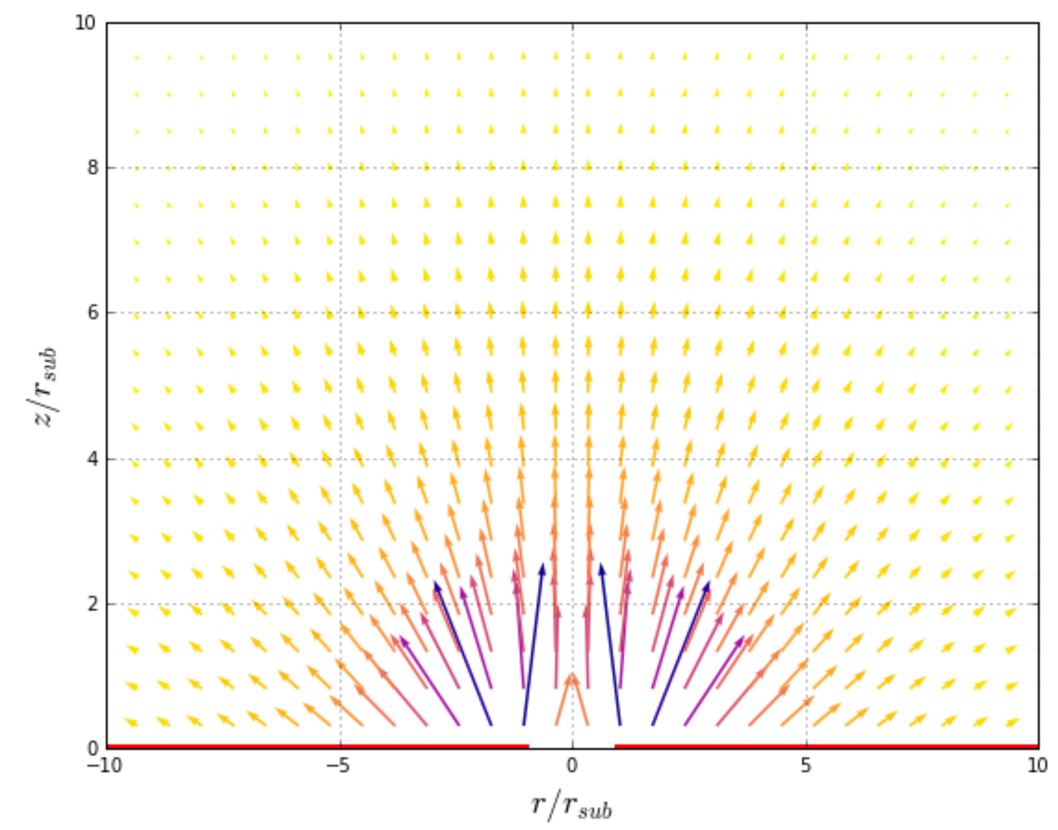

Fig 2. Spatial distribution of the disk radiation field in the plane perpendicular to the disk. The abscissa is the distance *r* from the central object and the ordinate is the height *z* from the disk surface, both are scaled by the sublimation radius.

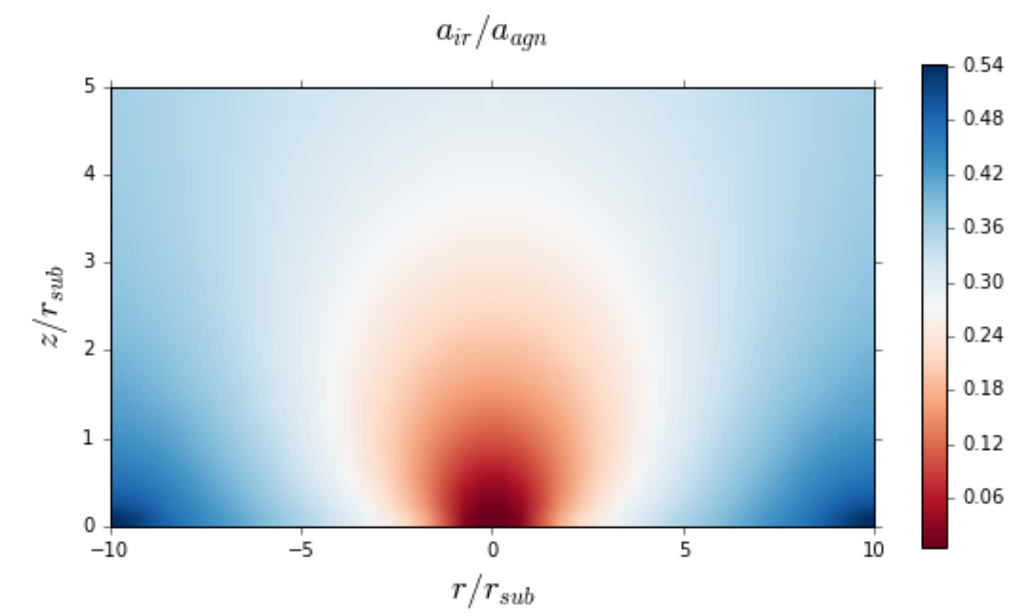

Fig 3. Ratio of the radiative acceleration of the infrared radiation pressure over the radiation pressure from the AGN.

Results

- The infrared radiation pressure that we typically find near the sublimation radius is of the order of 10^{-6} erg/cm^3 and **predominantly pointing in vertical (polar) direction**.
- Considering typical orbital time scales at the sublimation radius in the Seyfert galaxies of order 100 years, we estimate an **acceleration of dusty clouds by infrared radiation pressure of 100-200 km/s per orbit**. These results are consistent with outflowing maser clouds observed in NGC 1068 for a model matched in luminosity and Eddington ratio (Greenhill et al. 2003).
- In the unobscured case, radiation pressure from the AGN dominates over the infrared by a factor of ~3 (see Figure 3). The **infrared radiation pressure becomes dominant over the AGN with mild obscuration corresponding to column densities $N_H \approx 10^{21} cm^{-2}$**, thus giving the outflow a more polar tilt.

Conclusions

- Infrared radiation pressure from a dusty disk provides a **net vertical component** to the acceleration of dusty gas clouds around AGN.
- In unobscured environment the radial term from the AGN is about 3 times stronger than the infrared radiation pressure. However, **mild obscuration towards the AGN makes infrared radiation pressure the dominant component**.
- These findings suggest that **infrared radiation pressure is important for the dynamics of dusty environment** and may provide the uplift to explain the observed dusty wind features.