Dynamical Picture of BLR in 3D FRADO Model

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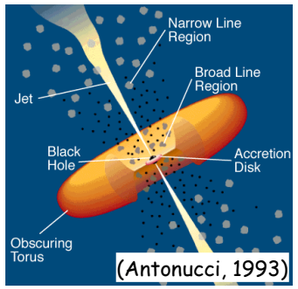
(1) Introduction

Key elements of an Active Galactic Nuclei (AGN) in the standard view:

- Black Hole (BH)
- Accretion disk (AD)
- Broad Line Region (BLR)
- Dusty/molecular torus
- Jet, ...



Broadening in the spectra of AGNs, so-called BLR, can be due to a complex dynamics and distribution of material above AD. Failed Radiatively Accelerated Dusty Outflow (FRADO) model (Czerny & Hryniewicz, 2011), based on radiation pressure of AD acting on dust at the surface layers of AD, addresses this dynamics.

(4) Conclusion

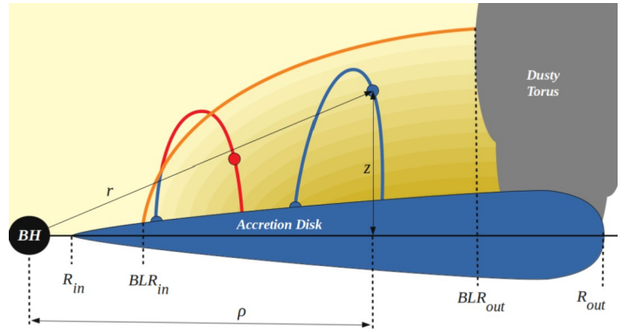
We showed the radiation acting dust is strong enough to form a wind, so BLR can be a dynamical (mostly failed) outflow. The dynamics strongly depends on Eddington ratio. Large ratios show a complex velocity field and large vertical velocities (single-peak emission expected), while for lower ratios vertical velocities are small and most of emission originates close to AD surface (double-peak line profiles expected). In the next step, we will calculate the shape of emission line profiles in full detail.

For more details, click on Naddaf et al. 2021

(2) This Work

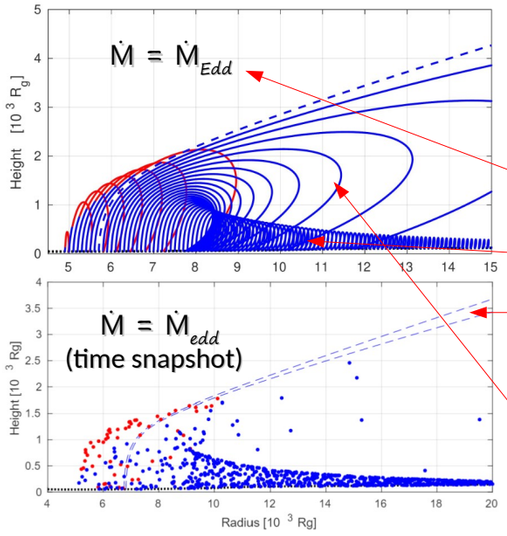
We developed the 3D (2.5D) version of FRADO model including:

- Realistic prescription of AD radiation pressure (radiative force)
- Advanced dust opacities (MRN dust model consisting of graphite & silicate grains)
- Dust sublimation process (Sublimation temperature: 1500 K)
- Shielding effect (to avoid too early dust sublimation by the hot inner disk)



Then we solved the equation of motion of dusty clumps under radiation force of AD and gravity of the central BH (This is a non-hydrodynamical single-cloud approach). As shown in the sketch, a dusty clump (in blue) is lifted up from AD surface due to radiation pressure; once it enters the sublimation region (above the orange curved line) it loses the dust content, the radiative force is switched off, and the dustless clump (in red) follows then only a ballistic motion. Overall, the cloud dynamics thus determines the 3D geometry of the BLR as can be seen in the results.

(3) Results



- Low Eddington ratio sources show almost a simple up/down motion with small vertical velocities, and BLR clouds remain close to disk surface resembling the static puffed-up disk model of Baskin & Laor (2018).

- In case of high Eddington ratio, the pattern of motion is complex including: an outer tail that again resembles static disk model, a stream of escaping clouds similar to empirical picture of AGNs (Elvis, 2000), and inner elongated elliptical orbits that provide a complex velocity field. Using a flat random number generator, a time snapshot of material distribution is shown here representing the BLR shape.