

Non-thermal features from broad-line region clouds

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Motivation

Does the **dynamics of the broad-line region** imprint **non-thermal features** in the **spectra** of active galactic nuclei?

Non-thermal model

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Astronomy
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Radiation from the impact of broad-line region clouds onto AGN accretion disks

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Broad-line region model

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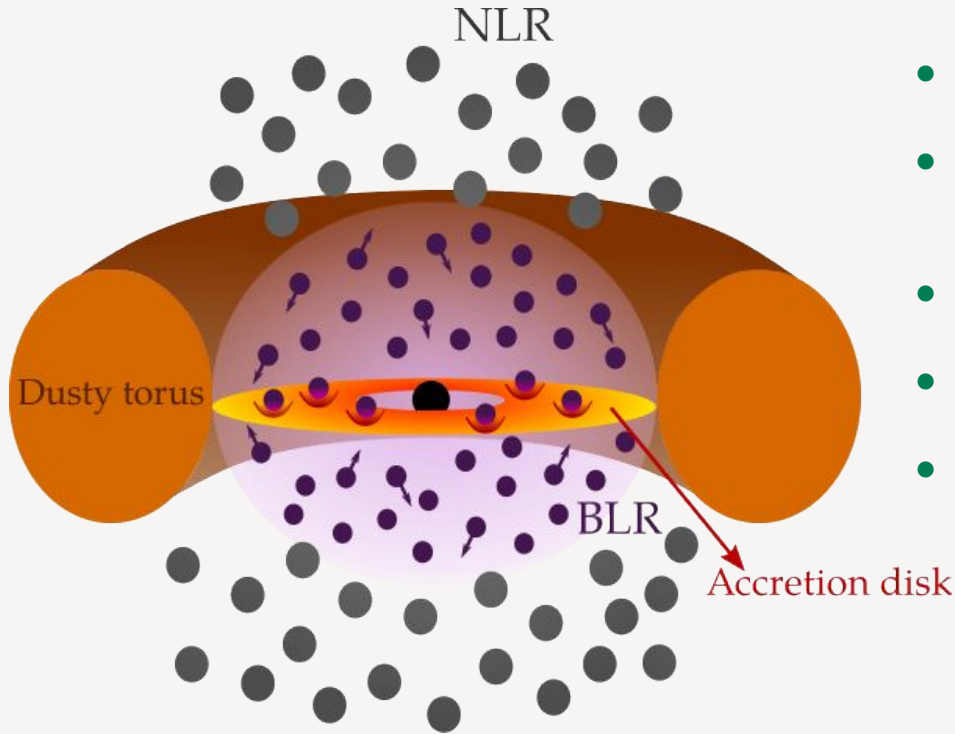


The Picture of BLR in 2.5D FRADO: Dynamics and Geometry

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Broad-line region



Müller, PhD Thesis, 2020

- Region **close to the central black hole** (< 1 pc)
- Keplerian orbits with **velocities** $10^3 - 10^4$ km s $^{-1}$
- Typical **cloud radius** ~ 1 AU
- **Total number** of clouds $\sim 10^8$ or more
- The clouds reprocess the disk emission and **emit photons with ~ 10 eV**

Non-thermal model

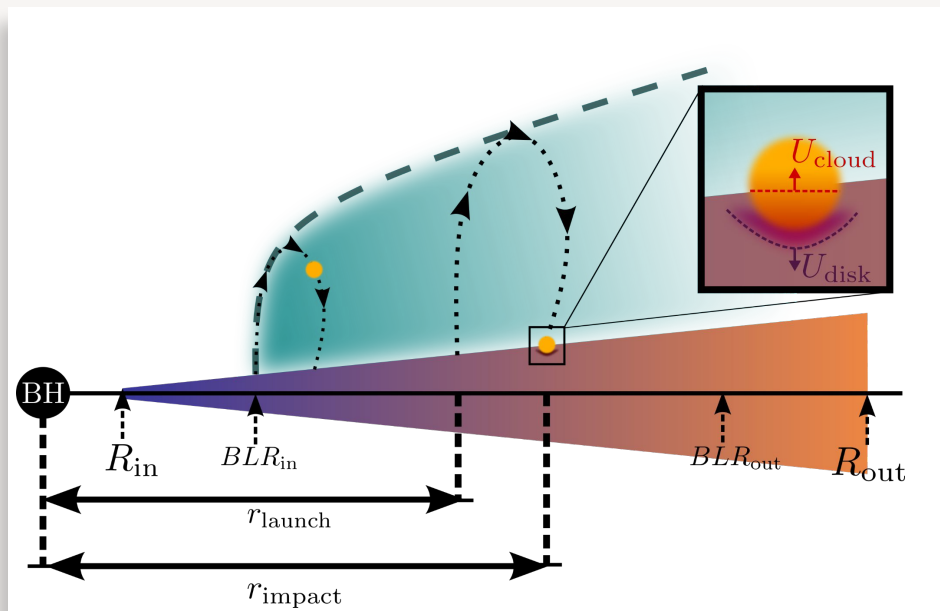
- **Clouds** are moving with **supersonic** velocities and **co-existing** with the **accretion disk**
- The **collisions** produce **shock waves** (Müller & Romero, A&A, 2020)
- **Diffusive shock acceleration** in strong, adiabatic, and super-Alfvénic shocks as observed in supernova remnants (Krymskii 1977; Bell 1978; Blandford & Ostriker 1978)
- Significant **non-thermal radiation** can be produced in the **X-ray** and **gamma-ray bands**, assuming **spherical broad-line region** and **clouds homogeneously distributed**.
Gamma-ray spectrum of NGC 1068 can be modeled (Müller & Romero, A&A, 2020)

But...

- Observational evidence for **flattened** broad-line regions (Gravity Collaboration et al. 2018)
- The origin of the **clouds** and the **accretion disk** should be related

FRADO model

- Failed Radiatively Accelerated Dusty Outflow (Czerny & Hryniewicz 2011; Czerny et al. 2015, 2016, 2017; Naddaf et al. 2020, 2021).
- Clouds motion led by the radiation pressure of the accretion disk on the dust.

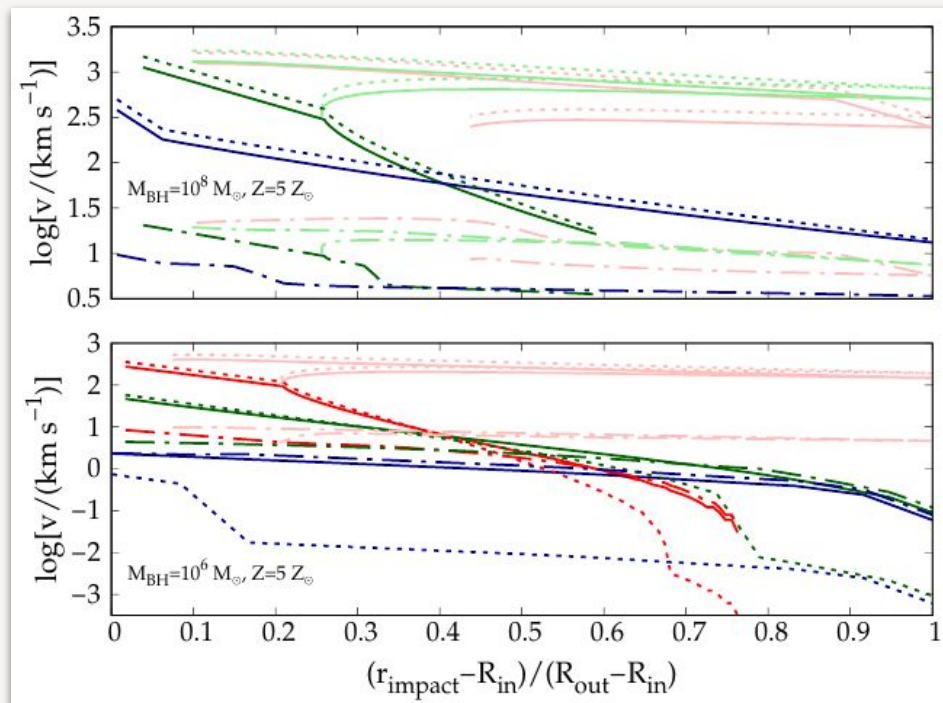


Müller et al. submitted

- Temperature below the dust sublimation but radiation pressure enough to expel matter from the disk
- Once the cloud elevates above the disk, the hotter radiation sublimates the dust
- The cloud follows then a ballistic motion

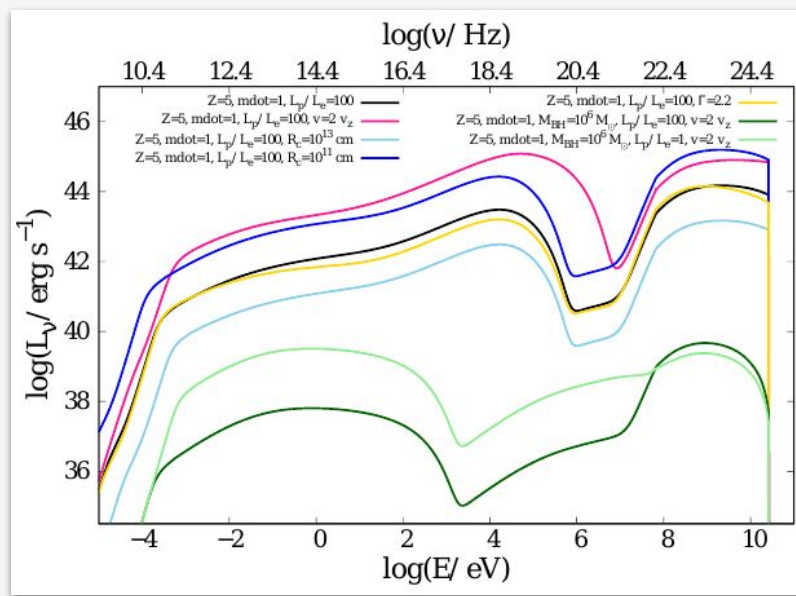
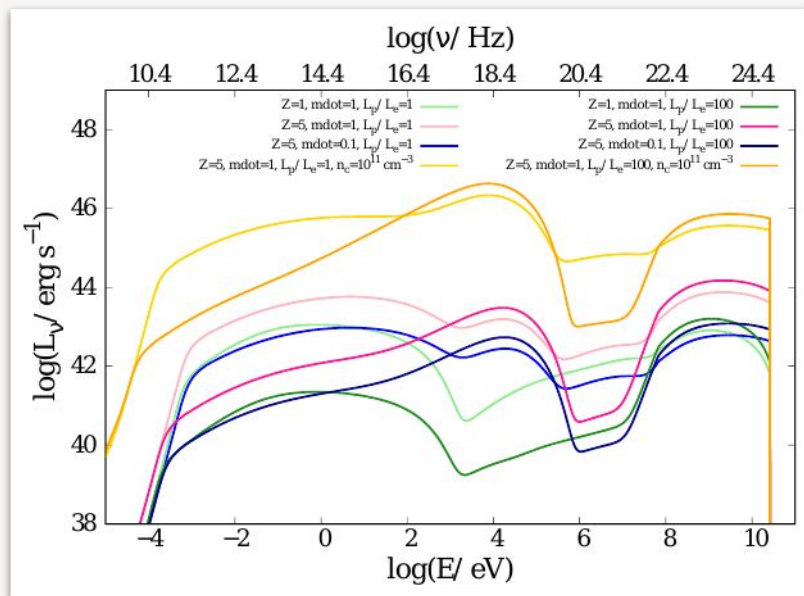
Results about the dynamics

- Only **high accreting systems** have clouds with velocities large enough to produce strong shocks
- The **metallicity** plays an important role. The velocity of the clouds increases with the metallicity. Only high metallicity systems produce strong shocks.



Müller et al. submitted

Spectral energy distributions



Müller et al. submitted

- The **innermost clouds** are the main contributors to the non-thermal emission
- The **velocities limit** the maximum energy of the particles and define the shape of the SED at MeV energies
- If the effective cloud velocity for the shock production is approx. twice the vertical velocity component, **spectra similar to gamma-ray narrow line Seyfert 1 galaxies**

Summary

- **Collisions of BLR clouds** with the accretion disk could lead to the **production of** relativistic particles and **non-thermal emission**
- Important in **high-accreting systems** ⇒ contribution to the **gamma-radiation** of non-jetted systems
- **Gamma-emission in Seyfert** galaxies
- Significant non-thermal **hard X-ray emission** ⇒ complements the corona
- **Maximum energies of the particles linked to the impact velocities** predicted by the BLR model ⇒ the electromagnetic radiation of non-thermal origin can be used **to test BLR models**

THANK YOU!