Non-thermal radiation from super-Eddington winds in AGNs

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Introduction

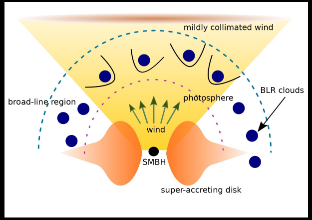
Black holes accreting matter above the Eddington rate launch powerful winds from the inner accretion disk. In AGNs, this wind interacts with clouds of the broad-line region and can generate adiabatic shock waves that accelerate particles by the type 1 Fermi mechanism[1]. We investigate the adiabaticity of these shocks, the acceleration of particles, and the non-thermal radiation associated with these sources.

Model

The clouds move around the black hole following Keplerian orbits. The size of the clouds is calculated from the total volume they occupy, and the filling factor in the BLR. The terminal velocity of the disk wind is set as the escape velocity at the critical radius[2]. We consider that the typical interaction occurs at R_{BLR}. We calculate the different dynamical timescales of the clouds following Araudo et al. (2010) [3] and Müller et al. (2020)[4]. For the calculation of non-thermal radiation we adopt a lepto-hadronic model.

Value
$M_{BH} = 10^7 M_\odot$
$\dot{M} = 100 \dot{M}_{cr}$
$\Omega_w = \pi$ sr
$v_w = 0.05\,c$
$R_{BLR} = 1.5 \times 10^{16}$ cm
$f_{BLR} = 10^{-6}$
$R_c = 3.2 \times 10^{11}$ cm
$n_c = 10^{10}$ cm^{-3}
$v_c = 3.5 \times 10^8$ cm s^{-1}
$Z = 0.3\,R_c$

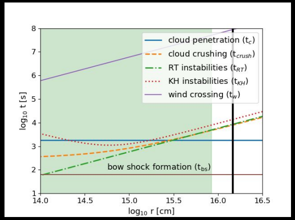
Model parameters

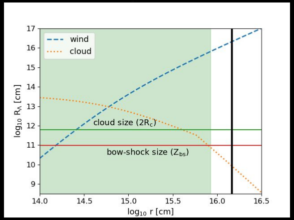


Sketch of BLR clouds propagating in the wind of a super-Eddington black hole (not to scale)

Shocks in wind-cloud interactions

In the interaction region, clouds can enter the wind before being destroyed by instabilities or crushing. The time it takes for a bowshock to form is very short in comparison with all other relevant timescales, so we assume the bowshocks are in a steady state most of the time. We determine that the shocks in the clouds are radiative, whereas the shocks in the wind are adiabatic.

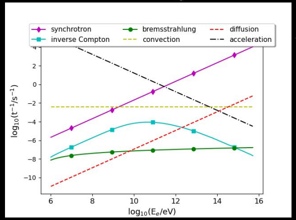


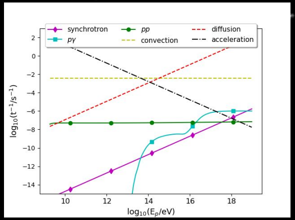


Left: Timescales for hydrodynamic instabilities and crushing in the BLR clouds. *Right*: Lengthscales of the shocks in the wind and in the clouds. The thick black vertical line indicates the position of the broad-line region. The shaded region corresponds to distances opaque to radiation.

Relativistic particles

We take into account radiative losses by synchrotron radiation, inverse Compton scattering of electrons with photons from the wind photosphere, relativistic Bremsstrahlung, and gamma-ray production caused by the decay of neutral pions generated in inelastic *pp* collisions. We alsoc calculate the escape time by advection and diffusion of the particles.



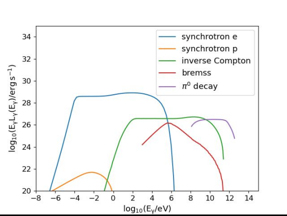


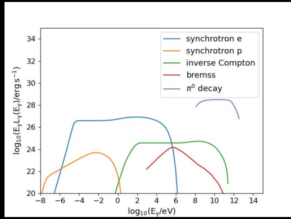
Value
$L_{k,bs} = 2.3 \times 10^{31}$ erg s^{-1}
$Z = 9.5 \times 10^{10}$ cm
$L_{rel} = 2.3 \times 10^{30}$ erg s^{-1}
$E^{e,p}_{min} = m_{e,p}c^2$
$E^{e}_{max} = 0.3$ TeV
$E^{p}_{max} = 37.8$ TeV
$a = 0.01,\ 100$
$\alpha_B = 10^{-1}$
$B_{bs} = 28.8$ G
$n_{bs} = 10^8$ cm^{-3}
$p = 2$
$D = D_{Bohm}$

Acceleration, cooling and escape timescales for relativistic particles. We assume diffusion in the Bohm regime. *Left*: electrons. *Medium*: protons. *Right*: adopted and calculated parameters.

Non-thermal radiation

We show the SEDs for the interaction of a single cloud with the wind for the different relative powers between relativistic protons and electrons. For 10^8 BLR clouds with have non-thermal bolometric luminosities of ~ 10^{35-36} erg s^{-1}. In all cases synchrotron radiation dominates the spectrum from radio up to hard X-rays, inverse Compton scattering is the most important radiative process at high energies up to GeV, and gamma rays by neutral pion decays produce the emission in the TeV range.





Non-thermal SEDs for different choices of hadron-to-lepton power ratio. *Left*: Lp/Le = 0.01. *Right*: Lp/Le = 100. We consider a single wind-cloud interaction.

Conclusions and future work

We have developed a model for the non-thermal emission in the central regions of AGNs at sub-parsec scales. Our model offers an explanation for the central compact radio emission observed in some radio-quiet galaxies, which have no jets[5]. As a next step of our research , we will study neutrino production in hadronic scenarios applied to super-Eddington tidal disruption events.

References

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3. Araudo et al., *Astronomy & Astrophysics*, 522, A97 (2010)
4. Müller et al., *Monthly Notices of the Royal Astronomical Society*, 496, 2474 (2020)
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