Jet-disk coupling model for low luminosity AGNs

Feng Yuan

Harvard-Smithsonian Center for Astrophysics, Cambridge, MA, USA

Sera Markoff

Center for Space Research, MIT, Cambridge, MA, USA

Heino Falcke, Peter L. Biermann

Max-Planck Institut für Radioastronomie, Bonn, Germany

Abstract

Low-luminosity AGNs (LLAGNs) are a very important class of sources since they occupy a significant fraction of local galaxies. Their spectra differ significantly from the canonical luminous AGNs, most notably by the absence of the "big blue bump" Up until now there is no model which can explain the spectra of LLAGNs. Taking NGC 4258 as an example, we propose a coupled jet-disk model for some LLAGNs.

Key words:
accretion, accretion disks—galaxies: active – galaxies: nuclei

1 Introduction: observational Results of LLAGNs

LLAGNs are very common in the local universe, e.g., 43% of all northern galaxies brighter than $B_T = 12.5$ mag are active in the form of emission-line nuclei classified as Seyferts or LINERs (Ho 2002).

On the other hand, observations indicate that LLAGNs seem to be quite different with luminous AGNs. Main observational results for LLAGNs are (e.g., Ho 1999; Terashima et al. 2002; Ho 2002),

Email address: `fyuan@cfa.harvard.edu` (Feng Yuan).

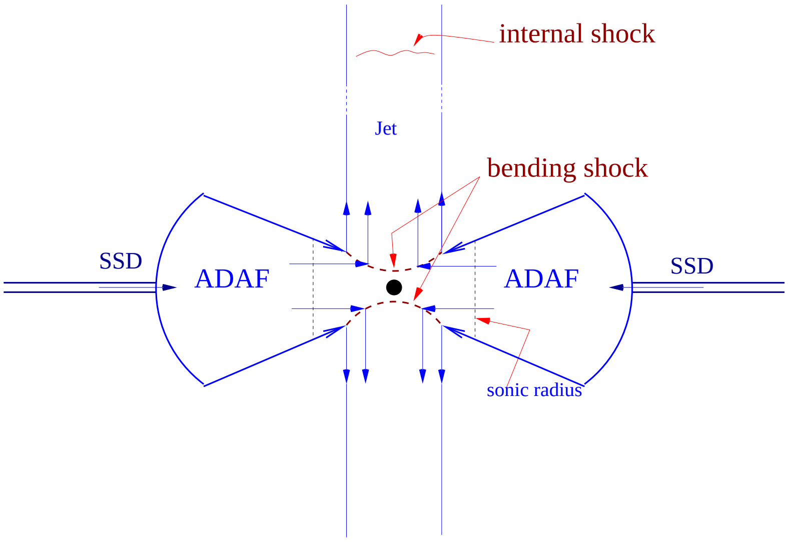

Fig. 1. The schematic diagram of jet-disk coupling model for NGC4258. At a certain radius r_j, some fraction of accretion flow is transferred into the jet. Assuming r_j is smaller than the sonic radius of ADAF, a standing shock should occur at r_j due to the bending. This "bending shock" will accelerate the post-shock electrons into a power law energy distribution.

- The bolometric luminosity is low relative to their Eddington luminosity;
- The Fe Kα line is extremely weak or absent;
- Spectral energy distribution
  - optical/UV slope is quite steep, with the averaged power-law index being 1.5 ($f_\nu \propto \nu^{-1.5}$), while in luminous AGNs it is 0.5-1.0;
  - there is no big blue bump
  - X-ray spectral index is very variable among LLAGNs, $\alpha = 0.6 - 1.2$
  - the spectrum peaks at mid-infrared
  - the radio spectrum is flat or inverted

2 Can ADAFs Interpret the Spectra of LLAGNs?

The above observational results suggest the existence of radiatively inefficient accretion flows, such as an ADAFs, in LLAGNs. However, the existence of ADAF does not mean the spectra of LLAGNs can be fitted by ADAF since the emission from other components such as jets may dominate over ADAFs as in Blazars.

Several work has been done to fit the spectra of LLAGNs using ADAF or ADAF-SSD (SSD: Shakura & Sunayev disk) models, including Sgr A* (Narayan et al. 1998), NGC 4258 (Gammie, Narayan & Blandford 1999), M 81 and

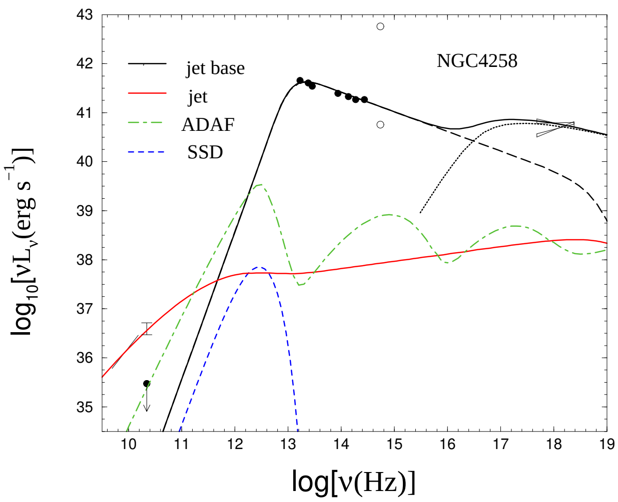

Fig. 2. The jet-disk model for NGC 4258. The infrared and X-ray spectra are produced by the synchrotron and SSC emission of the power-law electrons accelerated in the bending shock at the jet base, the radio spectrum by the electrons accelerated by internal shocks in the outer part of the jet.

NGC 4579 (Quataert et al. 1999). While the model can successfully explain the most important features of low-luminosity and absence of big blue bump of those sources, the detailed spectral fitting is not very satisfactory in some aspects. For all the sources, the model underpredicts the detected the low-frequency radio flux by more than one order of magnitude. For NGC 4258, the infrared spectrum is produced by the outer thin disk, therefore a very hard infrared spectrum with the classical form of $f_\nu \propto \nu^{1/3}$ is predicted, which is in serious conflict with the observational result of $f_\nu \propto \nu^{-1.4}$ (Chary et al. 2000). For M 81 and NGC 4579, the predicted optical/UV spectrum is too steep compared to observation (Quataert et al. 1999).

3 Jet-disk coupling model for LLAGNs

NGC 4258 is an ideal object to investigate the physics of LLAGNs due to the precise determination of the mass of the central black hole, its distance to us, and its abundant spectral data ranging from radio to X-ray especially at infrared waveband. Its spectrum seems to be very typical for LLAGNs. We propose a jet-disk coupling model for NGC 4258 (Yuan et al. 2002).

Fig. 1 shows the schematic diagram of our jet-disk coupling model. After obtaining the global solution of ADAF, we can calculate the post-shock equilibrium temperature of the post-shock plasma from shock jump conditions,

$$T_2^{eq} \simeq \frac{(\Gamma+1)}{2(\Gamma+1)^2}\frac{m_p}{k}v_1^2(r_0) = \frac{1}{5}\frac{m_p}{k}v_1^2(r_0).$$

The electrons will be accelerated into a power-law form after the shock. A fraction of shock energy, ϵ_e and ϵ_B, will be distributed into the electrons and magnetic field,

$$\epsilon_e = \frac{p-1}{p-2}\frac{\gamma_{\rm min} n_e m_e c^2}{e}, \qquad \epsilon_B = \frac{B^2}{8\pi e}.$$

Here $\gamma_{\rm min}$ is the minimum Lolentz factor of power-law electrons. The electrons number density is determined by the mass loss rate in jet, $\dot{M}_{\rm jet} = 4\pi r_0^2 n_e m_p v_2$. Then we can calculate the emission from the jet and underlying disk, with $\dot{M}_{\rm disk} = 10\dot{M}_{\rm jet}$. Fig. 2 shows the fitting results. We see that the emission from the disk is much weaker than from the jet. This is because most of the gravitational energy is stored in the ADAF rather than radiated away; and at the bending shock, a large fraction of the stored energy, $\epsilon_e \approx 0.2 - 0.3$, will be distributed in the electrons and radiated away immediately. Other observational features of LLAGNs, and also Sgr A*, can be interpreted by this model as well (Yuan et al. 2002; Yuan, Markoff, & Falcke 2001).

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