Coupling accretion flow and jets in black hole X-ray binaries: insights from the multi-wavelength emission of Cygnus X-1

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Abstract

We investigate the radio to MeV spectral energy distribution (SED) of the prototypical stellar-mass black hole, Cygnus X-1. We model the SED by combining the jet Internal Shocks Emission Model (ISHEM) with the JED-SAD model (Jet Emitting Disk – Standard Accretion Disk) which links accretion and ejection. During the fitting procedure the jet kinetic power and average Lorentz factor of the ISHEM jet are tied to those predicted by the JED-SAD model. This coupling provides a self-consistent fit across the electromagnetic spectrum, confirming the physical connection between the disk and jet. The ISHEM jet reproduces the flat radio to IR spectrum as driven by internal shocks, while the JED-SAD hybrid accretion flow model accounts for the X-ray components of the spectrum. Yet, the so called 'MeV excess' component -a long-standing puzzle- remains unaccounted for. Polarimetric observations with INTEGRAL have suggested a synchrotron origin in a highly ordered magnetic field for the MeV component. Although jet synchrotron emission may appear as a natural explanation, we find that the jet model struggles to account for the observed MeV flux levels. As an alternative, we suggest a magnetospheric emission scenario, where leptons accelerated near the horizon of the black hole emit synchrotron radiation in an extreme magnetic field (_˜10ˆ8 G). This component, integrated with ISHEM and JED-SAD, successfully reproduces the SED of Cygnus X-1, offering a plausible explanation for the MeV emission.

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