THERMAL AND NONTHERMAL EMISSION FROM THE EXTRAGALACTIC MICROQUASAR S26

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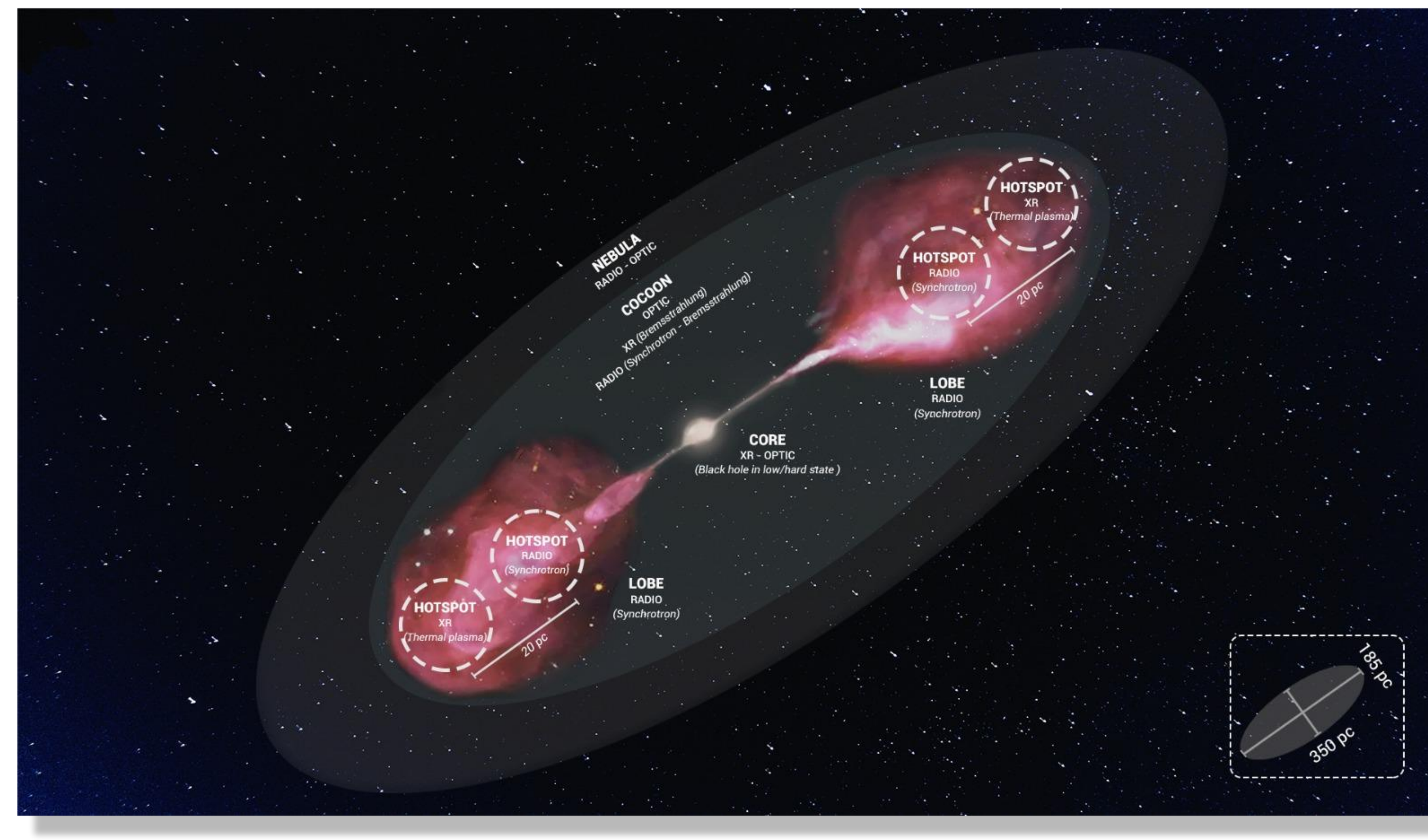
INTRODUCTION

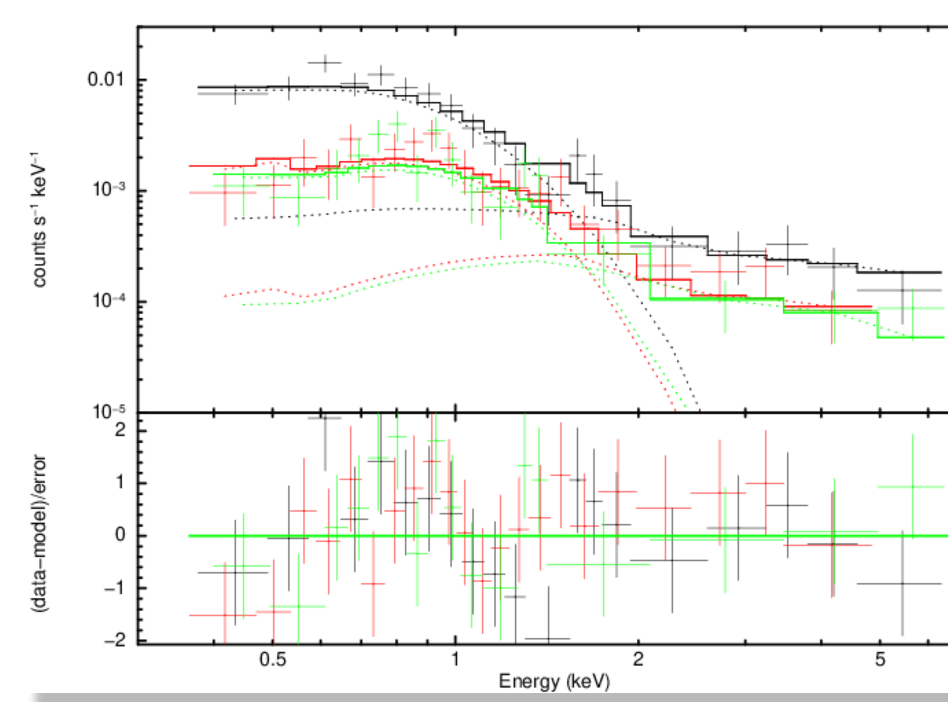
S26 is a unique microquasar that exhibits the most powerful jets observed in accreting binaries, with a kinetic luminosity of $L_{jet} \approx 5\times10^{40}$ erg s^{-1} (Pakull et al. 2010). According to the jet-disk symbiosis model, this implies that the accretion luminosity to the stellar black hole should be highly super-Eddington, on the order of $L_{acc} \approx L_{jet}$. However, the observed X-ray flux measured by the *Chandra* (Soria et al. 2010) and *XMM-Newton* telescopes is $L_{acc} \approx 10^{36}$ erg s^{-1}, orders of magnitude smaller than the jet power. We present here a study of the thermal and nonthermal radiation of S26 and we explore the relationship between the jet and the disk in this source. We analyze X-ray observations of the system obtained with *XMM-Newton* and develop a jet model to explain the emission. We study particle acceleration and radiative processes that occur in adiabatic shocks generated at the base of the jet and in the lobes. We also investigate the feasibility of microquasars as potential PeVatron sources, exploring their capacity to accelerate protons to energies of about 1 PeV or higher. A schematic of the system is shown in the figure on the right.



Artist's impression of a jetted source (for illustration only). The black hole and star are in the core. The extended lobes are at the ends of the two opposite jets, where shocks are formed at the hotspots. There, the backward shock accelerates particles to relativistic energies, producing synchrotron radio emission, and the forward radiative shock produces the thermal X-ray emission. Credits: NASA, ESA, S. Baum & C. O'Dea (RIT), R. Perley & W. Cotton (NRAO/AUI/NSF), and the Hubble Heritage Team (STScI/AURA).

OBSERVATION AND X-RAY SPECTRUM

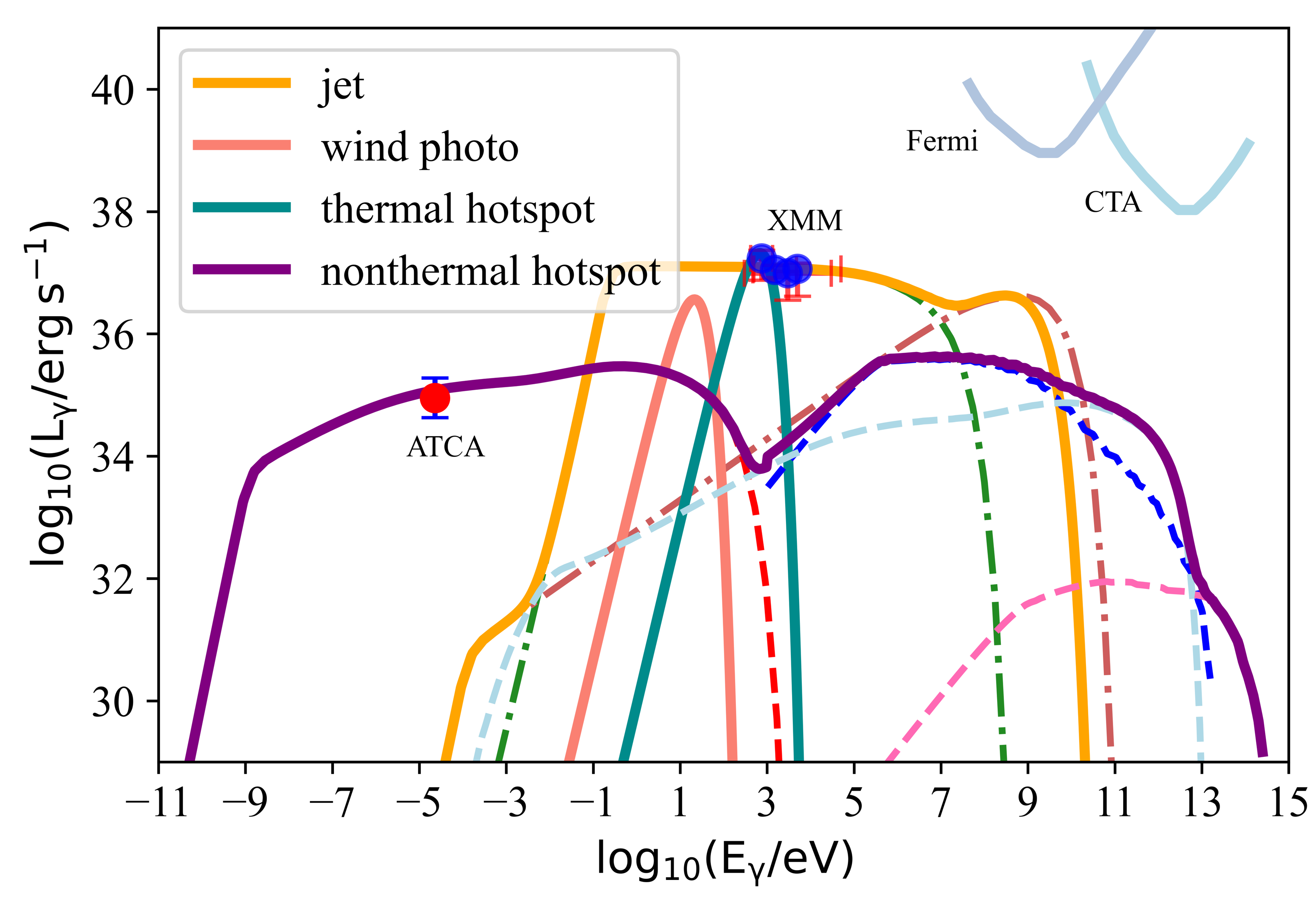
The *XMM-Newton* obsID 0804670301 was performed on May 20, 2017, and was aimed at source P13 of NGC 7793. After removing background contamination, we obtained about 56 ks of PN data and 54 ks each from the two MOS cameras. We reduced the observation using High Energy Astrophysics Software (HEASoft) and Science Analysis Software (SAS). We obtained the spectrum of S26 in the energy range 0.5 - 6 keV and fitted the data with a power law plus black body model; the black body component provides a good fit to the data for energies below 2 keV (thermal emission), while the power law describes the nonthermal emission at higher energies. Using this model, we calculated the flux in the 0.5 - 6 keV energy band and determined the luminosity in this range, assuming a source distance of 3.9 Mpc.



MODEL	PARAMETER	VALUE
TBABS	nH	1.2×10^{20} (fixed)
BBODY	kT	0.19 (-0.01, +0.01)
BBODY	norm	2.35×10^{-7} (-2.5×10^{-8}, $+2.5\times10^{-8}$)
POWERLAW	PhoIndex	0.66 (-0.4, +0.36)
POWERLAW	norm	1.16×10^{-6} (4.86×10^{-7}, 6.57×10^{-7})
Chi-Squared statistic	50.84 (53 d.o.f)	

RESULTS AND DISCUSSION

We have calculated the thermal and nonthermal emission from the core and lobes of S26 and plotted our results in the right panel. We assume a black hole mass of 10 solar masses and an accretion rate of 500 Eddington rates. The photosphere of the wind ejected from the accretion disk surrounds the disk, whose emission is completely reprocessed in the wind (its peak is at UV energies). The jet expands freely with a small opening angle until its lateral expansion pressure is equal to that of the surrounding environment. This equilibrium occurs at a certain height above the black hole, well above the wind photosphere. The pressure equilibrium induces a recollimation of the jet, leading to the formation of shocks (eg., Sotomayor Checa & Romero 2019). These shocks accelerate the particles to relativistic energies. The electrons are mainly cooled by the synchrotron process resulting from their interaction with the magnetic field. On the other hand, new large-scale shocks are formed at the end of the jet: a forward, radiative shock (thermal hotspot) and a backward, adiabatic shock (nonthermal hotspot). In the latter shock, particles are accelerated to relativistic energies. Electrons are cooled by synchrotron, inverse Compton and Bremsstrahlung; protons reach energies close to 1 PeV and are cooled by pp interactions downstream in the lobe. The electron-synchrotron cooling is responsible for the radio emission of the lobes. We have also calculated the thermal emission from the X-ray hotspots. The figure shows that our model fits the *XMM-Newton* and ATCA data well.



Luminosity of S26 as a function of energy (logarithmic scale). Total nonthermal emission from the jet base is plotted as a solid orange line, whereas the individual contributions are plotted as dotted-dashed lines (green for the electron synchrotron and brown for the proton synchrotron). The total nonthermal emission from the lobes is plotted as a solid violet line, while the individual contributions are plotted as dashed lines (red for electron-synchrotron, light blue for inverse Compton, blue for bremsstrahlung, and pink for proton-proton).

CONCLUSION

We propose that the four-order-of-magnitude difference between the jet and disk luminosities in S26 is caused by the complete absorption of the disk radiation by the wind ejected from the super-Eddington disk. The observed X-rays are the result of shocks formed near the base of the jet but above the wind photosphere by the electron-synchrotron mechanism, plus a thermal contribution from the hotspots. The observed radio emission can be explained as electron-synchrotron radiation from the lobes. We conclude that S26 is a super-Eddington microquasar whose disk emission is absorbed by a dense wind.

REFERENCES: **1.** Pakull M.W., Soria R., Motch C., 2010, Nature, 466, 209; **2.** Soria R., et al., 2010, MNRAS, 409, 541; **3.** Sotomayor Checa P., Romero G.E., 2019, A&A, 629, A76