Detection of Jets from ULX Holmberg II X-1

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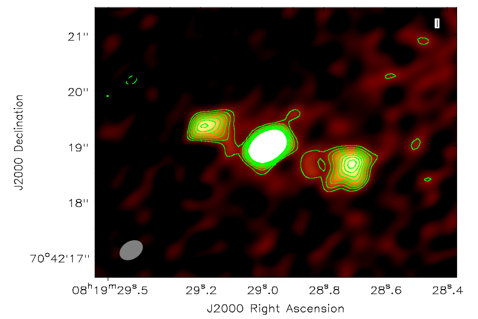
We report the discovery of a triple radio structure hidden inside the radio bubble of ULX Holmberg II X-1. The morphology shows a collimated jet structure that is consistent with optically thin synchrotron ejecta. The central component, with α=-0.8±0.2, is much brighter than the outer ones indicating a renewed radio activity. We estimate a minimum time-averaged jet power of ~2 x 10^{39} erg/s associated to a time-averaged isotropic X-ray luminosity of 4 x 10^{39} erg/s. These suggest that Holmberg II X-1 is a more massive black hole with M>25 $M_\odot$.

Introduction

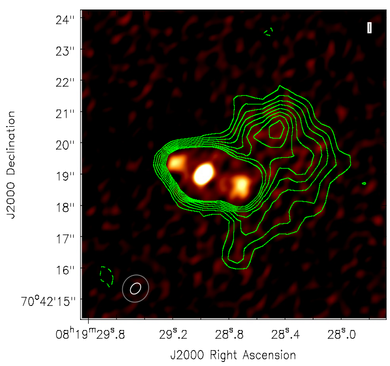
- Holmberg II X-1 lies at a distance of 3.39 Mpc [1] in a dwarf irregular galaxy, that are often thought to mimic the early cosmological conditions due to their low metallicity and where *massive* stellar-mass black holes (M_{BH} = 20 − 100 $M_\odot$) are predicted to form [2]
- From the predicted scale invariance of the accretion variability timescale and of the jets [3, 4, 5] follows that massive stellar mass black holes may show radio activity on a longer timescale.
- These powerful black holes may fundamentally regulate their environment in the form of both, jets and X-ray ionisation [6, 7, 8, 9], perhaps due to a higher mass and longer active cycles that may be relevant at the epoch of reionisation in the early Universe [10, 11].

JVLA detection of Holmberg II X-1



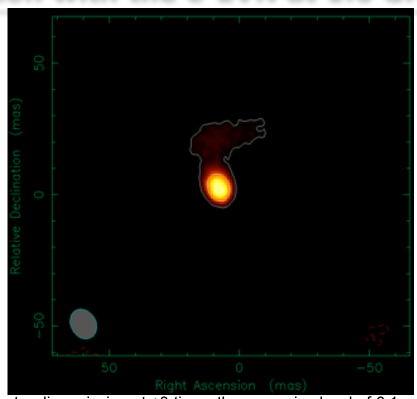
The C-band JVLA A-array image of Holmberg II X-1. Lowest contours represent radio emission at ±3 times the rms noise level of 2.5 μJy beam−1. Contours are increased by 1 σ and the peak brightness is 151 μJy beam−1

Large- and fine-scale structure



The low-resolution C-band JVLA A-array image. The figure shows the large-scale, radio bubble associated to Holmberg II X-1 together with the high-resolution, fine-scale structure of Fig. 1. Lowest contours represent radio emission at ±3 times the rms noise level of 3 μJy beam^{-1}. Contours are increased by 1 σ and the peak brightness is 192 μJy beam^{-1}

VLBI detection with the e-EVN at 1.6 GHz



Lowest contours represent radio emission at ±3 times the rms noise level of 6.1 μJy beam^{-1}. Contours are increased by 3σ and the peak is 58 μJy/b. Beam size is 12 mas x 10 mas.

Results & Discussion

The SW and NE components appear to be extended with an average intrinsic diameter of 545 ± 60 mas (corresponding to 9.0 pc) and 405 ± 60 mas (corresponding to 6.7 pc). The central component is unresolved and we place an upper limit on its size of < 3.9 pc. We estimate the projected distance between the outer components to be 38.5 pc

The steep spectral index and the relative brightness of the central component argues against a self- absorbed compact jet that is typically associated to an inefficient accretion state. Instead, it is consistent with optically thin compact ejecta.

We estimate the jet half opening angle to be ~ 11° and a relativistic Mach number of the outer components of M ≈ 5. The SW and NE component are likely adiabatically expanding, decelerating plasma blobs, similar to hot spots. The minimum total energy stored in the radio bubble is E = 2.6 × 10^{49} erg, assuming no proton acceleration [9]. We find that this energy can be deposited into the environment over t = E/Qj= 390 yr.

The isotropic X-ray luminosity needed to ionize the surrounding He II bubble is at least 4 × 10^{39} erg/s [12], that corresponds to average ionising rate over the past 3000 year. We find a minimum time-averaged jet power of Qj = 2.1 × 10^{39} erg/s based on FRII scaling realtionship [13]. Jet powers might only be as high as 10% of the bolometric luminosity and these estimates suggest a black hole mass of at least 25 $M_\odot$

The VLBI component can be described by a single point source model. We find a brightness temperature of T_b > 1.2 x 10^7 K, consistent with non-thermal emission (Cseh+14, in prep.).

Conclusions

Our results strengthen the view that physical properties of accretion and ejection are connected and scale invariant over a possibly homogeneously populated black hole mass range. Future studies may confirm a distinct formation channel of massive stellar mass black holes, that are possibly caught for a relatively short active time and evolve fast in environments akin to early cosmological conditions.

References

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