The mass of the central black hole in NGC 6388

D. Cseh1, P. Kaaret2, S. Corbel1, E. Körding1, M. Coriat1, A. Tzioumis1, B. Lanzoni4

1 Laboratoire Astrophyisque des Interactions Multi-échelles, CSA/DMSNRS-Universite Paris Diderot, CEA/Saclay, France
2 Department of Physics and Astronomy. University of Iowa, Iowa City, USA
3 Australia Telescope National Facility, CSIRO, Epping, Australia
4 Dipartimento di Astronomia, Università degli Studi di Bologna, Bologna, Italy

Contex

- X-ray emission in globular clusters arises from white dwarfs, neutron stars (NS), and black holes (BHs).
- In addition, the presence of intermediate-mass black hole (IMBH) accreting via Bondi–Hoyle process (accretion of intrachannel material released by stellar mass loss onto a BH) may also be revealed by the presence of an X-ray source located at the centre of the cluster.
- The fundamental plane of accreting black holes says: for a given X-ray luminosity \( L_x \) the SMBHs produce far more radio luminosity \( L_{\text{radio}} \) than stellar BHs.
- We use this fundamental relationship, and report on deep radio observations with the ATCA of NGC 6388.

NGC 6388

- Physical parameters: distance, \( d = 13.2 \pm 1.2 \) kpc; core radius, \( r_c = 7.2 \) arcsec; tidal radius, \( r_t = 454 \) arcsec; total cluster luminosity, \( V_c = 6.72 \); mass, \( M = 2.6 \times 10^4M_\odot \)
- The surface density profile has a cusp with a slope \( a = -0.2 \) in the inner one arcsecond of the globular cluster.
- This slope is shallower than expected for a post core collapse cluster and is consistent with an IMBH (Baumgardt et al. 2005).
- The surface density profile provided an estimated mass of \( 5700 \pm 500 M_\odot \) (Lanzoni et al. 2007) for the central black hole.

Discussion

- Using the fundamental plane of BHs which is a relationship between X-ray luminosity, radio luminosity and BH mass:
  \[ \log M_{\text{BH}} = 1.55 \log L_x - 0.98 \log L_{\text{radio}} - 9.95 \] (Körding et al. 2006)
- The application of the fundamental plane requires radiatively inefficiently accreting sources (ie. hard state objects). For any reasonable BH mass, source \#12 is consistent with radiatively inefficient accretion. (Assuming 10 \( M_\odot \), the \( L_{\text{x-ray}}/L_{\text{radio}} \) ~10^{-3}). Therefore the usefulness of the fundamental plane is justified.
- We obtain \( M_{\text{BH}} < 735 \) \( M_\odot \) limit on the BH mass. (Cseh et al. 2010)
- Assuming Bondi–Hoyle accretion, we use the X-ray luminosity to estimate the mass of the BH:
  \[ L_{\text{x-ray}} = 8.8 \times 10^{36} \epsilon \eta (M_{\text{BH}}/10^4 M_\odot)^{2/3} \] where \( \epsilon \) is radiative efficiency and \( \eta \) is the efficiency of the Bondi–Hoyle process.
- We obtain \( M_{\text{BH}} = 97 \) \( M_\odot \) if we don’t consider Bondi accretion then a quiescent stellar–mass BH in a binary system (or even a NS binary) does fit all the observational constraints.

Conclusion

- We identify a unique X-ray source coincident with the cluster centre of gravity with properties consistent with those expected for a black hole accreting at a low rate.
- No radio source was detected at the cluster center of gravity.
- Using the fundamental plane and our radio upper limit we find, the putative IMBH in NGC 6388 cannot be more massive than \( 1500 M_\odot \).

References


Chandra X-ray Observation

Naturally weighted ATCA image of NGC 6388 at 8.7 GHz.

ATCA radio Observation

We conducted radio observation with the Australia Telescope Compact Array between 24 and 26 December 2008.
- The crosses mark the positions of the Chandra sources. The red contours correspond to the \( \pm 3 \sigma \) level.
- The rectangle indicates the position of the Chandra image; the circle marks the center of gravity.
- There is no radio source detected with a r.m.s level of 27 \( \mu \)Jy at the cluster center of gravity or at the location of any of the Chandra X-ray sources (Cseh et al. 2010). The 3\( \sigma \) upper limit on the radio luminosity of the putative BH at the center of the cluster is \( L_{\text{radio}} < 8.4 \times 10^{28} \) erg/s at 5 GHz.