The mass of the central black hole in NGC 6388

D. Cseh[1], P. Kaaret[2], S. Corbel[1], E. Körding[1], M. Coriat[1], A. Tzioumis[3], B. Lanzoni[4]

[1] Laboratorie Astrophysique des Interactions Multi-echelles, CEA/DSM-CNRS-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, Universita' degli Studi di Bologna, Bologna, Italy

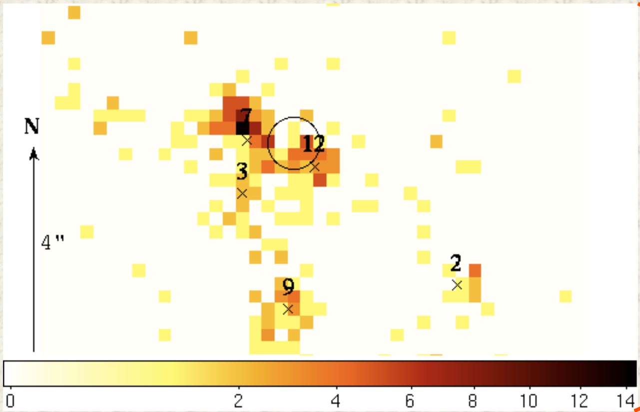
CONTEXT

•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 intracluster 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-ray}) the SMBHs produce far more radio luminosity (L_{Radio}) than stellar BHs.***
•We use this fundamental relationship, and report on ***deep radio observation***s with the ATCA of NGC 6388

NGC 6388

•Physical parameters: distance, d=13.2±1.2 kpc; core radius, r_c=7.2 arcsec; tidal radius, r_t=454 arcsec; total cluster luminosity, V_t=6.72; mass, M=2.6 x 10^6 M⊙
•The surface density profile has a cusp with a slope α = −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 ± 500 M⊙*** (Lanzoni et al. 2007***) for the central black hole.***

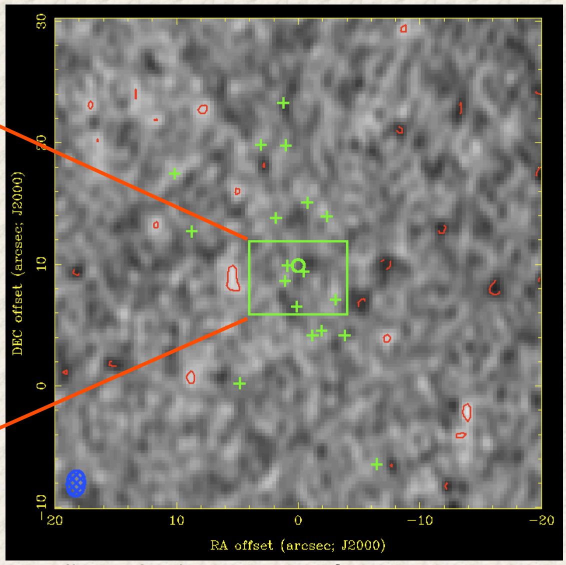
Chandra X-ray Observation



Chandra image of the core of NGC 6388 in the 2-10 keV band

•Chandra conducted observation on 21 April 2005 (PI H. Cohn) and had useful exposure of 45.2 ks. An analysis of this data was recently published by Nucita et al. 2008.
•The cicle indicates the cluster centre of gravity with an error radius of 5 arcsecond.
•By removing the pixel randomization we managed to ***resolved the centre*** of the cluster ***into three individual*** sources: #7,#3,#12, (Cseh et al. 2010).
•Source #12 overlaps the error circle of the cluster centre of gravity, therefore it is consistent with it.
•It has a power-law ***spectrum*** with Γ~1.9 and X-ray luminosoty L_{X-ray}=8.3 x 10^{32} erg/s in the 0.3-8 keV band. This is ***consistent with*** the spectra of quiescent stellar-mass BH (Corbel et al. 2008). It is also consistent with the spectrum expected from ***a quiescent IMBH.***

ATCA radio Observation



Naturally weighted ATCA image of NGC 6388 at 8.7 GHz.

•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 ±3σ level
•The rectangle indicates the position of the Chandra image; the circle marks the cluster center of gravity.
• There is ***no radio source detected*** with a r.m.s level of 27 μJy at the cluster centre of gravity or at the location of any of the Chandra X-ray sources (Cseh et al. 2010).
The 3σ upper limit on the radio luminosity of the putative BH at the center of the cluster is L_{radio}<8.4 x 10^{28} erg/s at 5 GHz.

DISCUSSION

•Using the ***fundamental plane of BHs*** which is a relationship between X-ray luminosity, radio luminosity and BH mass:

$$\log M_{BH}=1.55 \log L_{Radio} - 0.98 \log L_{X-ray} - 9.95$$ (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⊙ , the $L_{X-ray}/L_{Eddington}$ ~10^{-6}). Therefore the use of the fundamental plane is justified.
• We obtain ***M_{BH} < 735 ± 244 M⊙*** 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:

$$L_{X-ray}= 8.8 \times 10^{36}\, \epsilon\, \eta\, (M_{BH} / 10^3 M_\odot)^2 \quad ; \epsilon=[10^{-4}, 0.1] \text{ and } \eta=[10^{-3},0.1]$$

where ϵ is radiative efficiency and η is the efficiency of the Bondi-Hoyle process. We obtain M_{BH} ~ 970 M⊙. If we don't assume Bondi accretion then a quiscent 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⊙.***

REFERENCES

» Baumgardt H. et al. 2005, ApJ, 620, 238
» Corbel S. et al. 2008, MNRAS, 389, 1697
» ***Cseh et al. 2010, MNRAS, in press***
» Jenkins P. et al. 2005, MNRAS, 257, 401
» Körding E. et al. 2006, A&A, 456, 439
» Lanzoni B. et al. 2007, ApJ, 668, 139
» Nucita A. A. et al. 2008, A&A,478, 763