URSA MINOR DWARF GALAXY: A CHANDRA VIEW ON A POSSIBLE CENTRAL IMBH

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Dwarf spheroidals (dSphs), i.e. those objects at the faint end of the luminosity scale of the diffuse dwarf galaxies, are characterized by approximately spheroidal shapes and stellar contents in the range 3×10^3 M$_\odot$ to 2×10^7 M$_\odot$ (Martin et al. 2008) within a few kpc or less. Furthermore, these galaxies seem to be dark matter dominated at all radii (see e.g. Mateo 1997) because of values of the mass-to-light ratio much larger than usual (see Mateo 1998 a, Kleyna et al. 2001, Kleyna et al. 2002 and references therein).

dSphs are also intriguing objects to search for signatures from intermediate mass black holes (hereafter IMBHs) which have mass in the range 10^2-10^5 M$_\odot$, i.e. in the middle between the stellar mass black holes (with a few tens of solar masses) and the super massive ones (10^6-10^9 M$_\odot$) hosted in the center of many active galaxies and galactic nuclei. One of the major reasons why we expect the existence of IMBHs is that the formation of super massive black hole follows a down-to-top scheme, i.e. each of the super massive black hole eventually formed from the growing of a population of seeds with masses in the IMBH range: those objects that did not accrete enough amount of material (or did not participate to the accretion onto the the more massive black hole) remained as a (possibly isolated) IMBH.

By extrapolating the fundamental $M_{BH}-M_{Bulge}$ relation derived from the study of super massive black holes in galactic nuclei (see e.g. Magorrian et al. 1998), one expects to find IMBHs also at the center of dSphs (Maccarone et al. 2005). Further evidences have been also reported by Reines et al. (2011) who noted that the nearby dwarf starburst galaxy Henize2-10 hosts a compact radio source spatially coincident with a hard X-ray source (possibly an $\simeq 10^6$ M$_\odot$ accreting black hole); X-ray and radio observations of the nearby dwarf lenticular galaxy NGC 404 showed the existence of a source possibly associated to an IMBH in the mass range 2.0×10^5-2.9×10^6 M$_\odot$; a detailed X-ray timing analysis on the data coming from the source labeled as M82 X1 pushed these authors towards an IMBH of 100 M$_\odot$ hypothesis; Furthermore, it was found in the halo of the edge-on S0a galaxy ESO 243-49 the more convincing IMBH candidate having mass in the range 500-10^4 M$_\odot$;

In Nucita et al. 2013, we concentrate on the Ursa Minor dSph (hereafter UMi dSph) at J2000 coordinates[1] RA = $15^{\rm h}$ $09^{\rm m}$ $11.34''$ and Dec = $+67^\circ$ $12'$ $51.7''$, with a positional uncertainty of $\simeq 12.2''$ obtained as the sum in quadrature of the errors in RA and Dec, i.e. $2''$ and $12''$, respectively (see SIMBAD web-site[2]). Note that the SIMBAD coordinates are consistent with those quoted in Kleyna et al. (2004). The target is one of the nearest (its distance is 73 ± 11 kpc, as reported by NED) most diffuse and massive ($M \simeq 2.3 \times 10^7$ M$_\odot$) among the Milky Way dwarf satellites (Mateo 1998 a) and shows many distinctive features (see e.g. Lora et al. 2009) as the existence of a double peak in the brightness surface density. N-body numerical simulations demonstrated that the survival of the secondary density peak imposes an upper value on the mass of the possible black hole of $(2-3) \times 10^4$ M$_\odot$ if the compact object originally resided in the galaxy center (Lora et al. 2009). Note that this value is also consistent with that of $(1.0^{+5.0}_{-0.9}) \times 10^4$ M$_\odot$ derived by extrapolating the $M_{BH}-\sigma$ relation for elliptical galaxies. A further step in the IMBH paradigm in UMi dSph was done by Maccarone et al. (2005) who searched the NRAO VLA Sky Survey (NVSS) catalogue and found one source labeled as 150914+671258[3] (with a radio flux density of 7.1 ± 0.4 mJy at 1.4 GHz) within the 3σ error circle ($\simeq 20''$) of the center of the galaxy. Assuming that the UMi dSph gas density is $1/30-1/100$ as high as in globular clusters, Maccarone et al. (2005) estimated the mass

[1]According to the NASA/IPAC extragalactic database (NED, http : //ned.ipac.caltech.edu/), the UMi dSph center coordinates are RA = $15^{\rm h}$ $09^{\rm m}$ $10.20''$ and Dec = $+67^\circ$ $12'$ $52.0''$ with a positional uncertainty of $\simeq 3.5''$ obtained as the sum in quadrature of the errors ($\simeq 2.5''$) associated on both coordinates (see also Falco et al. 1999).
[2]http : //simbad.u − strasbg.fr/simbad/
[3]The NVSS radio source 150914+671258 has coordinates RA = $15^{\rm h}$ $09^{\rm m}$ $14.56''$ and Dec = $+67^\circ$ $12'$ $58.9''$ with positional uncertainty of $\simeq 2.1''$ (as the sum in quadrature of the errors on RA ($\simeq 0.33''$) and Dec ($\simeq 2.1''$).

of the putative IMBH to be a few 10^5 $M_\odot$, thus possibly emitting an X-ray luminosity of a few 10^{34} erg s^{-1} which is well within the capabilities of the *Chandra* and *XMM*-Newton satellites. In the above scenario, we analyzed a set of archive *Chandra* data (Nucita et al. 2013) and identified (with a statistical confidence of 2.5) an X-ray source (with unabsorbed 0.5-7 keV band flux of $\simeq 4.9 \times 10^{-15}$ erg s^{-1} cm^{-2}) at a few arcseconds from the reported galaxy center. The source is spatially coincident (within $\simeq 1.2''$) with the position of the radio source already observed in the NVSS, so that we have likely pinpointed the high energy counterpart of a massive black hole possibly hosted in the UMi dSph. The fundamental plane relation (Merloni et al. 2003 and Koerding et al. 2006) involving the black hole mass, X-ray and radio luminosities allowed us to estimate a mass of the putative compact object to be $(3.2^{+37.4}_{-2.9}) \times 10^6$ $M_\odot$ which seems to accrete at a very tiny fraction of the associated Eddington luminosity. Note that at the lower bound the compact object is still compatible with an IMBH hosted in the Ursa Minor, altough we cannot completely rule out a background agn.

References

Falco, E., et al., 1999, PASP, 111, 438

Kleyna, J.T., Wilkinson, M.I., Evans N. W., Gilmore G., 2001, ApJ, 563, L115

Kleyna, J.T., Wilkinson, M.I., Evans N. W., Gilmore G., & Frayn, C., 2002, MNRAS, 330, 792

Kleyna, J.T., Wilkinson, M. I., Evans, N. W., Gilmore, G., 2004, MNRAS, 354, L66

Koerding, E., Falcke, H., Corbel, S., 2006, A&A, 456, 439

Lora, V., Sanchez-Salcedo, F.J., Raga, A.C., & Esquivel, A., 2009, ApJ, 699, 113

Maccarone, T. J., Fender, R.P., & Tzioumis, A.K., 2005, in *From X-ray binaries to quasars: black holes on all mass scales*, edited by T.J. Maccarone, R.P. Fender, and L.C. Ho., Dordrecht, Springer (astro-ph/0412014v1)

Maccarone, T.J., et al., 2005, Astrophysics and Space Science, 300, 239

Magorrian, J., et al., 1998, AJ, 115, 2285

Martin, N. F, de Jong, J. T. A., Rix, H.-W, 2008, ApJ, 684, 1075

Mateo, M., 1997, in ASP Conf. Ser. Vol. 116, *The Nature of Elliptical Galaxies*, Astron. Soc. Pac., San Francisco, (Eds., Arnaboldi M. et al.)

Mateo, M., 1998 a, ARA&A, 36, 435

Merloni, A., Heinz, S., Di Matteo, T., 2003, MNRAS, 345, 1057

Nucita, A.A., et al., 2013, New Astronomy, accepted for publication

Reines, A.E., Sivakoff, G.R., Johnson, K.E., Brogan, C.L., 2011, Nature, 470, 66