Hunting for intermediate mass black holes in a sample of close dwarf spheroidal galaxies

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We analyse archival XMM-Newton and Chandra observations of some dwarf MW satellites and characterized the X-ray source population by cross-correlating with available databases. We also investigate if intermediate-mass black holes are hosted in the center of these galaxies. In the most interesting case of UMI dwarf, we put an upper limit to the central compact object luminosity of $\simeq 4 \times 10^{33}$ erg s^{-1}. As the target correlates in position also with a radio source, we estimated a black hole mass of $\simeq 2.76^{+32.00}_{-2.54}$ $\times 10^6$ M$_\odot$.

Keywords: Dwarf galaxies; intermediate mass black holes.

1. The dSph sample

When one extrapolates the M_{BH}-M_{Bulge} relation[4] found for super massive black holes in galactic nuclei, it is found that intermediate mass black holes (IMBHs, in the mass range $10^2 - 10^5$ M$_\odot$) may exist in globular clusters and dwarf galaxies (see e.g. Ref. 3). Following this idea, we analysed archival XMM-Newton and Chandra observations of the dwarf Milky Way satellites Leo T, Fornax, Ursa Minor, Draco, Leo I, and Ursa Major II to search for high energy signatures of an accreting IMBH expected to be located in the center of the respective hosting galaxy.[6–8]

A preliminar analysis on Chandra data (Observation ID: 12753) from the Leo T dSph showed no clear detection at the position where the IMBH is expected to be: we can estimate only the 68% upper limit to the (unresolved) source unabsorbed 0.2-7 kev band flux to be $< 5.9 \times 10^{-16} erg s^{-1} cm^{-2}$. This flux corresponds to a luminosity limit of $L_X \simeq 1.2 \times 10^{34} erg s^{-1}$ for a distance to the galaxy of $\simeq 420$ pc. Using the fundamental plane of black hole accretion[5] and the observed X-ray luminosity, it would be possible to get an estimate of the IMBH mass (if any) if a moderately deep radio observation will be performed.

In the case of the Fornax dSph,[2] recently constructed axisymmetric Schwarzschild models in order to estimate the mass profile of the dwarf galaxy and, once these models were tested versus the available kinematic data, it has been possible to put a 1-σ upper limit of $M_{BH} = 3.2 \times 10^4$ M$_\odot$ on the IMBH mass. By using a rather restrictive analysis on XMM-Newton data (ID 0302500101), we detected 107 X-ray sources (most of them being background objects). However, we can not exclude that a few of the detected objects belong to the Fornax dSph, as also clear when comparing the $0.2 - 2.4$ keV and the NIR (J band) fluxes with the J-K colour for the X-ray sources with a counterpart in the 2MASS catalogue. We also confirm a previous analysis[9] where it was claimed that a few sources are associated with the GC 3 and GC 4 globular clusters in Fornax. Finally, we searched for the Fornax IMBH and found that one of the X-ray sources might be associated with one of the possible galaxy centroid.[10]

In this framework, we estimated the IMBH accretion parameter (assuming a spherical accretion scenario) to be $\epsilon\eta \simeq 10^{-5}$.

As far as Ursa Minor is concerned, 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. As shown by N-body numerical simulations, it may host a central IMBH with upper limit of $(2-3) \times 10^4$ $M_\odot$ which is consistent with the estimate obtained by extrapolating the M_{BH}-σ relation. We searched for signatures from the IMBH possibly hosted in its center identifying in a Chandra observation (ID 12754) an X-ray source (with estimated unabsorbed flux in the 0.5-7 keV band of $\simeq 5.0 \times 10^{-15}$ erg s^{-1} cm^{-2}). Altough the confidence of the X-ray detection is as low a 2.5σ, the source is spatially coincident with a radio source (having flux density of $\simeq 7.1$ mJy at 1.4 GHz) already observed in the NRAO VLA Sky Survey.[3] In the black hole scenario, the fundamental plane relation involving the black hole mass, the X-ray and the radio luminosities allows us to estimate a mass of the putative compact object to be $(2.9^{+33.6}_{-2.7}) \times 10^6$ $M_\odot$ (being still compatible -altough at its lower bound- with the IMBH scenario), which seems to radiate at a very tiny fraction of the associated Eddington luminosity. By using webPIMMs and assuming a power law model with spectral index $\Gamma = 1.7$ and absorption column density $N_H = 2.2 \times 10^{20}\,\mathrm{cm}^{-2}$, we evaluated the minimum detectable unabsorbed flux (at a level of 1σ) to be $F^{Una}_{0.5-7\ \mathrm{keV}} \simeq 1.5 \times 10^{-15}$ erg s^{-1} cm^{-2} which corresponds to a flux of $F^{Una}_{0.5-2\ \mathrm{keV}} \simeq 6.6 \times 10^{-16}$ erg s^{-1} cm^{-2} in the 0.5-2 keV band. Thus the log N - log S diagram[1] allowed us to evaluate the expected number of background AGNs whithin $\simeq 25''$ from the UMi dSph center which turns out to be $\simeq 0.15$. Hence, the background AGN scenario cannot be completely excluded.

A deeper analysis of Ursa Minor was conducted in[8] on a set of XMM-Newton data (ID 0301690301, and 0301690401) who fully characterized the X-ray population in the galaxy. These authors confirmed the IMBH detection and, using previously estimates on the radio (5 GHz) fluxe, set a mass measure to $\simeq 2.76^{+32.00}_{-2.54} \times 10^6$ $M_\odot$.

For the Draco, Leo I and Ursa major galaxies we did not detect any central X-ray source. Hence only upper limits to the IMBH mass can be put. In these cases, we limited to the characterization of the local X-ray population. Indeed, identyfing local X-ray sources is of crucial importance for the evolutionary scenarios at the basis of this kind of galaxies. Infact, as globular clusters, dSphs host old stellar populations and X-ray sources are expected to be most likely LMXBs or CVs. However, at variance with respect to GCs, in the case of dSphs any X-ray binary should be primordial. Hence, LMXBs would turn off in a few hundred million years, making unlikely finding these systems in dSphs. Finding a few local sources would imply an intriguing challenge for the LMXB formation theory.

For Draco dSph (observed by XMM-Newton – IDs 0603190101, 0603190201, 0603190301, 0603190401, and 0603190501– and *Chandra* satellites – IDs 9568 and 9776–), Leo I (observed by XMM-Newton, ID 0555870201) and Ursa Major (target of an XMM-Newton observation, ID 0650180201) we analysed all the available high energy data and cross correlated the detected X-ray sources with well known archival catalogues. We address the reader to[8] (but also references therein) for a list of all the catalogues used in this search. As a result, a few X-ray sources per galaxy were recognized as local high energy sources (about thirty in total were classified highly probable to be such and further observations are needed) and this has implications in the formation and evolution scenarios of these galactic systems.

Acknowledgments

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