OBSERVING REQUEST
Telescope Access Program, China

Year: 2015 **Term:** Feb–Jul **Proposal type:** short-term

On the Nature of Eight Hyper Luminous X-ray Source Candidates

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Abstract of Scientific Justification

Intermediate mass black holes, which occupy the mass range between 10^2 and 10^5 solar masses, are the long sought missing link between stellar mass black holes and super massive black holes (SMBHs). Using IMBHs as seeds, SMBHs can form in a short time after the big bang. However strictly speaking we have not found any solid evidence that IMBHs exist. Neither of the IMBH candidates is uncontroversial before we are able to get a dynamical mass measurement. Hyper luminous X-ray sources (HLXs) are promising IMBH candidates recently. However only one consistent HLX has been found. The existing X-ray data is far more being exploited enough. We collect a large galaxy sample and detect X-ray sources from 10000 Chandra observations to find more HLXs. Our final catalog includes 86 HLXs and 293 X-ray sources luminous than $3 \times 10^{40}\,\mathrm{ergs}^{-1}$. The logN-logS relation shows a modest contamination by foreground or background sources. We find optical counterparts for 8 HLXs in SDSS images and propose to make spectroscopic observations to confirm their nature. We expect 4-5 of them are really located in their apparently host galaxies. This program will test our HLX catalog and find more HLXs. Extended observations can be used to detect possible line shifts and get their dynamical masses.

Summary of observing runs requested for this project

Run	Telescope	Cage	Instrument	PI	AO	Nights	Moon	Scheduling Optimal	Scheduling Acceptable	Sharing Poss.	Sharing Adv.
1	MMT	f/15	Red			1	dark	Jan	Jan-Feb	yes	no
or:											
1a										no	no

Scheduling constraints and unusable dates *(up to 4 lines)*: Please make this program after 2015-01-10 if possible.

no text past this line

A ⋆ appended to the proposal type indicates a continuation proposal; a ⋆ appended to the name of a proposer indicates the proposer is a (graduate) student; a proposer whose name is underlined is certified on the proposed telescope/instrument combination; if a ∗ appears within the PI or AO box in the observations summary table, the instrument is a PI instrument and/or Adaptive Optics are requested – signatures are required on the next page.

Target list (attach list if longer than 26 objects)

#	Object	RA	Dec	mag / color / type / redshift / comment / etc.
1	S7608-16	00:41:59.9	+25:33:51.1	$r = 20.06/Lx = 1.4e41$
2	S10562-9	01:19:42.7	+03:24:22.2	$r = 21.7/Lx = 1.1e41$
3	S3237-26	03:18:13.5	+41:52:12.3	$r = 23.6/Lx = 1.35e41$
4	S12822-5	13:52:27.6	+14:29:23.1	$r = 22.9/Lx = 1.9e41$
5	S3075-3	14:17:52.7	+26:45:39.5	$r = 20.01/Lx = 1.6e41$
6	S497-4	16:28:39.4	+39:33:38.1	$r = 22.6/Lx = 1.3e41$
7	S10804-10	16:29:06.1	+39:29:45.5	$r = 21.6/Lx = 1.2e41$
8	S7924-15	22:35:55.7	+33:57:38.7	r≈22.0/Lx=4.6e41

If this program uses a PI instrument, attach the approval email from the PI to this proposal. N/A

Graduate students *(provide the following information for* ***each*** *student named as PI or CoI on the cover page.)*

Student's Name	Advisor's Name	Thesis
Hang Gong	Jifeng Liu	yes

Scientific Justification *Please include overall significance to astronomy and significance within the proposal's discipline. Limit text to one page, with a maximum of two additional pages for figures, captions, and references.*

We have found twenty stellar mass black holes with dynamical mass measurements. And it has been a consensus that a galaxy with a bulge should host a SMBH. However little is known about the intermediate class of black holes (BHs):10^2 to 10^5 solar masses. The motivation we try to find IMBHs is not just because a big gap exists between stellar mass BHs and SMBHs. High redshift SMBHs do not have enough time to grow just via the accretion of stellar mass BHs after the big bang. Via mergers of IMBHs, SMBHs can form more efficiently and in a much shorter time. IMBHs can be the ideal seeds of SMBHs.

There are several kinds of IMBH candidates now. Ultra-luminous X-ray sources (ULXs, Colbert 1999) are off-nuclear X-ray sources located in nearby galaxies. With X-ray luminosities larger than $1 \times 10^{39}\,\mathrm{erg\,s^{-1}}$, they were once considered to be promising IMBH candidates. However ULXs do not necessarily radiate isotropically. The first dynamical mass measurement (Liu 2013) for a remarkable ULX, M101 X-1, have proven it is just a stellar mass BH. Globular clusters may host IMBHs too. Although new observations keep going, none of the detections of IMBHs in GCs such as G1 and Omega Cen can stand up to scrutiny (Pooley 2006). IMBHs may locate at the center of a galaxy too. However up to now even the smallest one is around 10^5 solar masses and the mass has a large uncertainty (Filippenko 2003). Finally, an unique source M82 X-1 deserves to be mentioned. It has a modest QPO (Pasham 2014) in between stellar mass BHs and SMBHs and a 3:2 frequency ratio. However the mass derived from QPO is unsettled since we do not know QPO's origin now.

Stellar BHs are difficult to achieve a $1 \times 10^{41}\,\mathrm{ergs^{-1}}$ luminosity even via very special radiation mechanisms (Ohsuga 2011). HLXs, which have $> 1 \times 10^{41}\,\mathrm{ergs^{-1}}$ X-ray luminosities, blazed a trail for IMBHs. Farrell(2009) discovered HLX-1 in the outskirts of a galaxy 90 Mpc away. Its X-ray luminosity could amazingly exceeds $1 \times 10^{42}\,\mathrm{ergs^{-1}}$. Later observations confirmed its optical counterpart and the redshift. Because HLX-1 is optically faint(R=24.6), it is hardly possible to detect line shift and get a dynamical mass now.

Finding HLXs with doable optical counterparts can be a shortcut to find IMBHs. In order to find luminous X-ray sources, two catalogs are needed: X-ray sources and galaxies. Previous searchers for ULXs used ready made X-ray source catalogs such as 2XMM-SSC (Walton 2011) or CSC, which are made based on part of the observation data. The galaxies generally used were from the RC3 Catalog which only includes 23000 galaxies. This leads to the lost of many luminous X-ray sources. For example, most galaxies of Liu(2011) are limited in 40 Mpc and there are only six sources luminous than $3 \times 10^{40}\,\mathrm{ergs^{-1}}$. The most luminous one is just $7.9 \times 10^{40}\,\mathrm{ergs^{-1}}$. Here we use galaxies in PGC catalog(Paturel 2003) and collect galaxy information via NED. Finally we make a catalog consist of 77000 galaxies(Figure 1) in 300 Mpc. RC3 is totally included. The lower limit of the main axis length is $10\,''$ which Chandra can easily resolve. We analyse nearly 10000 Chandra ACIS observations released before 2014. All the X-ray sources we detected and the $2D_{25}$ isophotes of the 77000 galaxies are cross correlated. For each X-ray source in the $2D_{25}$ of a galaxy, we use PIMMs to estimate whether their X-ray luminosities could exceed $5 \times 10^{39}\,\mathrm{ergs^{-1}}$. For sources brighter than $5 \times 10^{39}\,\mathrm{ergs^{-1}}$, we assume a power law($\gamma$=1.7) and use $modelflux$ to calculate their flux. The nh is fixed at the foreground column density. A luminosity cut is set at $3 \times 10^{40}\,\mathrm{ergs^{-1}}$ to include more sources. We remove all the X-ray sources located near $3''$ of any galaxy center. Then we visually inspect the X-ray images and remove the duplicated sources. For duplicated observations, we pick the brightest luminosity to be listed in our final HLX catalog.

Of all the 273 sources we find, 86 are HLXs. We use the logN-logS (Figure 2) relation to estimate the total contamination rate. If we take the area between 1D25 and 2D25 as the random field conservatively, at most 40% of the 86 HLXs are foreground or background sources. After getting rid of the AGNS and foreground stars recorded by $simbad$ and reference papers, we only find optical counterparts (Figure 3) for eight of the rest HLXs in SDSS images. In order to know their nature, we propose to do spectroscopic observations for one dark night. Potentially Hα, Hβ, HeI5876 and HII4686 can be used to analyse their distance and nature. We expect there are 4-5 sources really located in their apparently host galaxies. Once their distances are confirmed, we will propose extended observations to check whether spectral line shifts.

References

[Pasham et al.(2014)] Pasham, D. R., Strohmayer, T. E., & Mushotzky, R. F. 2014, Nature , 513, 74

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[Liu(2011)] Liu, J. 2011, ApJS , 192, 10

[Walton et al.(2011)] Walton, D. J., Roberts, T. P., Mateos, S., & Heard, V. 2011, MNRAS , 416, 1844

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[Colbert & Mushotzky(1999)] Colbert, E. J. M., & Mushotzky, R. F. 1999, ApJ , 519, 89

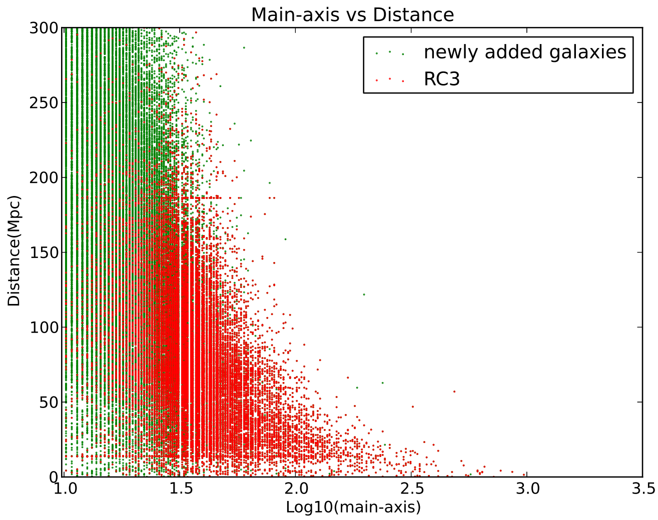

Figure 1: Our galaxy sample:greene+red,every RC3 catalog is included in our PGC sample

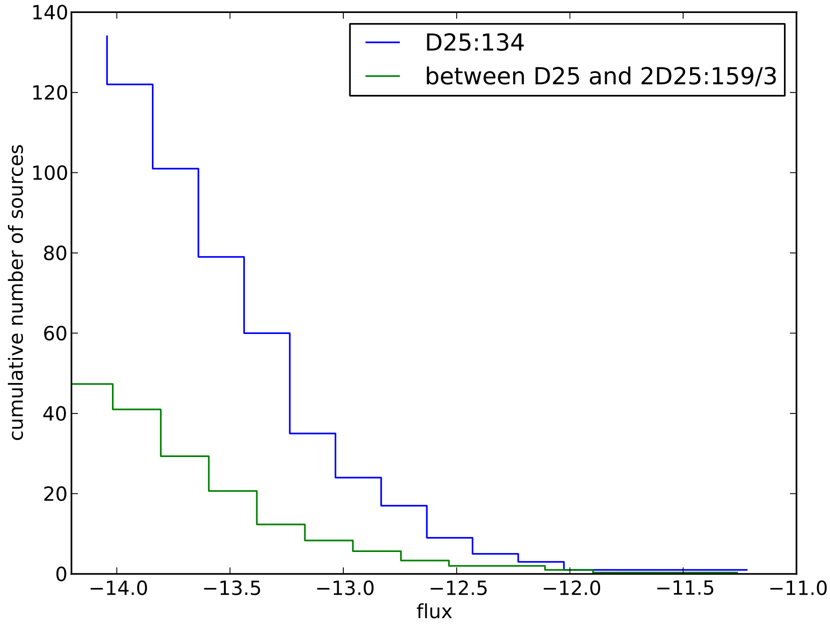

Figure 2: The logN-logS relation: galaxies between D25 and 2D25 are scaled by projected by sky area.No more than 40% of our the 86 HLXs are foreground or background sources

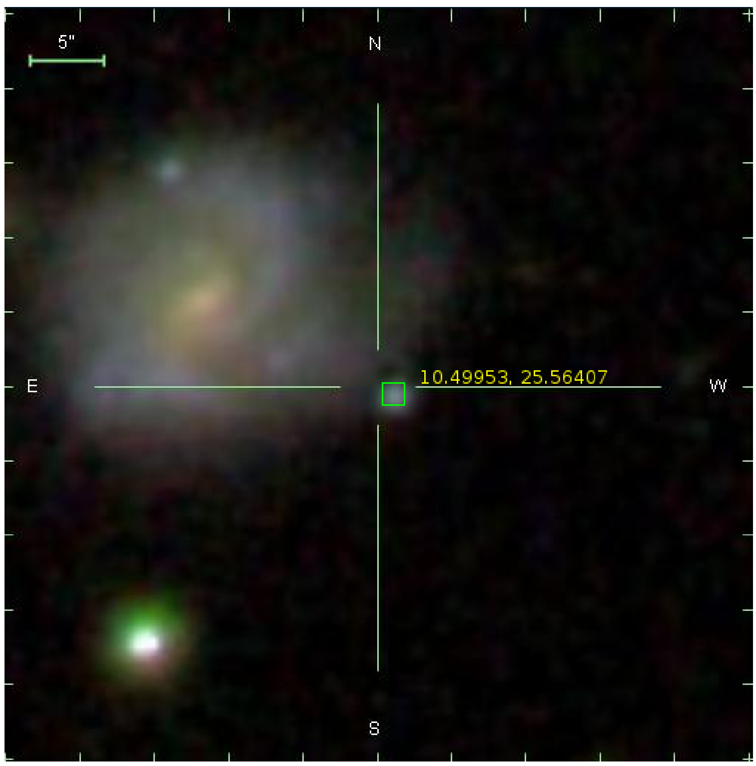

Figure 3: One of our HLX candidate: S7608-16

Experimental Design & Technical Description *Describe your overall observational program. How will these observations contribute toward the accomplishment of the goals outlined in the science justification? Justify sample size, instrument choice, signal-to-noise, exposure times, and lunar phase. Also briefly explain plans for data reduction, and what expertise or effort each team member will contribute to the project. (**up to one page**)*

Six of our sources are fainter than r=21.6. To measure the redshift of Hα and Hβ simutaneously, for all the 8 sources we propose to take the red channel spectra with a $1''$ slit and the G150 grating with a central wavlength of 4800A. This configration can easily tell the redshift of our sources which are 50 Mpc away typically. A wide HeII emission line may indicate the existence of a compact accretion disc and its flux correlates the activity of accretion. The central wavlength gives HeII a relatively good efficiency too. For the two brighter sources(r=20), we plan to add G600 observations (The central wavlength is also 4800A.) to check the potentially HeI and HeII emission line more carefully. All spectra are 3x1200 sec.

Data Plan. GH did P200/2.4m/2.16m/VLT data reduction before. If we meet technical details, we will consult the local stuff or MMT users around us.

TAP Usage and Context *The TAC needs to understand the scope of this project — (1) How many total TAP nights are you requesting this semester, including any CFHT time from a linked proposal, and if more time will be necessary in future semesters, how many nights will you need to complete the project (best guess)?; (2) If a substantial amount of observing for this project comes from non-TAP telescopes, tell us about that observing, and how the TAP part fits in; (3) If you are collaborating with people who have access to other telescopes, especially if you are part of a large collaboration, tell us who is leading the project, and how TAP time and your participation fit in. 4) Please explain the ways in which this program would help fulfill the goals of the Telescope Access Program. (**up to one page**)*

We apply for one dark nihgt from the MMT telescope in 2015A. Only one third of the 86 HLXs are in the field of SDSS. Most sources out of the SDSS field do not have deep observations. If this program gets approved, we will use the 2.4m telescope of Lijiang to do photometric observations before the MMT observation. Better targets may be added into or replace the 8 targets. We will collect real HLXs in 2015A first. If this program can be extended, the first radial velocity curves for one or two HLXs may be got in our country.