Transactions IAU, Volume XXXA
Reports on Astronomy 2015-2018
xxxx, ed.

DOI: 00.0000/X000000000000000X

COMMISSION X1 **Cross Division Commission X-1**

Supermassive Black Holes, Feedback and Galaxy Evolution

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TRIENNIAL REPORT 2021-2024

1. Background

The primary rationale for Commission X1 is to foster the exploration of the processes that couple the growth of supermassive black holes to their host galaxies, generally referred to as feedback processes. These processes are key ingredients in galaxy evolution models. In particular, feedback processes regulate the galaxy growth. The Commission's motivation is strengthened by the rich observational capabilities that are now available. In particular, detailed studies of supermassive black holes at high redshifts are now possible with the newest observational tools. The large complement of 441 current members for Commission X1 indicates the popularity and relevance of the topical area of supermassive black holes and galaxy evolution. The community interest in AGN feedback and galaxy evolution is shown by the more than 900 papers published on these topics in recent years and which has continued through 2023.

2. Developments within the past triennium

Although the covid pandemic limited the number of meetings that were held in the last three years, recent initiatives ensure that the impact of Commission X1 will continue throughout the decade of the 2020s. In particular, the launch in 2021 of JWST has revolutionized our view of the early Universe by probing the formation of galaxies and their central black holes to very early epochs (to redshift 10 and beyond). Examples of JWST science addresses Commission X1 intests are contained in the following sample of papers/press announcements:

• **probing the high redshift universe using the Pandora cluster (aka Abell 2744) to gravitationally lens distant galaxies and AGN**
(see `https://jwst-uncover.github.io/#publications` and the Chandra observation of the $z \sim 10$ black hole in one of the high redshift JWST-detected

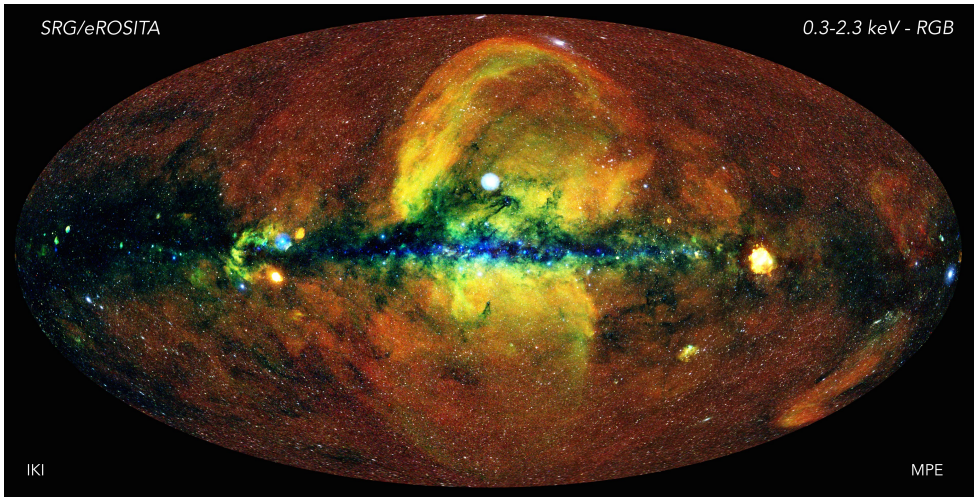

Figure 1. The eRosita first all-sky survey image showing more than one million X-ray sources of which about 77% are active galactic nuclei (AGN). As described in the press announcement, photons have been colour-coded according to their energy (red for energies 0.3-0.6 keV, green for 0.6-1 keV, blue for 1-2.3 keV). In addition to the individual AGN (uniformly distributed white points away from the Galactic plane), we see evidence of feedback in our own Galactic center from supernovae and our own supermassive black hole, Sagitarius A* as the diffuse hot gas (yellow and green) near the center of the image. credit: Jeremy Sanders, Hermann Brunner and the eSASS team (MPE); Eugene Churazov, Marat Gilfanov (on behalf of IKI) from the presskit, see text).

galaxies
(see `https://ui.adsabs.harvard.edu/abs/2024NatAs...8..126B/abstract`**)**

- **discovery of a "Rosetta stone" for probing galaxy formation**

(see `https://ui.adsabs.harvard.edu/abs/2024arXiv240310238C/abstract`**)**

- **discovery of AGN candidates to** $z \sim 12$

(see `https://academic.oup.com/mnras/article/525/1/1353/7238494`**)**

- **discovery of a galaxy with a very high ration of black hole mass to galaxy mass that may link early seeds to first luminous quasars**

(see e.g., `https://www.nature.com/articles/s41586-024-07184-8`

The continuing operations of the Hubble Space Telescope and the X-ray observatories Chandra, XMM-Newton, and the data releases from eROSITA are providing important discoveries and a better understanding of supermassive black holes and their impact on their host galaxies. With its first complete survey of the sky (182 days of observation), eROSITA has detected about 1.1 million X-ray sources of which 77% are active galactic nuclei (see Fig. 1 and https://www.mpe.mpg.de/7461950/erass1-presskit).

The first eRosita data release, covering just over 20,000 sq. degrees has been made public and provides an unprecedented view of the AGN sky. Radio surveys with LOFAR, GMRT, and ASKP-EMU are providing significant insights into Active Galactic Nuclei (AGN) feedback and other high energy processes. Through these observations, the exploration of supermassive black holes, the effects of blackhole feedback and galaxy evolution are leading to substantial advances in our understanding of how supermassive black holes affect their host galaxies.

The interest in the topics of Commission X1 is shown by the numerous topical conferences held during the last three years. These include: the IAU Symposium 376 "At

the cross-roads of astrophysics and cosmology: Period-luminosity relations in the 2020's" held for five days in April 2023.

Following the image of the supermassive black hole in M87, the Event Horizon Telescope publshed the image of the supermassive black hole at the center of our own Galaxy on 12 May 2022 (see https://iopscience.iop.org/article/10.3847/2041-8213/ac6674).

The American Astronomical Society High Energy Astrophysics Division (HEAD) 20 meeting was held in January 2023 in Hawaii. At this meeting, many talks and posters related to Commission X1 were presented. In addition, HEAD also hosted the Frontier Seminar Series where more than half the talks were related to Commission X1 topics.

The 32nd Texas Symposium on Relativistic Astrophysics was held in December 2023. Presentations included accretion processes around conpact objects, from stellar mass black holes and neutron stars to supermassive black holes.

The papers based on the presentations given at the IAU Symposium 359 "Galaxy Evolution and Feedback across different Environments" were published by Cambridge University Press in 2021 in the book "Galaxy Evolution and Feedback across Difference Environments."

In addition to the conferences listed above, there were numerous meetings relevant to Commission X1. These include:

- Extragalactic Spectroscopic Surveys: Past, Present and Future of Galaxy Evolution (GALSPEC2021), 12-16 April 2021 (online)
- A Holistic View of Stellar Feedback and Galaxy Evolution, 11-15 July 2022 (Ascona, Switzerland)
- Black Holes at All Scales, 31 Aug - 2 Sept (Sedona, Arizona)
- Epoch of Galaxy Quenching, 5 - 9 September 2022 (Cambridge, UK)
- Panchromatic View of the Life-Cycle of AGN, 14-16 September 2022 (Madrid, Spain)
- What Drives the Growth of Black Holes, 26-30 September 2022 (Reykjavik, Iceland)
- Young Astronomers on Galactic Nuclei, 17-19 October 2022 (San Sebastian, Spain)
- Extragalactic Jests on All Scales, 14-18 June 2021 (online)
- Galaxies with Active Nuclei on Scales from Black Hole to Host Galaxy, 13-17 September 2021 (Crimean Astrophysical Observatory)
- Growing Black Holes: Accretion and Mergers, 15-20 May 2022 (Kathmandu, Nepal)
- Black Hole Accretion Under the X-ray Microscope, 14-17 June 2022 (Madrid, Spain)
- Black Hole Winds at all Scales IAU Symposium 378, 12-16 March 2023 (Haifa, Israel)
- Galactic Center Workshop, 24-28 April 2023 (Granada, Spain)
- AGN Winds on the Chesapeake, 11-16 June 2023 (Easton, Maryland)
- Astrophysical Black Holes, 23-26 June 2023 (Hong Kong, China)
- Shedding New Light on the first Billion Years of the Universe, 3-7 July 2023 (Marseille France) Galaxy Transformation across Space and Time 4-8 September 2023 (Canberra Australia)
- The many facets of fuelling and feedback in jetted AGN, 10-15th September 2023 (Tropea, Italy)
- East Asia AGn Workshop, 25-27 September 2023 (Kagoshima, Japan)
- Galaxy Formation in Hangzhou: Observations and Physics of AGN Feedback, 9-13 October 2023 (Hangzhou, China)
- Winds throughout the Universe, 11-13 October 2023 (Annapolis Maryland)
- Black Holes on Broadway: The Next Generation of AGN Models, 4-7 Dec, 2023 (New York, USA)
- XVI Black Holes Workshop, 19-10 December 2023 (Porto Portugal)
- Building Galaxies from Scratch: Advances and Challenges in Simulating Galaxy Evolution 19-23 February 2024 (Vienna Austria)

The number of relevant meetings also indicates the current relevance of Feedback to many areaas of astrophysics.

In addition to the activities listed above, Jones served on the National Academy of Sciences committee for the IAU. She also reviewed applications for the IAU PhD Thesis prize and commented on the IAU Code of Ethics. She also reviewed 24 proposals for meetings or IAU symposia and solicited candidates for Vice President of Commission X1.

3. Future Plans

Commission X1 will support the community effort to explore the growth of black holes and the connection with galaxies for the next three years, by fostering international meetings, which will connect specific research interests of indivduals in a large range of black hole and galaxy studies. Depending on the interests of the community, we will develop a newsletter and/or SNS space for fast communications, particularly aiming for engaging younger members.

To continue supporting this active area which involves state-of-the-art instrumentation, we request that the X1 Commission continue for an additional three years.