Deciphering AGN outflows: Multi-wavelength monitoring of NGC5548

A proposal from an international team for a study project
at the International Space Science Institute
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Abstract

We propose a study project, carried out by an international team, aimed at deciphering the outflow properties of the bright Seyfert 1 galaxy NGC5548. The project is based on an ambitious multi-wavelength campaign on NGC5548 for which we were approved in year 2012 a Large Program (14×50 ks) with XMM-Newton, 12 joint HST/COS orbits, 41×1.5 ks with SWIFT and 245 ks of Chandra/HETGS. Simultaneous hard X-ray observations with Nustar are also foreseen. The campaign is planned to start before the Summer 2013 (Swift will start in May 17th, XMM in June 22nd) and will last for ∼80 days in total. The main scientific goal of this large project is to determine unambiguously the location, geometry and physical properties of the various absorption (wind/outflow) and emission (accretion disc, corona) components in this source. The international team covers the whole range of expertise needed for such a study: data reduction (at all wavelengths, from the optical-UV to the hard X-ray band), data analysis, data interpretation and theoretical simulations/modeling. The goal of this study project is to discuss at ISSI the observational results, their possible interpretations, as well as to define, coordinate and plan the writing of several scientific papers expected to result from the above campaign.

1 Scientific Rationale and Goals

Understanding outflows/winds and accretion/emission in AGNs: Active Galactic Nuclei (AGN) show large amounts of ionised gas outflowing from the central supermassive black hole (SMBH). The balance between accretion onto the SMBH and these outflows (mostly seen as ionized absorbers of the X-ray and UV light from the nucleus) affects the evolution of the SMBHs, their host galaxies, and the surrounding IGM. However, the physical properties of these outflows are generally poorly known. Our work aims at measuring their impact on the AGN powerhouses and their environments (the so-called "AGN feedback") in more detail than has ever been possible so far. Observations show that outflows contain multiple ionisation components, most likely stratified. The location of the outflow is however uncertain, and distance constraints can discriminate between different outflow production mechanisms. AGN outflows have been attributed to accretion disc winds, or thermal winds produced by irradiation of the obscuring torus. Accretion disc winds would have at least some components originating within several hundred gravitational radii. Thermal winds, however, should lie at pc scales, at or beyond the obscuring torus.

Closer to the SMBH, accretion dominates, producing the strong ionising flux that photoionises the outflow. Various models for the central region have been proposed, in particular for the soft X-ray excess. This includes blurred absorption or emission, or Comptonisation of disc photons in a warm corona. But up to now no clear conclusions have been given on its origin. However, these soft photons have a huge impact on the ionisation structure of the absorber, so understanding the soft excess is fundamental to understand outflows. In order to solve these questions, deep monitoring observations are needed. The time-averaged spectrum yields the structure of the outflow, the response to the luminosity variations limits the distance of the outflowing gas, and the luminosity variations themselves help to resolve the physical structure of the core. To address the above issues, we have proposed and been awarded a large multiwavelength campaign on the Seyfert 1 galaxy NGC5548, to be started before the Summer 2013 (see more details below). The campaign, led by XMM-Newton, has three main goals: determining the dynamical and physical structure of the outflow, constraining its distance and understanding the nature of the continuum emission.

Why NGC 5548? For successfully tackling the above open issues, several "source requirements" needed to be met, and NGC 5548 is the only AGN that fulfils all these requirements, in particular: i) It is X-ray bright : in the 2−10 keV band, NGC 5548 is one of the ten brightest Seyfert 1 galaxies. Its RGS spectrum will fully characterise the absorber components; ii) The continuum variability time scale is about 1−2 days, with little power at shorter time scales, giving excellent spectra in 50 ks exposures. NLS1s, extensively studied by XMM-Newton, vary too fast for time-resolved high-resolution spectroscopy; iii) Its luminosity variations are large enough (typically 60% max/min) that the resulting spectral changes can be measured by XMM-Newton/pn; iv) The column density of the outflow is large enough to allow variability to be detected, but without suffering of strong saturation; and v) The long-term spectral variability (3−6 years) of the outflow has been observed both in UV and X-ray lines.

Observational strategy? NGC 5548 will be observed during 40 days using 12×50 ks XMM-Newton exposures with 2−8 days (log) spacing, and 2×50 ks exposures half a year later. These observations will be simultaneous with HST/COS (12 orbits), Swift (41×1.5 ks before and during the XMM campaign), Nustar (hard X-ray spectrum), Chandra HETGS (245 ks) and ground-based optical observations.

2 Timeliness

Understanding the astrophysics of AGN winds/outflows, as well as their impact in terms of feedback, has attracted in recent years significant interest. Moreover, this topic has been identified as key science for future high energy observatories such as ASTRO-H (to be launched by JAXA in 2014) or Athena+ (currently being proposed for an ESA L2 mission). Obviously, the large amount of observatory time just awarded for the campaign on NGC 5548 and that will be available in the Summer 2013, is a unique (and clearly timely) chance for this ambitious scientific project to be realized now, and with an important legacy/benchmark value for also future projects.

3 List of expected outputs

Our intention is to write several scientific papers on the topics mentioned in the previous sections. Given the past experience for several of us on a similar multi-wavelength campaign on the Seyfert 1 galaxy Mrk 509 which brought to the publication of more than 12 papers so far, we expect several papers also from this campaign. The papers will probably be published in Astronomy and Astrophysics (for those led by European scientists), or Astrophysical Journal (for those led by US colleagues). We will ask from all participants to discuss, agree and/or contribute to all the planned papers. We nevertheless already identified a number of likely activities/measurements with associated leading authors and papers in Table 1 (see Appendix). Meetings and activities proposed at ISSI will be critical in defining, discussing, confirming, and finalizing these papers.

4 Added value of ISSI

Based on the direct experience from some of us (i.e. J. Kaastra, G. Branduardi-Raymont) gained at ISSI, we are choosing ISSI to support us on the above study project because we know ISSI offers excellent facilities and an inspiring and efficient atmosphere to carry out this project. The key role of XMM-Newton also makes this a European-led key project that supports choosing ISSI for meetings. The proposed project is also perfectly compliant with the research fields (Space Science Astrophysics) of interest to ISSI. The different observational datasets and different expertise in the team members (observational and theoretical) must be put together in an open and constructive discussion for the project to be successful. This can be done only in a series of focused meetings that we would like to organize at ISSI, away from distracting academic and administrative activities at the home institutes of the participants. Moreover, the project is too ambitious and too broad to be done by a small team of only a few people; we need the complementary expertise of all 6−8 senior team members plus the strength/energy of the 4−6 younger postdocs team members. At least a kick-off and a work meeting at a well-equipped location like ISSI are mandatory for the project to start well, and fast.

5 Confirmed participants

The following participants have confirmed their presence and willingness to work on this team:

- **Core Team:** Dr. Massimo Cappi (INAF/IASFBo, Italy), Dr. Jelle Kaastra (SRON, NL), Dr. Graziella Branduardi-Raymont (MSSL, UK), Dr. Pierre-Olivier Petrucci (Grenoble, F), Prof. Ehud Behar (TIIT, Israel), Dr. Stephane Paltani (University of Geneva, CH), Dr. Stefano Bianchi (Univ. of Roma Tre, Italy), Dr. Elisa Costantini (SRON, NL), Dr.

Jacobo Ebrero (SRON. NL), Dr. Katrien Steenbrugge (UCN, Chile), Dr. G. Ponti (MPE, Germany), Dr. Barbara Demarco (MPE, Germany).

- **Young Scientists (i.e. Post-doc + < 2 years):** Dr. M. Mehdipour (UCL, UK), Dr. C. Pinto (Cambridge, UK)
- **Other Scientists considering to attend on their own funds:** Dr. Jerry Kriss (STSCI, USA), Prof. Nahum Arav (Virginia Tech University, USA), Prof. De Vries (SRON, NL), Prof. Shai Kaspi (Technion Univ., Israel), Prof. Giorgio Matt (Univ. of Roma Tre, Italy), Prof. Bradley Peterson (Ohio State Univ., USA)

6 Schedule of the project

We envision the initial one-week meeting to take place in Fall 2013. Status of the overall data reduction, plus status of data analysis from specific instruments and for some specific goals (see Table 1) will be first presented and discussed.This process will take 2 to 3 days. Then smaller teams (3−4 people) will be formed and will focus in splinter sessions on specific topics to further progress in identifying possible criticalities and for planning further work/progress. This will take 1−2 days. The last day will serve to have all experts meet again and summarize progress achieved and work to be done. A list of possible papers with associated lead scientists will be agreed upon. During the next half year, the team members will work in a network on the analysis and interpretation of the data, and start draft papers at their home institutes, mainly by e-mail contact and possibly meetings at general astronomy conferences. The second one-week session will be held half a year later, around March/April 2014. The drafts will be submitted before this meeting, and will be discussed during the first part of the meeting. This discussion will focus on completeness, clarity, and coherence and cross- referencing between the different papers. The last part of the meeting will be spent on fine-tuning and improving the contents and text.

7 Facilities Required

Use will be made of the standard facilities of ISSI. A meeting room for up to 20 people is required (up to 12 people from the Core Team, plus up to 2 Young Scientists, plus up to 6 other scientists on their own fundings), equipped with a beamer and sufficient (wireless) internet access. A few desktop computers would be sufficient as most participants are expected to bring a laptop. Some limited printing facility is needed. For the splinter sessions room for about 3-4 groups of 3-5 people at the same time is needed, some of which might use the main meeting room. All these facilities are available at ISSI.

8 Financial support

For the (up to) 12 members of the Core Team, we request the standard support for international teams (per diem & lodging) as well as travel support for the team leader. For the Young Scientists, should this proposal be approved, we will ask for access to the Young Scientist scheme for up to two young scientists. Up to 6 other (mostly senior) scientists may participate as well but will do so on their own funds.

9 Appendices

9.1 Proposed Participants and pre-identified lead papers and topics

Table 1: Proposed Participants and pre-identified lead papers and topics

Lead contributor	**Topic**
Core Team	
Jelle Kaastra	Introduction of campaign X-ray distances of outflow using RGS/EPIC data
Elisa Costantini	Time-averaged RGS spectrum of outflow
Graziella Branduardi-Raymont	Modeling of broad- and narrow X-ray lines from RGS
Jacobo Ebrero:	Chandra HETGS data, with focus on emission and absorption lines velocity structure (and also accounting for archival HETGS data)
Ehud Behar:	Long-term variability outflow by comparing to archival grating data
Gabriele Ponti:	HETGS and EPIC Fe-K line emission study
Katrien Steenbrugge:	Abundances based on X-ray and UV data
Massimo Cappi:	Fe-K absorption (including any measurements or limits on UFOs in NGC 5548) Coordination with Nustar
Stefano Bianchi:	Reverberation narrow Fe-K line including archival data
Barbara DeMarco:	Time-variability within and between the EPIC data
Stephane Paltani:	Hard X-ray Comptonisation (may include archival Suzaku and/or INTEGRAL data)
Pierre-Olivier Petrucci:	Broad-band physical modeling of the continuum, including soft excess
Young Scientists	
Missagh Mehdipour:	Continuum UV & X-ray variability from Swift, OM & EPIC
Ciro Pinto:	ISM foreground absorption modeling
Other Scientists	
Jerry Kriss:	Description of UV spectra
Nahum Arav:	Velocity-resolved analysis of the UV lines
Cor de Vries:	RGS Data Reduction
Giorgio Matt:	Nustar coordination and analysis
Shai Kaspi:	Optical observations
Bradley Peterson:	HST reverberation campaign, if proposal successfull

9.2 Short CV of confirmed participants

9.2.1 Core Team

- Dr. Massimo Cappi, Senior Scientist at INAF/IASF-Bologna, Bologna, Italy; PhD in 1998, Saitama University, Japan.
  Fields of expertise: X-ray data analysis; active galactic nuclei

- Dr. Jelle S. Kaastra, Senior Scientist at SRON National Institute for Space Research in Utrecht, Netherlands (Ph.D. 1985 Utrecht University; nationality: Netherlands).
  Fields of expertise: X-ray spectroscopy of hot plasmas; clusters of galaxies; active galactic nuclei.

- Dr. Elisa Costantini
  research scientist at SRON, Netherlands Institute for Space research, The Netherlands.
  PhD in 2004, Ludwig Maximilian University (LMU), Munich (Germany)
  Fields of expertise: X-ray data analysis, gas environments and physics of Active Galactic Nuclei, Interstellar medium, and X-ray binaries.

- Prof. G. Branduardi-Raymont, Professor of Space Astronomy at University College London, Mullard Space Science Laboratory; Ph.D. in 1977, University College London; nationality: Italy.
  Fields of expertise: X-ray astronomy, observing and instrumentation; high resolution X-ray spectroscopy of cosmic sources; solar system objects; active galactic nuclei.

- Dr. Jacobo Ebrero, Postdoc researcher at SRON Netherlands Institute for Space Research in Utrecht, The Netherlands., Ph.D. in 2008, Universidad de Cantabria, Spain.
  Fields of expertise: X-ray data analysis and spectroscopy; active galactic nuclei.

- Prof. Ehud Behar, Assoc. Professor of Physics at the Technion, Haifa Israel. PhD in 1999 from The Hebrew University of Jerusalem. Fields of expertise: X-Ray Spectroscopy of Astrophysical and Laboratory Plasmas; Active Galactic Nuclei, Stellar Coronae, Interstellar and Intergalactic Medium, Laboratory Astrophysics.

- Dr. Gabriele Ponti, Marie Curie Post Doc at Max Planck Institute for Extraterrestrial Physics; PhD in 2007, Bologna University, Italy
  Field of expertise: X-ray data analysis; Active Galactic Nuclei, Galactic Centre; Black Hole Binaries

- Dr. Katrien Steenbrugge, profesor asociado at Universidad Catolica del Norte, Chile; PhD 2005 Leiden Universiteit, The Netherlands.
  Fields of expertise: X-ray spectroscopy of active galactic nuclei.

- Dr. Stefano Bianchi, Researcher at Università degli Studi Roma Tre, Rome, Italy; PhD in 2004, Università degli Studi Roma Tre.
  Fields of expertise: X-ray data analysis; active galactic nuclei

- Dr. Barbara De Marco, Post doctoral fellow at Max-Plack Institute for Extraterrestrial Physics, Garching, Germany; PhD in 2009, SISSA/ISAS Trieste, Italy.
  Fields of expertise: X-ray data spectral and timing analysis; active galactic nuclei

- Dr. Stephane Paltani, Faculty position at Department of Astronomy, University of Geneva, Switzerland; PhD in 1996, University of Geneva, Switzerland.
  Fields of expertise: Active galactic nuclei, AGN and galaxy population and evolution

- Dr. Pierre-Olivier Petrucci, Senior Scientist at IPAG/CNRS Grenoble, France (Ph.D. in 1998 J. Fourier University, France).
  Fields of expertise: X-ray data analysis and modeling; compact objects (X-ray binaries, AGN)

9.2.2 Young Scientists

- Dr. Missagh Mehdipour, Research associate at Mullard Space Scienece Laboratory, University College London, UK; Ph.D. in 2012, University College London.
  Fields of expertise: Active Galactic Nuclei; X-ray spectroscopy

- Dr. Ciro Pinto, Research associate at University of Cambridge, Institute of Astronomy, Cambridge, UK; PhD in 2013, Radboud University Nijmegen, The Netherlands.
  Fields of expertise: X-ray spectroscopy of plasmas; X-ray binaries; interstellar dust.

9.2.3 Other Scientists (on own funds)

- Dr. Gerard A. Kriss, Astronomer at STScI, Baltimore, MD, USA; PhD in 1982, Massachusetts Institute of Technology, Cambridge, MA, USA.
  Fields of expertise: UV/optical instrumentation, calibration, and data analysis; UV, optical and X-ray spectroscopy of active galactic nuclei; intergalactic medium.

- Dr. Nahum Arav , Associate professor, physics department, Virginia Tech, USA; PhD in 1994, University of Colorado, Boulder, USA.
  Fields of expertise: Outflows from active galactic nuclei, and spectroscopic observations

- Dr. Cor de Vries, SRON Netherlands Institute for Space Research in Utrecht, The Netherlands.
  Fields of expertise: X-ray high resolution instruments (RGS) data reduction and analysis

- Prof. Giorgio Matt, Professor at Università degli Studi Roma Tre, Rome, Italy.
  Physics Laurea at the Universita' degli Studi di Roma "La Sapienza" in 13/12/1985.
  Fields of expertise: X-ray data analysis; active galactic nuclei

- Dr. Shai Kaspi, Researcher at the Tel Aviv University School of Physics and Astronomy and the Wise Observatory, Tel Aviv, 69978, Israel. Fields of expertise: Phone: +972 03 6405247 Fax: +972 03 6408179 Email: shai@wise.tau.ac.il

- Bradley Peterson, Professor and Chair of Astronomy at the University Distinguished Scholar, The Ohio State University, USA
  B.Physics, University of Minnesota, 1974 and Ph.D., University of Arizona, 1978
  Fields of expertise: UV, optical and X-ray spectroscopy of active galactic nuclei

9.3 Addresses, telephone, fax, e-mail of all participants

Table 2: Addresses, telephone, fax, e-mail of all participants

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