Minutes of the Hard X-ray Astrophysics workshop, 2014, January 13-14, Paris
http://sigma-2.cesr.fr/phenix/home

The first part (Monday morning) has been devoted to some **scientific presentations** dedicated to the advances expected from an instrument with a sensitivity 10 to 100 times better than current missions in an energy range between 10 and 300 keV or even 600 keV. X-ray Binaries, AGNs, Galactic Center, SNR and GRB will clearly benefit from such characteristics.

Main objectives pointed out concern (summary):

- Black Holes Binaries: Determination of the spectral shape (cut-off), of the (ionised) reflection components (allowing reliable spin estimation), polarisation measurement, including during soft states and transitions.
- Neutron stars: Cyclotron line shaping with a high sensitivity. Depends on the hard X-ray continuum which itself will be better constrained.
- Galactic Centre Region: Flaring behaviour of Sgr A* to test accretion process in SMBH as well as its past activity through reflected emission (seen precisely in Hard X-rays). Future activity also expected with an object approaching Sgr A* and its potential disruption in 2014. In addition, hard X-ray emission from point sources, extended structures (PWN, filaments,…) or diffuse non-thermal component are still to be explained.
- ULX/Intermediate BH: Hard X-ray observations planned by Nustar but up to 80 keV only. Spectral transitions suspected and require broad band coverage.
- AGN: Accurate measurement of Fe line + underlying continuum, crucial to reveal the AGNs geometry but also its spin value. High sensitivity observations with E > 100 keV will allow to discriminate the nature of the hard X-ray emission (Compton or SSC) and to understand the link with the TeV emission for Blazars. Compton thick AGNs (absorbed up to ~ 10 keV) will be another important topic as well as the determination of the fraction of the CXB emission (peaks ~ 30 keV) due to extragalactic populations relatively to the true diffuse component.
- SNR: Two distinct scientific objectives with the ^{44}Ti line study (nucleosynthesis) and the hard X-ray continuun from electrons (shock acceleration)
- Polarimetry: Following Integral results showing a high fraction of polarisation in hard X-rays, it is obvious that more sensitive polarisation measurement in the hard X-ray range will give crucial information on the physical processes at work in the vicinity of compact objects.

Moreover, objectives for an all sky monitor instrument have been presented. They include in particular GRBs follow-up: Physics of the afterglow, its emergence and link with the prompt emission will be major topics together with polarisation measurements.
Polarimetry appears indeed as an important issue for many sources (XRB, GRB, GC, ULX, AGNs…).
A wide field instrument has also to be considered to discover and survey sources, give alert and study source evolution, including transient events.

Then, **instrumental developments** have been addressed:

Three types of detectors and associated frond-end electronics have been presented:

- Full custom ASICs and hybridation technology with CdTe detector developed at CEA/Sap have been described together with their measured performances. (O. Limousin)
- A 3D CdZnTe proto-type detector has been developed at DTU and is proposed in the MXGS instrument for the ASIM mission onboard the ISS. (C. Budtz-Jørgensen)
- A 3D Germanium DSSD has been developed at IRAP with associated electronics. Energy and position reconstruction are done in the digital domain. (O. Coeur-Joly and I. Mateu)

Two other major advances for Hard-X ray instruments have been proposed:
- Starting from Nustar experience, mirrors studies performed at DTU open the way toward major progress through new material combinations, new coating and improvement of building techniques. In particular, these studies show that the energy range of hard X-ray mirrors can be increased up to a few hundreds of keV. (F. Christensen)
- A self-spread out and self locked mast is under study at CNES (with industry). A 1 m long mast prototype exists and a 4 m long one is planned for 2014, together with mathematical model. The aim is to be able to scale capacities up to a 40 m long mast. (E. Hinglais and C. Casteras)

Two additional instrument concepts have been discussed:
- A wide field polarimeter (WPOL) based on a coded mask associated with a Compton camera consisting in 2 DSSD planes. It combines imaging and polarimetry capabilities in the range 5-200 keV. (P. Laurent)
- Recent advances and tests using bent crystal of Ge or GaAS have been reported. Then, the feasibility study of a wide band laue lens (90 keV - 670 keV) allows to propose a concept of 20 m focal lens telescope. The detector could consist of HPGe or CZT layers. (E. Caroli)

Lastly, we have discussed more precisely the possibility of proposing a hard X-ray focusing telescope for M4 indeed. A possibility is along the M3 proposal called PheniX, proposed by J.P. Roques et al, which considered two 40m focal lens telescopes made of a Germanium detector, reading the photons focused by mirror up to 200 keV, and an ASM. This mission has been described as it was for M3. The optical design has been presented by M. Chauvin. From this point, the concept can be refined/improved for an M4 proposal: an extension towards higher energy can be envisaged using improved mirrors (Danish team presentation). Possible options are to use other detectors (CdTe or Si). Potentially, we could also complement the mission by the Laue lens developed by the Italian teams.

In conclusion, there were discussions on scientific topics to be put in front. Some people think it is important to put one strong main topic (ie compact objects), others were considering that this telescope will make images and then it should be emphasized on spectro-imaging of diffuse sources (SNR, galaxy clusters,...).
A special emphasis has been put indeed on polarization, to be considered together with spectro-imaging.
It has been finally decided that a M4 focusing mission to cover the field above 4-5 keV (to include de Fe lines) up to 200 keV or more (511 keV?) can be envisaged. Another meeting in Toulouse in spring should precise this.
Concerning the scientific case, complementarities with future high sensitivity observatories have been discussed (SKA, CTA, Athena+).

This two day meeting was an occasion to review the scientific objectives linked to the hard X-ray domain, as well as the progress made in the instrumental domain. These points were addressed during very informative and high level presentations. The scientific presentations showed that a number of important scientific questions could be solved/would benefit from a hard X-ray mission providing an important sensitivity gap and polarimetry capabilities. The attainable sensitivity improvement is near one order of magnitude with respect to NuStar and 2 orders of magnitude with respect to Integral.
On the instrumental side, impressive progress has been made on several technical aspects: mirrors and Laue lens – hard X-ray detectors – frond-end electronics – long focal length (mast). It is clear that mature technology and solutions able to solve important scientific questions exist.

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