A study of combined capabilities of *XMM* and *INTEGRAL* in observations of AGNs.

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ABSTRACT

The *INTEGRAL* satellite is scheduled for launch in April 2001, about one year after *XMM*. The capabilities of its two main instruments, the imager IBIS (15 keV - 10 MeV, 12' spatial resolution) and the spectrometer SPI (20 keV - 8 MeV, E/dE 500 @1MeV), are complementary to those of *XMM* instruments for the study of AGNs. While *XMM* will yield the details of the complex soft X-ray emission of AGNs and thus help describe the gas in the AGNs, *INTEGRAL* will help to measure the properties of the primary X-ray emission and thus to deconvolve the primary component from the response of the surrounding gas. In this poster we present a preliminary study, based on the respective sensitivities of both instruments, of the feasibility of coordinated programs using both satellites.

1. Introduction

INTEGRAL is the European Space Agency's Gamma ray astronomy mission, dedicated to fine spectroscopy and imaging. The two main instruments will cover the energy range from ∼15 keV to ∼10 MeV: the spectrometer SPI will achieve an energy resolution of $E/\Delta E=500$ at 1MeV, while the imager IBIS will provide images of γ-ray sources with an angular resolution of only 12' (FWHM). In addition, two monitoring instruments will provide complementary observations in the X-ray band (Jem-X, 3-35 keV) and in the optical (OMC). All four instruments are co-aligned; SPI, IBIS and Jem-X are coded mask instruments and one of their main advantages is a wide field of view ($\sim 30^\circ \times 30^\circ$, Partially Coded at zero sensitivity) which in part compensate for the lower sensitivity of γ-ray instruments. Their characteristics are listed in Table 1 together with those of XMM instruments as well.

INTEGRAL is scheduled for launch in April 2 2001, aboard a Proton launcher. Thanks to its 72 hours long orbit, it will provide long uninterrupted periods of observations. Due to the proximity with the *XMM* launch the two satellites will be operative in the same period.

Table 1: Summary of the characteristics of of the two satellites instruments.

Instrument	Energy Range	Detector	Field of View (a)	Resolution		
		Area (cm^2)		Spectral (b)	Spatial (c)	Timing
IBIS	15-200 keV(d)	2621(d)	9° × 9° (FC)	14 @100 keV (d)	12′	5 ms(d)
	0.1-10 MeV(e)	3100(e)	29° × 29°(PC)	17 @ 1 MeV (e)	12′	20 min (e,f)
SPI	0.3-8 MeV	505.5	16°(FC)	500 @ 1 MeV	2°	0.06 ms
Jem-X	3-35 keV	500 (×2)	4.8°(FC)	47 @ 1 keV	3′	0.1 ms
EPIC	0.1-15 keV	1500 (×3)	33.5′×33.5′	20-50	6/15″	3sec-0.03ms
RGS	0.35-2.5 keV	100	5′	200-800	-	16 ms
OM	2.25-7.75 eV (g)		17′	0.5/1.0 nm	∼1″	50 ms

[a] FC=Fully Coded, PC=Partially Coded. [b] E/ΔE. [c] FWHM. [d] ISGRI. [e] PICSIT. [f] Imaging mode. [g] 1600-5500 Å

2. The goal: resolving the different components of an AGN spectrum

AGNs have been studied for many years and some general understanding of their behavior is available in every restricted part of the electromagnetic spectrum. Nevertheless, in the last years it became clear that to achieve a deeper understanding of the physical processes which are taking place in this kind of objects an important and promising approach is the possibility of performing simultaneous observations over a wide range of energies, as shown by recent results from BeppoSAX, whose sensitivity extends over the 0.1-300 keV range. In the energy range covered by X-ray instruments (which spans ideally the interval between few tenth to some tens of keV) there are in fact many different components which contribute to the shape of the spectral distribution. Even if the overall spectrum in the 2-10 keV range follows a powerlaw with photon indexes always close to α=1.7, a clear deviation from it is often measured either at lower and higher energies: below ∼1 keV there is a flux excess which is interpreted as the high energy tail of the UV bump (Turner & Pounds, 1989). This may be originating from absorption and reemission processes in the material surrounding the X ray source (probably in an accretion disk or in a corona); above few keV X-ray reprocessing becomes important, as it can be seen from the presence of a fluorescence iron line and of a compton reflection hump extending from ∼5 to ∼100 keV (Lightman & White, 1988). Finally, at higher energies, CGRO observations showed two different behaviors of AGNs (Kurfess, 1994): the spectrum of NCG4151, a Seyfert galaxy, shows a cutoff around few hundreds of keV which is consistent with thermal componization models. 3C273, on the other hand, didn't show any such a feature, as its emission was detected with EGRET up to very high energies (few GeV). A spectral break (but not an exponential cutoff) was detected around 1MeV, where the νF_ν distribution peaks, showing that the largest part of the energy is produced here (Fig. 1).

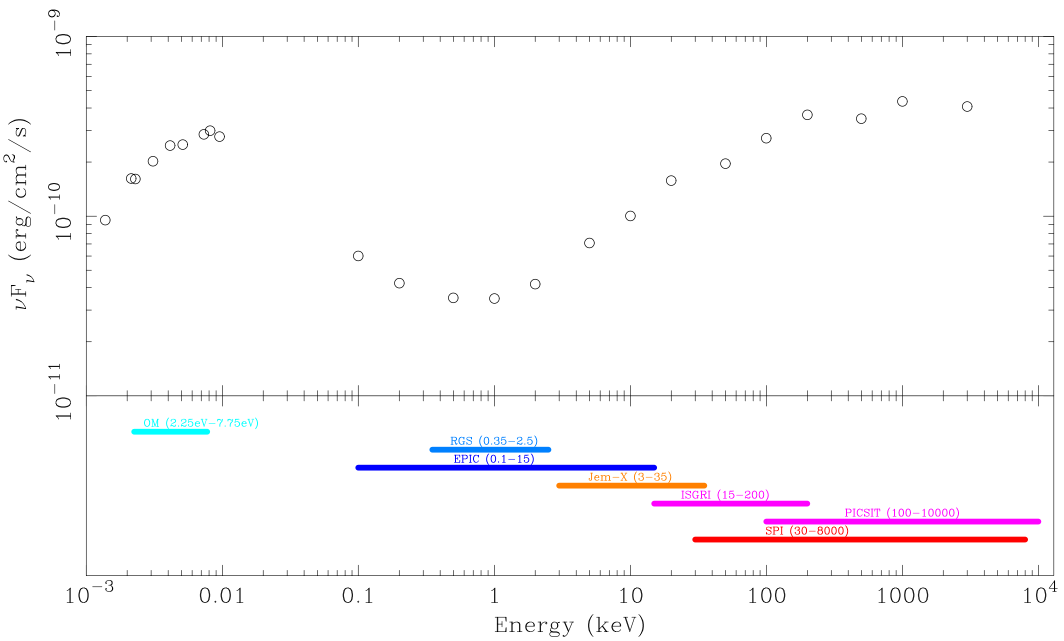

Fig. 1.— The νF_ν representation of 3C273 spectrum (build from the average values in Türler et al. 1998) is shown above the energy coverage of *XMM* and *INTEGRAL* instruments.

3. The mean: simultaneous measurements over a wide energy band using *XMM* and *INTEGRAL*

Spectral features in the soft region, emission lines and absorption edges, and the iron line around 6.4 keV will be observed and studied thanks to *XMM* capabilities . Nevertheless, to create a self-consistent model of the emission processes which take place inside AGNs, their spectral properties need to be analyzed on a wide energy range. A first reason is that in reprocessing models, where the important quantity is the incoming energy flux and not the photons flux, we must take into account the region of the spectrum where the greatest amount of energy is released. The spectrum of 3C273 shows indeed that the νF_ν distribution peaks around 1MeV; if we aim at studying the emission model we therefore need simultaneous observations on the whole high energy region of the spectrum, trying to put constraints on the fraction of energy reprocessed, on the geometry of the system and on possible correlations in the temporal variability between the different components of the spectrum. Another reason is that *ASCA* and *BeppoSAX* observations of iron line features have shown that its fitted shape it is strongly dependent on the assumptions made on the continuum below, which cannot be constrained within the narrow 2-10 keV band: it is in fact necessary to fix simultaneously the intrinsic powerlaw index and the amount of reflection, which itself depends on many parameters as system inclination angle, ionization state and on the high energy part of the spectrum (e.g. on the exponential cutoff energy). Simultaneous *XMM* and *INTEGRAL* AGNs observations will be of prime importance in the coming years.

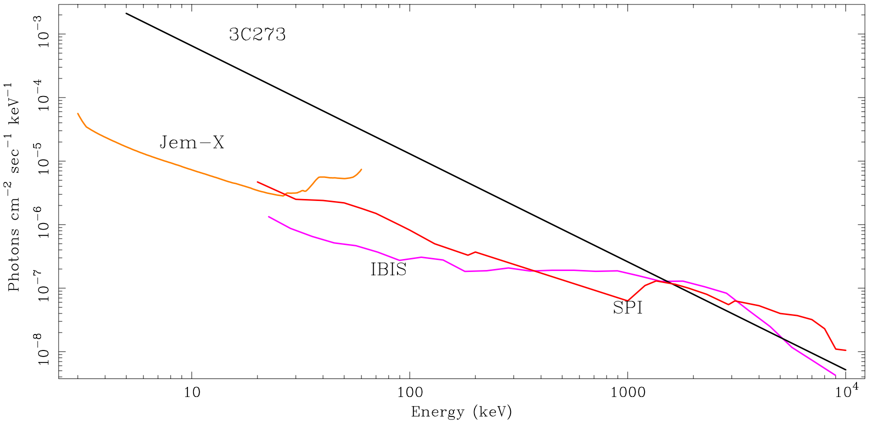

Fig. 2.— The continuum sensitivity of *INTEGRAL* instruments compared with a powerlaw approximation of 3C273 spectrum (t=10^6 sec, dE=E, 3σ).

4. Technical feasibility

One of the main differences between *XMM* and *INTEGRAL* is their sensitivity. γ-ray instruments are in fact quite limited compared with X-ray ones, as numerous factors come into play at γ energies : the background (cosmic and particle induced), the impossibility to apply focusing techniques and the fact that the spectrum of normal sources decreases with increasing energies. Nevertheless *INTEGRAL* will partially compensate those restrictions: its instruments have large areas ($\sim$3000 cm^2 for IBIS, 505 cm^2 for SPI) and will indeed be capable of measuring gamma ray sources spectra in an amount of time of the order of some hours (Fig. 2 shows the 3σ sensitivity limit for dE=E and 10^6 seconds). Another big advantage is that thanks to the large FOVs many objects will be visible at the same time, so that *INTEGRAL* could indeed observe around a given sky direction for periods of time of the order of some weeks, during which *every* source would be *continuously* monitored. The fact we want to underline here is that the amount of time *INTEGRAL* will need to constrain the medium/high energy spectral shape is not much larger then the time that an *XMM* observation might take to detect low contrast features on the bright soft X-ray continuum of AGNs: their measure critically depends in fact on the precision that one can obtain on the measure of the underlying continuum.

We consider as an example the continuum spectrum of 3C273 in the *XMM* and *INTEGRAL* energy range, modeled in this energy range by a powerlaw $f_\nu(E) = 0.013 \cdot E^{-1.7}$photons cm^{-2} sec^{-1} keV^{-1} and estimate the time needed to obtain a signal to noise ratio greater then a given value for spectral features detection. To compute the signal to noise ratio for the *XMM* instruments we apply the simplified formula

$$S/N \simeq S/\sqrt{S} \simeq \sqrt{f_\nu(E) \cdot \mathrm{Area} \cdot \Delta\mathrm{E} \cdot \mathrm{t}}$$

supposing the observation is photon statistic dominated and neglecting the background. In the RGS the galactic diffuse emission can indeed contribute to a certain level, but this only means that the resulting integration times could be slightly underestimated. With EPIC we are interested in studying the broad iron line at 6.4 keV, and therefore consider an energy bin of width dE=0.1 keV at E=6 keV; for the RGS we used instead E=0.5 keV and dE=10^{-3}, (comparable with the instrument resolution). The EPIC and the RGS Effective Area are respectively ∼1600 cm^2 (@ 5 keV) and 100cm^2. Then we consider ISGRI, the layer of IBIS sensitive at lower energies: in this case we cannot neglect the background and therefore must apply the formula for coded mask instruments:

$$S/N = \frac{\frac{1}{2}\cdot \mathrm{Area}\cdot \mathrm{t}\cdot \mathrm{f}_\nu(\mathrm{E})\Delta\mathrm{E}}{\sqrt{\frac{1}{2}\cdot \mathrm{Area}\cdot \mathrm{t}\cdot (2\cdot \mathrm{B(E)} + \mathrm{f}_\nu(\mathrm{E}))\Delta\mathrm{E}}}$$

where B(E) is the background flux and the factor $\frac{1}{2}$ takes into account the open fraction of the mask. ISGRI's effective area is 2621 cm^2; we consider a bin at E=100 keV of width dE=E and use an estimate for B=10^{-4} counts·cm^{-2}·sec^{-1} (Lei, 1998).
All results can now be expressed with the formula:

$$t_{obs} = C \cdot (S/N)^2$$

where $\mathrm{C}_{\mathrm{EPIC}}$=3.7 s, $\mathrm{C}_{\mathrm{RGS}}$=237 s and $\mathrm{C}_{\mathrm{ISGRI}}$=221 s and represented as in Fig. 3: EPIC sensitivity, as we expected, is outstanding also for features detection, and few hundreds of seconds would be sufficient to achieve a S/N ratio greater than 10; for the RGS, indeed, to achieve the same S/N ratio value is needed an amount of time of the order of ∼ 10^4-10^5 seconds, which is comparable with the results obtained for ISGRI.

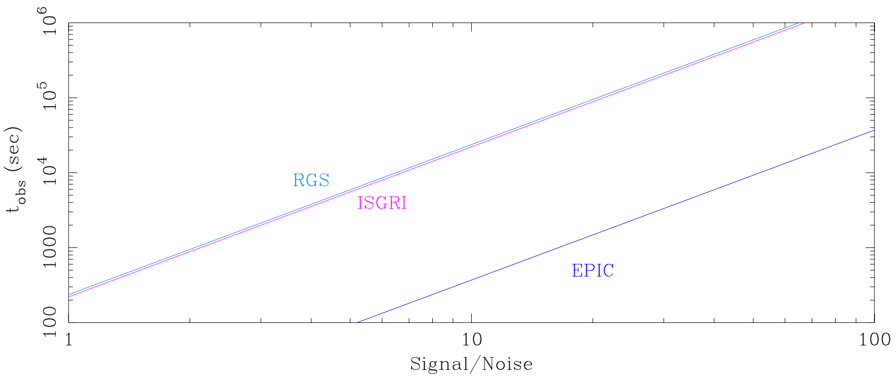

Fig. 3.— A graphical representation of the results of our computation. t_{obs} is the integration time required to reach a given signal to noise ratio value for spectral features detection.

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