A survey for gamma-ray emission from OB associations with *INTEGRAL*: some preliminary results

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Abstract: Recent studies indicated that there might be a correlation between OB associations and unidentified gamma-ray sources from the 3EG catalogue. Moreover, when extrapolating the fluxes measured by EGRET at energies higher than 100 MeV with a power-law down to the energy range of ISGRI, the expected count rates should be large enough to be detected with *INTEGRAL*. As most of these OB associations are located within the Galactic plane, they are being observed by *INTEGRAL* as part of the Core Program (CP) during both the Galactic Plane Scans (GPS) and the Galactic Center Deep Exposure (GCDE). Combining public and CP data, we have performed a survey for gamma-ray emission from OB associations and the first results are presented in this paper.

1 OB Associations

OB associations are made up of a group of stars, specifically including O type stars, and eventually B type stars. As these stars are very massive, they exhibit features such as fast stellar winds :

$$v_\infty \simeq 2000 \text{ km s}^{-1},$$

and large mass loss rates :

$$\begin{aligned} \dot{M} &\simeq 10^{-5} M_\odot \text{yr}^{-1} \text{ (for O type stars)} \\ \dot{M} &\simeq 10^{-4} M_\odot \text{yr}^{-1} \text{ (for WR type stars)}. \end{aligned}$$

The presence of massives stars also implies that they are rather young ($< 10^7$yr), and that these associations are found in star forming regions such as the spiral arms of the Galaxy. It should also be noted that the stars belonging to these associations are too far apart from each other to be bound by gravitation, as opposed to clusters.

OB associations are formed when an instability causes a cloud of interstellar matter to collapse, thus giving rise to a set of stars of all masses. When the most massive one reaches the end of its life and explodes as a supernova, it creates a shock front that will expand and cause the density in another region to increase.

O stars are detected in X-rays, and so are a fraction of B stars.

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Figure 1: The Scorpius constellation, showing the Upper Scorpius OB association (Preibisch et al. 1998).

2 OB associations in γ-rays

Recent studies on the possible association of unidentified EGRET sources with different types of galactic objects indicated a significant correlation of sources from the 3 EG catalogue with OB associations (Romero, Benaglia & Torres 1999). Most of these OB associations, being usually located in the Galactic Plane, are observed during the *INTEGRAL* Core Programme. Deriving (accurate) positions and fluxes of these sources with the IBIS instrument onboard *INTEGRAL* might allow us to identify the counterparts of these sources. Furthermore, it might also help us determine whether the observed continuum emission is coming :

- from radio-quiet pulsars (as suggested by Romero et al. 1999);
- from shock fronts created by the interactions of the stellar winds of massive stars with the ambient ISM (Manchanda et al. 1996); or
- from hydrodynamic shocks in the winds :
  - of individual stars (Chen & White 1991); or
  - of massive colliding wind binary systems (Eichler & Usov 1993, Mücke & Pohl 2001, Benaglia et al. 2001).

The results of this study should help us to identify the so-far unknown counterparts of a large number of galactic γ-ray sources. For instance, in the third scenario hereabove, observations of non-thermal radiation at other energies (γ- and X-rays) should allow to constrain the properties of the relativistic electrons and hence provide an elegant means to measure the magnetic fields of early-type stars. Due to the spectral features of these stars, their magnetic fields cannot be measured by classical techniques (e.g. Zeeman splitting).

The sources listed by Romero et al. (1999) have photon indices near $\Gamma \sim 2$. Therefore, the number of photons at a given energy is $n(E) = \alpha \times E^{-\Gamma}$. According to Romero et al., the EGRET fluxes (> 100 MeV) are:
• 34×10^{-8} ph cm^{-2} s^{-1} for a typical WR counterpart,
• 47×10^{-8} ph cm^{-2} s^{-1} for a typical Of counterpart, and
• 45×10^{-8} ph cm^{-2} s^{-1} for a typical OB association counterpart.

For a power-law spectrum, the flux above 100 MeV is given by

$$\int_{100\,\mathrm{MeV}}^{\infty} n(E)\,dE = \alpha \int_{100\,\mathrm{MeV}}^{\infty} E^{-2}\,dE = \alpha/(10^5\,\mathrm{keV})$$

yielding
$\alpha_{\mathrm{WR}} = 34 \times 10^{-3}\,\mathrm{ph\,cm^{-2}\,s^{-1}\,keV}$,
$\alpha_{\mathrm{Of}} = 47 \times 10^{-3}\,\mathrm{ph\,cm^{-2}\,s^{-1}\,keV}$ and
$\alpha_{\mathrm{OB}} = 45 \times 10^{-3}\,\mathrm{ph\,cm^{-2}\,s^{-1}\,keV}$.
Extrapolating the power-law spectrum to the IBIS energy range (15 keV – 10 MeV), we find for a typical OB association a continuum flux of $45 \times 10^{-9}\,\mathrm{ph\,cm^{-2}\,s^{-1}\,keV^{-1}}$ @ 1 MeV.

3 Analysis with *INTEGRAL*

The preliminary results were first obtained with the Off-line Scientific Analysis (OSA) software, version 4.2. The analyses are being repeated with OSA 5.0 to take advantage of the better background reduction introduced with this new release.

The only instrument used up to now is ISGRI, a coded-mask imager offering a spatial resolution of 12′ over an energy range from approximately 23 to 1000 keV (Lebrun et al. 2003).

4 Candidates and data

The data taken by *INTEGRAL* more than one year ago are now in the archive, which means that approximately one and a half year of data is available. Below is a table giving for each OB association (adapted from Humphreys 1978) in our sample the approximate time during which it was located in the fully coded field of view of the ISGRI instrument.

Region	Right Ascension [deg]	Declination [deg]	ISGRI time [ks]
Sgr OB1	272.0	-21.5	1091
Cyg OB3	301.2	35.8	2320
Cyg OB1	304.4	37.6	2470
Cyg OB8	303.2	41.0	1625
Cyg OB9	305.8	39.9	1861
Cyg OB2	308.1	41.3	2230
Cas OB5	359.1	61.6	2276
Cas OB6	40.8	61.4	39
Gem OB1	92.5	21.6	1241
Vel OB1	132.5	-45.0	1705
Car OB1	158.9	-59.1	1737
Coll 228	160.7	-60.0	1688
Car OB2	166.9	-59.8	1110
Ara OB1a	249.9	-46.8	1649
NGC 6204	251.6	-47.0	1601
Sco OB1	253.1	-42.2	1146

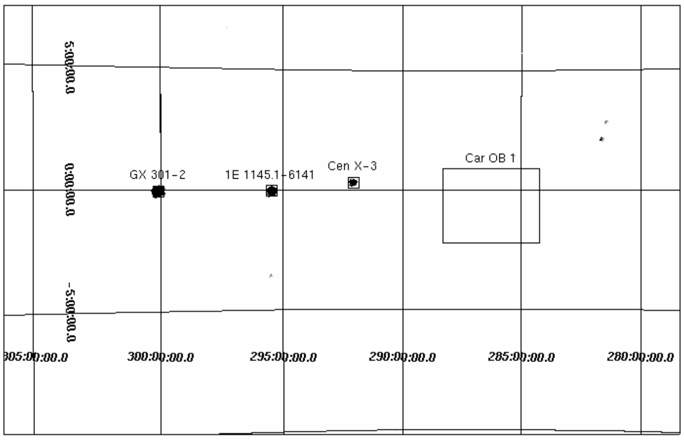

Figure 2: ISGRI significance map of the Car OB 1 region (20 – 40 keV), produced with OSA 5.0.

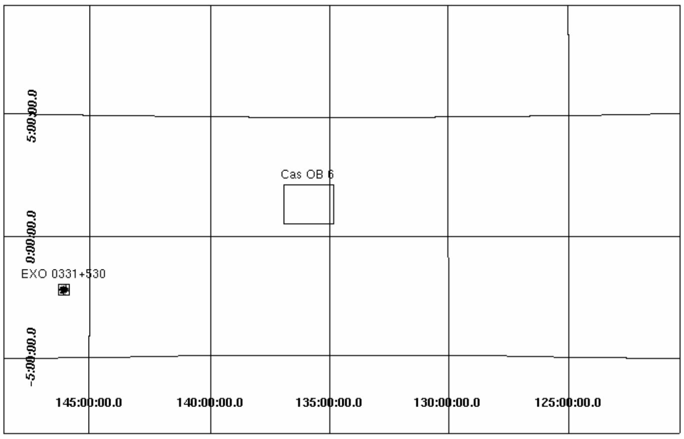

Figure 3: ISGRI significance map of the Cas OB 6 region (20 – 40 keV), produced with OSA 5.0.

5 Preliminary results

The first tests carried out using OSA 4.2 did not allow to detect any signal from the few OB associations that were studied. The improvements in OSA 5.0, especially in the background correction, might help change this situation.

References

Benaglia P., Romero G.E., Stevens I.R., et al., 2001, A&A, 366, 605
Chen W., White R.L., 1991, ApJ, 366, 512
Eichler D., Usov V., 1993, ApJ, 402, 271
Humphreys R., 1978, ApJS, 38, 309
Lebrun F., Leray J.P., Lavocat P., et al., 2003, A&A, 411, L141
Manchanda R.K., Polcaro V.F., Norci L., et al., 1996, A&A, 305, 457
Mücke A., Pohl M., 2001, in *Interacting Winds from Massive Stars*, eds. A.F.J. Moffat, N. St.-Louis, ASP Conf. Series, 260, 355
Preibisch Th., Guenther E., Zinnecker H., et al., 1998, A&A, 333, 619
Romero G.E., Benaglia P., Torres D.F., 1999, A&A, 348, 868