A&A manuscript no.
(will be inserted by hand later)

Your thesaurus codes are:
missing; you have not inserted them

ASTRONOMY
AND
ASTROPHYSICS
October 12, 2006

XMM–Newton and ESO observations of the two Unidentified γ–ray Sources 3EG J0616−3310 and 3EG J1249−8330*

N. La Palombara[1], R. P. Mignani[2], E. Hatziminaoglou[3], M. Schirmer[4], G.F. Bignami[5,6], P. Caraveo[1]

[1] INAF – IASF Milano, Via E. Bassini 15, I–20133 Milano (I)
[2] Mullard Space Science Laboratory, University College London, Holmbury St Mary, Dorking, Surrey RH5 6NT (UK)
[3] Instituto de Astrofisica de Canarias, Via Lactea, E–38200 La Laguna–Tenerife (E)
[4] Isaac Newton Group of Telescopes, Edificio Mayantigo, Calle Alvarez Abreu 68, E–38700 Santa Cruz de la Palma (E)
[5] Centre d'Étude Spatiale des Rayonnements (CESR), CNRS–UPS, 9 Avenue du colonel Roche, F-31028 Toulouse (F)
[6] Università di Pavia, Dipartimento di Fisica Teorica e Nucleare, Via Ugo Bassi 6, I–27100 Pavia (I)

the date of receipt and acceptance should be inserted later

Abstract. The limited angular resolution of γ–ray telescopes prevents a direct identification of the majority of sources detected so far. This is particularly true for the low latitude, probably galactic, ones only 10 % of which has been identified. Most counterparts of the identified low–latitude γ–ray sources are *Isolated Neutron Stars* (INS), both *radio–loud* and *radio–quiet* (Geminga–like) objects, which are characterised by an extremely high value of the *X–ray–to–optical* flux ratio $f_{\rm X}/f_{\rm opt}$. Therefore, the systematic X–ray and optical coverage of low–latitude unidentified γ–ray sources aiming at high $f_{\rm X}/f_{\rm opt}$ sources seems one of the most promising ways to spot INS candidate counterparts. Since low latitude sources are heavily affected by the interstellar absorption at both X–ray and optical wavelengths, we have focussed on two middle–latitude, probably galactic, *GRO/EGRET* sources: 3EG J0616−3310 and 3EG J1249−8330. These two sources, which could belong to a local galactic population, have been selected owing to their relatively good positional accuracy, spectral shape and lack of candidate extragalactic radio counterparts. Here we report on X-ray observations of the two γ–ray error boxes performed with *XMM–Newton* and on their optical follow–up carried on with the *Wide Field Imager* at the ESO/MPG 2.2m telescope. Less than half of the $\sim$ 300 sources detected by the X–ray coverage have no optical counterparts. Among those, we have selected few interesting sources with $f_{\rm X}/f_{\rm opt} \geq 100$, which we consider promising INS candidates.

Key words: stars: neutron– γ–rays: observations – X–rays: general, surveys, catalogues

* This work is based on observations obtained with *XMM-Newton*, an ESA science mission with instruments and contributions directly funded by ESA Member States and NASA. Optical observations have been obtained with the ESO/MPG 2.2m at La Silla (Chile) under programs 68.D–0478(A) and 68.D–0478(B).

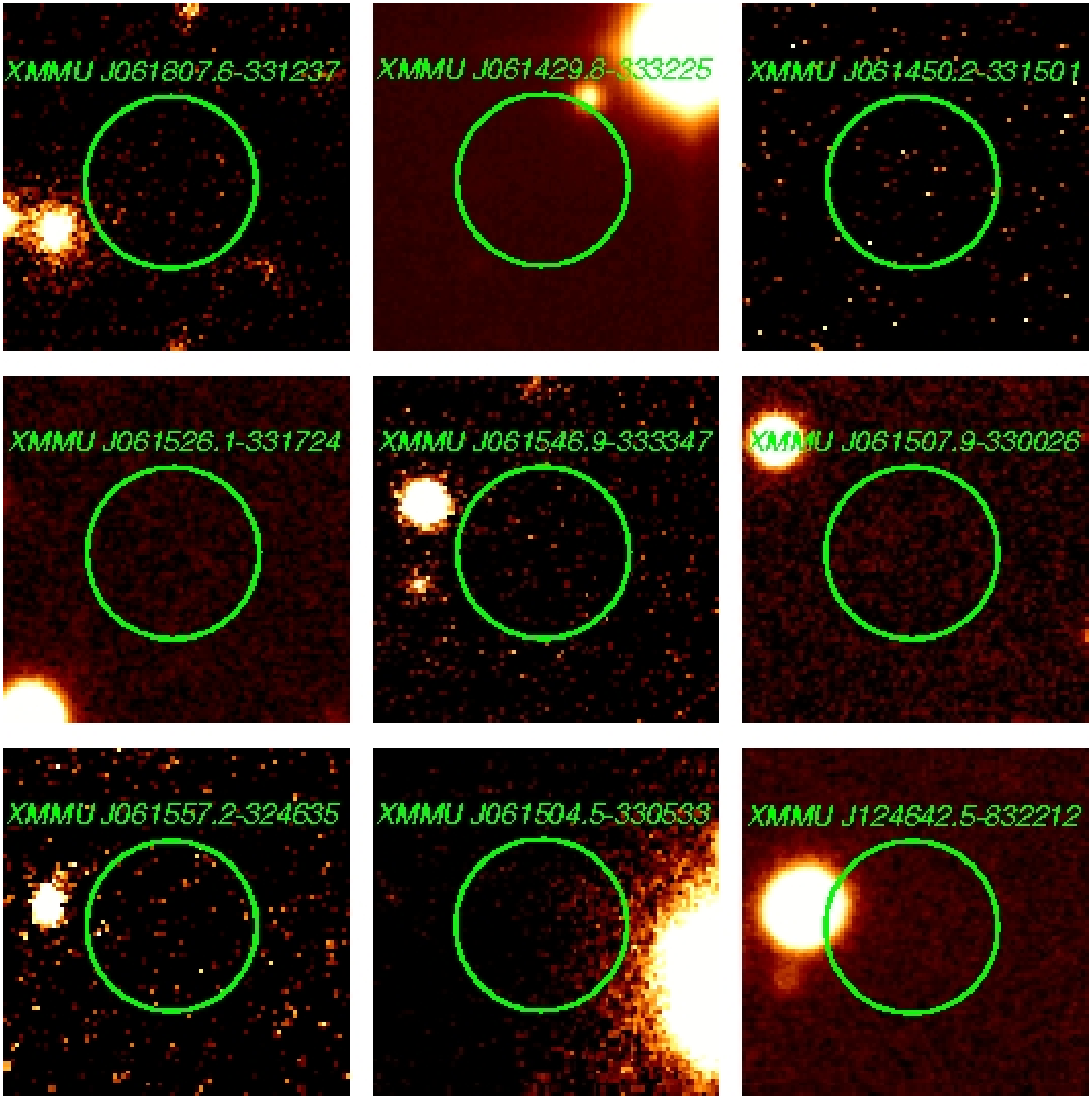

Fig. 1. Finding charts of the X–ray sources listed in Table 7. For each source the 5″ radius error circle is superimposed on the corresponding V–band *WFI* image.

Table A1. Range of the applicable $B-V$ colours for the selected classes of objects

CLASS	(B-V) min	(B-V) max	REFERENCE
Stars	-0.2	+1.8	Esa (1997)
WDs	-0.3	+1.6	Bergeron et al. (1995)
CVs	+0.2	+2.0	Henden & Honeycutt (1995)
Galaxies	+0.2	+1.6	Prugniel & Heraudeau (1998)
Clusters	+1.0	+1.5	Chieregato (2005)
AGN	-0.6	+1.6	Veron-Cetty & Veron (2003)

Appendix A: Correction of the Classification Scheme

According to Chieregato (2005), for each class of sources the f_X/f_{opt} in the *XMM–Newton* is obtained from the corresponding *Hamburg/RASS* one as follows:

$$\frac{f_{X,\rm XMM}}{f_B} = \frac{f_{X,\rm Hamburg-RASS}}{f_B} \times \frac{f_{X,\rm XMM}}{f_{X,\rm Hamburg-RASS}} \quad (A1)$$

We considered separately the corrections due to the different energy ranges and to the different spectral models:

$$\frac{f_{X,\rm XMM}}{f_{X,\rm Hamburg-RASS}} = \frac{f_{0.3-10,\rm PL}}{f_{0.1-2.4,\rm MOD}} = \frac{f_{0.3-10,\rm PL}}{f_{0.1-2.4,\rm PL}} \times \frac{cf_{0.1-2.4,\rm PL}}{cf_{0.1-2.4,\rm MOD}} \quad (A2)$$

For each of the eight *XMM–Newton* pointings we estimated both the flux ratio $f_{0.3-10,\rm PL}/f_{0.1-2.4,\rm PL}$ and the conversion factor $cf_{0.1-2.4,\rm PL}$. In addition, for each class of sources we estimated also the specific conversion factor $cf_{0.1-2.4,\rm MOD}$.

The $f_{X,\rm XMM}/f_V$ values were obtained from the $f_{X,\rm XMM}/f_B$ ones according to the relation:

$$\frac{f_{X,\rm XMM}}{f_V} = \frac{f_{X,\rm XMM}}{f_B} \times \frac{f_B}{f_V} \quad (A3)$$

where

$$\frac{f_B}{f_V} = \frac{f_{B,\rm Vega}}{f_{V,\rm Vega}} \times 10^{-(B-V)/2.5} = 1.957 \times 10^{-(B-V)/2.5} \quad (A4)$$

For each class of celestial source we considered the range of $B-V$ colours which include 99 % of the total sample (see Table A1).

For candidate counterparts with only *GSC–2.3* photometry, we considered the correction factor for the different blue magnitude:

$$\frac{f_{X,\rm XMM}}{f_{B_J}} = \frac{f_{X,\rm XMM}}{f_B} \times \frac{f_B}{f_{B_J}} \quad (A5)$$

where:

$$\frac{f_B}{f_{B_J}} = \frac{f_{B,\rm Vega}}{f_{B_J,\rm Vega}} \times 10^{-\frac{B-B_J}{2.5}} = 0.822 \times 10^{-\frac{B-B_J}{2.5}} \quad (A6)$$

and $B - B_J = 0.28 \times (B-V)$ (Reid et al. 1991). Also in this case we referred to Table A1 for the $B-V$ colours of each class of source.

Appendix B: Measurement of the X–ray–to–optical flux ratios

We computed the $f_{X,\rm XMM}/f_{opt}$ ratios for all the candidate counterparts. X–ray fluxes are the same determined in §**??** while optical fluxes were obtained from the measured *WFI* magnitudes using the Pogson formula $f_m = f_{m=0} \times 10^{-m/2.5}$, assuming $f_{m=0}$ = 2.904, 6.478, 3.240, 3.828 and 1.997×10^6 erg cm^{-2} s^{-1} for $m = U, B, V, R$ and I passbands, respectively (Zombeck 1990).

Since for the B_J band, there is no simple relation to obtain the optical flux, we first estimated its Vega band flux. This is given by the relation $f_{B_J=0} = f_{\lambda_{\rm eff}(B_J)} \times W_{\rm eff}(B_J)$, where $\lambda_{\rm eff}(B_J)$ and $W_{\rm eff}(B_J)$ are, respectively, the effective wavelength and width of the filter, while $f_{\lambda_{\rm eff}(B_J)}$ is the specific flux calibration at $\lambda_{\rm eff}(B_J)$ for $B_J = 0$. By referring to the *Asiago Database on Photometric Systems* (Moro & Munari 2000) we found $\lambda_{\rm eff}(B_J) = 4731$ Å and $W_{\rm eff}(B_J) = 1333$ Å. In order to obtain the specific flux calibration f_{4731}, we considered the spectral distribution of Vega provided by Hayes (1985) and performed a linear interpolation between 4725 and 4750 Å. In such a way we obtained $f_{4731} = 5.457 \times 10^{-9}$ erg cm^{-2} s^{-1}Å^{-1} and $f_{B_J=0} = 1333 \times 5.457 \times 10^{-9} = 7.274 \times 10^{-6}$ erg cm^{-2} s^{-1}. Finally, we used the Pogson formula $f_{B_J} = f_{B_J=0} \times 10^{-B_J/2.5}$ to obtain the optical flux for a given magnitude B_J. In the case of the F band magnitude, we applied the same procedure but assuming $\lambda_{\rm eff}(F)$ = 6555 Å, $W_{\rm eff}(F)$ = 767 Å and $f_{6555} = 1.731 \times 10^{-9}$ erg cm^{-2} s^{-1} Å thus obtaining $f_F = 1.328 \times 10^{-6} \times 10^{-F/2.5}$ erg cm^{-2} s^{-1}.

References

Bergeron, P., Wesemael, F., & Beauchamp, A. 1995, , 107, 1047
Chieregato, M. 2005, Ph.D. Thesis
Esa. 1997, VizieR Online Data Catalog, 1239
Hayes, D. S. 1985, in IAU Symp. 111: 'Calibration of Fundamental Stellar Quantities', 225–249
Henden, A. A. & Honeycutt, R. K. 1995, , 107, 324
Moro, D. & Munari, U. 2000, , 147, 361
Prugniel, P. & Heraudeau, P. 1998, VizieR Online Data Catalog, 7206
Reid, I. N., Brewer, C., Brucato, R. J., et al. 1991, , 103, 661
Veron-Cetty, M. P. & Veron, P. 2003, VizieR Online Data Catalog, 7235
Zombeck, M. V. 1990, 'Handbook of space astronomy and astrophysics' (Cambridge University Press, 1990, 2nd ed.)