УДК 524.62

ФОНОВОЕ ИЗЛУЧЕНИЕ ГАЛАКТИКИ В ЖЕСТКИХ РЕНТГЕНОВСКИХ ЛУЧАХ ПО ДАННЫМ ОБСЕРВАТОРИИ «ИНТЕГРАЛ»

Р.А. Кривонос, М.Г. Ревнивцев, С.Ю. Сазонов,
Е.М. Чуразов, С.А. Гребенев, Р.А. Сюняев

HARD X-RAY EMISSION FROM THE GALACTIC RIDGE

R. Krivonos, M. Revnivtsev, E. Churazov, S. Sazonov, S. Grebenev, R. Sunyaev

Фоновое излучение Галактики в рентгеновском диапазоне энергий было открыто более 30 лет назад и до недавнего времени его происхождение оставалось неизвестным. Сразу после его открытия было предложено два возможных механизма образования. С одной стороны, предполагалось наличие очень горячего газа в Галактике, с другой стороны, наблюдаемое излучение представлялось результатом суммарного излучения неразрешенных точечных источников малой рентгеновской светимости. Недавние исследования фонового излучения Галактики, проведенные на спутниках РХТЕ и ИНТЕГРАЛ, показали справедливость последнего предположения. В данной работе представлены результаты исследования морфологии фонового излучения Галактики с помощью телескопа IBIS обсерватории ИНТЕГРАЛ. Карта распределения интенсивности фонового излучения хорошо согласуется с распределением звездной массы Галактики, полученной из наблюдений на длинах волн 3.5–4.9 мкм. Форма спектра излучения в диапазоне энергий 17–130 кэВ совпадает со спектром типичных двойных систем малой рентгеновской светимости, излучающих в этом диапазоне энергий, – аккрециирующих белых карликов. С использованием известной светимости центральной части Галактики в спектральной области 3.5–4.9 мкм получена оценка светимости фонового излучения в рентгеновском диапазоне энергий $\sim 10^{38}$ эрг/с (17–60 кэВ). При такой светимости общее количество аккрециирующих белых карликов в двойных системах с малой рентгеновской светимостью ($>10^{32}$ эрг/с) составляет 10^5.

We present results of study of the Galactic ridge X-ray emission (GRXE) in hard X-rays performed with IBIS telescope aboard INTEGRAL. Imaging capabilities of coding aperture telescope make it possible to account for flux from bright Galactic point sources and wide field of view permits to collect large flux from underlying GRXE emission. Extensive study of the IBIS/ISGRI detector background allowed us to construct the model which predicts the detector count rate with ~1% accuracy in the energy band 17–60 keV. Derived longitude and latitude profiles of the ridge emission are in good agreement with Galactic distribution of stars obtained from infrared observations. This along with obtained hard X-ray spectrum of the Galactic ridge emission strongly indicates its stellar origin which support findings of [1]. Derived unit stellar mass emissivity of the ridge in the energy band 17–60 keV $\sim 1.0 \times 10^{27}$ agrees with that obtained for accreting magnetic white dwarf binaries - dominant contributors to the GRXE at these energies. At energies higher than 70–80 keV no additional contribution to the total emission of the Galaxy apart from detected point sources is detected.

Intoduction

Emission of our Galaxy in different spectral bands has very different origin. For example, in near infrared, optical, and ultraviolet spectral bands the Galactic emission is dominated by stars. In hard gamma rays the Galactic emission is due to interactions of high energy cosmic rays with the Galactic interstellar matter (ISM). In X-ray and soft gamma ray energy bands the emission of the Galaxy is dominated by some hundred bright compact sources (accreting neutron stars and black holes). An additional weak X-ray component was detected, which was not resolved into point sources in existing observations. This glow was called the Galactic ridge X-ray emission (GRXE), because it concentrates towards the Galactic plane forming something like a ridge of X-ray glow.

In order to determine the origin of the hard X-ray Galactic background it is very important to investigate whether the GRXE in hard X-rays is distributed similar to the stellar distribution, indicating its stellar origin, or it more closely follows the interstellar gas density distribution, thus connecting to the high energy gamma ray background seen e.g. by EGRET. Does the spectrum of the GRXE have a cutoff at energies ~30–50 keV due to the typical cutoff in spectra of magnetic CVs [2], or it has a power law spectral shape up to higher energies as would be expected if the Galactic background emission were induced by cosmic ray electrons?

In this paper we present results related to the spatial distribution of the GXRE, investigation of the spectrum can be found in [5].

Method

The method of the sky reconstruction employed in the IBIS telescope (coded mask imaging) does not allow one to study directly diffuse structures that are significantly larger that the size of the mask pixels. Therefore, in order to study large scale structures, such as the GRXE, we should use IBIS/ISGRI as a collimated instrument. The detector collects photons from point sources and diffuse emission. Measurement of the point sources contribution to the total detector count rate makes it possible to recover the flux of the GRXE. The success of such approach strongly depends on the accuracy of the instrumental background modelling.

At any given time the detector count rate of IBIS/ISGRI consists of:

– Cosmic X-ray Background (CXB),

– Emission from point sources,

– Galactic ridge X-ray emission, if the field of view of the telescope is directed towards the Galactic plane,

– Detector internal background, caused by different processes including activation of different elements of the spacecraft, interaction of the detector material with cosmic-rays, etc.

The Cosmic X-ray Background contributes ~0.5 Crab in the energy band 17–100 keV and can be considered very uniform over the sky. The contribution of point sources to the detector count rate can be almost perfectly predicted using the telescope coded mask imaging technique. The list of detected sources used in our subtraction procedure includes more than 360 sources on the entire sky. Typically the detection limit for regions near the Galactic plane is at the level of ~1 mCrab.

The possible remaining contribution of undetected point sources on the detector can be estimated using the luminosity function of Galactic X-ray sources [4]. The majority of the inner Galactic plane was observed by INTEGRAL/IBIS for more than 0.5–0.8 Ms. Such an exposure corresponds to an IBIS/ISGRI detection sensitivity . 1 mCrab . 10^{11} erg/s/cm^2 in the energy band 17–60 keV, which in turn corresponds to a source luminosity . 10^{35} erg/s for the Galactic Center distance. The contribution of sources brighter than this limit was subtracted from the detector count rate. Therefore, from Fig.12 in [3] we can conclude that the contribution of undetected point sources does not significantly affect the emission of the GRXE.

To predict the detector count rate not caused by photons arriving from the sky we have used a specialy constructed background model (see [5] for details).

Results

We constructed longitude and latitude profiles of the integrated emission from point sources and of the hard X-ray Galactic ridge emission. For construction of the longitude profile of the GRXE we selected those INTEGRAL observations where the IBIS axis was directed within 5 degrees of the Galactic plane and then averaged the obtained GRXE (see Fig. 1 and figures in [5]).

In order to extract information about the three dimensional structure of the Galactic ridge in hard Xrays we have compared the profiles of GRXE proxies (with known properties) with those obtained by us from INTEGRAL/ISGRI data. In particular, the current understanding of the GRXE morphology implies that the best tracer of the GRXE is the near infrared surface brightness [1].

The map of the NIR intensity was then convolved with the IBIS/ISGRI collimator response function. The resulting longitude and latitude profiles of the COBE/DIRBE NIR intensity are shown by the solid line on Fig.1. We also constructed a map of the IBIS/ISGRI surface brightness distribution of the GRXE in the 17-60 keV energy band (see Fig. 3). The map of the NIR intensity is shown by contours.

It is clearly seen that the GRXE intensity distribution very closely follows the NIR intensity distribution and thus traces the stellar mass density in the Galaxy. In order to show that the correlation of the hard X-ray GRXE with the cosmic–ray induced gamma–ray background emission is not nearly as good as its correlation with the NIR intensity, we present Fig.2. Here one can see the distributions (convolved with the IBIS/ISGRI collimator response function) of the EGRET gamma–ray background, Galactic neutral hydrogen (HI), and molecular gas (CO emission).

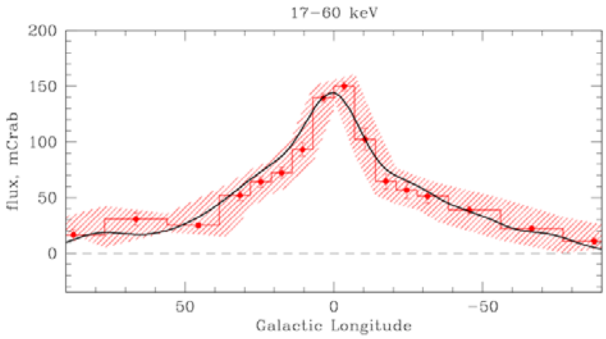

Fig. 1. Longitude profile of the GRXE measured by INTEGRAL/IBIS/ISGRI (histogram and shaded region) in the 17-60 keV energy band along with the intensity profile of the Galactic NIR emission obtained by COBE/DIRBE at 4.9 μm (solid line). The NIR map was convolved with the IBIS collimator response.

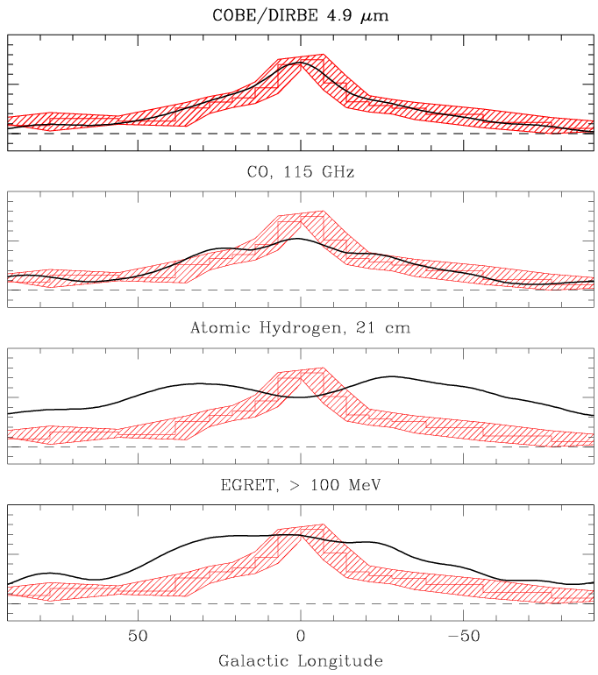

Fig. 2. Profile of the GRXE in hard X-rays (17-60 keV) observed by IBIS/ISGRI along with the profiles of EGRET gamma–ray background, neutral hydrogen (HI) emission, and molecular gas (CO) emission. All the profiles were convolved with the IBIS/ISGRI collimator response function and arbitrary normalized for better visibility.

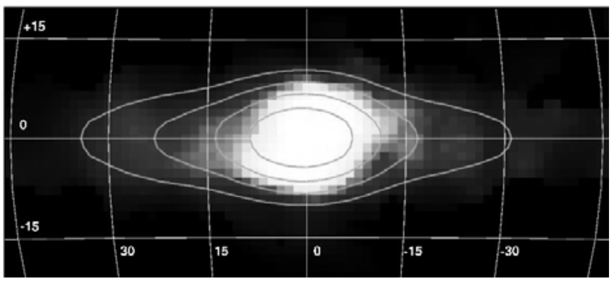

Fig. 3. Map of the Galactic di_use emission observed by INTEGRAL/IBIS/ISGRI in the energy band 17–60 keV. The map was convolved with a gaussian filter (sigma=1.3). Contours represent the near infrared intensity measured by COBE/DIRBE at 4.9μm. NIR contours were convolved with the IBIS collimator response function.

Conclusion

We have shown that the surface brightness distribution of the GRXE in the energy band 17–60 keV very closely follows the near infrared surface brightness distribution throughout the Galaxy which is well known tracer of the stellar mass of the Galaxy. The surface brightness distributions of the gamma–ray background (EGRET data, 30 MeV–10 GeV), neutral interstellar matter (HI map), and molecular interstellar gas (CO map) do not show such correspondence with the hard GRXE intensity. The hard X-ray (17–60 keV) emissivity of the Galactic ridge, recalculated per unit stellar mass is (0.9–1.2) $.10^{27}$ erg/s/Msun. The total Galactic hard X-ray luminosity of the GRXE is (4.2–0.3) 10^{37} erg/s in the 17–60 keV energy band.

GRXE in hard X-rays traces well the stellar mass density distribution, thus providing strong support to the idea that the bulk of GRXE is provided by weak compact sources. In particular, for the considered 17–100 keV energy band, the dominant contribution to the GRXE should come from accreting white dwarf binaries. This result was further strengthened by the detection of a high energy cutoff in the rigde spectrum [5].

REFERENCES

1. Revnivtsev M., Sazonov S., Gilfanov M., Churazov E.,Sunyaev R. Origin of the Galactic ridge X-ray emission // arXiv:astro-ph/0510050. 2005.
2. Suleimanov V., Revnivtsev M., Ritter H., RXTE broadband X-ray spectra of intermediate polars and white dwarf mass estimates // Astronomy and Astrophysics. 2005. V. 435. P. 191.
3. Sazonov S., Revnivtsev M., Gilfanov M., et al. X-ray luminosity function of faint point sources in the Milky Way // Ibid. 2006. V. 450. P. 117.
4. Grimm H.-J., Gilfanov M., Sunyaev R. The Milky Way in X-rays for an outside observer. Log(N)-Log(S) and luminosity function of X-ray binaries from RXTE/ASM data // Ibid. 2002. V. 391. P. 923.
5. Krivonos R., Revnivtsev M., Churazov E., et al. Hard X-ray emission from the Galactic ridge, arXiv:astro-ph/0605420. 2006.

ИКИ РАН Москва;
Институт астрофизики, Гархинг, Германия.
krivonos@hea.iki.rssi.ru