IGR J16318-4848: an X-ray source in a dense envelope?

©2003 M. Revnivtsev\textsuperscript{1,2}, S. Sazonov\textsuperscript{1,2}, M. Gilfanov\textsuperscript{1,2}, R. Sunyaev\textsuperscript{1,2}

\textsuperscript{1} Max-Planck Institute for Astrophysics, Garching, Germany
\textsuperscript{2} Space Research Institute, Russian Academy of Sciences, Moscow, Russia

The hard X-ray source IGR J16318-4848 was recently discovered by the INTEGRAL observatory (Courvoisier et al.) and subsequently uncovered in archival data of ASCA observations in 1994 (Murakami et al.). We present results of a detailed analysis of the ASCA data. The spectrum of the source in the 0.5–10 keV band is extraordinarily hard and is virtually unobservable below 4 keV because of strong photoabsorption (\(n_H L > 4 \cdot 10^{23} \text{ cm}^{-2}\)). The 4–10 keV emission is dominated by a K\(\alpha\) line of neutral or weakly ionized iron with an equivalent width of \(\sim 2.5\) keV. There is also an indication for a second line at \(\sim 7\) keV. Our analysis of archival observations of the IGR J16318-4848 infrared counterpart, discovered by Foschini et al., shows that the point source is detected at different wavelengths in the 1–15 \(\mu\)m range. The available data suggest that IGR J16318-4848 is an X-ray binary system enshrouded by a dense envelope. It is possible that the source is a wind-fed high-mass X-ray binary similar to GX 301-2. We argue that IGR J16318-4848 might be the first representative of a previously unknown population of highly absorbed galactic X-ray sources, which remained undetected with X-ray missions before INTEGRAL.

Introduction

The launch of the powerful hard X-ray/gamma-ray observatory INTEGRAL (\url{http://astro.estec.esa.nl/SA-general/Projects/Integral/integral.html}) will possibly lead to the discovery of a new population of sources highly absorbed below \(\sim 10\) keV, which could have been missed by previous X-ray missions.

It has remained a puzzle for many years why there are no X-ray sources in rich molecular clouds, where intense star formation is known to be taking place and where massive binaries should be present in principle. Another reason for us to expect the existence of X-ray sources in molecular clouds is connected with the possibility of a passage through them of numerous single and binary neutron stars (\(\sim 10^9\) per galaxy) and black holes (\(\sim 10^7\)–\(10^8\) per galaxy). Simple estimates using the Bondi formula indicate that a significant brightening of such an object could result from accretion of the surrounding molecular cloud. However, the large optical depth to absorption of massive molecular clouds can considerably diminish the outgoing X-ray radiation and make such sources practically unobservable for X-ray telescopes operating in the soft or standard X-ray bands as well as for all-sky monitors, most of which also work in these bands.

From another point of view, super-Eddington accretion, widely discussed by theorists, could also lead to almost total obscuration of X-ray sources below \(\sim 10\) keV. Two basic scenarios of supercritical accretion are being considered: the formation of a geometrically and optically thick accretion disk, which carries trapped radiation into the black hole (Abramowicz et al. 1988), or the appearance of a strong outflow of matter from an accreting black hole or a neutron star (Shakura & Sunyaev 1973). It is possible that at a certain stage, binaries like SS 433 behave in this way and we have observed the same regime during an outburst of V4641 Sgr, where a dense, absorbing atmosphere was formed around the accreting object (Revnivtsev et al. 2002).

Yet another possible class of objects that could have remained undetected with X-ray observatories before INTEGRAL is binary X-ray sources, including X-ray pulsars, embedded in dense wind material from a donor star. Such an envelope could render the X-ray source almost invisible at energies below \(\sim 5\) keV due to photoabsorption. Moreover, the envelope could become Compton thick in extreme cases, leading to a downscattering of hard X-ray photons to lower energies and the formation of an emergent spectrum with a peak at 10–20 keV.

The discovery (Courvoisier et al. 2003) of the strongly absorbed source IGR J16318-4848 by the INTEGRAL observatory is significant. Thanks to its high sensitivity at energies above 15 keV, INTEGRAL is capable of discovering relatively weak, highly absorbed X-ray sources of the types described above.

The INTEGRAL observatory spends a considerable amount of time scanning the Galactic plane. During one of such scanning observations, on Jan. 29, 2003 a previously unknown source was discovered. It was named IGR J16318-4848. According to the data of the IBIS telescope (oper-
ating in the energy band 15 keV-10 MeV) the position of the source was determined to be: R.A. = 16\textdegree 31\textquoteleft\textdegree 52s, Dec = -48\textdegree48\textquoteleft.5 (equinox 2000, position uncertainty 2\textquoteleft; Courvoisier et al. 2003). The measured flux from the source in the 15–40 energy band was at a level of 50–100 mCrab and varied on a time scale of hours.

An analysis of archival data of observations of this field with the ASCA observatory (on Sept. 3, 1994) revealed the presence of a weak source at the position coincident with the INTEGRAL localization of IGR J16318-4848 (Murakami et al. 2003). The authors pointed out that the spectrum of the source was strongly absorbed and also mentioned the possible presence of a 6.4 keV iron line. Subsequent observations of the source by the XMM-Newton observatory showed the presence of strong iron lines at ~6.4 keV and ~7.0 keV (Schartel et al. 2003, de Plaa et al. 2003). An analysis of archival observations of the field showed the presence of an infrared counterpart at R.A. = 16\textdegree 31\textquoteleft\textdegree 48s, Dec. = -48\textdegree49\textquoteleft.2 (equinox 2000, position uncertainty 0.2\textquoteleft; Foschini et al. 2003)

In this paper we present the results of a detailed analysis of the ASCA observations of IGR J16318-4848. We discuss the possible nature of the source, considering all available data on the source in different energy bands, part of which is published here for the first time.

**Analysis of the ASCA observation**

A region of the sky including the position of IGR J16318-4848 was observed by ASCA (Tanaka et al. 1994) on Sept. 3, 1994 4:11UT–7:11UT. The total exposure time was ~4 ksec. In our analysis, we used the data of all instruments of the observatory – the gas spectrometers GIS and solid state spectrometers SIS. For the data reduction we used the standard software package LHEASOFT 5.2. For the spectral approximation the XSPEC package was used. In order to avoid biased best fit parameters in modeling the source spectrum at a low source count rate, we applied the Churazov et al. (1996) method of weighting the spectral points.

A clear sign of stray light from the near and relatively bright source 4U1624-49 is seen on ASCA detectors (the flux of 4U1624-49 is approximately 50 mCrab and its distance from the center of the ASCA field of view is approximately 50\textquoteleft). Because of this, in order to avoid a 4U1624-49 contribution to the spectrum measured from IGR J16318-4848, we used two types of background. Background #1 was taken from standard empty field observations and background #2 from an annulus around the source with an inner radius of 4\textquoteleft and an outer radius of 8\textquoteleft. Note that in the latter case the statistical quality of the IGR J16318-4848 spectrum is worse because the exposure time of the background spectrum #2 is much lower than that for background #1.

A GIS image of the sky around IGR J16318-4848 smoothed with a 0.5\textquoteleft gaussian is presented in Fig. 1. The circle denotes the uncertainty of the source localization by INTEGRAL/IBIS. A single source inside this circle is clearly seen. Its coordinates are R.A. = 16\textdegree 31\textquoteleft\textdegree 48s, Dec. = -48\textdegree49\textquoteleft.2 (equinox 2000, position uncertainty 0.8; Murakami et al. 2003).

For the study of a broadband (0.5–10 keV) spectrum of IGR J16318-4848, we used background #2, because at low energies (<3–4 keV) the stray light contribution becomes very important. In Fig. 2 we present spectra of IGR J16318-4848 obtained by GIS and SIS. It can be seen that a strong 6.4 keV line is present in the spectrum, and that the source is barely detectable below 4 keV.

![Fig. 1. Image of the sky around IGR J16318-4848 obtained by the ASCA observatory.](image)

![Fig. 2. Spectrum of IGR J16318-4848 obtained with the GIS and SIS spectrometers at 3.5–10 keV. Note that to derive these spectra we used background #2, which has lowered the statistical quality of the spectra (cp. Fig. 3).](image)
Let us first consider the region of the Fe line (5–9 keV). For this purpose it is better to use SIS data, because the SIS detectors have a much higher energy resolution than GIS. In this energy band, the stray light contribution becomes very small and we can use background #1, which allows us to maximize the statistical quality of the data.

We approximated the spectrum in the 5–9 keV energy band (Fig. 3) by a power law model, \( F \propto E^{-\alpha} dE \), with a gaussian line at the energy \( \sim 6.4 \) keV (\( K_{\alpha} \) line of neutral iron). Because our spectrum has quite poor statistical quality and we perform the spectral approximation in a very narrow energy band, the value of the power-law index does not play an important role. Therefore, we fixed this value at \( \alpha = 1.0 \). The fitting (using the weighting method of Churazov et al. 1996) yields a very good value of \( \chi^2 = 185.9/339 \) dof. However, there still remain some residuals at energies around \( \sim 7.0 \) keV, which may hint at the presence of an additional emission line. Inclusion in the model of a \( K_{\beta} \) line of neutral iron with the centroid energy and width fixed (this means an addition of only one parameter to the model) results in an improvement of \( \chi^2 \) value by \( \Delta \chi^2 \sim 12 \). From the statistical point of view, such reduction of the \( \chi^2 \) value means that the inclusion of the additional parameter in the model is needed at the false alarm probability level of \( \sim 10^{-5} \).

Therefore, there is a strong indication that the SIS spectrum of IGR J16318-4848 contains two lines at energies 6.46 \( \pm \) 0.02(\( \pm 0.06 \)) keV and 7.05 keV (the value in the brackets denotes the systematic uncertainty of ASCA energy scale calibration). The equivalent widths of these lines are 2.5 \( \pm \) 0.5 keV and 2.0 \( \pm \) 0.6 keV, respectively. The ratio of the fluxes of \( K_{\alpha} \) and \( K_{\beta} \) lines is \( F_{\alpha}/F_{\beta} = 2.4 \pm 0.8 \) without the correction for photoabsorption and \( F_{\alpha}/F_{\beta} = 3.6 \pm 1.5 \) taking into account the photoabsorption (\( n_{H}L = 9.3 \cdot 10^{24} \) cm\(^{-2} \), see Table 1).

Fig. 3. a) Spectrum of IGR J16318-4848 according to combined data of SIS0 and SIS1. The solid and dashed lines represent models with one and two emission lines. b) and c) Residuals between the observed points and the model that includes one emission line (b) and two lines (c).

We note that the theoretically predicted ratio of the fluorescent \( K_{\alpha} \) and \( K_{\beta} \) yields is higher, \( \sim 8 \). Part of the difference is probably caused by the radiative transfer in the dense medium obscuring the X-ray source.

Note that the presence of the second emission line at energy \( \sim 7 \) keV is confirmed by the results of XMM-Newton observations (Schartel et al. 2003, de Plaa et al. 2003).

By including in the model neutral photoabsorption and fixing the parameters of the emission lines, we can now perform a fit of the whole X-ray spectrum obtained using data of all ASCA instruments. The resulting best fit values of the parameters are presented in Table 1.

Archival observations of the source in different energy bands

The X-ray coded-mask telescopes MIR/KVANT/TTM (Brinkman et al. 1985) and GRANAT/SIGMA (Paul et al. 1991) observed the sky region around IGR J16318-4848 several times (SIGMA observations of this field are described e.g. in Trudolyubov et al. 1998), however the source was never detected by these instruments. Given the sensitivity of these telescopes, we can thus put upper limits on the average X-ray flux from the source: \( F_{2-30 \text{ keV}} < 2 \cdot 10^{-10} \) erg/s/cm\(^2 \) (TTM) and \( F_{40-100 \text{ keV}} < 10^{-10} \) erg/s/cm\(^2 \) (SIGMA). The sensitivity of these telescopes to short (with a duration of the order of a day) flares is worse – the peak flux of the source during such a flare could not have been higher than \( 5 \cdot 10^{-10} \) and \( 2 \cdot 10^{-10} \) ergs/s/cm\(^2 \), respectively. Comparison of the GRANAT/SIGMA upper limit with the flux detected by INTEGRAL/IBIS gives an indication that the source could be variable at
least at time scale of years. However, we should note that the energy band mentioned by INTEGRAL/IBIS (Courvoisier et al. 2003) does not overlap with energy band of GRANAT/SIGMA (40 keV - 1 MeV).

An analysis of archival observations of the field of the source made by Foschini et al. (2003) showed the presence of an infrared counterpart in several spectral bands (J, H, K, 8.6 µm), and also made it possible to place an upper limit on the source brightness in the R band ($m_R > 21$).

We reanalyzed the data of the 2MASS infrared survey and obtained the following magnitudes: $m_J \sim 10.2$, $m_H \sim 8.5$, $m_K \sim 7.5$. Note, that the data of 2MASS survey in the sky region at hand do not, at the present time, allow one to perform precise photometric measurements. Therefore, the values above should be regarded as rough estimates of the real brightness values.

Our analysis of the DSS2 survey (http://archive.eso.org/dss/dss/) and the CAI/MAMA survey (http://dsmama.obspm.fr/) clearly showed the presence of the counterpart in the I spectral band with $m_I \sim 15$ and a weak detection in the R spectral band with $m_R \sim 19 – 20$.

Finally, our analysis of data of the MSX Galactic plane survey (Price et al. 2001) showed the presence of the IGR J16318-4848 counterpart at 11–13 µm (~0.54 Jy), 13–16 µm (~0.44 Jy) and a possible detection at 18–26µm (~0.4 Jy).

All the flux values of IGR J16318-4848 discussed above, obtained at different times and in different band, are collected together in Fig.5.

**Fig. 4.** Spectrum of IGR J16318-4848 according to the SIS (open circles) and GIS (filled circles) data.

**Fig. 5.** Broadband spectrum of IGR J16318-4848. Crosses represent the measured fluxes of the source in infrared bands. Filled circles represent the source flux, corrected for the galactic reddening with $A_v = 13$, open circles with $A_v = 20$. The dotted and dashed curves represent a rough approximation of the near infrared points by a Planck spectrum with effective temperatures 3000 K and 20000K respectively.

**Discussion**

The results of observations of IGR J16318-4848 in the 2–10 keV band have shown that the spectrum of the source is unique.

- The observed 2–10 keV spectrum consists almost entirely of emission line photons. The position of the lines indicates that we are observing fluorescence of neutral or weakly ionized material.

- The observed photoabsorption is very high – the line-of-sight column density $n_H L > 4 \cdot 10^{23} \text{ cm}^{-2}$ (the exact value, obtainable from the observations, depends strongly on the assumed spectral shape of the unabsorbed source), and thus considerably exceeds that of the interstellar gas in the Galaxy toward the source $\sim 2 \cdot 10^{22} \text{ cm}^{-2}$ (Dickey & Lockman 1990, Dame et al. 2001). We can therefore conclude that most of the absorption observed in the X-ray spectrum of IGR J16318-4848 takes place in the close vicinity of the source.

**Active galactic nucleus?**

It is interesting to note that similar X-ray spectra with strong absorption and a strong fluorescence line of neutral iron are observed from some Seyfert 2 galaxies (e.g. Moran et al. 2001). This raises a natural question: could it be
that IGR J16318-4848 is a heavily absorbed active galactic nucleus (AGN)? In this scenario, it would be practically unfeasible to observe the galaxy itself at the coordinates $l = 335.6, b = -0.45$ neither in the near infrared – due to the huge interstellar extinction along the Galactic plane in the direction of the source ($A_V \sim 15-30$, Schlegel et al. 1998, Dickey & Lockman 1990, Dame et al. 2001), nor in the far infrared because of the strong emission of the Galaxy (see Kraan-Korteweg & Lahav 2000).

In the extragalactic scenario, the IGR J16318-4848 distance could not be larger than $\sim 5$ Mpc, as follows from the absence of any significant redshift of the iron X-ray line (the present paper, de Plaa et al. 2003). Therefore, the luminosity of the AGN corrected for the intrinsic absorption was less than $\sim 6 \cdot 10^{41}$ erg s$^{-1}$ at 2–10 keV during the ASCA and XMM observations, and was likely an order of magnitude higher during the outburst detected by INTEGRAL. It is interesting that there are already 3 known heavily absorbed AGNs ($n_H L$ ranging from $10^{23}$ to $5 \cdot 10^{24}$ cm$^{-2}$), with similar X-ray luminosities, located within 5 Mpc from us: Centaurus A, Circinus Galaxy and NGC 4945 (Matt et al. 2000).

However, there is a very serious argument against the AGN hypothesis: the infrared spectrum of IGR J16318-4848 (dereddened by $A_V \sim 20$, see Fig. 5) is drastically different from observed spectra of the nuclei of heavily absorbed Seyferts (e.g. Marconi et al. 2000). We note that the contribution from the stellar population of the host galaxy to the infrared spectrum shown in Fig. 5 cannot be significant, because the observed source is compact (the size is less than 100 pc for a distance of 5 Mpc).

**Source in a molecular cloud?**

As regards the more likely origin in our Galaxy, there are practically no galactic sources showing such an X-ray spectrum constantly. In the case of IGR J16318-4848, the ASCA and XMM observations, separated by approximately 8.5 years, revealed very similar spectra and fluxes (the present paper, Murakami et al. 2003, Schartel et al. 2003, de Plaa et al. 2003).

The only known exception is the molecular cloud SGR B2, whose emission is possibly the result of reprocessing of a bright flare of Sgr A$^*$ – a supermassive black hole in the center of the Galaxy (Sunyaev et al. 1993, Murakami et al. 2000). However, a location of IGR J16318-4848 in a big molecular cloud can be almost certainly ruled out given the maps in the molecular CO line (Dame et al. 2001). Moreover, we can infer from the XMM data (Schartel et al. 2003) that the angular size of the cloud, from which scattered and fluorescent X-ray emission would be observable, cannot exceed 5-6". Therefore, if the source distance is $\sim 8$ kpc, then the linear size of the cloud is less than $\sim 0.3$ kpc. In order to provide the necessary absorption column, $> 4 \cdot 10^{23} \text{ cm}^{-2}$, a uniform cloud of this size must have a density $\gtrsim 10^6 \text{ cm}^{-3}$, which is far greater than the typical densities of molecular clouds in the Galaxy (e.g. Solomon et al. 1987).

**X-ray binary in eclipse?**

Similar photoabsorption is observed during eclipses/dips in X-ray binaries (e.g. Church et al. 1998).

We cannot exclude in principle the possibility that both observations, by ASCA and XMM, occurred during eclipse of the X-ray source – the ASCA observation lasted only 4 ksec, while the XMM one 27 ksec. If the orbital period of the IGR J16318-4848 binary is longer than 2–3 days, then that could be possible but unlikely. However, even in this case the almost complete absence of flux at energies $< 3$ keV is unusual (compare e.g. with the spectrum of Vela X-1 or Cen X-3 in eclipse, Sako et al. 1999, Wojdowski & Liedahl 2001).

**X-ray source in a compact envelope?**

If the ASCA and XMM observations of IGR J16318-4848 did not fall on eclipses in an X-ray binary, then the presence of strong absorption leads inevitably to the conclusion that the source must be enshrouded by a dense envelope. This envelope could also provide the fluorescent iron lines ($K_{\alpha}$ and $K_{\beta}$).

Let us consider the IGR J16318-4848 infrared counterpart. The main problem here is that the distance to the source is unknown and the distribution of gas and dust close to the Galactic plane is known fairly crudely. Therefore, the amplitude of the interstellar extinction $A_V$ may be anywhere between 0 and $\sim 30$.

Fig. 6 shows two possible near-IR spectra that have been obtained by dereddening the measured fluxes assuming $A_V = 13$ and 20. The dereddened spectrum can be fit fairly well by a Planck spectrum with a temperature of $T_{\text{eff}} \sim 3000$ K in the former case and with $T_{\text{eff}} \gtrsim 6000$ K in the latter. The corresponding source luminosities (assuming isotropic emission from a spherical surface) are $\sim 2 \cdot 10^{37} (D/5 \text{kpc})^2$ and $\sim 6 \cdot 10^{38} (T_{\text{eff}}/10^4 \text{K})^3 (D/5 \text{kpc})^2$ erg s$^{-1}$, where $D$ is the source distance. Note that the shape of the spectrum allows us to independently conclude that the extinction toward the source cannot be significantly higher than $A_V \sim 20$, otherwise the inferred near-IR spectrum would become steeper than the Rayleigh–Jeans law.

The maximum possible value $A_V \sim 20$, consistent with interstellar absorption, corresponds to a neutral column density of $n_H L \sim 3 \cdot 10^{22} \text{ cm}^{-2}$, which is at least an order of magnitude smaller than the absorption inferred from the X-ray spectrum of IGR J16318-4848. This suggests that the dense cloud obscuring the X-ray source is compact, likely of the size of the binary or smaller.

If the emission that we are observing in the spectral bands K–R comes from the surface of a stellar companion, then this star could be a red giant at a distance of $\sim 4$ kpc, with an effective temperature of $\sim 3000$ K and a
luminosity of \( \sim 10^{37} \) erg s\(^{-1} \). Interestingly, such a star is
the companion of the famous black hole and X-ray transient GRS 1915+105 (Greiner et al. 2001). However, the
X-ray spectrum of GRS 1915+105 is completely different
from the heavily absorbed spectrum of IGR J16318-4848.

A more promising solution, also consistent with the
measured fluxes, is a massive optical companion
categorized by \( T_{\text{eff}} \gtrsim 10000 \) K and \( L \sim 6 \cdot 10^{38} (T_{\text{eff}}/10^4 \) K\)\(^3 (D/5 \text{kpc})^2 \) erg s\(^{-1} \). This in turn suggests
two major possibilities described below.

First, IGR J16318-4848 could be similar to the system
SS 433, in which supercritical accretion occurs via a
geometrically and optically thick disk surrounded by a
powerful wind from the disk (e.g. Fabrika 1997). Then the
infrared emission from IGR J16318-4848 could be associated
with the outer regions of the disk and the supermassive optical companion, while the wind could provide
the needed X-ray absorption. We note, however, that SS
433 is famous for its jets, from which optically thin X-ray emission with a lot of Doppler-shifted lines of hot
(with a temperature of the order of 10\(^8\) K) plasma is detected (Kotani et al. 1996). No such spectral signatures
have been observed from IGR J16318-4848 in observations
with ASCA and XMM.

It can also be that IGR J16318-4848 is similar to GX
301-2, which is an X-ray pulsar accreting via a powerful
wind from the B supergiant Wray 977, which is characterized by \( T_{\text{eff}} \sim 2 \cdot 10^4 \) K and \( L_{\text{bol}} \sim 6 \cdot 10^{36} \) \( \sim 5 \cdot 10^{39} \) erg
\( \sim \) s\(^{-1} \) depending on whether GX 301-2 is at a distance of 1.8
kpc (Parkes et al. 1980) or 5.3 kpc (Kaper et al. 1995).

If IGR J16318-4848 has a companion similar to Wray 977
and is at a distance of \( \sim 2 \sim 5 \) kpc, then the observed near
IR spectrum could be accounted for. Moreover, the X-ray spectrum of GX 301-2 shows strong photoabsorption varying from 2 \( \cdot 10^{21} \) to 2 \( \cdot 10^{24} \) cm\(^{-2} \) during a \( \sim 41 \) day orbital cycle and also florescent iron lines that are similar
to those observed in the spectrum of IGR J16318-4848
(Endo et al. 2002). We finally note that in systems with
massive shells (such as GX 301-2 or Cyg X-3), the optically
thin emission of this shell can provide a significant contribution to the overall IR emission at wavelengths >5–10
\( \mu\)m (Davidson & Ostriker 1974, Ogley et al. 2001), and we
observe a change of the spectral slope just in this region
(see Fig. 1).

The authors thank Rodion Burenin for his assistance
in the analysis of the infrared observations. This research has made use of data obtained through
the High Energy Astrophysics Science Archive Research Center
Online Service, provided by the NASA/Goddard Space Flight Center.

**Publications**

Abramowicz M., Czerny B., Lasota J., Szuszkiewicz E., AStroph. J. **332**, 646 (1988)
Brinkman A., Dan J., Mels W. et al., Non-thermal and Very High Temperature Phenomena in X-ray Astronomy,
Ed. by G. C. Perola and M. Salvati (Institute Astronomico, Rome), 263 (1985)
Churazov E., Gilfanov M., Forman W. Jones C., Astrophys. J. **471**, 673 (1996)
Church M.J., Balucinska-Church M., Dotani, T., Asai K., Astroph. J. **504**, 516 (1998)
Courvoisier T., Walter R., Rodriguez J., Bouchet L., Lutovinov A., IAU Circ. 8063 (2003)
de Plaa J., den Hartog P., Kaasstra J., in ’t Zand J., Mendez M., Hernsen W., Astronomer’s Telegram 119
(2003)
Dickey J.M., Lockman F.J., Ann. Rev. Astron. Astrophys. **28**, 215 (1990)
Davidson A., Ostriker J., Astroph. J. **189**, 331 (1974)
Dame T., Hartmann D., Thaddeus P., Astroph. J. **547**, 972 (2001)
Endo T., Ishida M., Masai K. et al., Astroph. J. **574**, 897 (2002)
Fabrika S., Astroph. and Space Science **252**, 439 (1997)
Fitzpatrick E., PASP **111**, 63 (1999)
Foschini L., Rodriguez J., Walter R., IAU Circ. 8076 (2003)
Greiner J., Cuby J.G., McCaughrean M.J., Castro-Tirado A.J., Mennickent R.E., Astron. Astrophys. **373**, L37
Kaper L., Lamers H., Ruymaekers E. et al., Astron. Astroph., **300**, 446 (1995)
Kotani T., Kawai N., Matsuoka M., Brinkmann W., PASJ **48**, 619 (1996)
Kraan-Korteweg R.C., Lahav O., Astron. Astrophys. Rev. **10**, 211 (2000)
Marconi A., Oliva E., van der Werf P.P., Maiolino R., Schreier E.J., Macchetto F., Moorwood A.F.M., Astron.
Astrophys. **357**, 24 (2000)
Matt G., Fabian A.C., Guainazzi M., Iwasawa K., Bassani L., Malaguti G., MNRAS **318**, 173 (2000)
Moran E., Kay L., Davis M. et al., Astroph. J. **556**, 75L (2001)
Murakami H., Koyama K., Sakano M., Tsujimoto M., Astroph. J. **534**, 283 (2000)
Murakami H., Dotani T., Wijnands R., IAU Circ. 8070 (2003)
Ogley R., Bell Burnell S., Fender R., MNRAS **322**, 177 (2001)
Paczynsky B., Wiita P. J., Astroph. Astroph. **88**, 23 (1980)
Parkes G., Culhane J., Mason K., Murdin P., MNRAS **191**, 547 (1980)
Paul J. et al., Advances In Space Research, **11**, 289 (1991)
Price S., Egan M., Carey S. et al., Astron. J. **121**, 2819 (2001)
Revnivtsev M., Gilfanov M., Churazov E., Sunyaev R., Astron. & Astroph. **391**, 1013 (2002)
Sako ., Liedahl D., Kahn S, Paerels F., Astroph.J. **525**, 921 (1999)
Schartel N., Ehle M., Breitfellner M. et al., IAU Circ. 8072 (2003)
Schlegel D.J., Finkbeiner D.P., Davis M. et al.,
Astrophys. J. 500, 525 (1998)
Schmitt et al., Astron.J 114, 592 (1997)
Solomon P., Rivolo A., Barret J., Yahil A., Astroph.
J. 319, 730 (1987)
Sunyaev R., Markevitch M., Pavlinsky M., Astroph. J.
407, 606 (1993)
Tanaka Y., Inoue H., Holt S., PASJ 46, 37 (1994)
Trudolyubov S., Gilfanov M., Churazov E. et al.,
Astron. Astroph. 334, 895 (1998)
Wojdowski P., Liedahl D., Astroph.J. 547, 973 (2001)