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R. DiStefano
Harvard-Smithsonian Center for Astrophysics

C.M. Becker
Department of Physics and Center for Space Research, MIT

and

G. Fabbiano
Harvard-Smithsonian Center for Astrophysics

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The Integrated X-Ray Spectrum of Galactic Populations of Luminous Supersoft X-Ray Sources

R. DiStefano¹, C.M. Becker², G. Fabbiano¹

¹ Harvard-Smithsonian Center for Astrophysics, Cambridge, MA 02138

² Department of Physics and Center for Space Research, MIT, Cambridge, MA 02139

Abstract. We compute the composite X-ray spectrum of a population of unresolved SSSs in a spiral galaxy such as our own or M31. The sources are meant to represent the total underlying population corresponding to all sources which have bolometric luminosities in the range of $10^{37} - 10^{38}$ ergs s⁻¹ and kT on the order of tens of eV. These include close-binary supersoft sources, symbiotic novae, and planetary nebulae, for example. In order to determine whether the associated X-ray signal would be detectable, we also “seed” the galaxy with other types of X-ray sources, specifically low-mass X-ray binaries (LMXBs) and high-mass X-ray binaries (HMXBs). We find that the total spectrum due to SSSs, LMXBs, and HMXBs exhibits a soft peak which owes its presence to the SSS population. Preliminary indications are that this soft peak may be observable.

1 Motivation

Computations of the fraction of luminous supersoft X-ray sources (SSSs) that could have been detected by ROSAT surveys indicate that SSSs form a significant population in the Local Group (Di Stefano & Rappaport 1994; DR). DR estimated that the numbers of presently active and not self-obscured SSSs in M31, the Milky Way, and the Magellanic Clouds are 800 – 5000, 400 – 1000, and 50 – 100, respectively.

Observations of some spiral galaxies have revealed the presence of soft excesses in their X-ray spectra (see, e.g., Kim, Fabbiano, and Trinchieri 1992). These observations, in concert with the predictions of large galactic SSS populations for spiral galaxies, lead to the natural question: Are SSSs responsible for the observed soft excesses?

2 Method

We approach the answer in two steps. First we compute the composite X-ray spectrum of a population of unresolved SSSs in a “typical” spiral galaxy. Spirals with a significant hot ISM, or with an active nucleus would require a separate treatment. The galaxy is “observed” by folding the composite spectrum through the ROSAT PSPC response matrix (pspcb_gain2.256.rsp); the simulated pulse

height spectrum is computed. Second we add the composite spectra due to other types of sources, to determine if any unique signature of the SSS population can be unambiguously identified. To test the sensitivity of the results to input assumptions, we carry out a number of different simulations. We vary (a) the input spectra of LMXB and HMXB “contaminants”, and (b) the angle, θ , the disk of the external spiral galaxy makes with our line of sight to it.

Interstellar Gas In our simulations, the X-ray sources are embedded in the galaxy’s gas distribution, which is modeled as an exponential disk with scale height z_{gas} . We take the column density along a line of sight perpendicular to the disk to be 10^{21} cm^{-2} . To this we add a column density chosen uniformly from the range $2 - 5 \times 10^{20} \text{ cm}^{-2}$, comparable to that associated with looking out of the plane of the Galaxy.

Luminous Supersoft X-Ray Sources Using the results of DR, we seed the galaxy with 1000 SSSs. The temperature and luminosity distribution is taken from the work of Rappaport, Di Stefano, & Smith (1994; RDS). Although RDS modeled close-binary systems, the distributions of properties compare well with known SSS of all types (e.g., old novae). DR and Motch, Hasinger, and Pietsch (1994) found that SSSs are likely to be part of a disk population. We have therefore chosen $z_{\text{SSS}}/z_{\text{gas}} = 0.4$.

Other X-Ray Sources Fabbiano (1989) indicates that X-ray emission from normal spiral galaxies is dominated by neutron star binaries. We therefore consider LMXBs and HMXBs as “contaminants” to the SSS contribution. Based on observations of the Milky Way and M31 (Fabbiano 1989), we seed our galaxy with 30 HMXBs (scale height: $z_{\text{HMXB}}/z_{\text{gas}} = 0.4$) and 100 LMXBs (scale height: $z_{\text{LMXB}}/z_{\text{gas}} = 1.5$).

In addition, other sources of X-radiation are present in typical galaxies; these include cataclysmic variables, stars with active coronae, supernovae, and black hole candidates. Since we are primarily interested in the sources as “contaminants” to the composite spectrum of SSSs, it is the low energy portion of the source X-ray spectra that is of most concern to our simulations. Unfortunately, the effects of interstellar absorption at these wavelengths lead to significant uncertainties. Given these uncertainties, we have attempted to simplify our simulations by (1) explicitly including only LMXBs and HMXBs as contaminants to the composite SSS spectrum, and (2) characterizing the associated spectra so as to systematically vary the soft component most relevant to our study. We carry out all of our simulations three times, first, with spectra for both LMXBs and HMXBs that we regard to be “pessimistic”, in that the soft components of these sources are overemphasized by choosing only the softest observed spectra for LMXBs and HMXBs. In this “worst case” scenario, the copious soft radiation emitted by our too-soft population of LMXBs and HMXBs should also provide an upper limit to the soft radiation likely to be associated with the other types of X-ray source that we have not explicitly included in our simulations. In two separate sets of simulations we have used spectra that are in the mid-range (the “realistic” case) and upper end (“optimistic” case) of hardness observed for both LMXBs and HMXBs (see the caption to Figure 2 for details).

Fig. 1. The angular dependence of the (a) count rate, (b) $HR1 = (C+B-A)/(C+B+A)$ (solid) and $HR2 = (C-B)/(C+B)$ (dashed), where $A = (0.1 - 0.4 \text{ keV})$, $B = (0.4 - 0.9 \text{ keV})$, and $C = (0.9 - 2.0 \text{ keV})$. The SSS component of the composite spectrum is represented by the thin line. Thick lines correspond to the composite spectrum due to all sources in the “realistic” case.

3 Results

Significant features of the composite SSS spectrum as observed by the ROSAT PSPC are shown in Figure 1. Our simulation results, which include the spectra of LMXBs (thermal bremsstrahlung) and HMXBs (power law), are shown in Figure 2. The SSS component is clearly identifiable in the realistic and optimistic cases, where the soft excess can not be explained through any linear combination of LMXB and HMXB components in the optimistic case. The more complete analysis required for the pessimistic case is underway.

4 Conclusions

If SSSs exist in typical spiral galaxies in the numbers inferred by Di Stefano & Rappaport (1994) for both our own Galaxy and M31, then they are likely to be associated with a soft X-ray excess. Further work will quantify the effect and explore whether the observed soft excesses in some spirals may in fact be due to the presence of a population of luminous supersoft X-ray sources. A parallel investigation for elliptical galaxies is also underway. The present work indicates the possibility of detecting evidence of SSSs populations in distant galaxies through the observation of soft excesses in galactic spectra is promising.

Fig. 2. Simulated 50 ks observation of a galaxy at 5 Mpc in the (a) pessimistic case: $kT = 1.3$, $\alpha_{ph} = 3.5$; (b) realistic case: $kT = 5.0$, $\alpha_{ph} = 2.5$; and (c) optimistic case: $kT = 10.0$, $\alpha_{ph} = 1.5$. The dashed traces (longest to shortest) are the contributions to the composite spectrum from the SSS, HMXB, and LMXB components. Note that all cases are somewhat “pessimistic”, in that HMXBs are embedded with the same scale height used for SSSs

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