II. CONSTRaining THE GALACTIC NOVA RATE FROM A SURVEY OF THE SOUTHERN SKY DURING 1995–1997

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Received 1999 October 15; accepted 2000 May 22

ABSTRACT

The good energy resolution (3–4 keV FWHM) of the Transient Gamma-Ray Spectrometer (TGRS) on board the Wind spacecraft makes it sensitive to Doppler-shifted outbursts of 511 keV electron-positron annihilation radiation, the reason being that the Doppler shift causes the cosmic line to be slightly offset from a strong instrumental background 511 keV line at rest, which is ubiquitous in space environments. Such a cosmic line (blueshifted) is predicted to arise in classical novae because of the annihilation of positrons from $\beta$-decay on a timescale of a few hours in an expanding envelope. A further advantage of TGRS—its broad field of view, containing the entire southern ecliptic hemisphere—has enabled us to make a virtually complete and unbiased three-year search for classical novae at distances up to $\approx 1$ kpc. We present negative results of this search and estimate its implications for the highly uncertain Galactic classical nova rate and for future space missions.

Subject headings: gamma rays: observations — novae, cataclysmic variables — nuclear reactions, nucleosynthesis, abundances — white dwarfs

1. INTRODUCTION

Classical novae are observed rather frequently in our Galaxy (Liller & Mayer 1987; Shafter 1997) and have also been studied in external galaxies; typically $N \sim 3–4$ per year are detected in our Galaxy (Duerbeck 1995; Warner 1995). Most of the discoveries and observations of Galactic novae have been made by amateur astronomers with little access to spectroscopic and photometric equipment. Sky coverage has been episodic and extremely hard to calculate. Classification attempts have also been hindered. As a result, many of the most basic properties involving their global rate and distribution are surprisingly uncertain. For example, a number of arguments suggest that the Galactic rate of novae must be much higher than $N$.

First, the typical limiting apparent magnitude obtainable with amateur apparatus and methods has been increasing steadily in recent years, but for the period covered by this paper may be taken to be $m_V \sim 8$, within a very wide range, and with extremely uneven coverage. Application of the expanding-photosphere method to a subset of relatively nearby and bright novae has yielded the empirical relation

$$M_V = 2.41 \log t_2 - 10.7 \text{ for } t_2 < 50 \text{ days}$$

$$= -9 \text{ for } t_2 \leq 5 \text{ days}$$

$$= -6.6 \text{ for } t_2 > 50 \text{ days}$$

(Warner 1995) for the absolute magnitude, where $t_2$ (the speed class) is the time taken for $m_V$ to increase by 2 from discovery. It follows that the distance out to which amateur astronomers are detecting typical novae is $\sim 10$ kpc, or only about one-half the volume of the Galaxy. Furthermore, the rate of discoveries at the faintest magnitudes ($m_V > 6$) is greater than what would be extrapolated from brighter novae. This indicates that a new population—presumably associated with the Galactic bulge rather than the disk—is present and poorly sampled (Duerbeck 1990; see below).

Second, even within that part of the Galaxy that is effectively searched for novae, the discovery rate is blatantly incomplete. Not only does the discovery rate for novae with $3 < m_V \leq 6$ fall below the extrapolated rate for brighter events (thus, in contrast to the preceding argument, suggesting that many events in this range are missed: Duerbeck 1990), but there is a marked deficiency of discoveries in the southern celestial hemisphere (Warner 1995). This is relevant to our work, since the Transient Gamma-Ray Spectrometer (TGRS) detector is permanently pointed at the southern sky (§ 2.1). During its period of operation (1995–1997), five novae were discovered in the southern hemisphere (Harris et al. 1999, hereafter Paper I), but there is no way of knowing how many were missed. The possibility of detecting undiscovered novae as bright as $m_V = 3$ (marginally within TGRS's capabilities) is one of the justifications for the present work.

Third, in Galactic latitude, the distribution of classical novae is somewhat concentrated toward the equatorial plane (scale heights for disk and bulge populations 125 and 500 pc, respectively: Duerbeck 1984, 1990). They must therefore be affected to some degree by interstellar extinction, and a deficiency of discoveries close to the plane is indeed observed (Warner 1995).

In terms of the composition of their ejecta, novae are classified into CO-rich and ONe-rich; it is thought that the distinction reflects the composition of the underlying white dwarf material, with the ONe class coming from more massive progenitors, the cores of which burned beyond the early He-burning stage which yields C and O. Different levels of positron annihilation line flux are expected from each class (§ 4). If the progenitors of the ONe subclass are
really more massive, they will tend to lie closer to the Galactic plane, and the resulting novae will be more strongly affected by extinction and relatively underrepresented in the discovered sample (of which they compose approximately one-third: Gehrz et al. 1998). Evidence of this has been detected by Della Valle et al. (1992).

Fourth, the three preceding factors would all tend to enhance the true Galactic nova rate above that observed. However, a second, quite distinct approach to the problem tends to produce systematically lower rates. In this approach, several external galaxies (particularly the Magellanic Clouds, M31 and M33) have been monitored for novae, and their observed rates extrapolated in some fashion to the Milky Way (Ciardullo et al. 1987; Della Valle & Livio 1994). The usual basis for extrapolation is absolute blue luminosity (Della Valle & Claudi 1990). As can be seen in Table 1, the results from this approach are systematically smaller than attempts to correct for the missing Galactic novae directly. The original explanation for this effect was provided by Duerbeck (1990), who postulated two different classes of event by spatial distribution—disk and bulge novae. It was claimed that the bulge population has a systematically slower speed class and is therefore generally less luminous by equations (1), (2), and (3), which might account for the discrepancy, given a larger bulge in the main external source of novae, M31. As will be seen (§4.1), our search method is probably relevant only to a disk population.

A third approach to the problem is theoretically possible, by which classical nova outbursts are assumed to be part of a life cycle of which other cataclysmic variables are manifestations. The Galactic nova rate is then derived from the assumed space densities of these related objects, together with some model for the outburst recurrence time (Warner 1995). This approach is more reliable at predicting the Galactic space density rather than the global rate, which is more directly related to the measurements we shall present.

It is important to correct for and combine these various factors into an overall global Galactic nova rate, which would govern the input of novae into Galactic chemical evolution, dust grains, and interstellar radioactivity (Gehrz et al. 1998). However, attempts to do so have yielded wildly discordant results, ranging from 11 to 260 nova yr^{-1} (see Table 1).

We have therefore adopted in this work yet a fourth (and the simplest) approach, which is to make an unbiased search for novae in our Galaxy. The detection of γ-ray lines from radioactive decays of the nucleosynthesis products produced in novae is such an approach; these decays in general emit positrons, the annihilation of which with electrons produces a line at 511 keV. An obvious advantage of this approach is the very small absorption of γ-rays in the Galaxy. We will also see that problems of uneven coverage and sensitivity are minimal. These advantages are realized when the γ-ray detector TGRS, on board the Wind mission, is used (§2.1).

In Paper I, we determined that TGRS does indeed have the capability to perform a sky survey for classical novae. The target of Paper I was to detect the positron annihilation line in five known novae; although none was detected, the viability of such a method was established. The key to the method (see §2 below) is that the line arises in nova material expanding toward the observer and is therefore broadened and blueshifted (Leising & Clayton 1987). Its peak is therefore shifted away from a strong background line at exactly 511 keV, which arises in the instrument itself from decays of unstable nuclei produced by cosmic ray spallation.

Section 2 gives a brief description of the detector and data and of our analysis. None of these is substantially different from that of Paper I, where the reader may find a more detailed description.

2. OBSERVATIONS AND ANALYSIS

2.1. Spacecraft and Instrument

The TGRS experiment is very well suited to a search for the 511 keV line for several reasons. First, it is located on board the Wind spacecraft, which has an orbit so elliptical that it has spent virtually all of its mission since 1994 November in interplanetary space, where the γ-ray background level is relatively low. Second, these backgrounds are not only low but very stable over time. Third, TGRS is attached to the south-facing surface of the rotating cylindrical Wind body, which points permanently toward the south ecliptic pole. The detector is unshielded, and TGRS therefore has an unobstructed view of the entire southern ecliptic hemisphere. Taken together, these three facts make possible a continuous and complete survey of the southern sky. Fourth, and most important, the TGRS Ge detector has sufficient spectral resolution to detect a 511 keV line which is slightly Doppler-shifted away from the background 511 keV line mentioned in §1. The Doppler blueshift in the nova line, for the epochs less than 12 hr that we consider, is predicted to be 2–5 keV (Hernanz et al. 1999; Chugai & Kudryashov 2000), which compares with the TGRS energy resolution at 511 keV of 3–4 keV FWHM (Harris et al. 1998 and Paper I).

The TGRS detector is a radiatively cooled 35 cm² n-type Ge crystal sensitive to energies between 20 keV–8 MeV. Since the launch of Wind in 1994 November, TGRS has accumulated count rates continuously in this energy range. The few gaps in the data stream are caused either by perigee passes, which are rare (lasting ~1 day at several month intervals) thanks to Wind's very eccentric orbit, or to memory readouts following solar flare or γ-ray burst triggers, which may last for ~2 hr. The data were binned in 1 keV energy bins during 24 minute intervals.

We searched in 6 hr intervals data covering a period of nearly three years, from 1995 January to 1997 October.

| Method | Rate yr⁻¹ | Reference |
|--------|-----------|-----------|
| M31, M33, LMC comparison | 24±26⁹ | 1 |
| Extrapolate from known nearby novae | ~34 | 2 |
| Correct incompleteness and extinction | 73 ± 24³ | 3 |
| Correct incompleteness and extinction | 35 ± 11⁴ | 4 |
| Correct incompleteness and extinction | 260⁵ | 5 |
| Monte Carlo simulation | 41 ± 20⁶ | 6 |
| M31 comparison | 46⁷ | 7 |
| Extrapolate luminosity function | ~175⁸ | 8 |
| External galaxies comparison | 11–46⁹ | 9 |
| M31 comparison | <13¹⁰ | 10 |

References.—(1) Della Valle & Livio 1994; (2) Warner 1989; (3) Liller & Mayer 1987; (4) Shafter 1997; (5) Sharov 1972; (6) Hatano et al. 1997; (7) Higdon & Fowler 1987; (8) Allen 1954; (9) Ciardullo et al. 1990; (10) Van den Bergh 1988.
In the fall of 1997 the performance of the detector began to degrade seriously, and the energy resolution became too coarse to resolve the 511 keV background and nova lines. This degradation is believed to result from crystal defects induced by accumulated cosmic ray impacts, which trap semiconductor holes and reverse the impurity charge status. A region of the crystal thus becomes undepleted and the effective area is reduced (Kurczynski et al. 1999). We terminated our search of the data when the photopoint effective area at 511 keV fell below an estimated 80% of its original value. The total live time accumulated was about 7.7 × 10^7 s, which was nominally 88% of the entire interval. In fact, the distribution of live times among the 6 hr intervals was such that 41% of all intervals had the full 6 hr of live time, and almost 99% of intervals contained some live time.

2.2. Analysis

Our analysis procedure relies heavily on the most recently theoretically predicted properties of the 511 keV line (Hernanz et al. 1999; Chugai & Kudryashov 2000), mainly its light curve, energy, and shape. The timescale over which the background spectra described above are summed is set by the predicted γ-ray light curve from the “thermonuclear flash” that powers a nova. In this process, ignition takes place in a degenerate accreted H layer on the surface of a CO or ONe white dwarf. The nuclear reactions (involving both accreted material and some material dredged up from the interior of the white dwarf) are dominated by proton captures. The timescale for this process is set by the β-decay timescales of the unstable nucleosynthesis products produced by proton captures on the abundant elements C, O, and Ne. These unstable species fall into two groups, one having very rapid decays (∼ minutes: e.g., 13N, 14O, 15O, 17F) and the more slow-decaying 18F (t_1/2 = 110 minutes). The light curve results from the convolution of these decays with the reduction of opacity to 511 keV γ-rays caused by envelope expansion; it thus tends to be double-peaked at values ∼10–100 s and ∼3–6 hr (Gómez-Gomar et al. 1998), with significant emission lasting for ∼12 hr (Hernanz et al. 1999). The 10–100 s peak is ultimately caused by the decay of 13N, the other members of the very short-lived group having already decayed at this epoch; this peak is thus especially prominent in the light curve of the CO type of novae (though these isotopes are essential to the energetics of both types). The 3–6 hr peak reflects the survival of slower decaying 18F in both types (Gómez-Gomar et al. 1998).

With these timescales in mind, we summed the 24 minute background spectra into 6 hr intervals. The 4,005 resulting 6 hr spectra were fit by a model (described in Paper I) containing the strong background 511 keV line at rest and a broadened blueshifted nova line. The energies of the nova line were fixed at the predicted values (516 keV after 6 hr, dropping to 513 keV after 12 hr: Gómez-Gomar et al. 1998; Hernanz et al. 1999; Chugai & Kudryashov 2000). The widths were taken to be 8 keV FWHM and the profiles to be Gaussian, as in Paper I. Instrumental broadenings of these lines and of the background 511 keV line were very small during 1995–1997 (Harris et al. 1998). Although our analysis is somewhat sensitive to the departure of the actual line parameters from these predictions, we believe that it should be adequate to detect lines in the parameter range appropriate for fast novae. For example, we estimate that lines with energies in the range 513–522 keV are detected with ≥50% of true amplitude, corresponding to expansion velocities 1,200–6,500 km s^{-1}, which bracket the range observed in fast novae (Warner 1995).

The 4,005 count spectra were fitted to the above model (plus an underlying constant term) and the line amplitudes were divided by the photopoint effective area at 511 keV. This photopoint efficiency was determined from Monte Carlo simulations as a function of energy and zenith angle (Seifert et al. 1997), taking into account the effects of hole-trapping in the detector (§ 2.1); we found that the efficiency remained extremely stable until the fall of 1997, whenupon it rapidly fell to 80% of its value at launch. The effective area is a slowly varying function of the zenith angle of the source. To calculate the average effective area, we assumed the Galactic distribution of the synthetic population of several thousand novae computed by Hatano et al. (1997), for the southern part of which the mean TGRS zenith angle is 60°, corresponding to an effective area 13.6 cm^2. The fits were performed by the standard method of varying the model parameters to minimize the quantity χ^2, with errors on the parameters computed from the parameter range where χ^2 exceeded the minimum by +1 (Paper I).

With a sufficiently large sample of spectra, there is a probability that a fitted line of any given amplitude may be produced by chance. We therefore imposed a rather high value of significance as the threshold above which a detection would be established. If the significances are normally distributed (see § 3 below), then our sample size of 4,005 spectra implies that a threshold level of 4.6σ yields a probability of less than 1% of a single false detection by chance (Abramowitz & Stegun 1964).

3. Results

A typical fit to a 6 hr spectrum is shown in Figure 1 (there is a more detailed discussion in Paper I). The fits are generally acceptable, with values of χ^2 per degree of freedom close to 1. The amplitudes of the nova lines are significantly positive in all cases (see below). This arises from a significant departure of the blue wing of the 511 keV background line from the Gaussian shape assumed in the fits, the origin of which is unclear (Paper I). The full series of measurements for a nova line of FWHM 8 keV and blueshift 5 keV (parameters corresponding to typical predicted values after 6 hr: Hernanz et al. 1999 and Paper I) is shown in Figure 2. It can be seen that the systematic positive offset mentioned above was extremely stable throughout the mission; there are very weak linear trends on ∼ year timescales that are almost invisible in Figure 2. We subtracted this quasi-constant systematic value from all nova line measurements.

3 Not only does this accumulation time contain most of the predicted line fluence, but detection of the line in the following 6 hr period would provide an independent confirmation of a detection. However, we found in Paper I that detection of the line after 12 hr is hindered not only by low flux but also by worsened blending with the background 511 keV line. The details of how measurements in the 6–12 hr interval may be combined with those in the 0–6 hr interval are given in Paper I.

4 The profiles are poorly documented in published models, but the Gaussian approximation is probably reasonable at an epoch of a few hours (Leising & Clayton 1987). In the calculations on which the models by Gómez-Gomar et al. (1998) and Hernanz et al. (1999) are based, the correct profiles were used.
A very similar time series was obtained for a nova line at position predicted for 12 hr after the explosion (513 keV), except that the error bars were very much larger (see Paper I, § 3.4). Each fitted 6 hr line was combined with the following 12 hr fit in the proportions suggested by the light curve of Hernanz et al. (1999). The results closely resembled those of Figure 2 after subtraction of the quasi-constant systematic since the 12 hr lines contributed little on account of their large error bars.

It is also clear from inspection of Figure 2 that there are no highly significant line amplitudes lying above the mean. We further show in Figure 3 that the distribution of significant deviations from the mean is very close to normal. The variability in the error bars comes almost entirely from the variability in live times, which is small (§ 2.1). There is therefore a well-defined mean 1 σ error of $8.2 \times 10^{-4}$ photons cm$^{-2}$ s$^{-1}$ (compare results of Paper I for zenith angle 60°). The 4.6 σ threshold based on this average error is shown by

Fig. 2.—Measured fluxes in the nova 6 hr line during the entire interval 1995 January–1997 October. Dotted line: mean 4.6 σ upper limit, above which candidate line detections would lie.
4. DISCUSSION

4.1. Limit on the Galactic Nova Rate

Recent developments in the theory of nucleosynthesis in classical novae (Hernanz et al. 1999) have been discouraging for our purpose of a positron annihilation γ-ray search since new measurements of nuclear reaction rates have led to much lower predictions of the flux in this line after 6 and 12 hr. The discussion in Paper I of the capability of constraining the global Galactic nova rate using our present results was therefore overoptimistic. Nevertheless, we will discuss the application of our method in general terms so that, even though the data have not been derived, it may be useful for more sensitive future experiments (e.g., INTEGRAL) or for more optimistic theoretical predictions.

A formal expression for the number of novae detectable by TGRS is

\[ N_{\text{obs}} = R_{\text{gal}} T_{\text{tot}} \int_{0}^{1.4 M_\odot} \Phi(M) \times f(\phi > \phi_{\text{min}}) w(\phi > \phi_{\text{min}}) d\phi_{\text{min}} dM , \]

where \( R_{\text{gal}} \) is the Galactic nova rate; \( \phi_{\text{min}} \) is a given (time varying) threshold flux for detection by TGRS; \( f(\phi > \phi_{\text{min}}) \) is the fraction of the mass of the Galaxy within TGRS’s detection radius \( r_d \) and \( r_d = [\phi_{\text{pred}}(M)/\phi_{\text{min}}]^{1/2} \); \( T_{\text{tot}} \) is the total TGRS live time; \( w(\phi > \phi_{\text{min}}) \) is the fraction of TGRS live time for which \( \phi > \phi_{\text{min}} \); \( \Phi \) is the distribution of white dwarf masses in classical novae; and \( \phi_{\text{pred}}(M) \) is the predicted 511 keV line flux at 1 kpc for mass \( M \).

The white dwarf mass distribution in novae, \( \Phi(M) \), is very poorly known. Whereas field white dwarf masses appear to peak at \( \approx 0.6 M_\odot \) and to decline in number for higher masses up to the Chandrasekhar limit 1.4 \( M_\odot \) (Warner 1990), the mass distribution in nova systems must be weighted toward higher masses. This is because the thermonuclear runaway occurs when the basal pressure of the material accreted onto the white dwarf exceeds some critical value. The critical pressure is proportional to the \(-4\) power of the white dwarf radius, to the white dwarf mass, and to the accreted mass. Since white dwarf radii decrease with increasing white dwarf mass, the accreted mass necessary to reach critical pressure is a strongly decreasing function of white dwarf mass. If the accretion rate from the secondary star is roughly independent of white dwarf mass, it follows that explosions on more massive white dwarfs will recur after much shorter intervals (Gehrz et al. 1998). There have not been reliable measurements of this effect, although theory indicates that the ratio of ONe:CO novae of 1:2 is compatible with a distribution peaking at about 1.2 \( M_\odot \) (Truran & Livio 1986). Further, the mass ranges corresponding to the CO and ONe compositions are poorly known and may well overlap (Livio & Truran 1994).

Theoretical predictions of 511 keV line emission are available only for a few values of \( M \). In Table 2 we show the parameters of the most recent models suitable for use in equation (4) (Hernanz et al. 1999). Earlier models suggest that emission from lower mass CO white dwarf events is considerably less (Gómez-Gomar et al. 1998). In view of the remarks above about the ONe:CO ratio, we will make the crude assumption that the ratio of “low-mass” CO objects to “high-mass” CO objects to ONe objects is 1:1, where “high-mass” CO objects have the properties given in Table 2 and “low-mass” CO objects are assumed to produce no 511 keV line emission at all. This eliminates the integral over \( M \) in equation (4).

The remaining integral in equation (4) can be approximated by the value of the integrand when \( \phi_{\text{min}} \) has its mean value—this follows from our result in §§ 2.1 and 3 that the variation of live times in our sample (and therefore of the errors in Figure 2) is very small. For a given model in Table 2, therefore, taking \( \phi_{\text{min}} = 4.6 \times 8.2 \times 10^{-4} = 3.8 \times 10^{-3} \) photons cm\(^{-2}\) s\(^{-1}\), the problem is reduced to the computation of the fraction \( f \) of Galactic mass that lies within the radius \( r_d = (\phi_{\text{pred}}/3.8 \times 10^{-3})^{1/2} \) kpc.

As an example, let us consider the Hernanz et al. (1999) model of a 1.15 \( M_\odot \) CO nova from Table 2. Here \( \phi_{\text{pred}} = 3.1 \times 10^{-3} \) photons cm\(^{-2}\) s\(^{-1}\), so that \( r_d = 0.9 \) kpc. Within this value of \( r_d \) we determined that 0.61% of the Galaxy’s mass resides, according to the widely used Bahcall-Soneira model of the Galaxy (Bahcall & Soneira 1984): one-half of this value (i.e., the southern hemisphere) gives \( f = 0.00305 \). For the 1.15 \( M_\odot \) CO model, equation (1) then reduces to

| Model    | CO  | ONe |
|----------|-----|-----|
| White dwarf mass (\( M_\odot \)) | 1.15 | 1.25 |
| Line flux at 1 kpc \(^a\) (photon cm\(^{-2}\) s\(^{-1}\)) | \( 3.1 \times 10^{-3} \) | \( 1.8 \times 10^{-3} \) |
| Detection radius \( r_d \) (kpc) | 0.9 | 0.7 |
| Galactic rate (yr\(^{-1}\)) \(^a\) | <123 | <238 |

\(^a\) Estimated average flux during the first 6 hr of the explosion obtained by fitting the Harris & Leising (1994) formula for emission of a β-decaying line under circumstances of decreasing opacity to fluxes at several epochs from Hernanz et al. (1999), in the approximation that the β-decaying species are \(^{18}\)O and \(^{18}\)F. The resulting light curve qualitatively resembles that computed by Gómez-Gomar et al. (1998) with a smaller contribution from \(^{18}\)F, as expected (Hernanz et al. 1999).
be limited to novae within the SPI field of view, which is \( \sim 25\) FWHM.

The search method we have used, i.e., an ex post facto search in background spectra, ought to be perfectly feasible with \textit{INTEGRAL}. The chief requirements for this method are very high energy resolution and a sufficiently low and stable background. While the SPI detector has excellent resolution, the background level in it has not yet been rigorously computed. Nevertheless, qualitative arguments suggest that the background will be no worse than that in TGRS. Like \textit{Wind}, \textit{INTEGRAL} will be in a high-altitude elliptical orbit that avoids extensive exposure to Earth’s trapped radiation belts and to albedo \(\gamma\)-rays from Earth’s atmosphere. The main disadvantages of \textit{INTEGRAL} for nova detection are the small SPI field of view and the planned observing strategy, which cuts down the amount of time spent pointing toward the main concentration of novae near the Galactic center.

We can make use of the planned program of \textit{INTEGRAL} observations of the central Galactic radius in the first year of operation (Winkler et al. 1999) to estimate the rate at which novae might be detected in the SPI data. As previously, we assume that novae follow the Bahcall & Soneira (1984) Galactic distribution. The planned first-year \textit{INTEGRAL} observations may be approximated by a \(31^\circ \times 11^\circ\) grid with 2° spacing between \(-30^\circ \geq l \geq 30^\circ\) and \(-10^\circ \geq b \geq 10^\circ\), the exposure to each point being 1,180 s per pass, with 12 passes per year covering the whole grid. Thus the live time for the whole grid is 0.153 yr. From the Bahcall-Soneira model, the pointing geometry, and the SPI aperture \(\sim 25^\circ\), we calculated that the \textit{INTEGRAL} detection radius \(\sim 3\) kpc intercepts \(\sim 0.75\%\) of the Galactic nova distribution. The live time 0.153 yr is then multiplied by a typical Galactic nova rate \(\sim 50\) yr\(^{-1}\) (of which two-thirds are practically detectable, as assumed in § 4.1), and by the intercepted fraction, to imply that \textit{INTEGRAL} ought to detect 0.04 novae yr\(^{-1}\). Unless theoretical estimates of the 511 keV line flux turn out to be considerably larger, the prospects for such a detection appear to be small. The same conclusion probably applies to a different method of detecting 511 keV line emission indirectly by observing the 170–470 keV continuum produced by Compton scattering in the nova envelope using SPI’s large-area CsI shield (Jean et al. 1999).

We are grateful to M. Hernanz and A. Kudryashov for helpful discussions and for providing prepublication results and to J. José (the referee) for constructive comments. Peter Kurczynski (University of Maryland) helped in assessing the instrument performance. Theresa Sheets (LHEA) and Sandhia Bansal (HSTX) assisted with the analysis software.

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