

An *INTEGRAL*/IBIS view of young Galactic SNRs through the ^{44}Ti gamma-ray lines

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Abstract

We present preliminary results of *INTEGRAL*/IBIS observations on Cas A, Tycho and Vela Junior supernova remnants in the line emission of ^{44}Ti . This radioactive nucleus is thought to be exclusively produced in supernovae during the first stages of the explosion. It has a lifetime of about 87 yr and is then the best indicator of young SNRs, as exemplified by the detection of ^{44}Ti in the youngest known Galactic supernova remnant Cas A with *GRO/COMPTEL* and latter with *BeppoSAX*. In this paper, we will focus on this SNR for which we confirm the detection of ^{44}Ti and point out the importance to know the nature of the hard X-ray continuum, the Tycho SNR, for which no indication of ^{44}Ti was ever reported, and Vela Junior, for which the claimed detection of ^{44}Ti with *COMPTEL* is still controversial. The *INTEGRAL*/IBIS observations bring new constraints on the nature of these SNRs and on the nucleosynthesis which took place during the explosions.

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1. Introduction

Supernovae (hereafter SNe) are the main galactic nucleosynthesis sites of production of radioisotopes which may be observed through their γ -ray line emission. Some of them are short-lived such as ^{44}Ti . The radioactive decay chain $^{44}\text{Ti} \rightarrow ^{44}\text{Sc} \rightarrow ^{44}\text{Ca}$, with a half-life of about 60 yr (Wietfeldt et al., 1999), produces three lines at 67.9, 78.4 (from $^{44}\text{Sc}^*$) and 1157 keV (from $^{44}\text{Ca}^*$) with similar branching ratios. This radioactive nucleus is thought to be created in all types of SNe but with a large variation of yields per type: from a few 10^{-5} to $\sim 2 \times 10^{-4} M_{\odot}$ for the most frequent SNe of Type II (Woosley and Weaver, 1995; Thielemann et al., 1996) and Type I $_{bc}$ (Woosley et al., 1995) and up to $3.9 \times 10^{-3} M_{\odot}$ for the rare event of the He-detonation of a Sub-Chandrasekhar white dwarf (Woosley et al., 1986; Woosley and Weaver, 1994). As reported by Iwamoto et al. (1999), the ^{44}Ti yields for standard Type Ia SNe are between 8×10^{-6} and $5 \times 10^{-5} M_{\odot}$. It is primarily generated in the α -rich freeze-out from nuclear statistical equilibrium occurring in the explosive silicon burning stage of core-collapse SNe, while a normal freeze-out Si burning is at play in Type Ia SNe (Thielemann et al., 1986). Therefore, it probes deep into the interior of these exploded stars and provides a direct way to study the SN-explosion mechanism itself. On the other hand, it is strongly dependent on the explosion details, mainly on the mass-cut in core-collapse SNe (the mass above which matter is ejected), the energy of the explosion and asymmetries.

The *INTEGRAL* observatory (Winkler et al., 2003) carries two main instruments: IBIS (Ubertini et al., 2003) and SPI (Vedrenne et al., 2003). Both can provide images and spectra, based on the coded mask aperture system, working from 15 to 1 MeV and from 20 to 8 MeV, respectively. The line-sensitivity of the IBIS low-energy camera ISGRI (Le-

run et al., 2003) is really appropriate to detect the two low-energy ^{44}Ti γ -ray lines at 67.9 and 78.4 keV ($\Delta E \sim 6$ keV FWHM at 70 keV). With a spectral resolution of ~ 2 keV at 1 MeV, SPI can measure the ejecta velocity due to the Doppler broadening. We present here preliminary results on three young SNRs: Cas A, Tycho and RX J0852-4622 (Vela Jr).

2. The Cassiopeia region: Cas A and Tycho SNRs

The Cassiopeia region was observed by *INTEGRAL* for a duration of ~ 1.5 Ms. Fig. 1 shows the region as observed by IBIS/ISGRI in the 25–40 keV band. Several sources have been revealed, amongst them Cas A detected at $\sim 25\sigma$ confidence level and Tycho SNR detected at $\sim 6\sigma$ confidence level.

The discovery of the 1157 keV ^{44}Ti γ -ray line emission from the youngest Galactic SNR Cas A with COMPTEL (Iyudin et al., 1994) was the first direct proof that this isotope is indeed produced in SNe. This has been strengthened by the *BeppoSAX*/PDS detection of the two low-energy ^{44}Ti lines (Vink et al., 2001). By combining both observations, Vink et al. (2001) have deduced a ^{44}Ti yield of $(1.5 \pm 1.0) \times 10^{-4} M_{\odot}$. This huge value compared to those predicted by most of the models could be due to several effects: a large energy of the explosion ($\sim 2 \times 10^{51}$ erg), asymmetries (Nagataki et al., 1998) currently observed in the ejecta expansion, and a strong mass loss of the progenitor consistent with the scenario of a Type Ib SN (Vink, 2004). In the case of Cas A, the knowledge of the continuum emission is critical to properly measure the ^{44}Ti line flux. Unfortunately, it is still debated whether the non-thermal hard X-ray continuum is synchrotron radiation or non-thermal bremsstrahlung from supra-thermal electrons (see Vink, 2005 for a recent review and references therein).

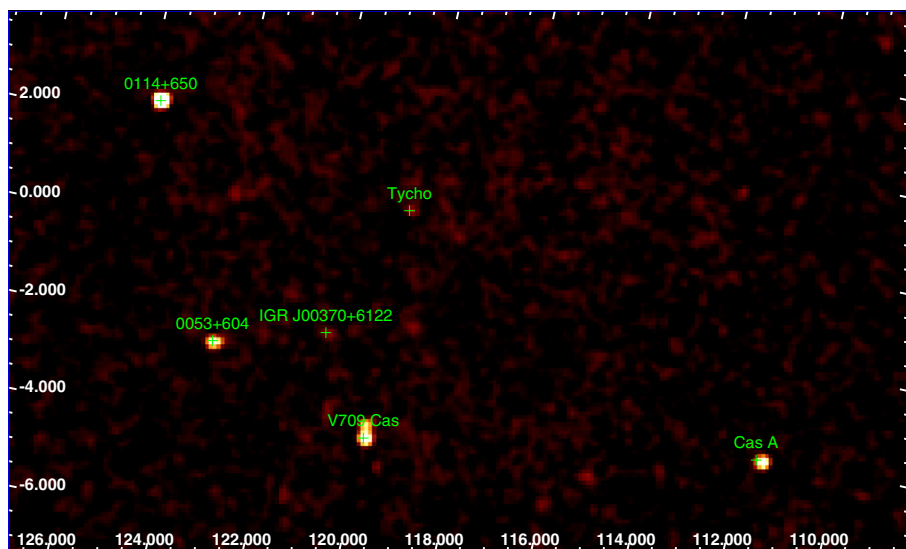


Fig. 1. A IBIS/ISGRI image of the Cassiopeia region in the 25–40 keV energy band. Cas A and Tycho are detected at $\sim 25\sigma$ and 6σ , respectively.

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