

Young Galactic SNRs and ^{44}Ti

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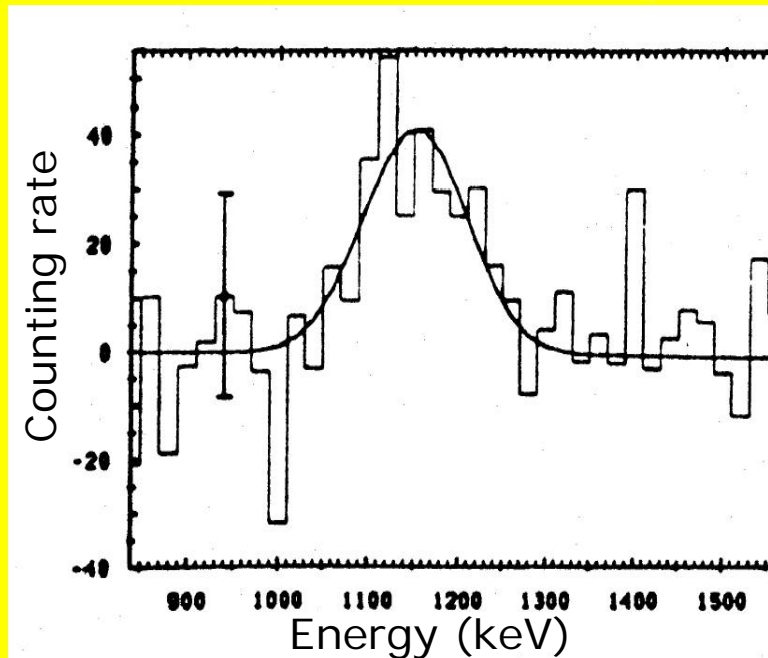
- **A first case !**

- **★ Cassiopeia A**

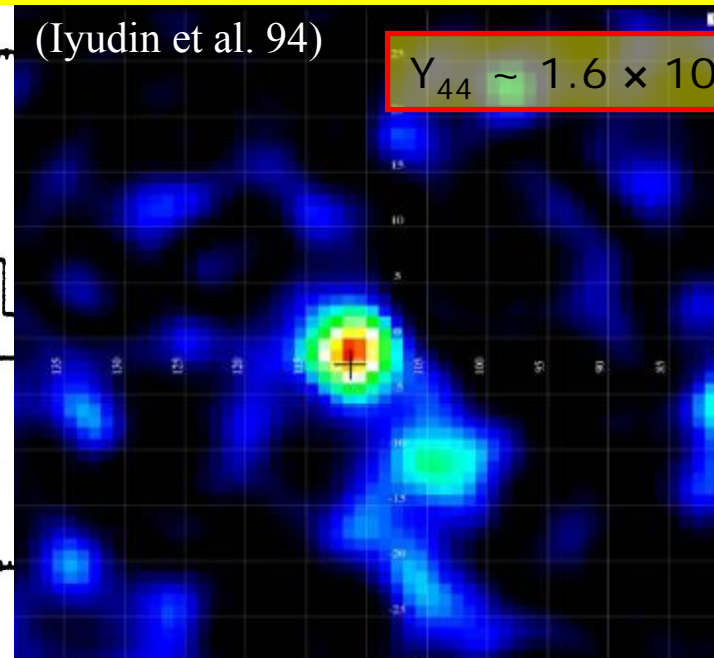
- **👉 Historical event (Flamsteed, 1680) ? (Stephenson & Green 02)**

- **👉 Dynamical age ~ 330 yrs , Distance ~ 3.4 kpc (Reed et al. 95)**

- **👉 Progenitor = $20\text{-}25 M_{\odot}$, but is scenario selfconsistent? (Young et al. 06)**



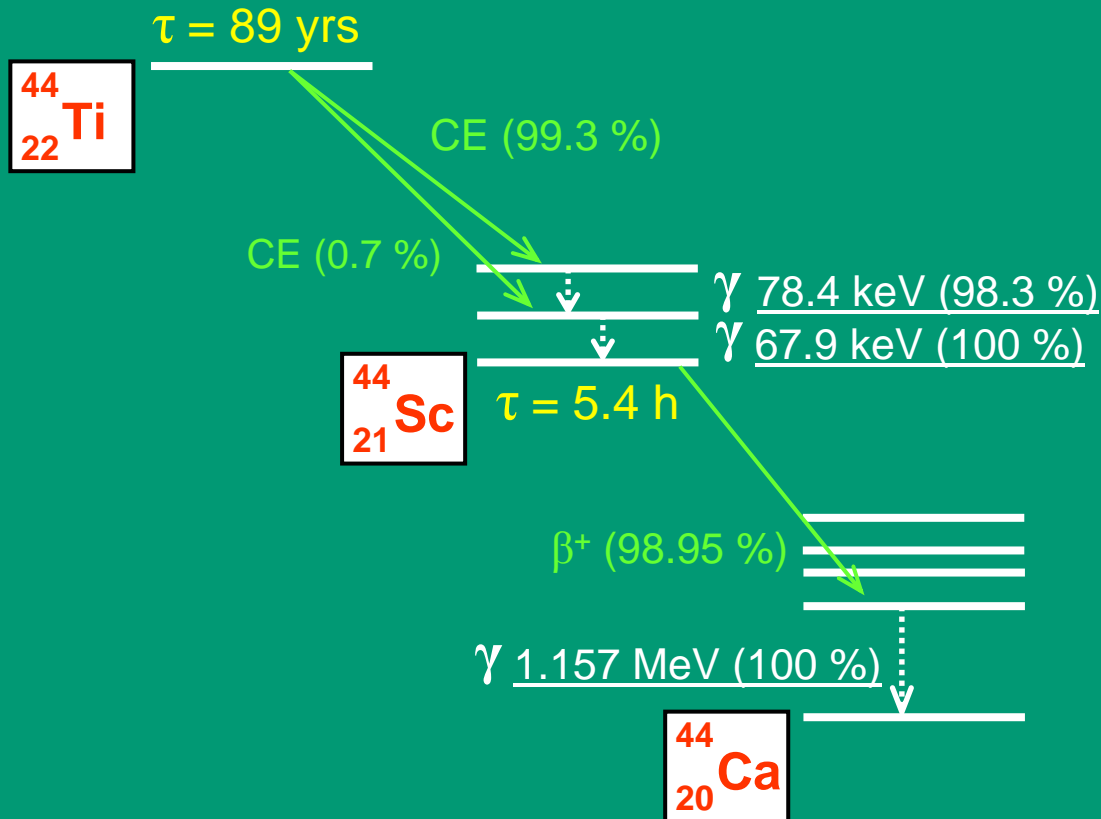
(Iyudin et al. 94)



$$Y_{44} \sim 1.6 \times 10^{-4} M_{\odot}$$

SNRs and ^{44}Ti

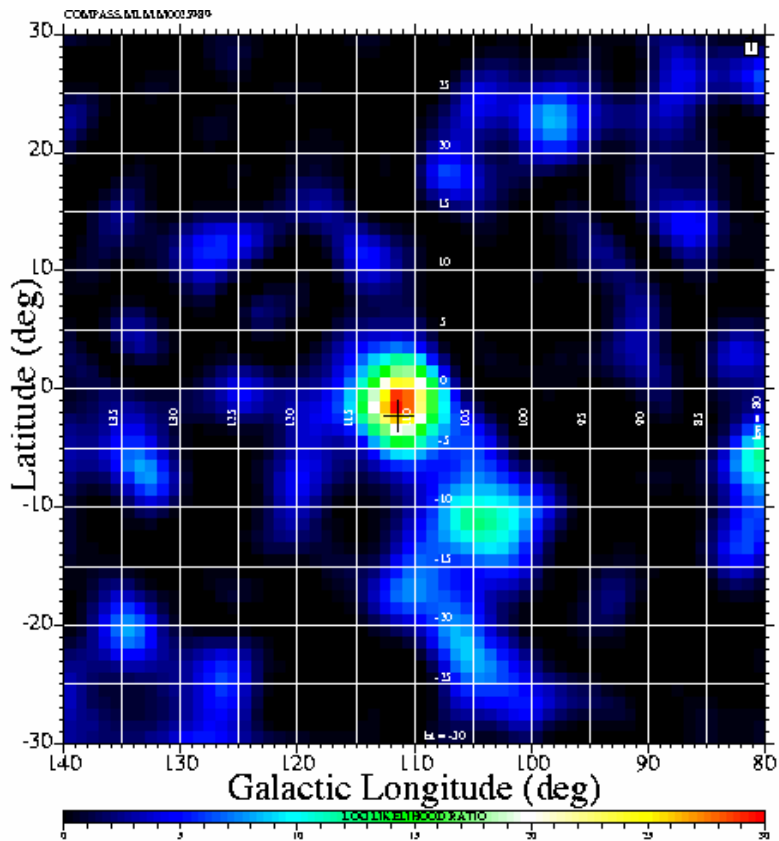
- Exclusively produced in SN explosion



^{44}Ti γ -ray lines \Leftrightarrow young SNRs (age < 1000 yrs)

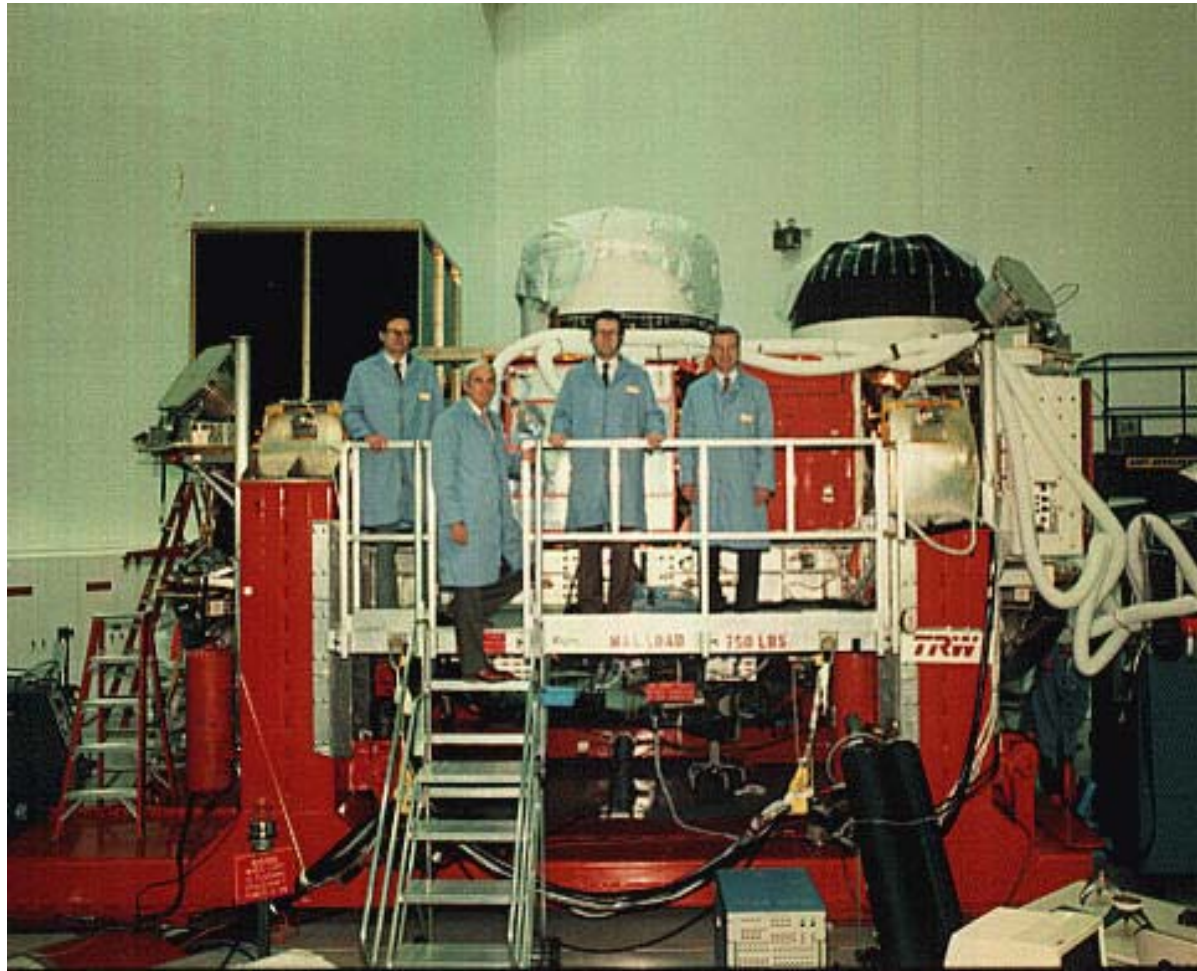
First detection of ^{44}Ti decay line at 1.157 MeV

CGRO

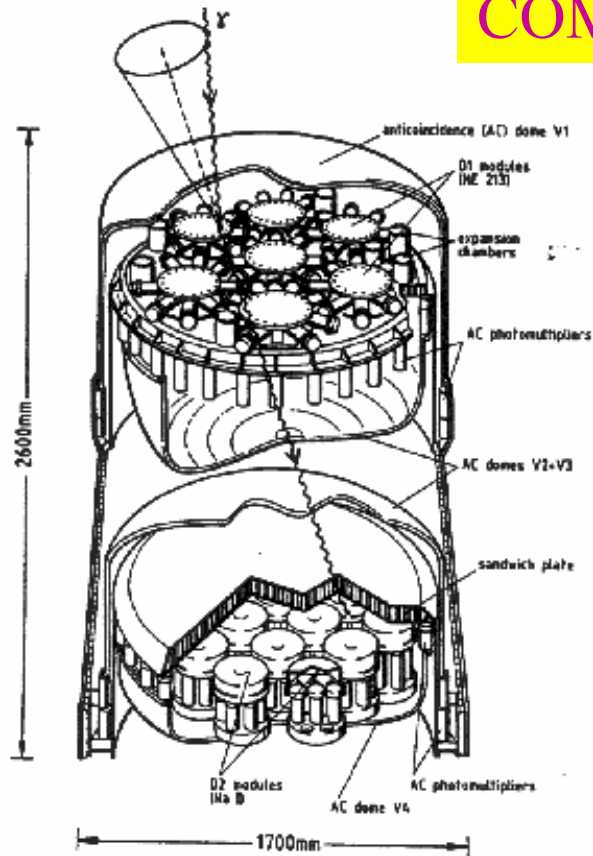


CGRO - Instruments PIs

- Dr. J. Kurfess, NRL - OSSE
- Dr. J. Fishman, MSFC - BATSE
- Dr. V. Schönfelder, MPE - COMPTEL
- Dr. C. Fichtel, GSFC - EGRET



COMPTEL



- event location (x,y) in D1
- energy deposit in D1
- pulse-shape in D1
- time-of-flight (ToF) from D1 to D2
- event location (x,y) in D2
- energy deposit in D2
- absolute time (1/8 msec)

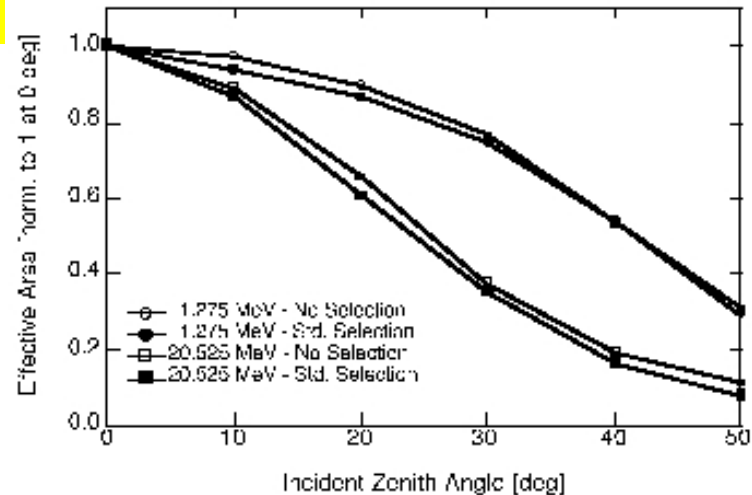


Figure II.5 The simulated COMPTEL effective area as a function of the photon incidence angle at two different energies.

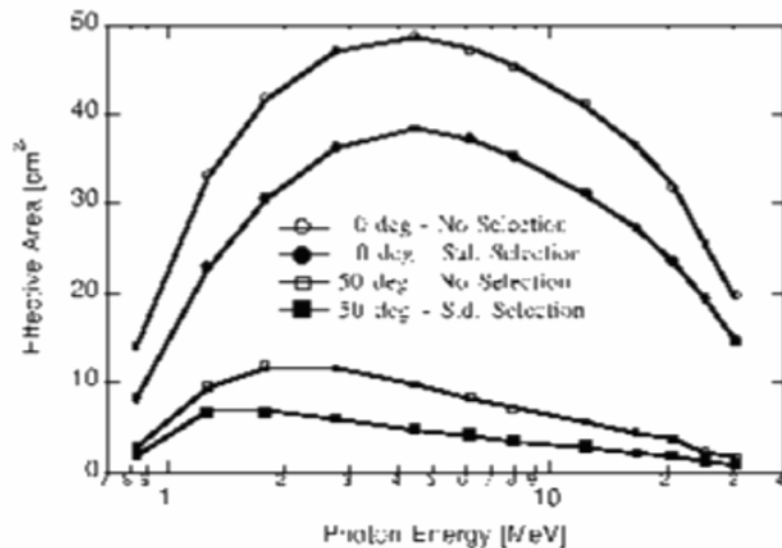
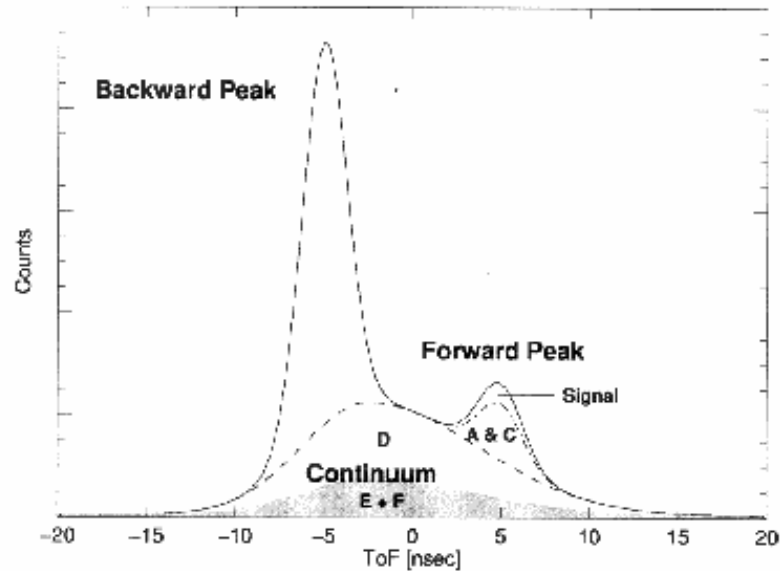


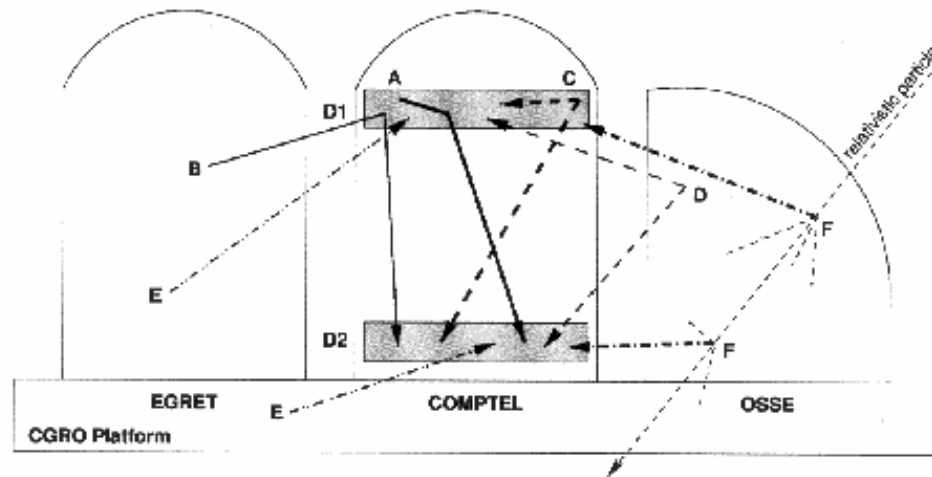
Figure II.4 The simulated COMPTEL effective area as a function of the incident photon energy for two different incidence angles.

Some nuances of COMPTEL event selection

Time-of-flight spectrum

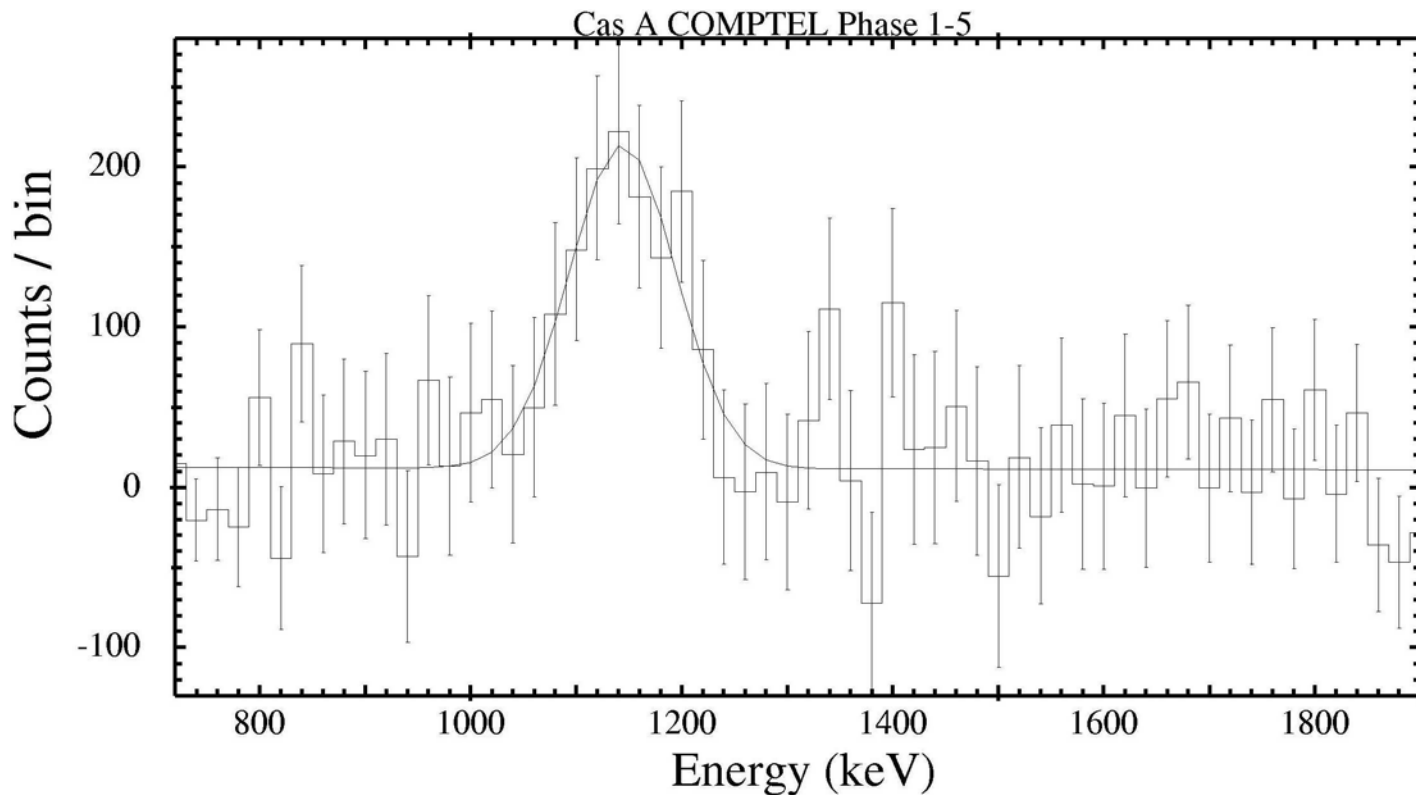


Background components

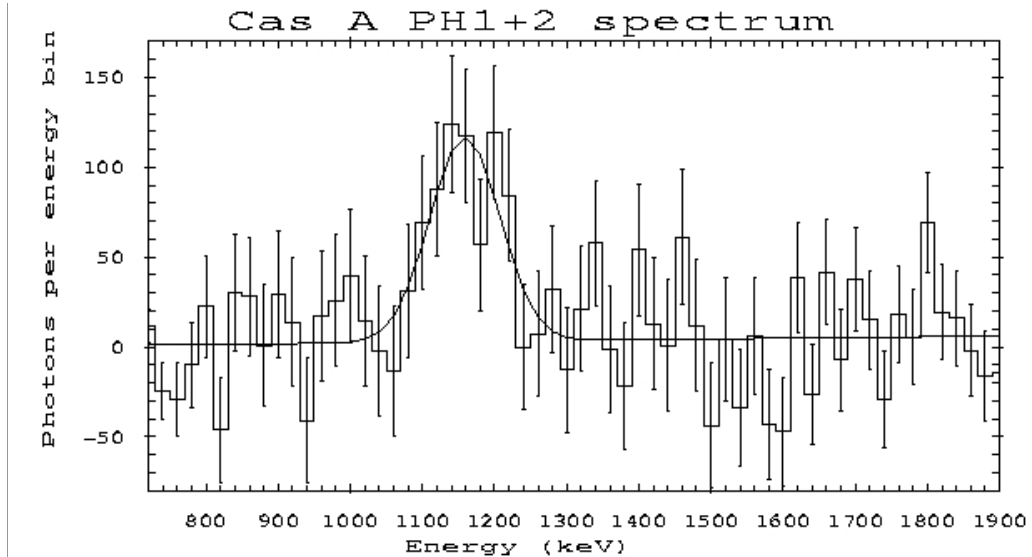


Cas A ^{44}Ti 1.157 MeV line properties

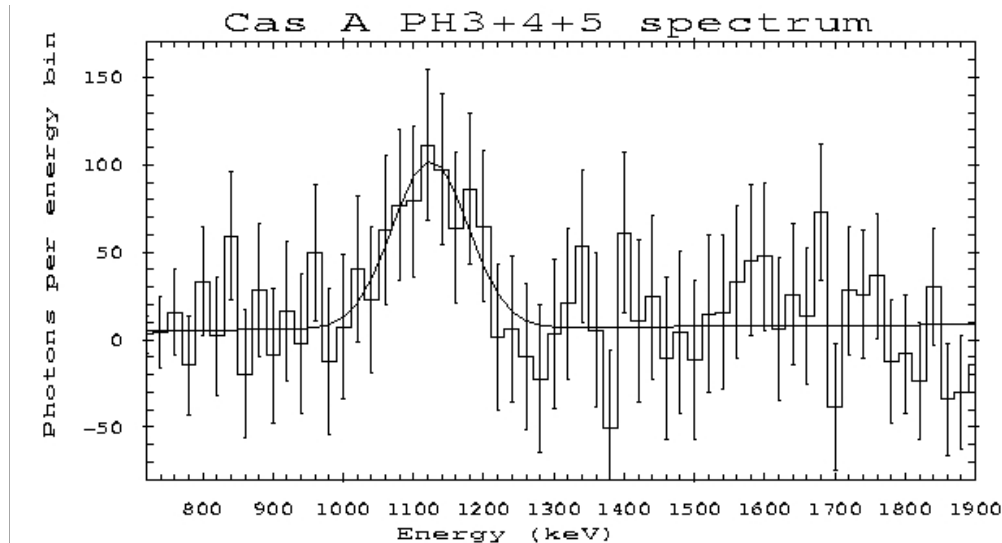
$E_{\text{line}} = 1.144 \pm 0.014$ MeV; FWHM=117 keV; $v_D = 7200 \pm 2900$ km/s;
 $M_{^{44}\text{Ti}} = 1.6 \pm 0.3 \times 10^{-4} M_{\odot}$, for $d=2.8$ kpc and $\tau_{^{44}\text{Ti}} = 96$ yrs, age=315 yr
see: Iyudin et al. (1997), ESA SP-382, p.37.



44Ti spectra of COMPTEL for different CGRO phases



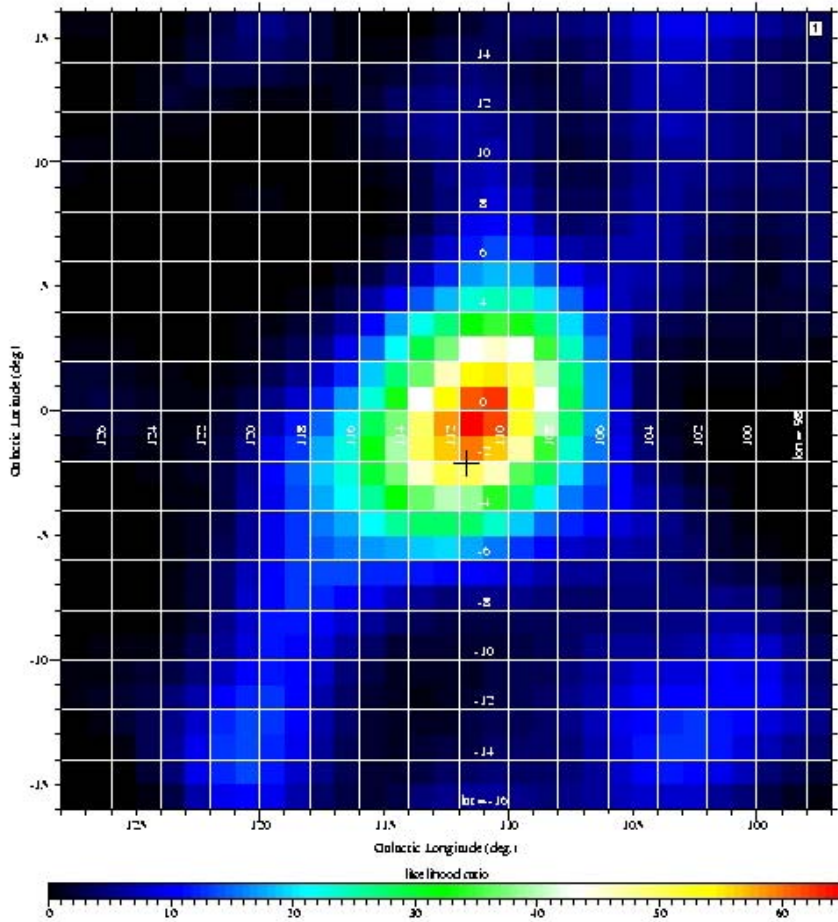
PH1+2
 $E_{\text{line}} = 1159 \pm 20 \text{ keV};$
 $\sigma_{\text{r.m.s.}} = 49 \pm 14 \text{ keV};$
 $\sigma_{\text{Doppler}} = 19 \text{ keV}$



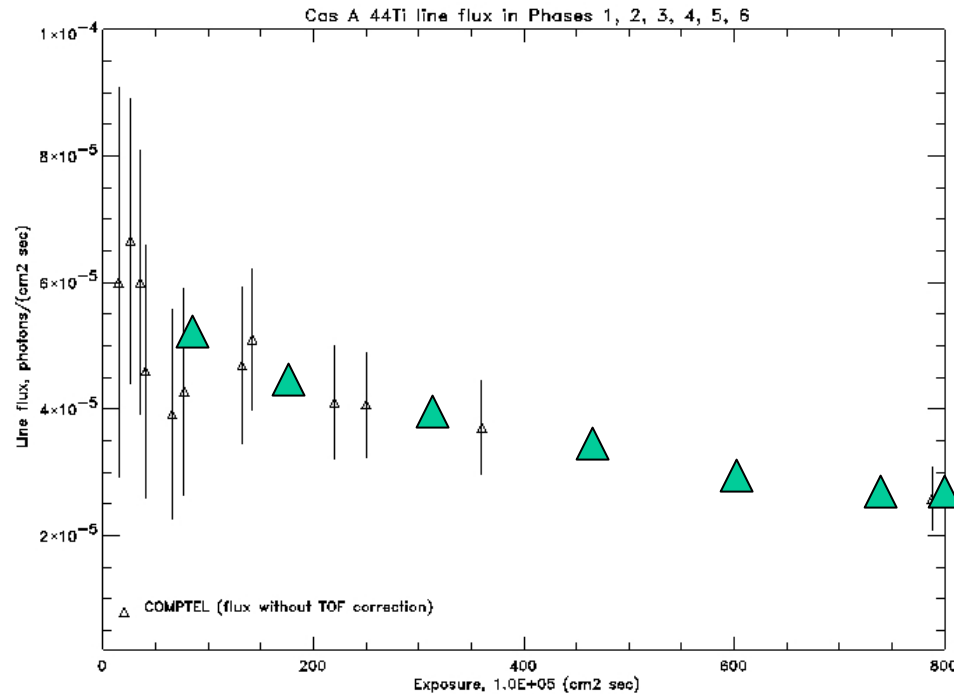
PH3+4+5
 $E_{\text{line}} = 1124 \pm 25 \text{ keV};$
 $\sigma_{\text{r.m.s.}} = 54 \pm 10 \text{ keV};$
 $\sigma_{\text{Doppler}} = 30 \text{ keV}$

COMPTEL Cas A results @ 1.157 MeV line

Cas A region, $E_g=1.157$ MeV, PH1+2+3+4+5+6



For: $F_{1.157} = (3.3 \pm 0.6) \cdot 10^{-5} \text{ ph cm}^{-2} \text{ s}^{-1} \rightarrow$
 $Y_{44\text{Ti}}^1 = (1.1 \pm 0.2) \cdot 10^{-4} M_{\odot} @ d_1 = 2.8 \text{ kpc}!$
 Note: $d_2^2/d_1^2 = 1.475 !! (d_2 = 3.4 \text{ kpc})$
 $\tau_{44\text{Ti}} = 87.7 \pm 1.7 \text{ yrs}$



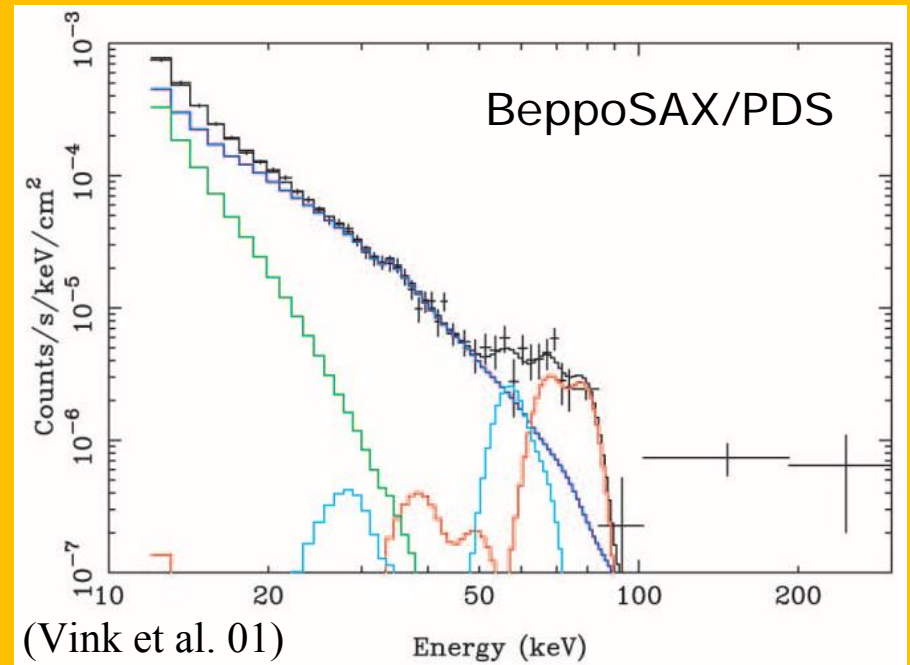
SNRs and ^{44}Ti

- From an observational point of view... Few cases !

★ Cassiopeia A

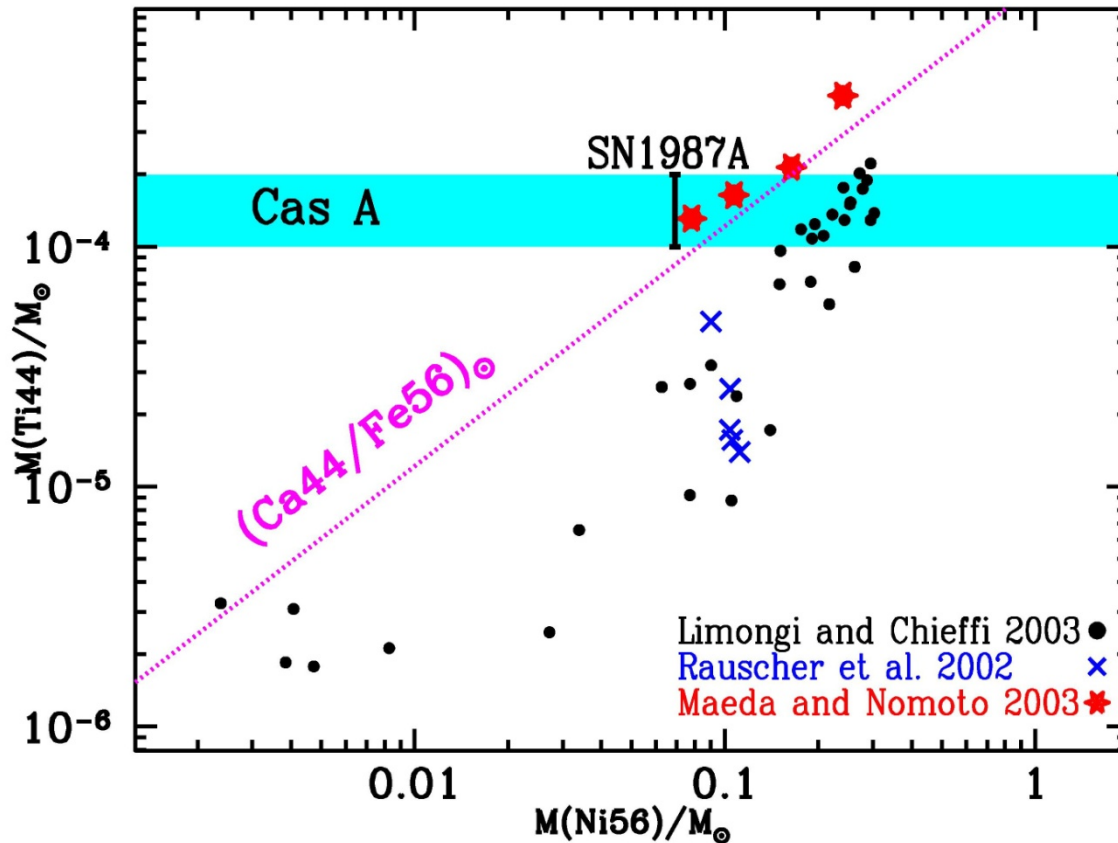
- ☞ Historical event (Flamsteed, 1680) ? (Stephenson & Green 02)
- ☞ Dynamical age ~ 330 yrs , Distance ~ 3.4 kpc (Reed et al. 95)
- ☞ Progenitor = 20-25 M_{\odot} (Vink 04) but complete scenario ? (Young et al. 06)

- Nature of the continuum ?
(Allen et al. 97 ; Vink & Laming 03)
- High $^{44}\text{Ti}/^{56}\text{Ni}$... asymmetries ?
- Atypical explosion ? (Young et al. 06)



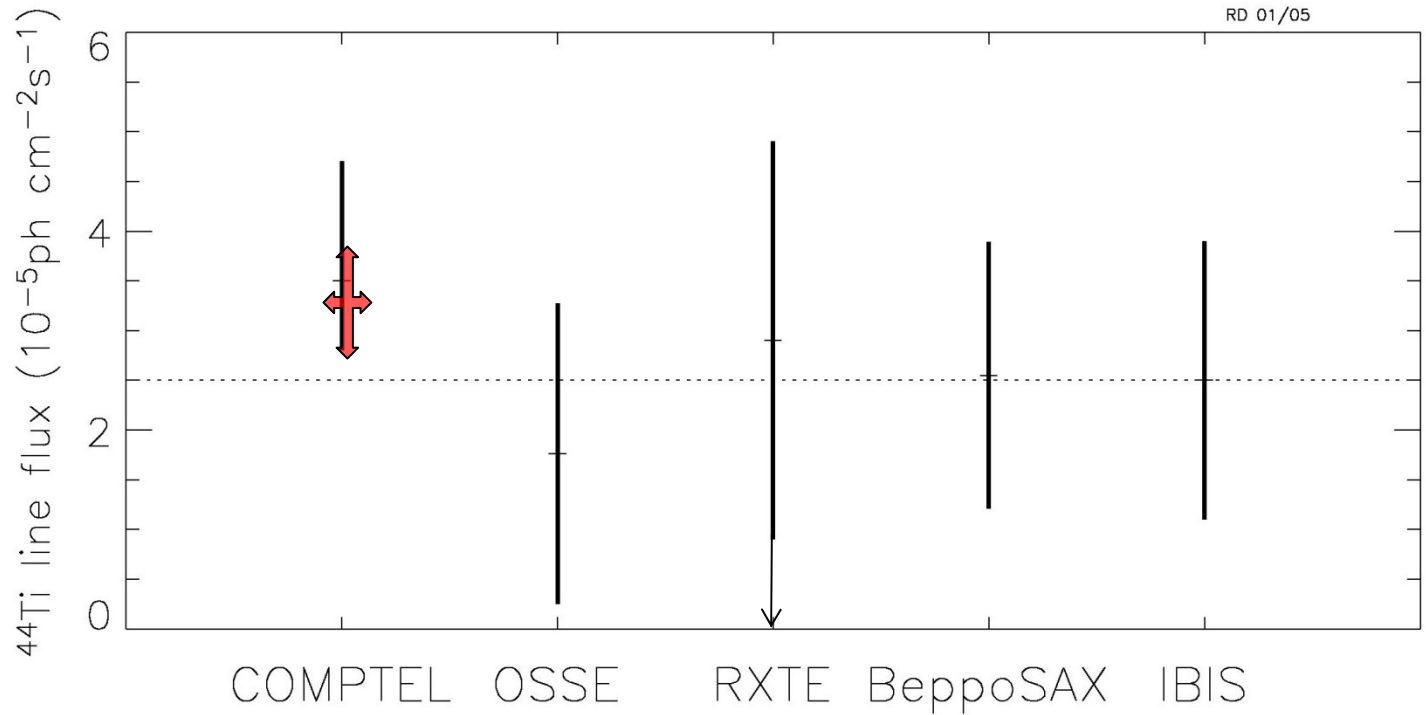
Asymmetric explosion required!?

$Y^{44}\text{Ti}_{\text{measured}} > Y^{44}\text{Ti}_{\text{model}} \rightarrow$ asymmetric explosion (jets??)
 $V_{\text{exp}} \geq V_{\text{transverse}} \approx 6500\text{--}14500$ km/s (Fesen et al. 2006;
Hammel and Fesen 2008)



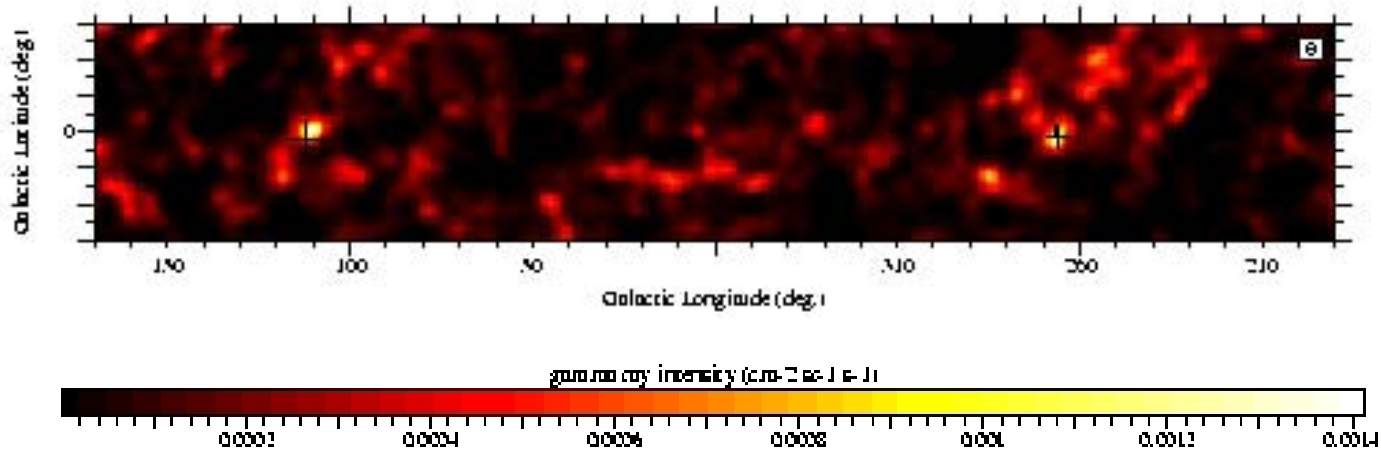
44Ti flux

Correction as of 01/2009



All-sky ^{44}Ti map of COMPTEL

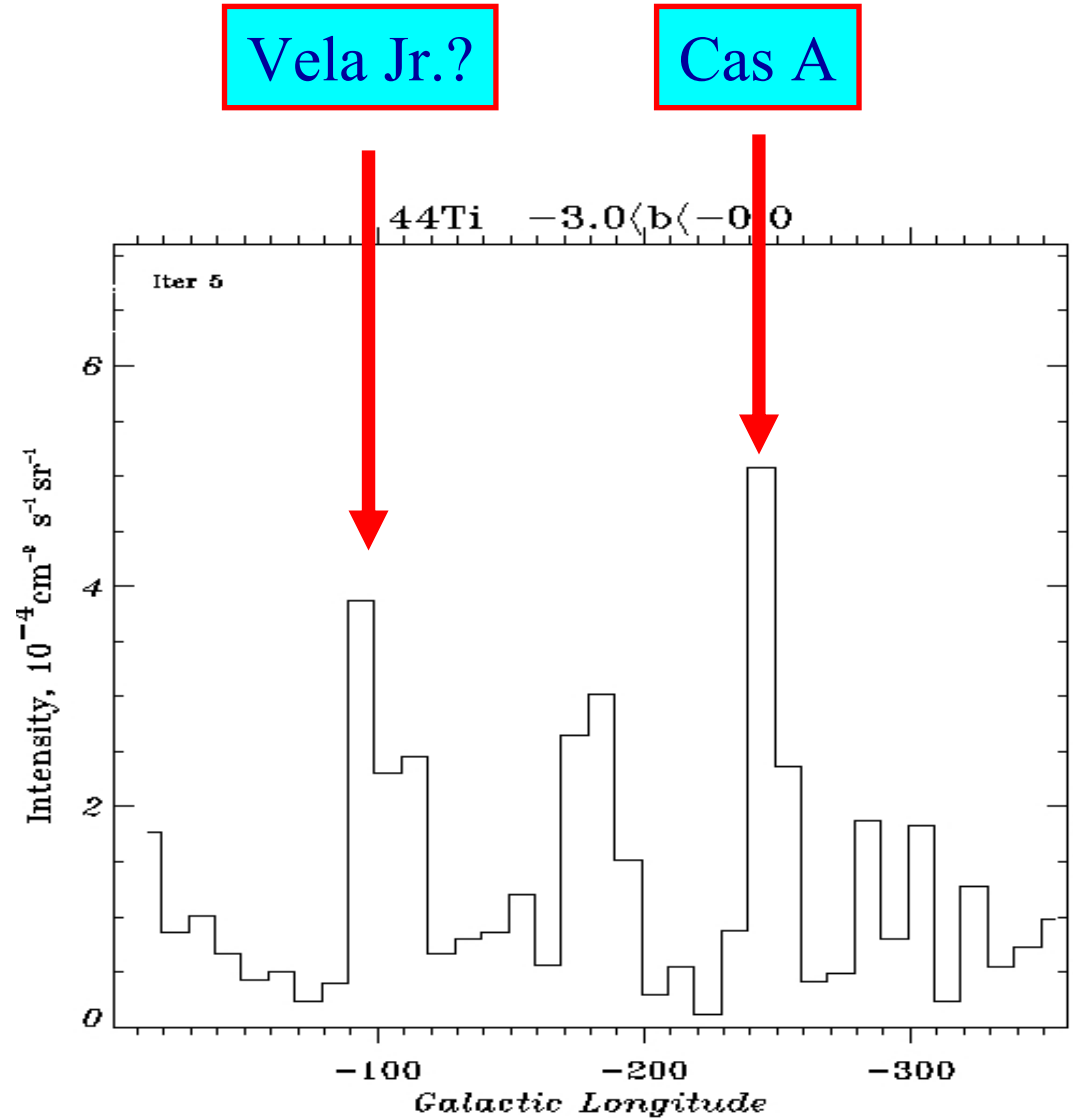
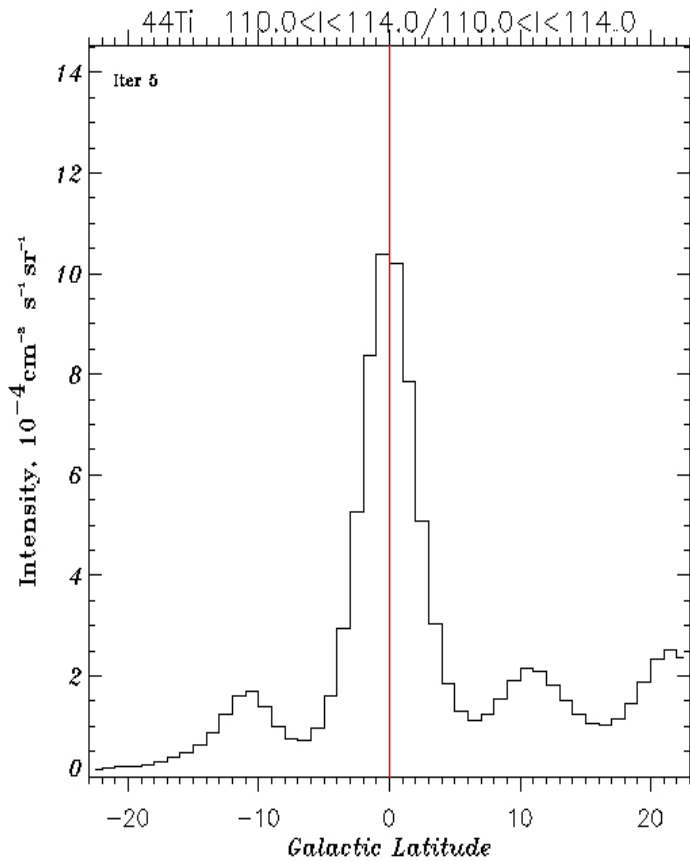
Iyudin et al. (1999)



^{44}Ti Yield Derived From 1.157 MeV γ -Ray Line Flux

SNR name	Date A.D.	SN Type	Distance (kpc)	1.157 MeV flux ($10^5 \gamma \text{cm}^{-2} \text{s}^{-1}$)	^{44}Ti yield ($10^4 M_{\odot}$) $\tau=87.0$ yrs
Cassiopeia A	~ 1680	Ib/II?	2.8	3.3 ± 0.6	1.1 ± 0.2
Kepler	1604	Ia/Ib?	2.4	1.3 ± 0.6	1.0 ± 0.5
Tycho	1572	Ia	2.5	≤ 1.6	≤ 1.0
CTB80	1408?	II?	0.8	1.7 ± 0.6	9.2 ± 3.4
GROJ0852-4642	1300?	II?	0.2	3.8 ± 0.7	0.5 ± 0.1
Lupus SN	1006	Ia	1.4	≤ 1.5	≤ 86

1.157 MeV line profiles



RXJ0852.0-4622/GROJ0852-4642

$PH1+2+3+4+5+61 \rightarrow F_{line1} = (3.8 \pm 0.7) \cdot 10^{-5} \text{ ph cm}^{-2} \text{ s}^{-1};$
 $E_{line1} = 1163 \pm 16 \text{ keV}; \sigma_{r.m.s.} = 71 \pm 12 \text{ keV};$
 $\sigma_{Doppler} = 55 \text{ keV} \rightarrow V_{Doppler} = 14,300 \pm 3,700 \text{ km s}^{-1};$
 $E_{line2} = 1808 \pm 18 \text{ keV};$
 $\sigma_{r.m.s.} = 80 \pm 12 \text{ keV};$
 $\sigma_{Doppler} = 54 \text{ keV} \rightarrow V_{Doppler} \approx 9,000 \text{ km s}^{-1}$

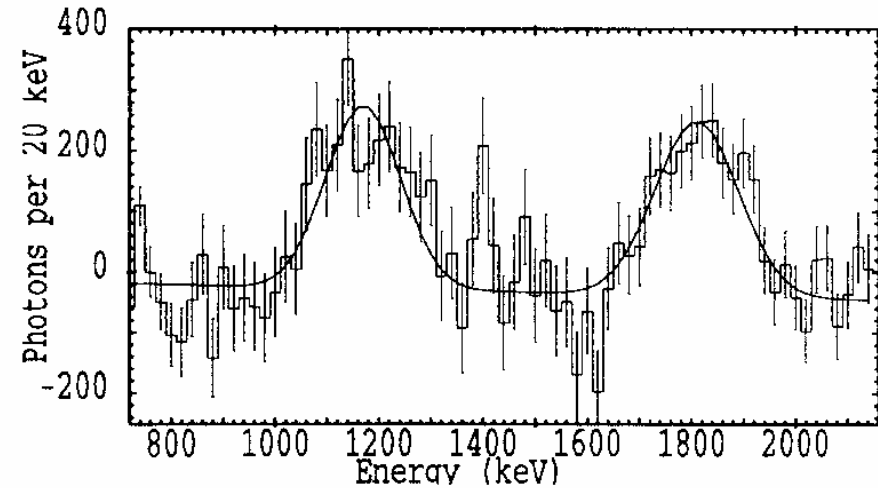
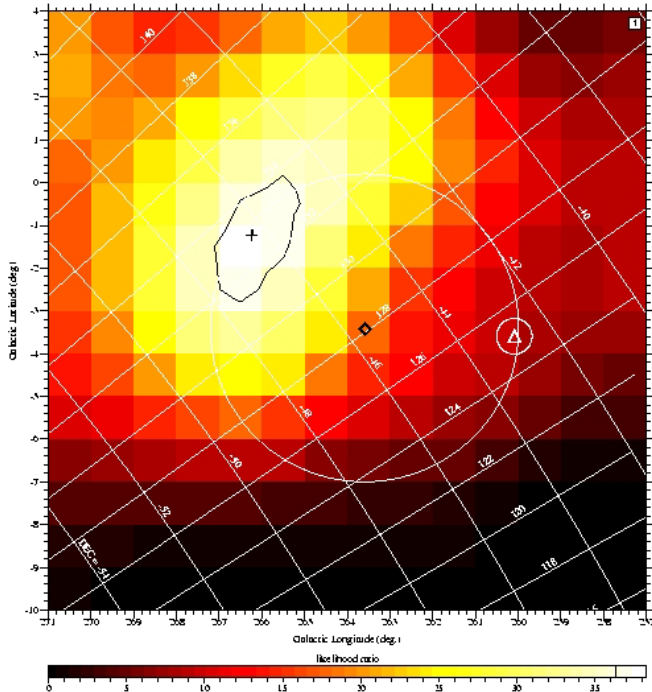


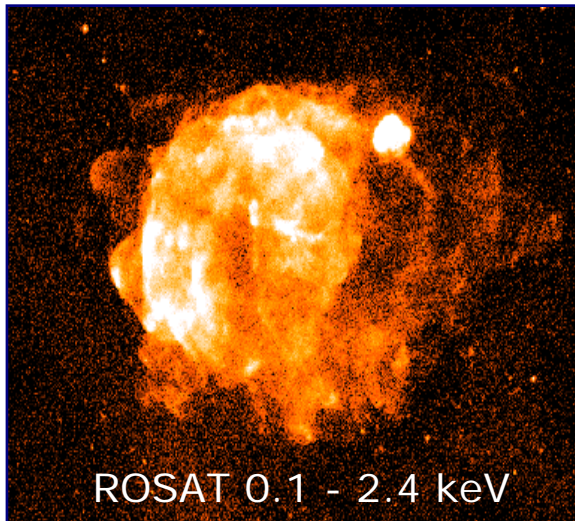
Fig 2: *GROJ0852-4642* residual spectrum derived for a combination of 32 VPs (Iyudin et al. 1998).

SNRs and ^{44}Ti

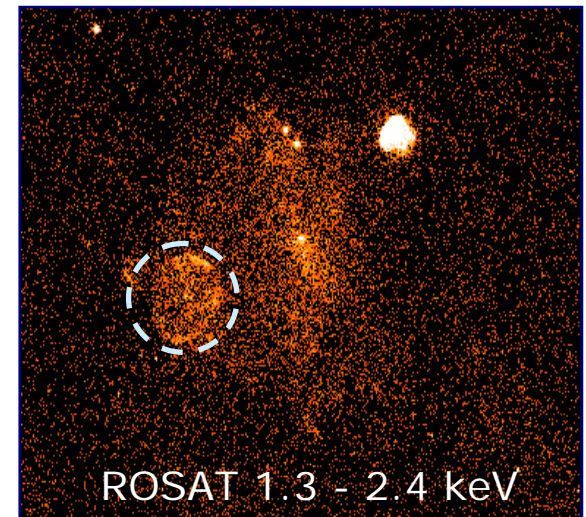
- From an observational point of view... Few cases !

★ Vela Junior

- 👉 Detected by **COMPTEL** (Iyudin et al. 98) and **ROSAT** (Aschenbach 98)
- 👉 Scenario « young & nearby » ?
- 👉 Reality of the ^{44}Ti detection ?



Y_{44} ?



- 👉 A lot of interrogations... (Slane et al. 01, Schönfelder et al. 00, Iyudin 2001)

Summary: 1.157 MeV Line Astrophysics

- 1.157 MeV Line Address
 - ☆ Supernova Explosion Mechanisms (thermonuclear, core-collapse SN)
 - ☆ Cosmic-Ray Accelerator Injection Aspects (LECR)
- Core Collapse SN Asymmetries Reflected in ^{44}Ti
- LECR Observations still not Sensitive Enough!?
- **Waiting for GRIPS!!!**