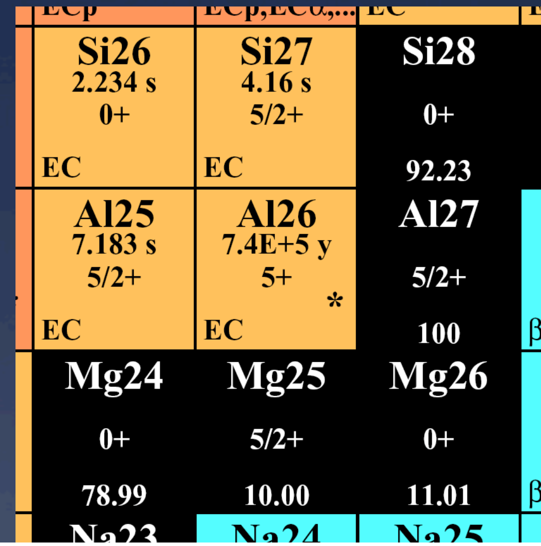
INTEGRAL Studies of Nucleosynthesis lines

M. Leising & D. Hartmann

IUG meeting 2009 dec

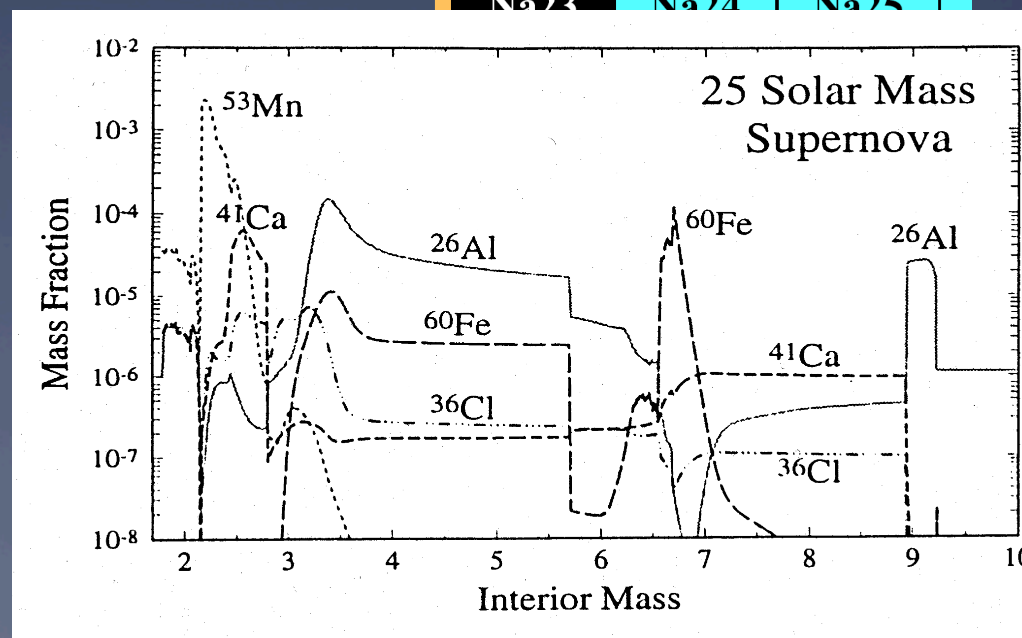
^{26}Al
1809 keV 1.04 My



^{25}Mg + p → ^{26}Al + γ
(^{27}Al + ν → ^{26}Al + n)

Massive star winds
Core-collapse SNe
Classical novae
AGB stars

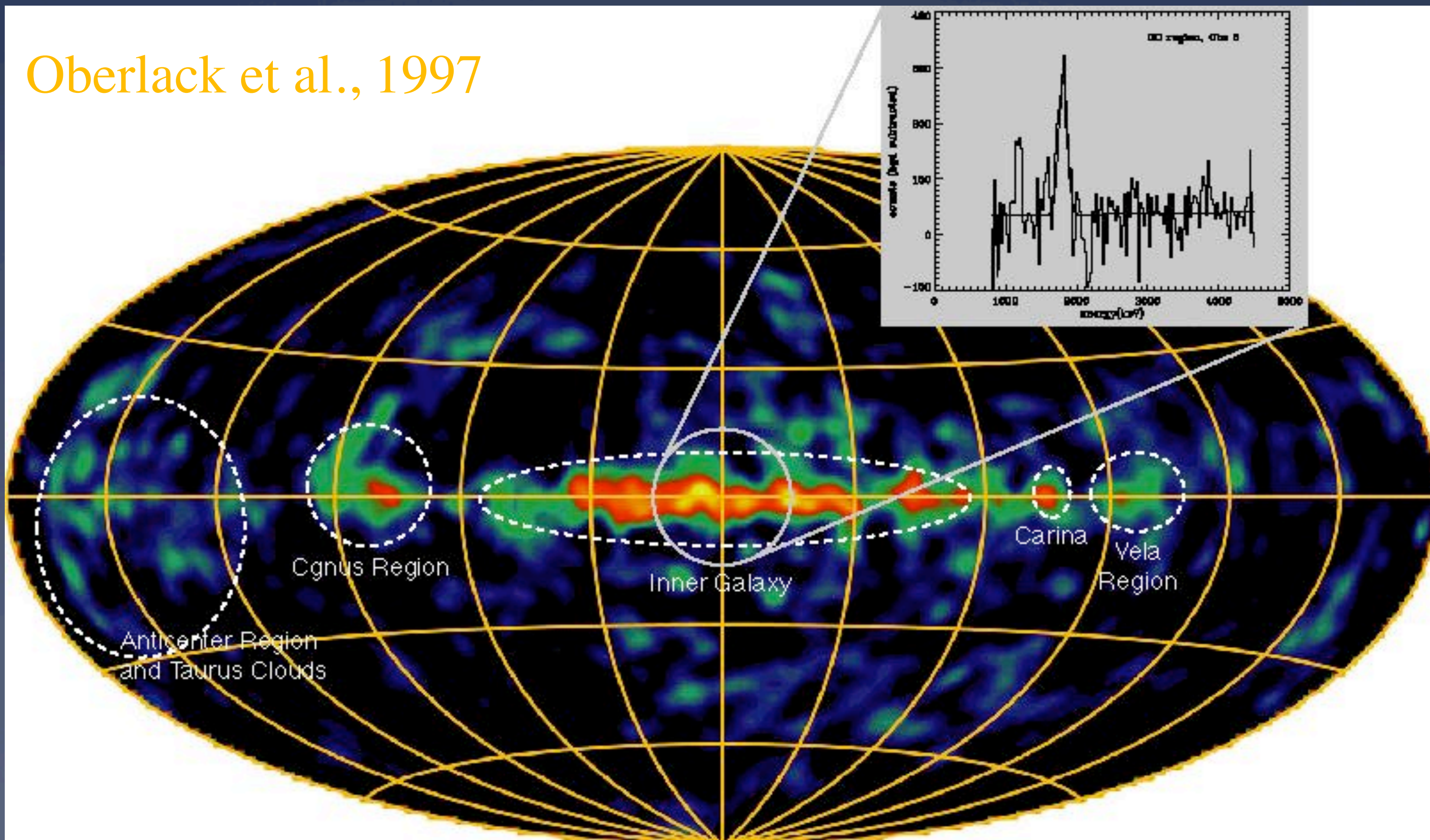
present in early Solar System



Woosley & Weaver 95

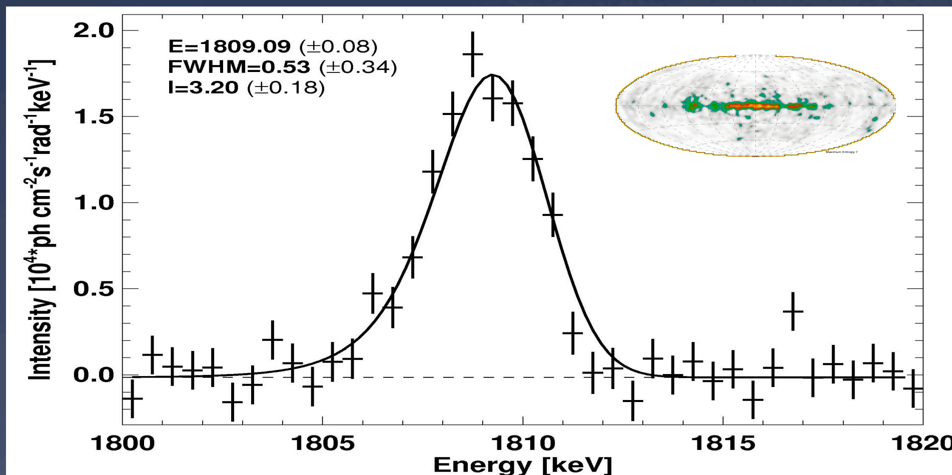
^{26}Al - CGRO COMPTEL

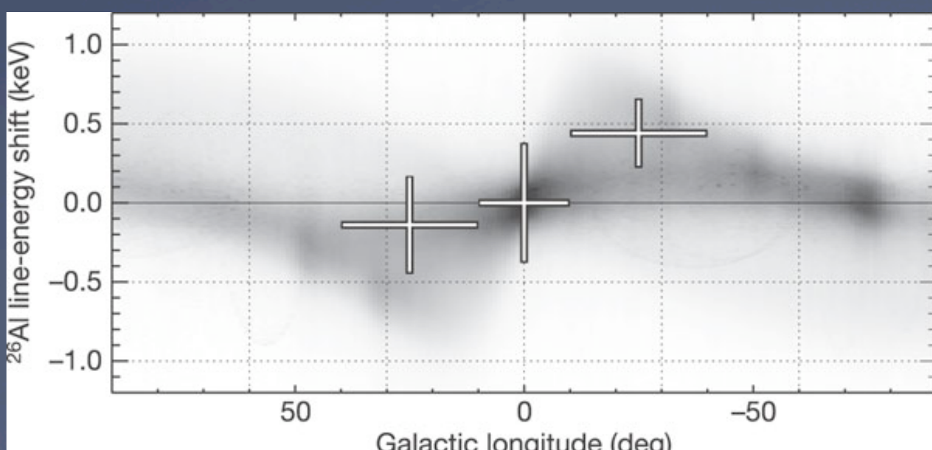
Oberlack et al., 1997



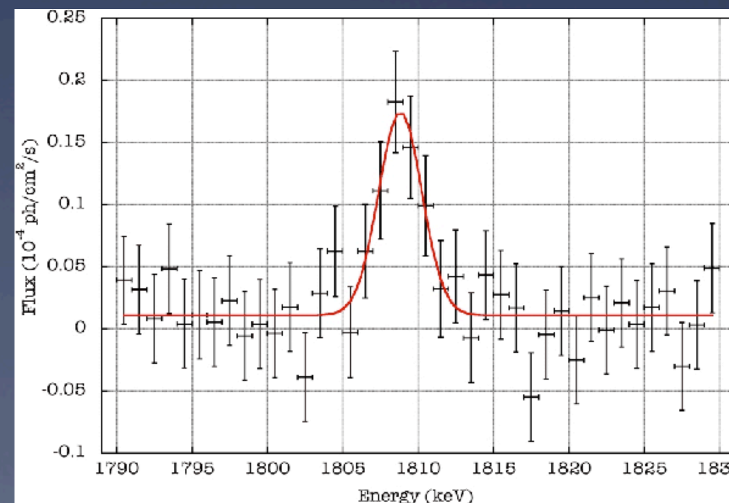
INTEGRAL/SPI ^{26}Al Observations

Central galaxy: Diehl et al. 2006

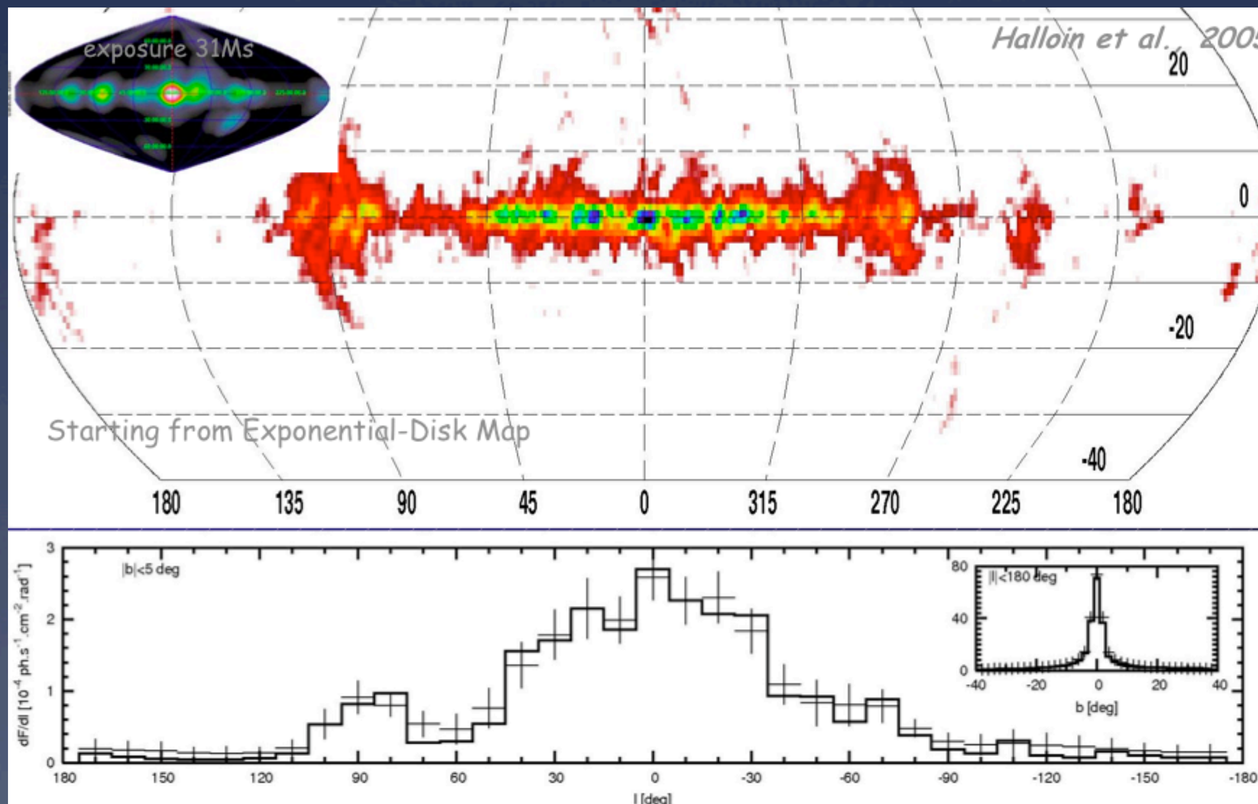




Cygnus OB Association: Martin et al. 2009



INTEGRAL SPI – ^{26}Al



Summary:

Flux (1.809 MeV) = 4.0 10^{-4} cm^{-2} s^{-1} --> $M_{ism}(^{26}Al)$= 2.5 $M_{\odot}$

e.g. core collapse SNe at 2.5 $century^{-1}$ with $M_{ej}(^{26}Al)$=10^{-4} $M_{\odot}$

And progenitor winds

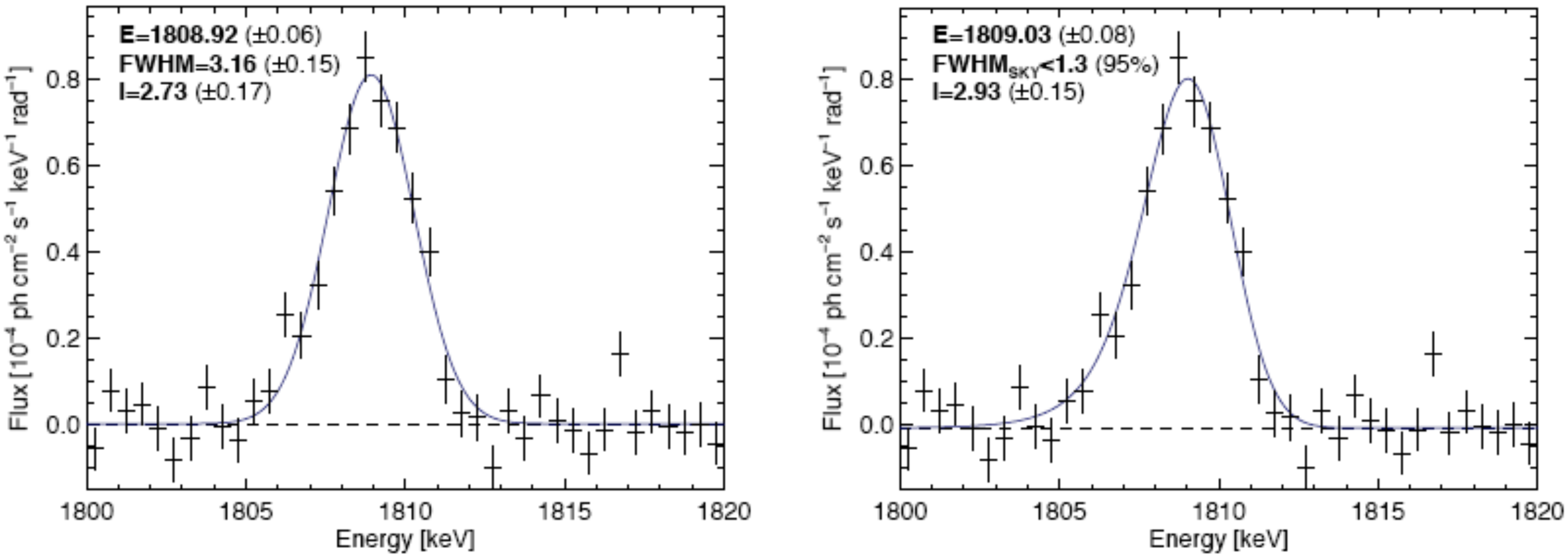
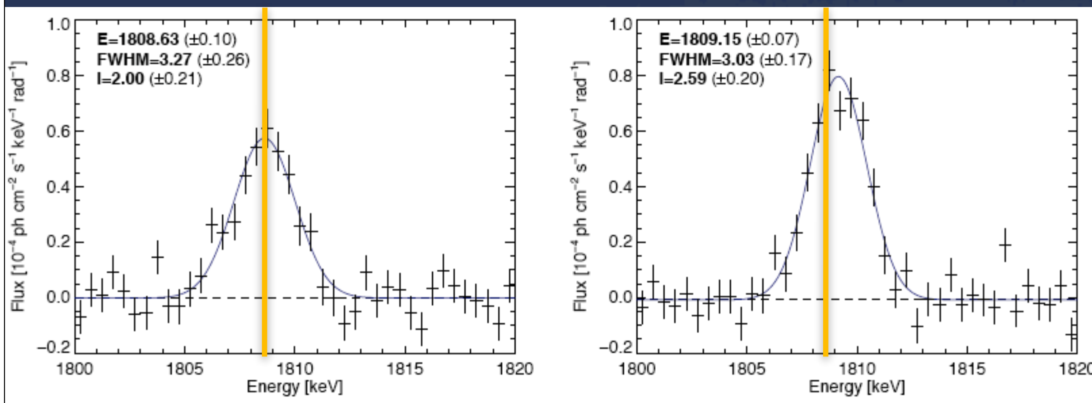
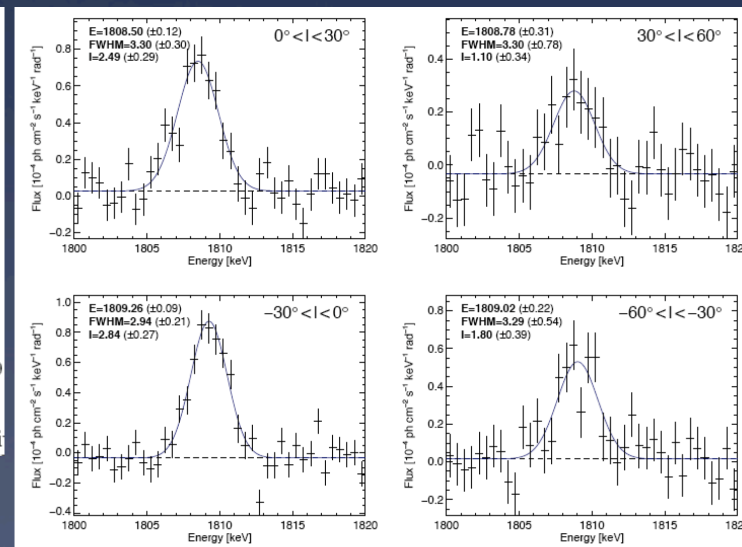
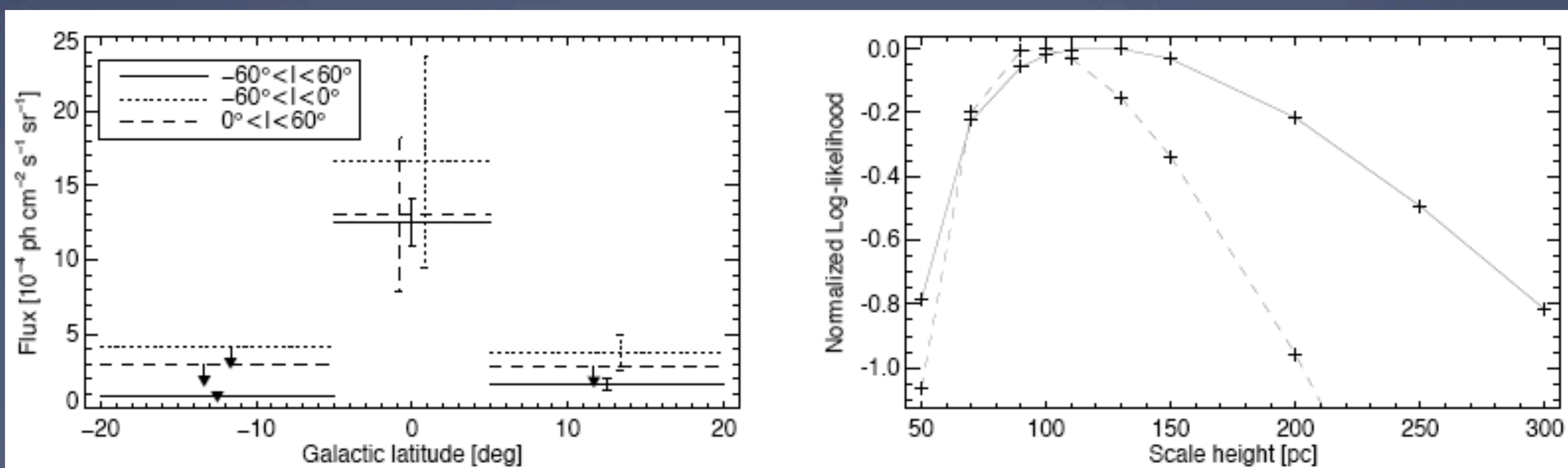


Fig. 5. Spectrum derived from sky model fitting using the COMPTEL ^{26}Al Maximum Entropy image. The left figure shows the ^{26}Al line fitted with a Gaussian, the width of $\sim$ 3.16 keV (FWHM) being consistent with instrumental line widths around 1.8 MeV. The right figure shows the line fitted with a composite line-shape model using the time-averaged instrumental response as it results from cosmic-ray degradation and annealings during the time of our measurement, convolved with a Gaussian representing the cosmic (intrinsic) ^{26}Al line width. The latter is found to be (< 1.3 keV, 2σ). Both fits find that the line is intrinsically narrow. Systematic variations of derived line fluxes using two spatial models are less than the statistical uncertainty in the measurement (fluxes are quoted in units of 10^{-4} ph cm^{-2} s^{-1} rad^{-1})

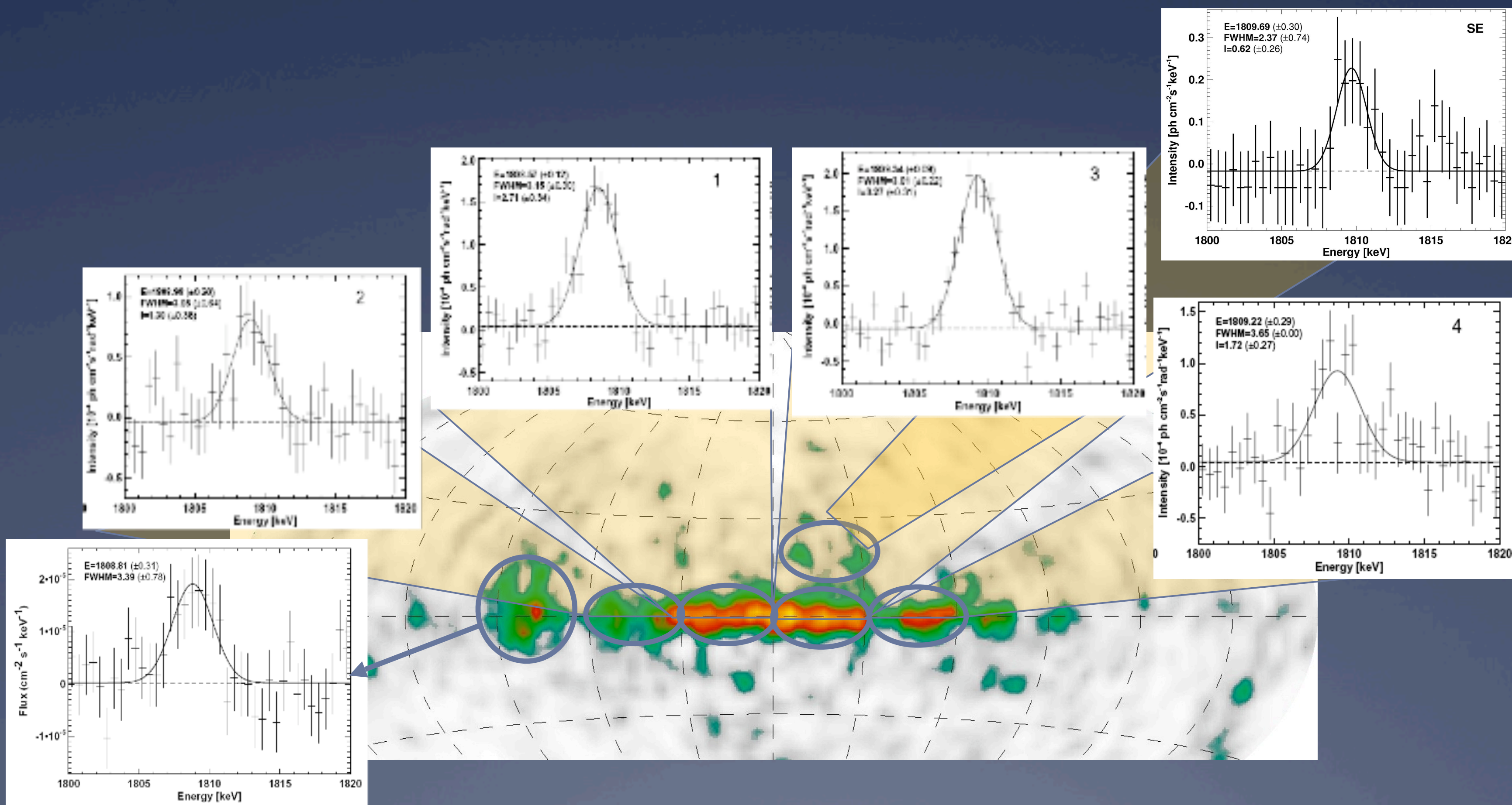


. ^{26}Al spectra for two Galactic quadrants (**left** $0° < l < 60°$, and **right** $-60° < l < 0°$). Line centroids relati





Next steps: ^{26}Al

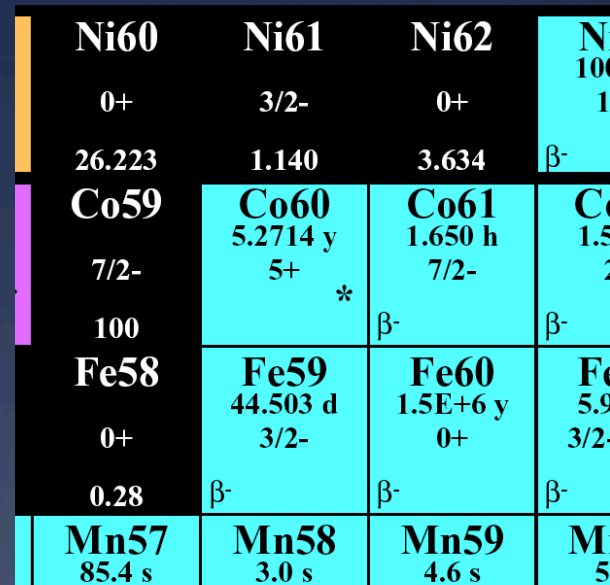


Courtesy R. Diehl

^{60}Fe 2.2 (3.0) My

1173,
1333 keV

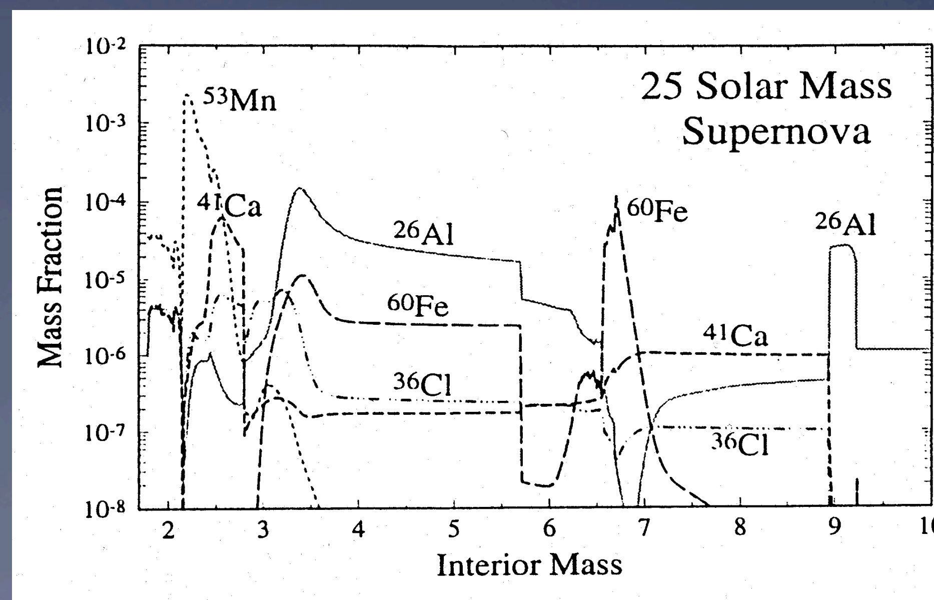
59 keV



n captures on Fe

Core-collapse SNe
Ne-burning
He-burning

AGB stars ?
SNe Ia ?



Woosley & Weaver 1995

^{60}Fe 2.2 (3.0) My

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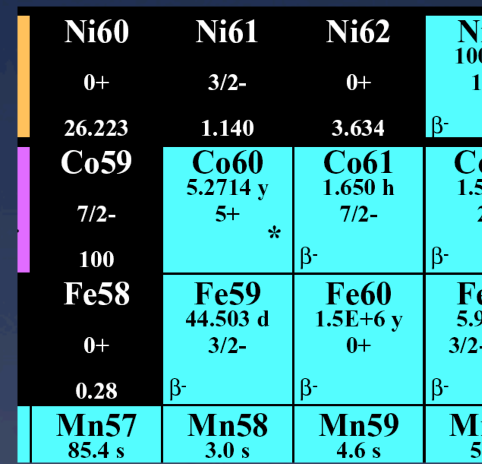
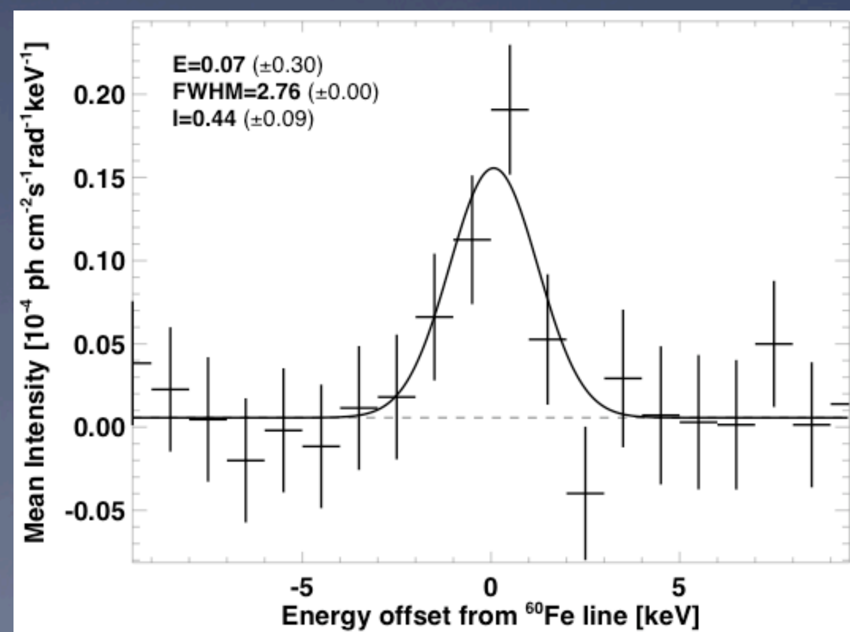


Only upper limits, some below theoretical expectations, until RHESSI (marginal) detection [Smith, D. M. 2004].



INTEGRAL SPI (Wang et al. 2007)

Flux (^{60}Co lines) = 4.4 10^{-5} cm^{-2} s^{-1}

--> $M_{ism}(^{60}Fe)$= 1.2 M_0

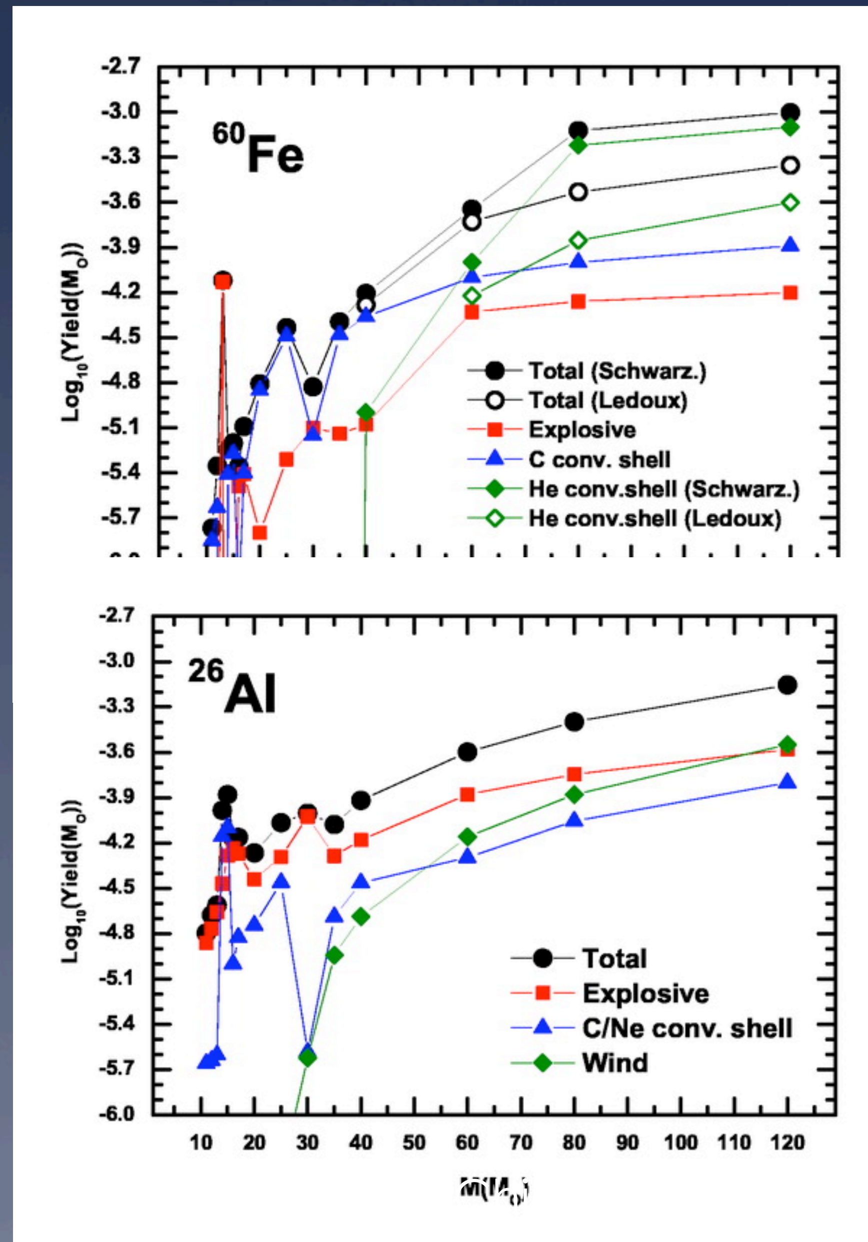
^{60}Fe relative

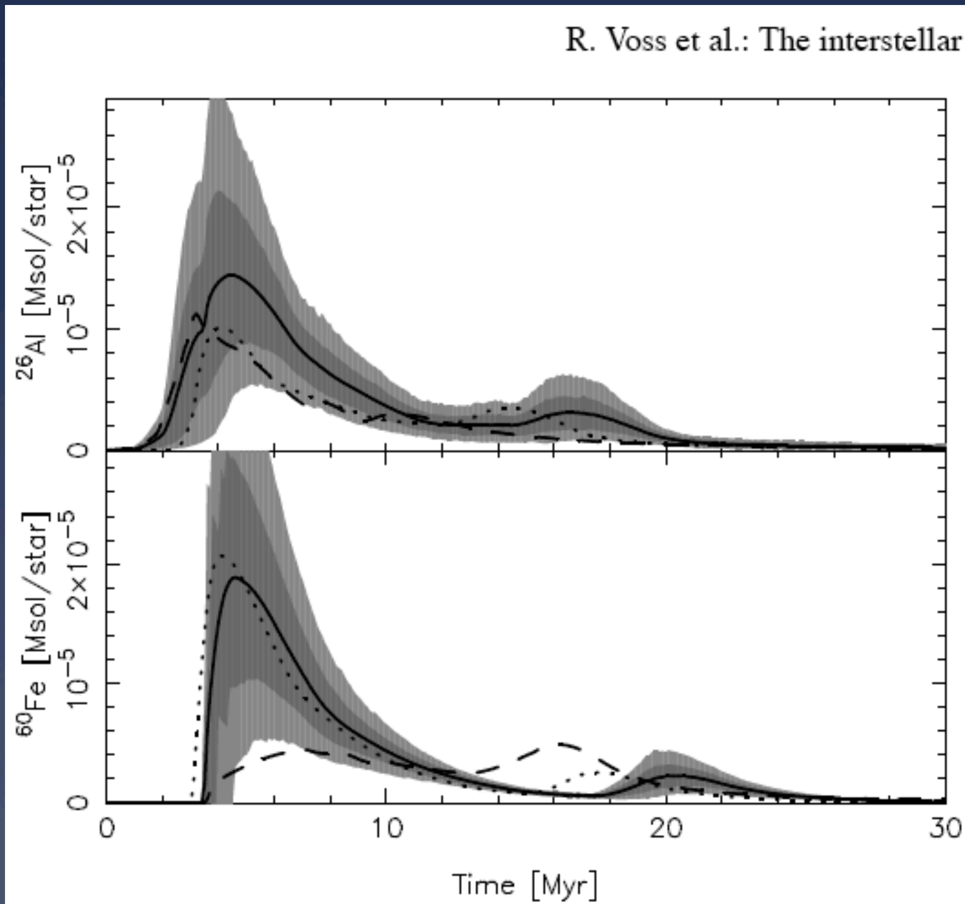
Mass production ratio (SPI only*):

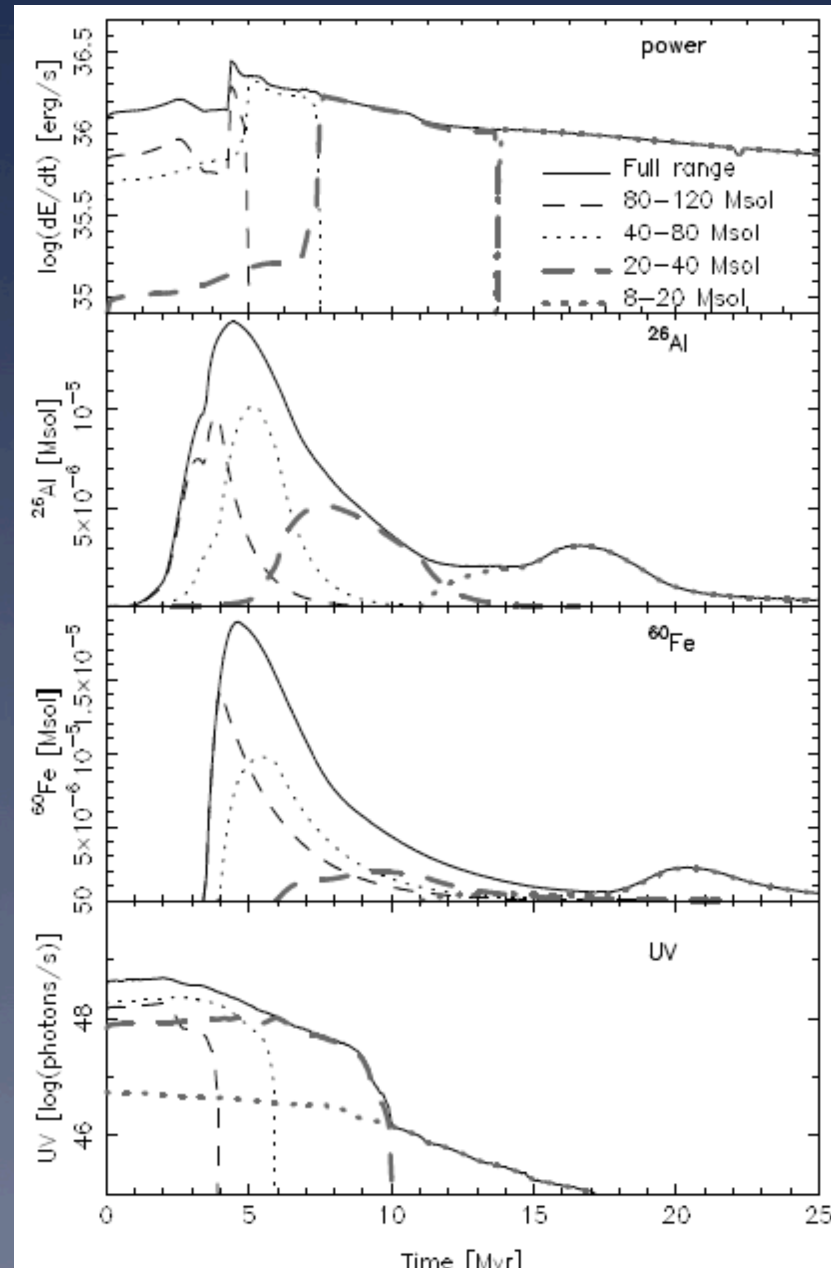
$P(60)/P(26) = 0.25 \pm 0.09$

n.b. other ^{26}Al sources (novae, AGB)

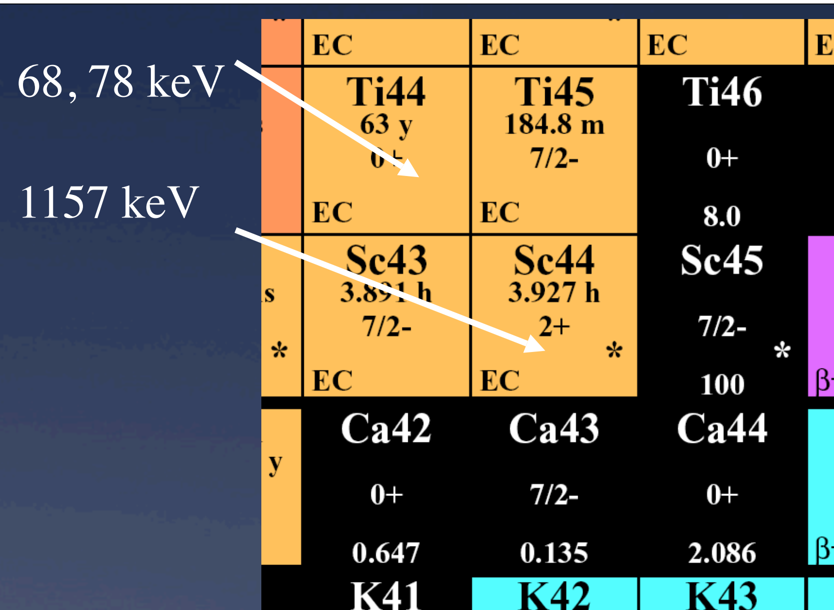
* ~Cancel uncertainties due to angular distribution, etc.




R. Voss et al.: The interstellar
26Al [Msol/star]
60Fe [Msol/star]
0
10−5
2×10−5
0
10
20
30
Time [Myr]


power
log(dE/dt) [erg/s]
35
35.5
36
36.5
Full range
80−120 Msol
40−80 Msol
20−40 Msol
8−20 Msol
26Al
26Al [Msol]
5×10−6
10−5
60Fe
60Fe [Msol]
5×10−6
10−5
1.5×10−5
UV
UV [log(photons/s)]
46
48
0
5
10
15
20
25
Time [Myr]

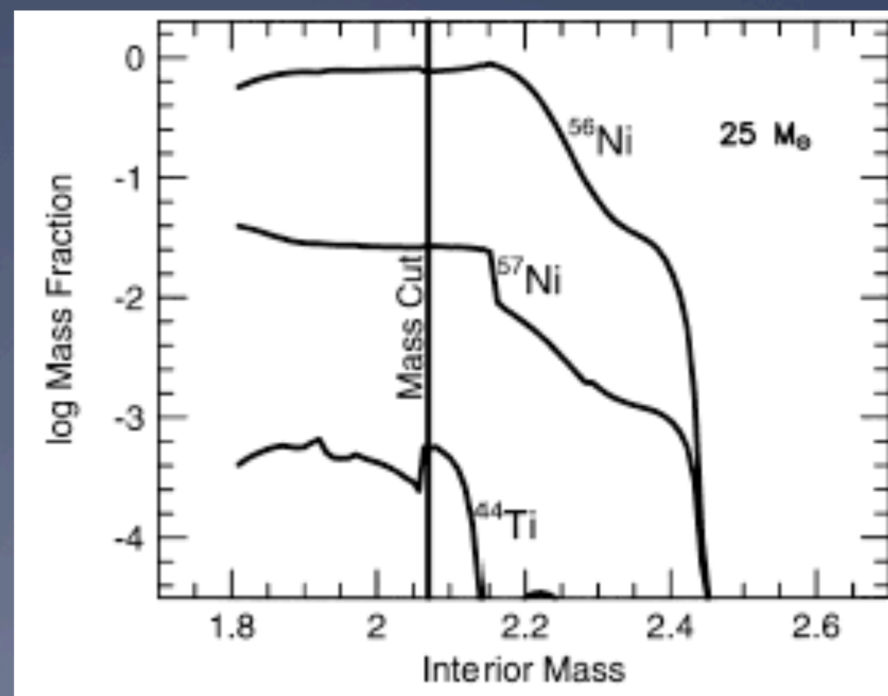
^{44}Ti emission from SNR



Source of 44Ca in nature

Made in α-rich freezeout of NSE

- high T → *last matter ejected*
- Fast expansion → *jets*



Woosley & Weaver 1995

^{44}Ti -- Cas A, IBIS

Renaud et al. 2006

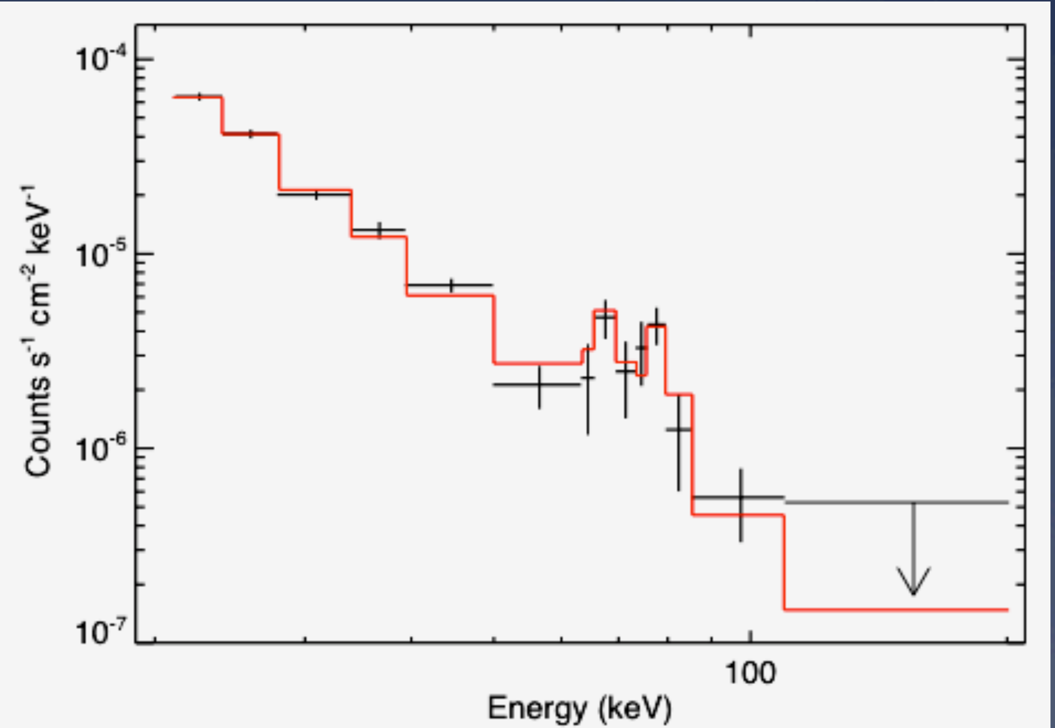


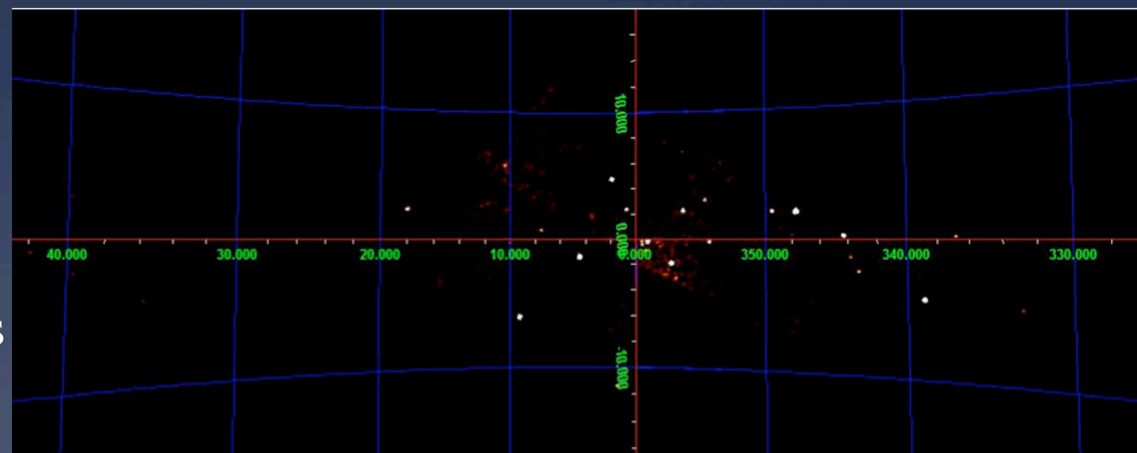
FIG. 3.— IBIS/ISGRI spectrum of Cas A and the best-fit model as descri

Summary: all instruments consistent with:
Line fluxes = 2.5 10^{-5} cm^{-2} s^{-1}

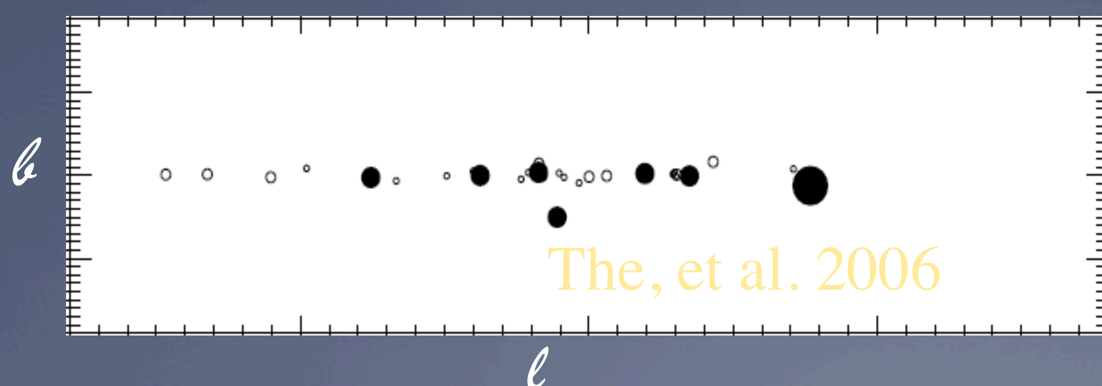
M_{44} = 1.6 10^{-4} $M_{\odot}$

Where are the other ^{44}Ti SNR?

IBIS -
Renaud et al. 2004,
following many others



Re: Cas A
standard rates/yields
^{44}Ca abundance



The, et al. 2006

Solution?
Rare events (yet unseen) make most ^{44}Ca, Cas A yield high for core collapses?

Summary

* ~ slow sqrt(t) improvement
* Significantly more data in hand & accumulating
* Local 26Al regions
* Improved 60Fe detection
* Spur theoretical studies
* 44Ti search updated