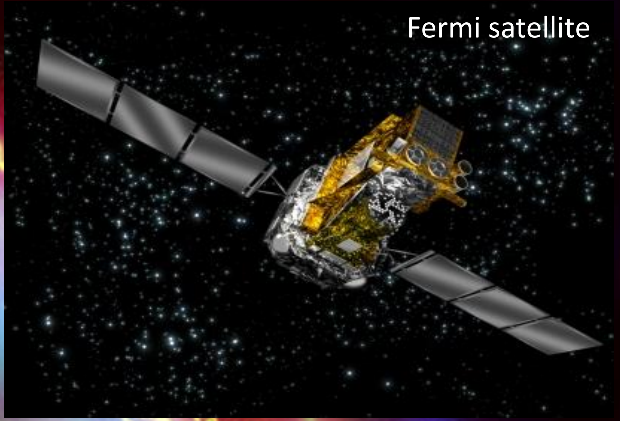

How Not to Miss the Supernova of the Century: Using Fermi GBM as an Alarm for a Future Galactic Type Ia Event

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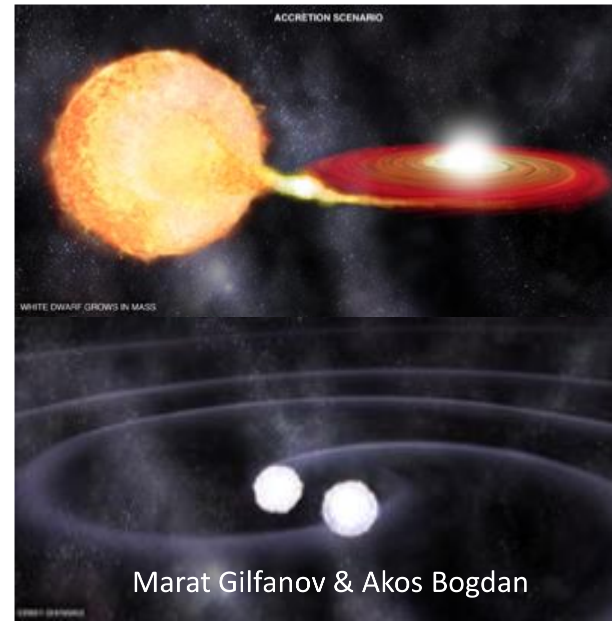
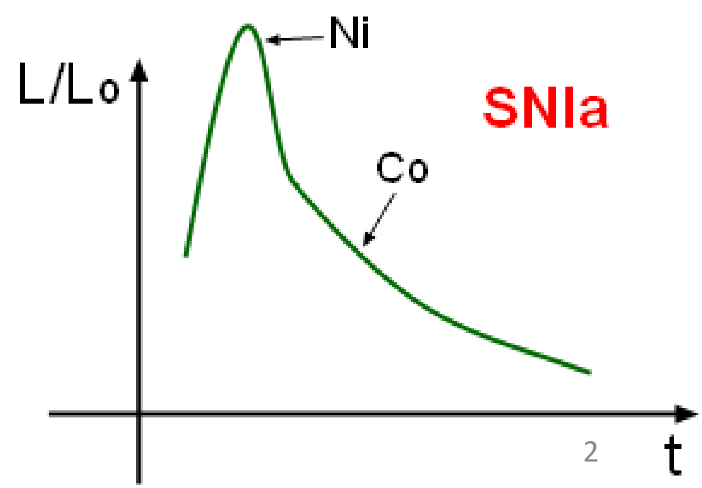
Kepler's SNR
Credit: NASA/ESA/JHU/R.Sankrit & W.Blair

Type Ia Supernova (SN Ia)

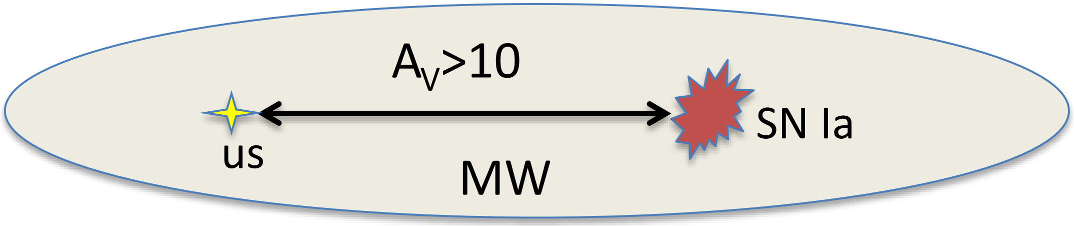
- Galactic Type Ia Supernova rate: ~1.4 events/century;
- Accelerator of cosmic rays—> GeV and TeV gamma-rays ;
- Formation model: single vs. double degenerate scenarios;
- "Standard candle" ;
- Nucleosynthesis sites of iron-group elements;
- Light curve is powered by ^{56}Ni radioactive decay.





A Galactic SN Ia May Be Unnoticed

- Optical or IR? large extinction in the plane—> faint



- Radio or soft X-ray? not seen for SN2014J
- Neutrinos? –> weak and in low energy
- A Galactic Type Ia SN could happen anywhere any time, most MW plane are not monitored at most wavelength—>It's possible that we'll miss it!

Gamma-rays can act as monitor of a Galactic SN Ia

Type Ia SN:

(confirmed by SN20

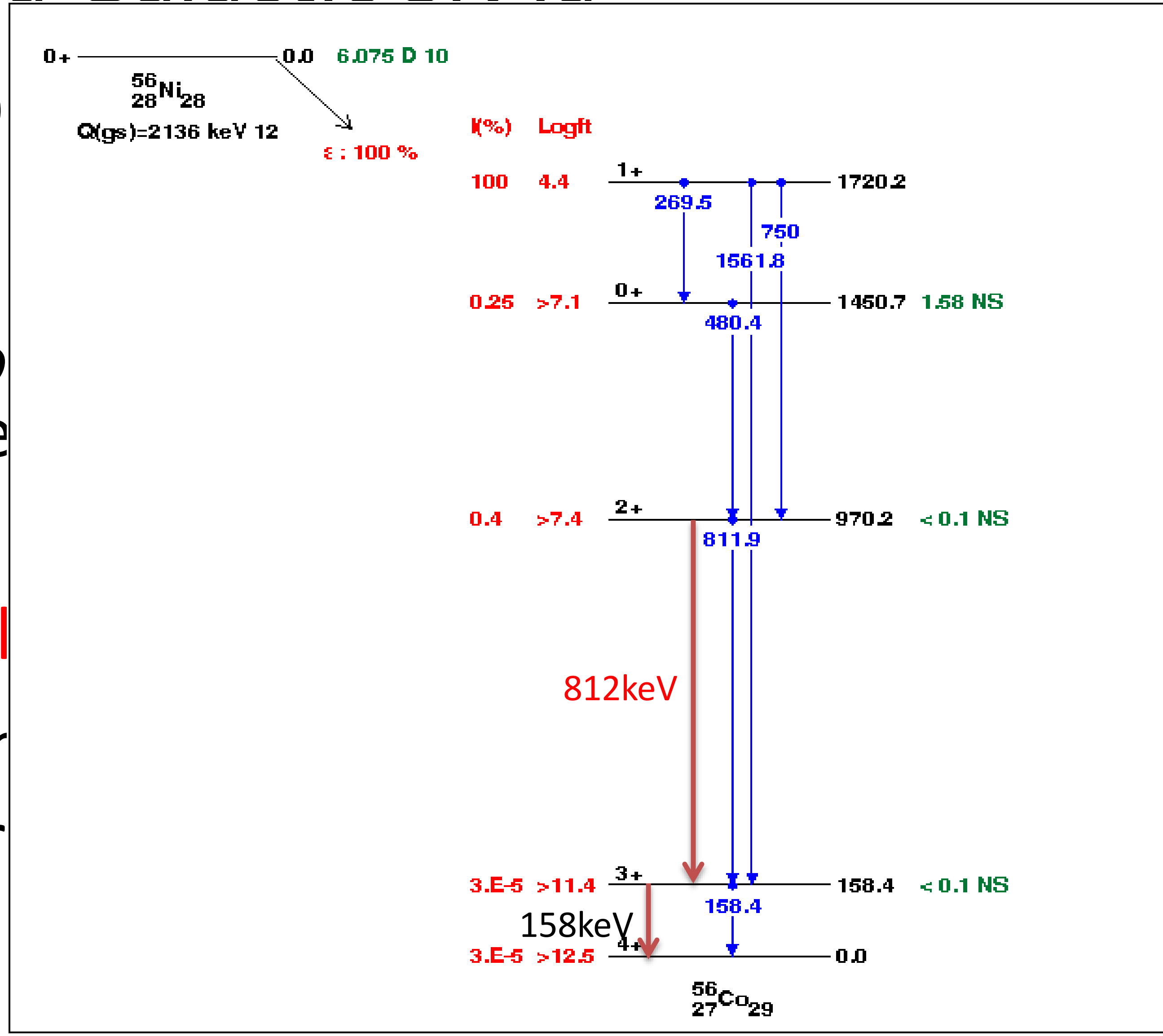
^{56}Ni

^{56}Co

- The decay line
2.6MeV

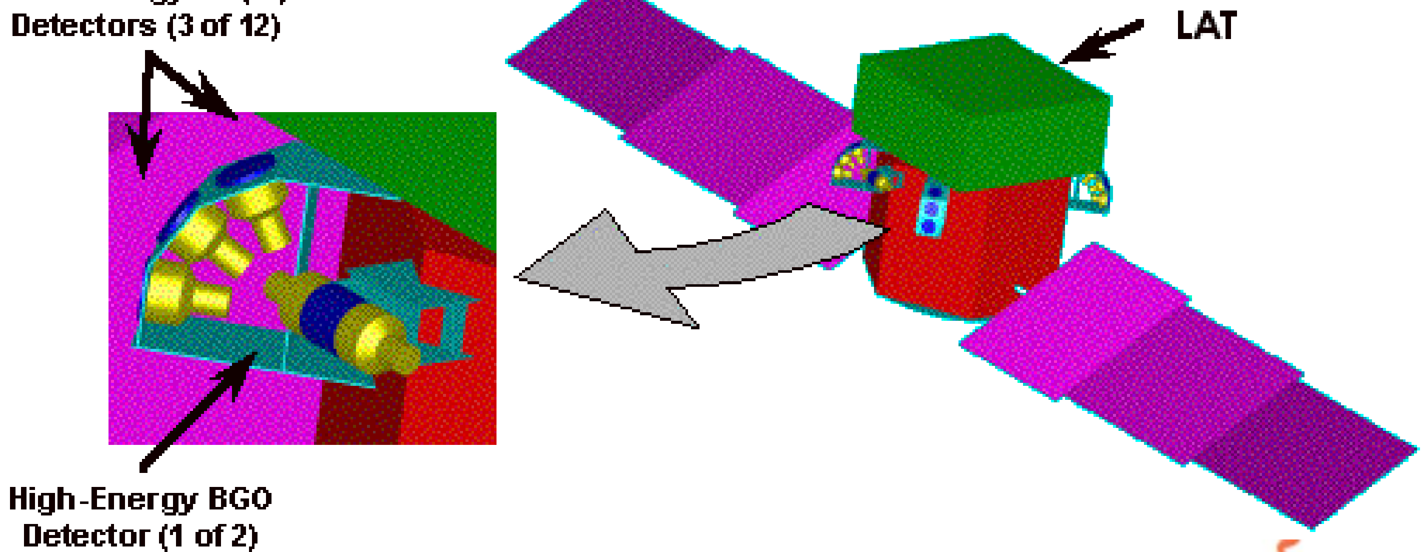
- MW is opticall

We need a gam
above energy r
the sky!

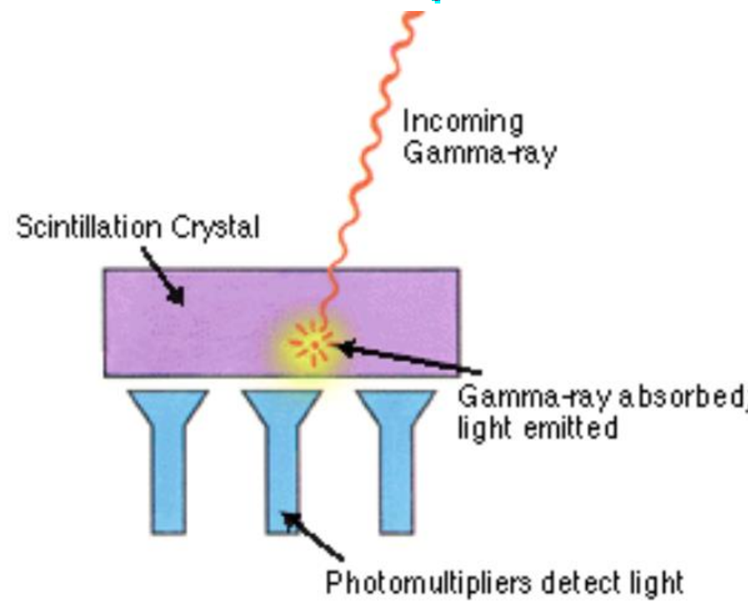


Fermi Gamma-ray Burst Monitor

Credit: Fermi website

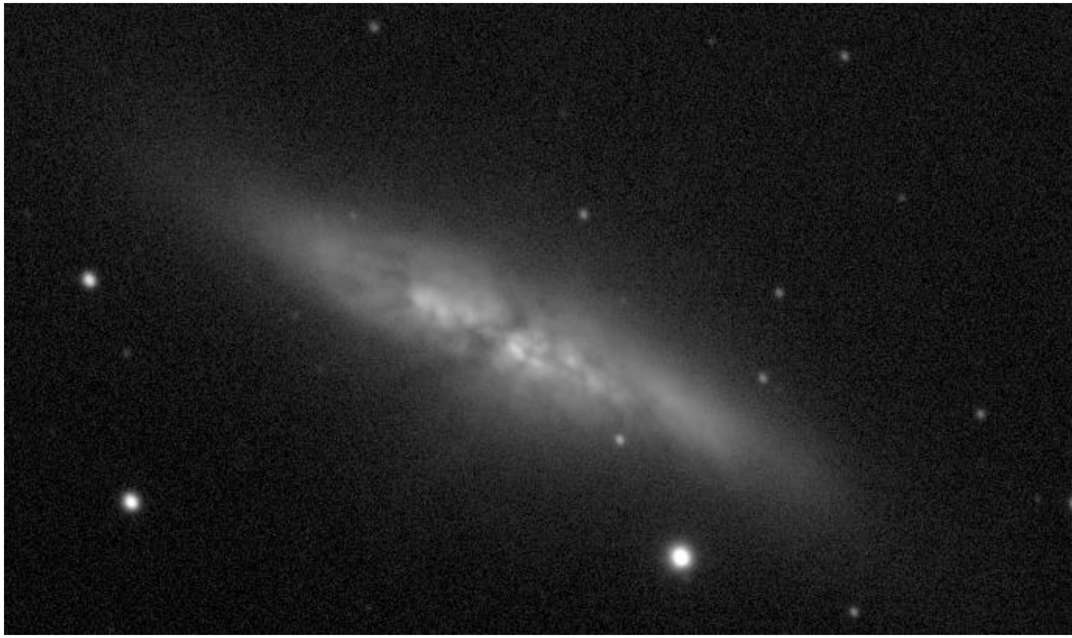


- Scintillation detector:
  12 NaI (8 keV -1 MeV)
  2 BGO (150 keV - 40 MeV)
- Field of view: 9.5 steradian
- Energy resolution: 12% FWHM at 511keV

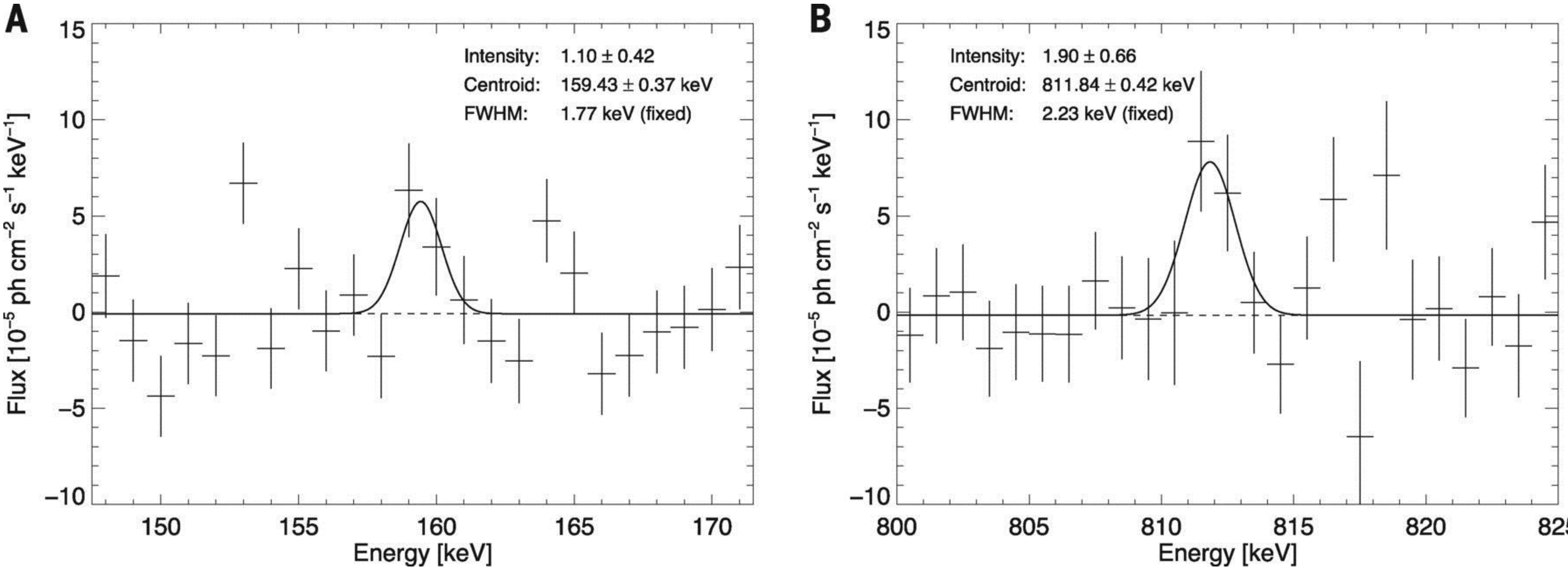


Type Ia SN2014J

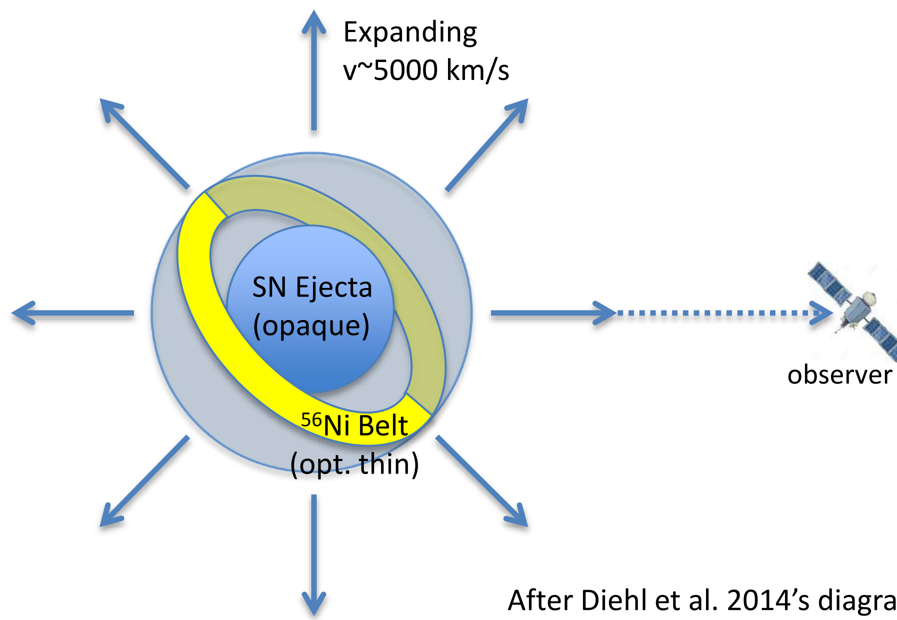
- SN2014J in M82 (~3.5Mpc)
- Discovered: Jan 21,2014
- INTEGRAL SPI observation: Jan 31-Apr 24
- Both 56Ni and 56Co lines were seen as early as ~20 days after the explosion



SN2014J in M 82
Credit: UCL/University of London Observatory/Steve Fossey/Ben Cooke/Guy Pollack/Matthew Wilde/Thomas Wright

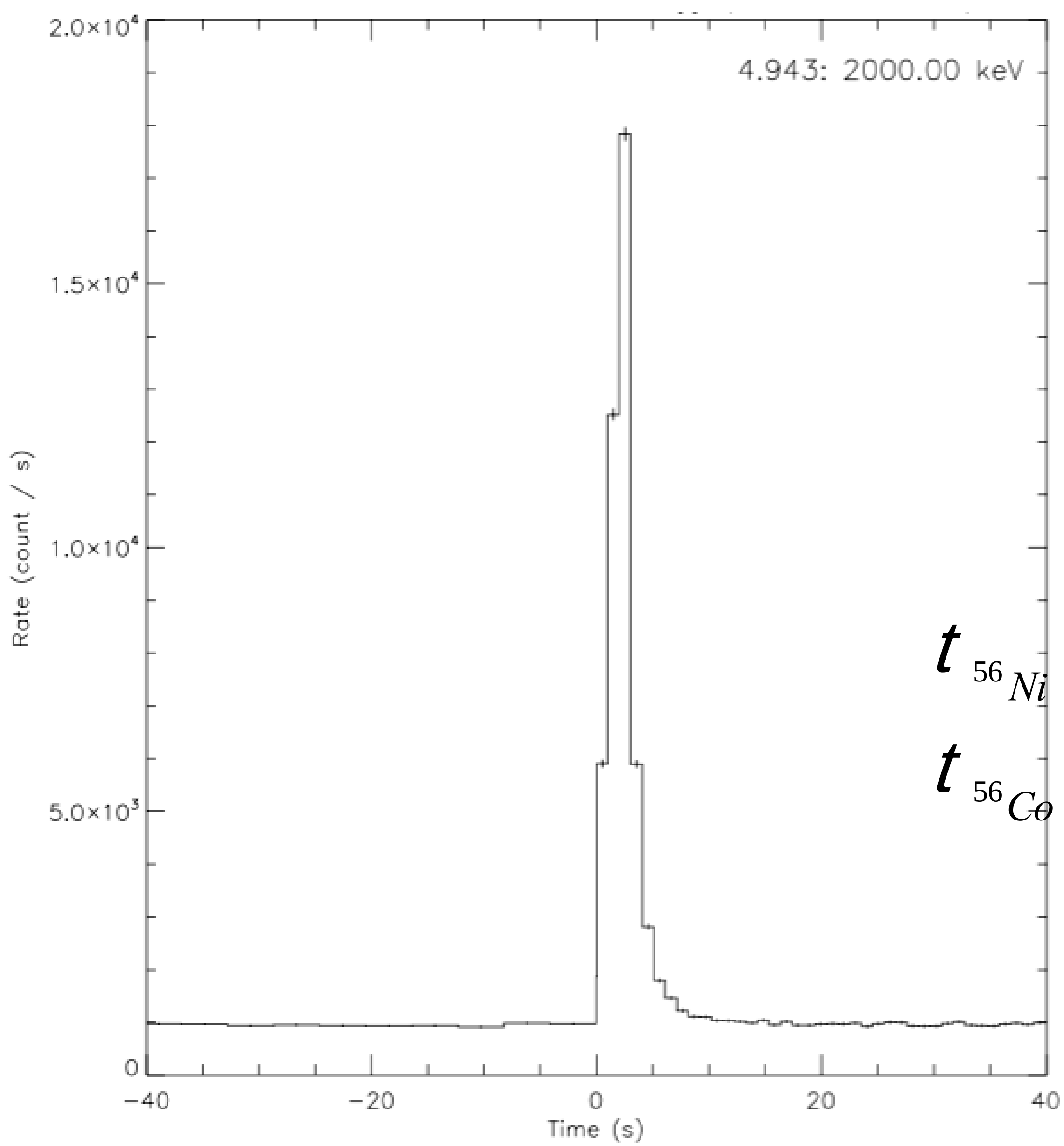


- Compton scattering—> opaque during first 10-20 day for gamma-ray lines—> early seen ^{56}Ni lines: ^{56}Ni belt model (Ni belt mass ~ 10% total Ni mass)



After Diehl et al. 2014's diagram

• If a G… will
we c… SN Ia?



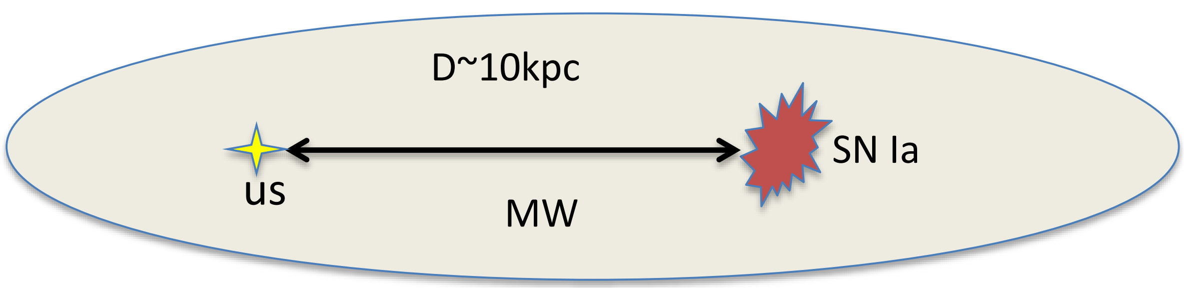
$$t_{^{56}Ni} = 8.8\ days$$

$$t_{^{56}Co} = 111.3\ days$$

Galactic Type Ia Alarm: Approach

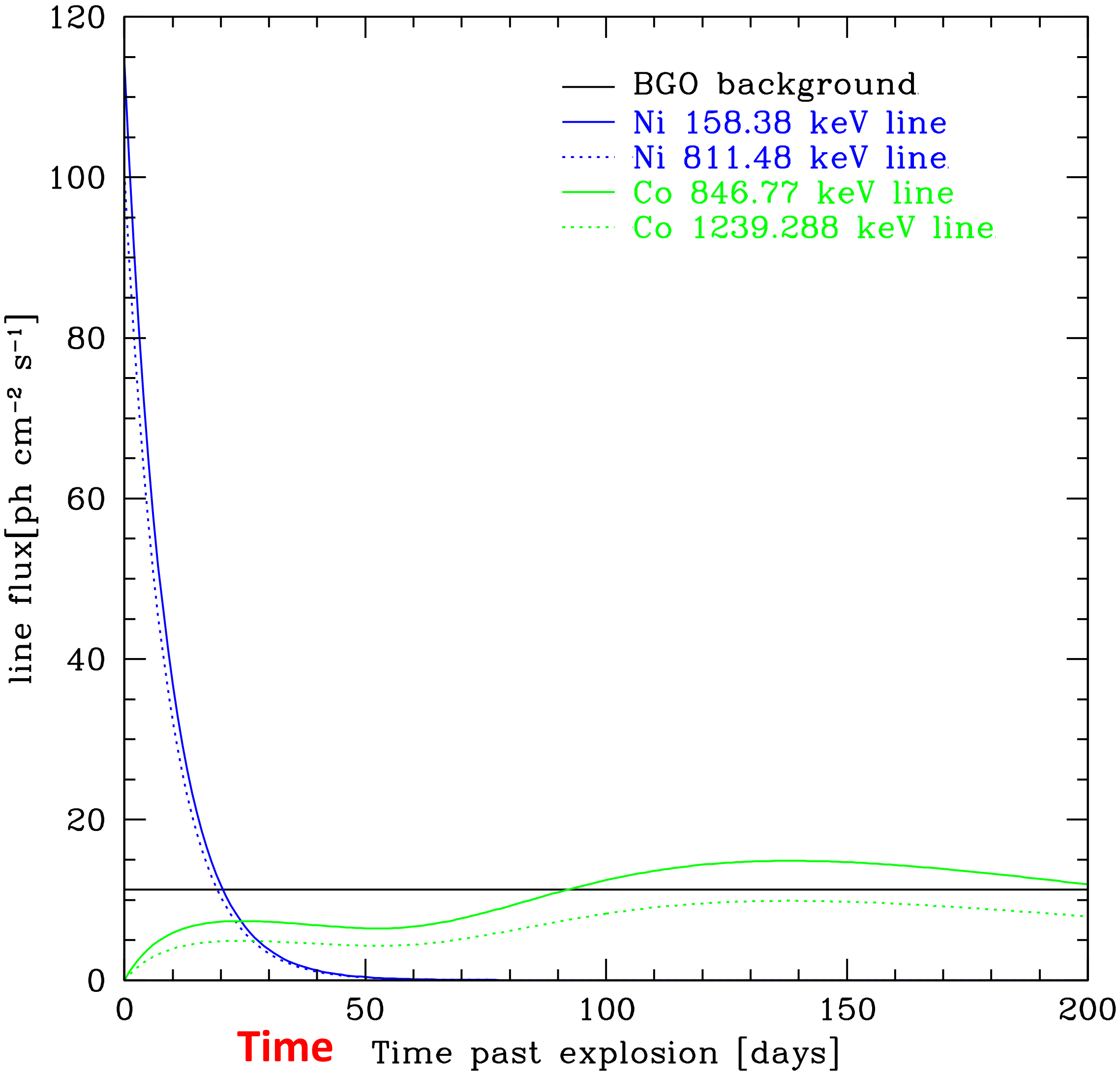
Galactic SN Ia:

- Use earliest SN2014J detection at 17 days to constrain the parameters in a Ejecta+Belt model
- Fiducial distance: 10 kpc



Light Curves

PRELIMINARY



line Flux

Time

Ni & Co lines signal in GBM BGO detector

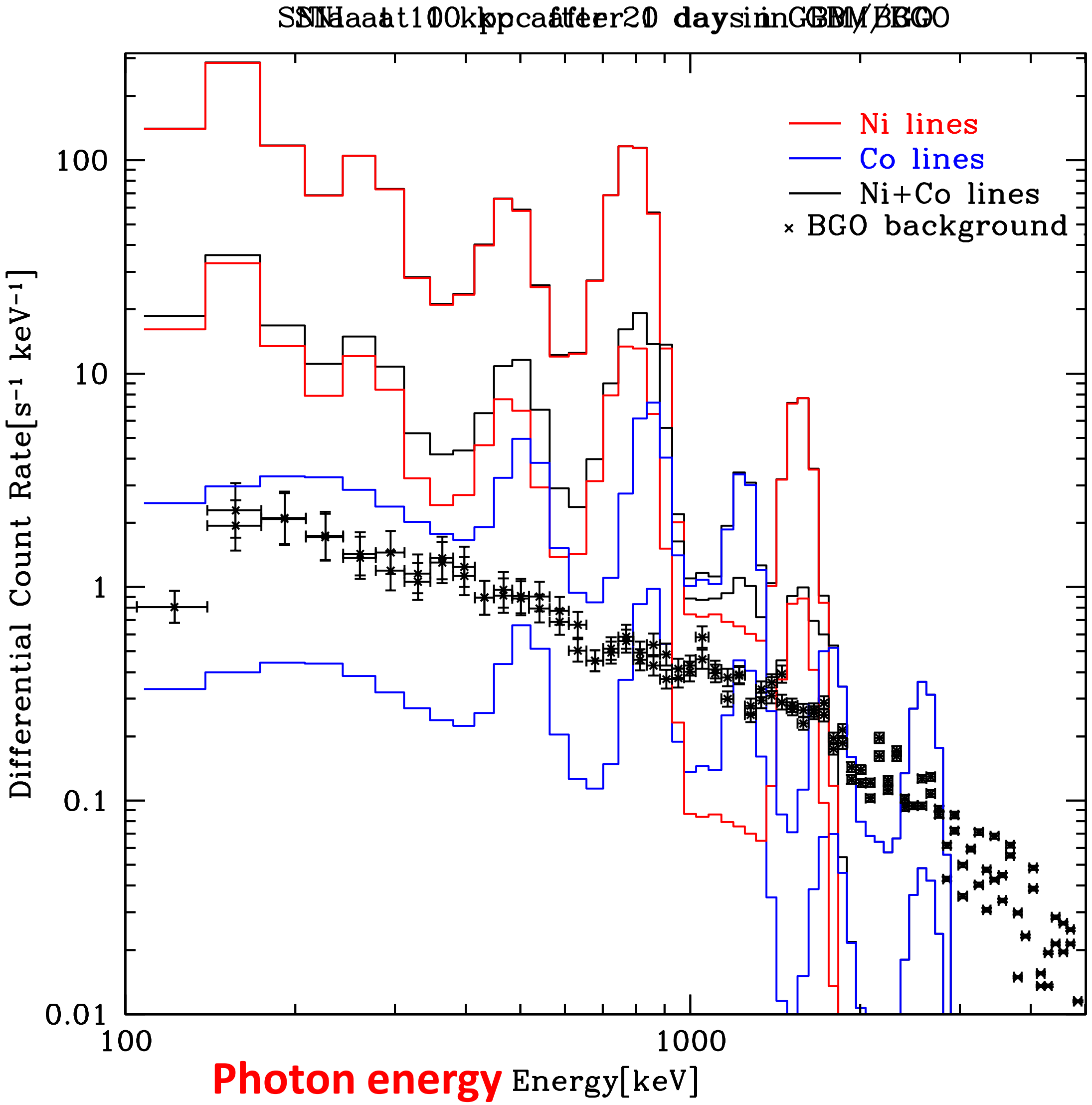
Average background signal in BGO: ~1700 ph/s

$$t_{^{56}Ni} = 8.8\ days$$

$$t_{^{56}Co} = 111.3\ days$$

Spectra

PRELIMINARY



Ni and Co lines signal in GBM BGO detector at 1 day and 20 days after Galactic SN Ia explosion

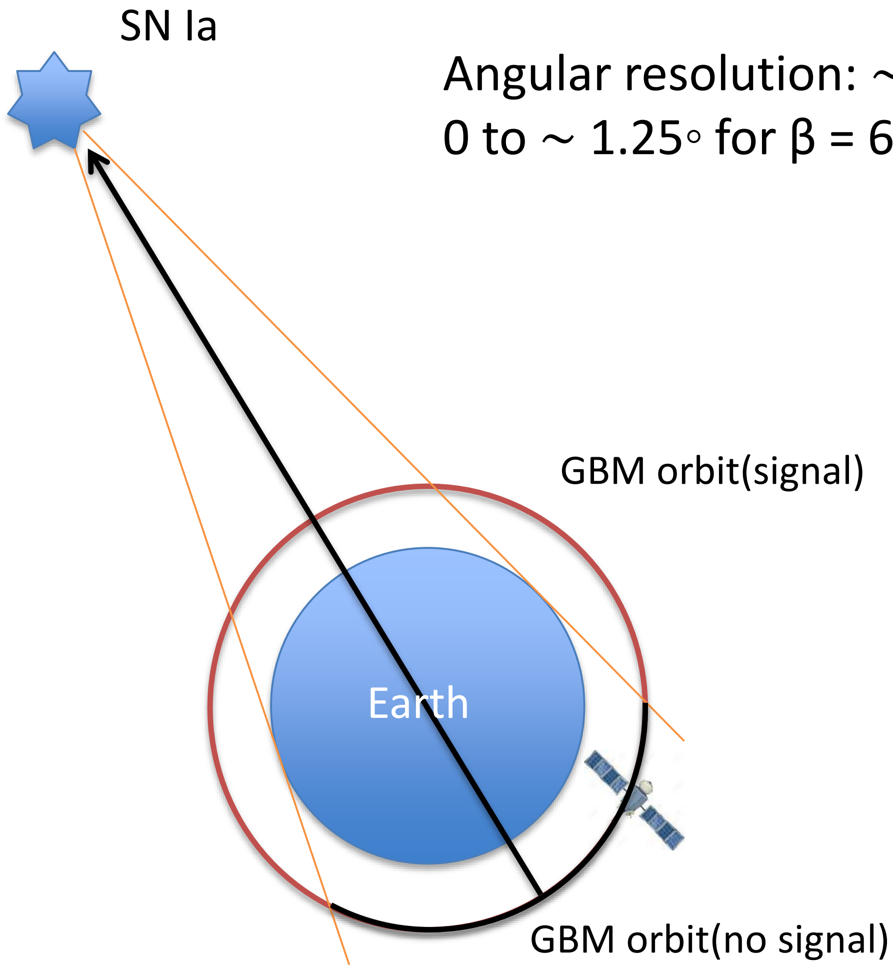
$t_{^{56}Ni} = 8.8\ days$

$t_{^{56}Co} = 111.3\ days$

Localization

- Earth Occultation

Angular resolution: ∼ 0.5◦ for β = 0 to ∼ 1.25◦ for β = 66◦



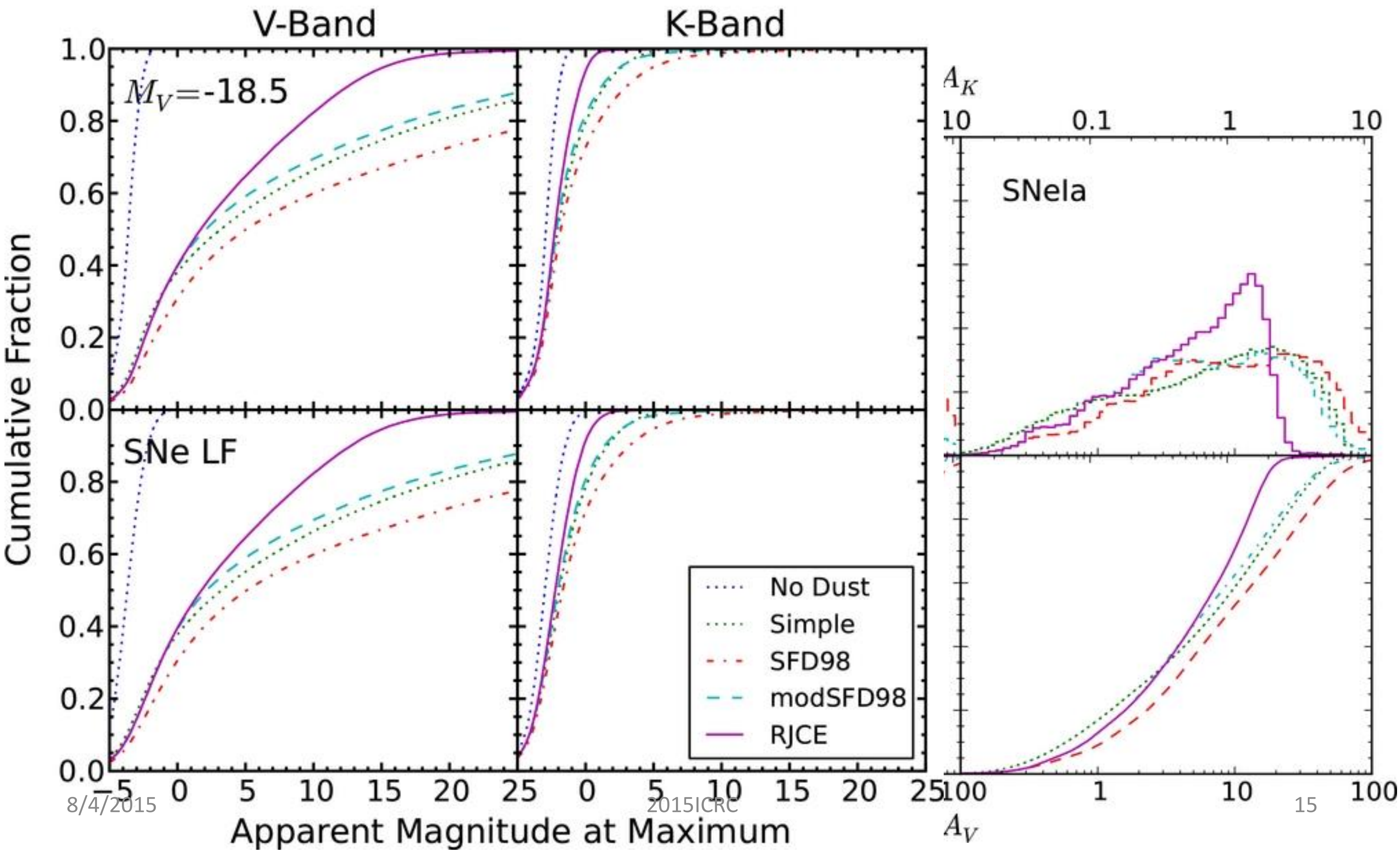
Summary and Future work

- A Galactic Type Ia SN may go unnoticed in lower energy band but will be a large gamma-ray signal observed in Fermi GBM.
- Fermi GBM is an ideal alarm for a future Galactic SN Ia.
- We will build models with a range of ejecta structures to simulate the signals from a future Galactic SN Ia to get a range of the strengths of the signal and the timescales to confirm the signal.

- Back up slides

Extinction and Apparent Magnitude of A Future Galactic Supernova

Adams et. al. 2013



Optical Depth of Galactic gamma-rays

- MW is optically thin to gamma-rays.

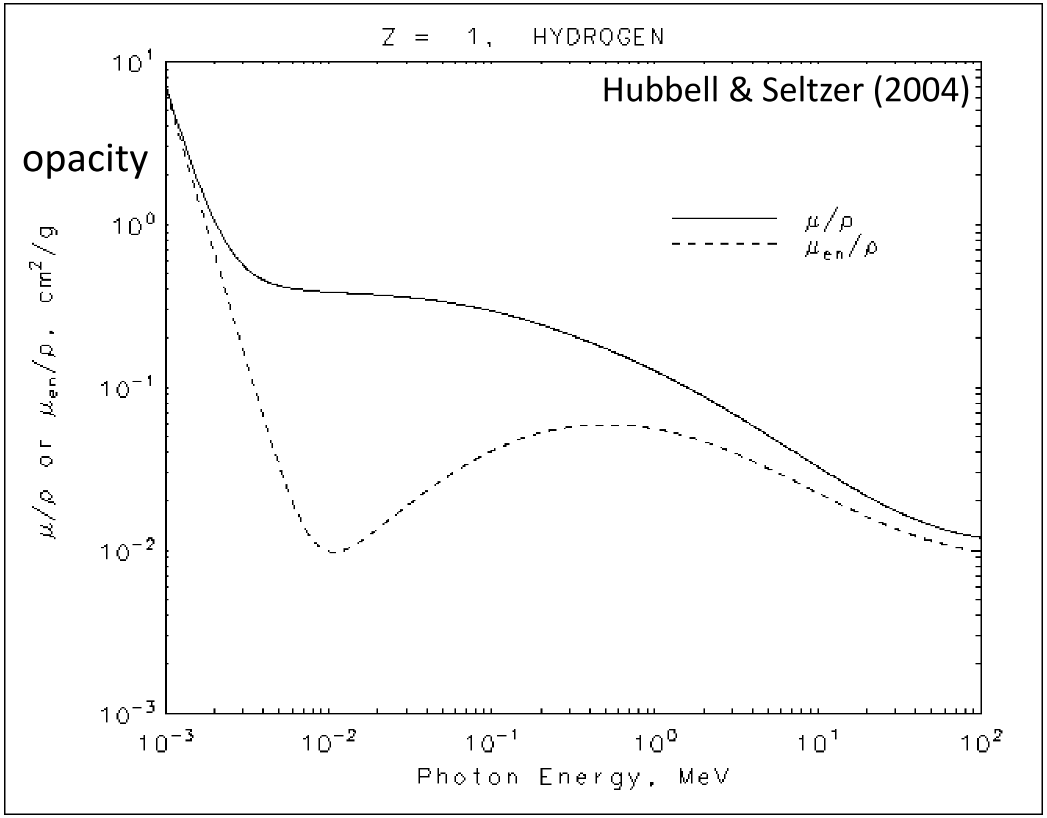
Optical depth of photons in MW:

$$\tau = \int n_H \sigma \, ds \sim N_H \sigma = N_H \frac{\mu}{\rho} m$$

$$\frac{A_V}{N_H} = \frac{3.1}{5.8 \times 10^{21} H cm^{-2} mag^{-1}}$$

$$A_V \sim 30, \text{ for } E_\gamma > 10^{-1} MeV,$$

$$\frac{\mu}{\rho} < 1 \Rightarrow \tau < 1 \text{ optical thin}$$

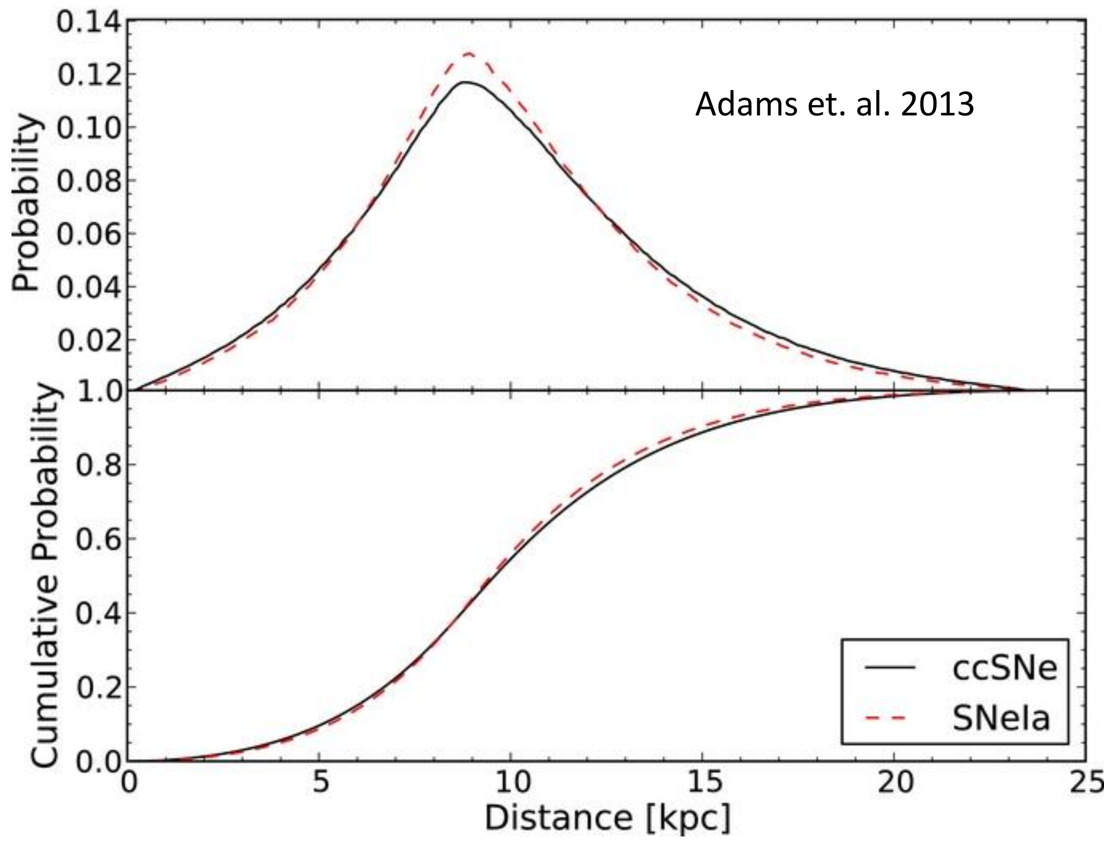


We need a gamma-ray detector that is sensitive to decay line energy range and continuously monitors the sky!

Galactic Type Ia Alarm: Approach

Galactic SN Ia:

- Fiducial distance: d~10 kpc



Model: Ejecta+Belt

- We build a simple zeroth-order model, ignoring the Compton continuum emission, combining Bussard et al. 1989’s uniform ejecta model and Diehl et al. 2014’s belt model to get the flux:

$$\Phi_{total} = \Phi_{ejecta}\left(M_{Ni,\,ejecta} = (1-f)M_{Ni,\,\mathrm{total}}\right) + \Phi_{belt}\left(M_{Ni,\,\mathrm{belt}} = fM_{Ni,\,\mathrm{total}}\right)$$

- Use earliest SN2014J detection to constrain the parameters in our model for SN Ia: $M_{Ni,total} = 0.5M_{\odot}, f = 10\%, \tau_{belt} = 0$
- The optical depth in ejecta is:

$$\tau_{ejecta} = \int n_e \sigma\, dl \approx \frac{3M_{ej}}{4\pi \mu_e m_p}\frac{\sigma}{v_0^2 t^2} \approx \left(121.09\, day / t\right)^2,$$

$$where\ M_{ej} = 1.4M_{\odot}, \mu_e = 2, \sigma \approx \sigma_{\mathrm{Thompson}} = 6.65 \times 10^{-25} cm^2$$

Model: Ejecta+Belt

The Ni gamma-ray line flux(ignoring the Doppler shift) is:

$$\Phi_{Ni}(E_0) = \frac{dN_\gamma}{dt\,dA} = \frac{\beta_{E_0}}{4\pi D^2}\frac{M_{Ni,\,\mathrm{ejecta}}}{56 m_p}\frac{e^{-t/\tau_{Ni}}}{\tau_{Ni}} \times e^{-\tau},$$

$$\Phi_{Ni,total}(E_0) \approx 1.16\times 10^3 cm^{-2}s^{-1}\frac{\beta_{E_0}}{[D/10kpc]^2}[0.9e^{-\tau}+0.1]e^{-t/\tau_{Ni}}$$

Similarly, the Co gamma-ray line flux (ignoring the Doppler shift) is:

$$\Phi_{Co,total}(E_0) \approx 99.5 cm^{-2}s^{-1}\frac{\beta_{E_0}}{[D/10kpc]^2}[0.9e^{-\tau}+0.1]\times[e^{-t/\tau_{Co}} - e^{-t/\tau_{Ni}}]$$