



OHIO
UNIVERSITY



Detection prospects of γ -rays from Type Ia supernovae with COSI

IRENA-CENAM 2025: Frontiers in Nuclear Astrophysics Meeting

Anirban Dutta

Michigan State University

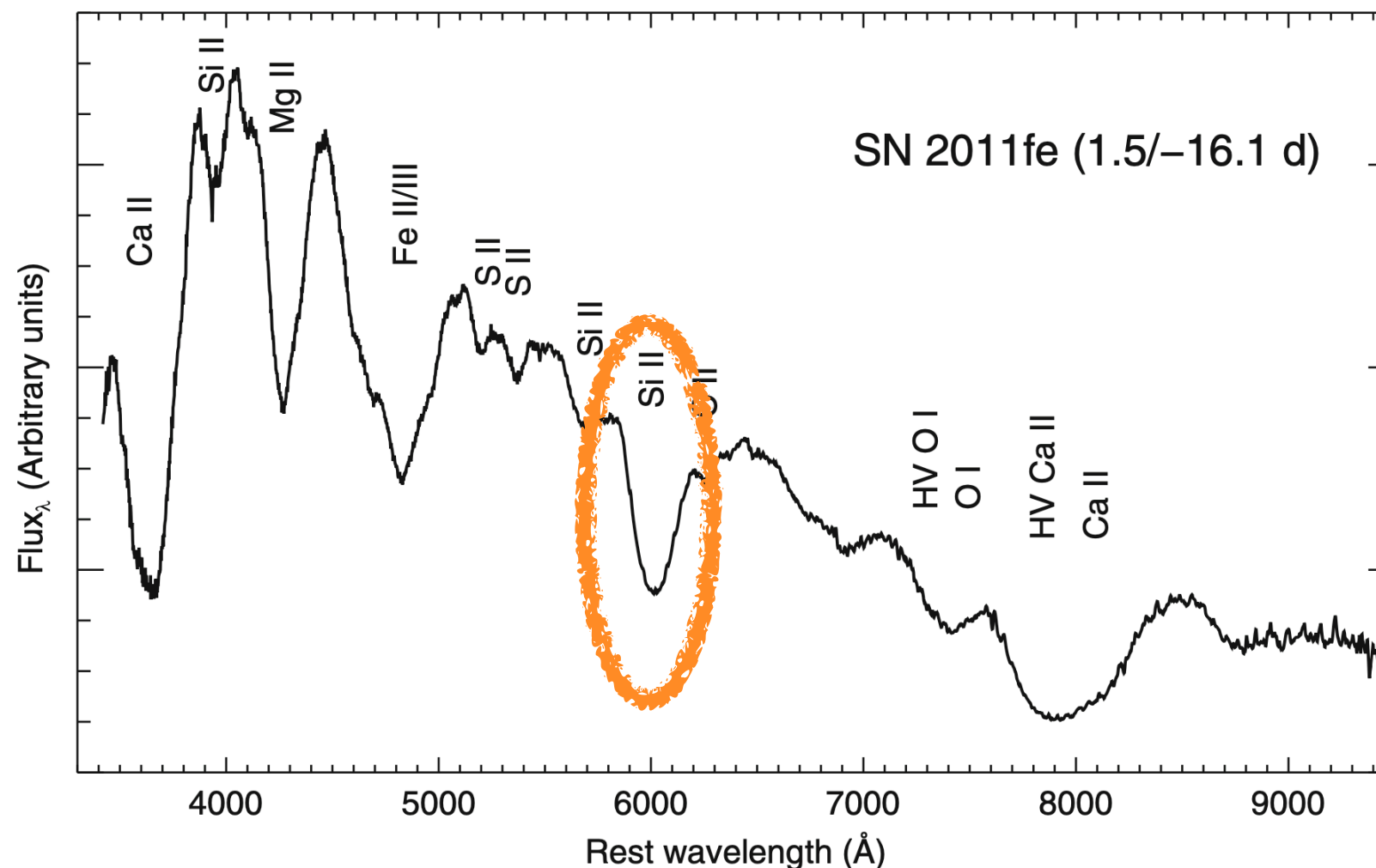
May 19, 2025

Observational properties of Type Ia supernovae

Stellar explosions with a peak luminosity $\sim 10^{43}$ erg /s

Typically no H in their spectra.

Ionized intermediate mass elements like - Mg II, Si II, Ca II



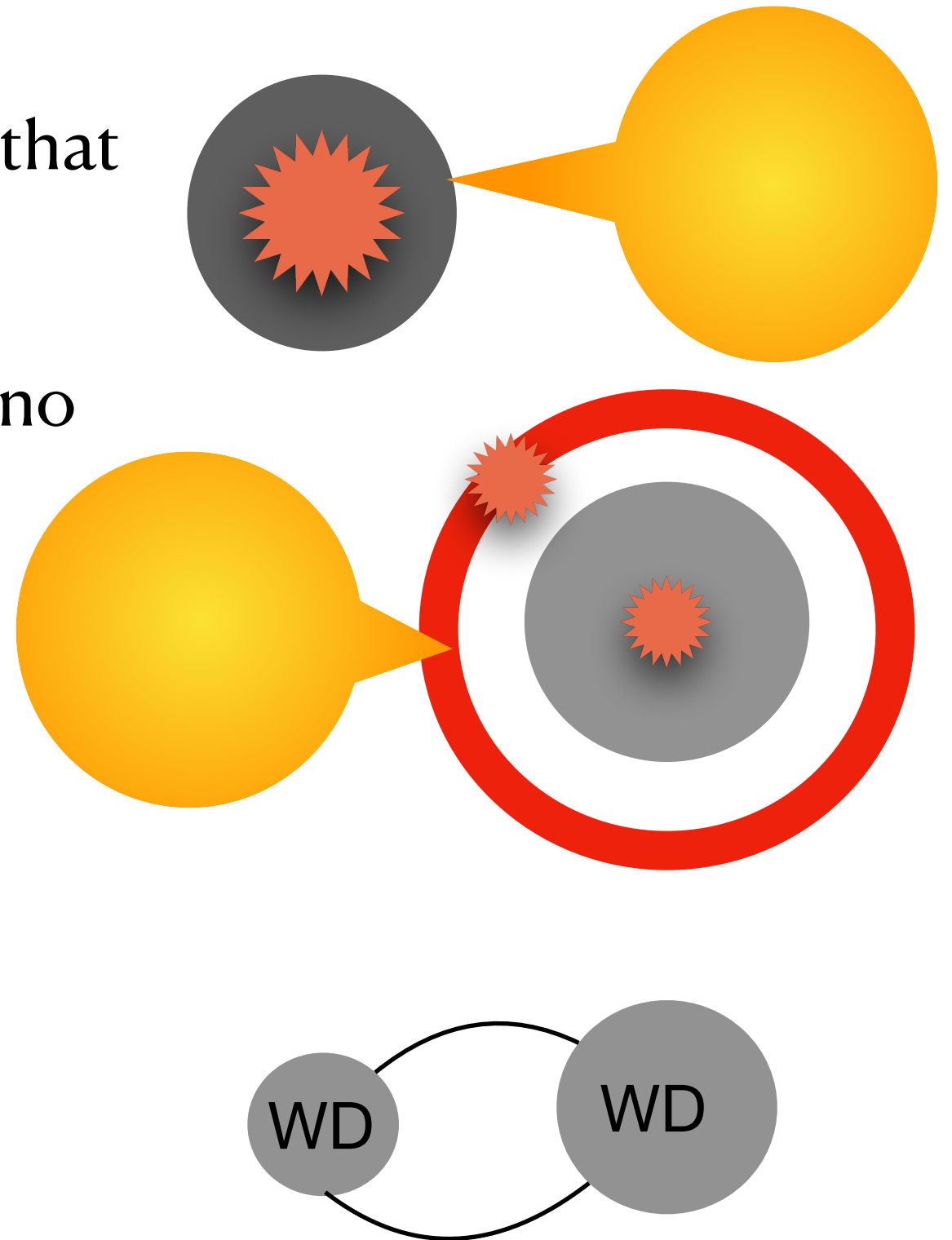
Nugent+ 2011

What are Type Ia supernovae?

Explosions of compact system - that of a WD.

Isolated WDs are inert owing to no nuclear reactions.

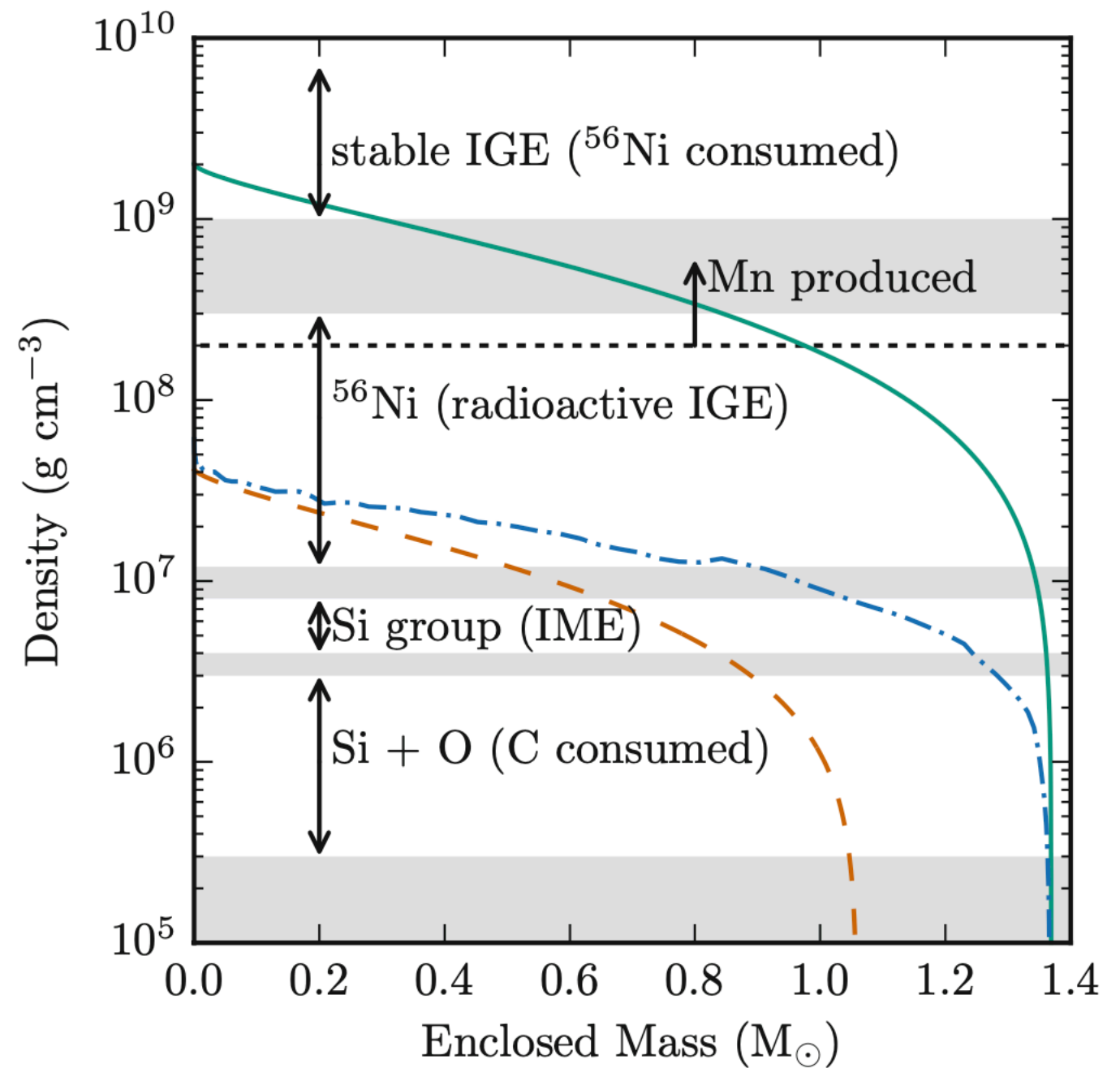
Explosion by accretion, merger collision.



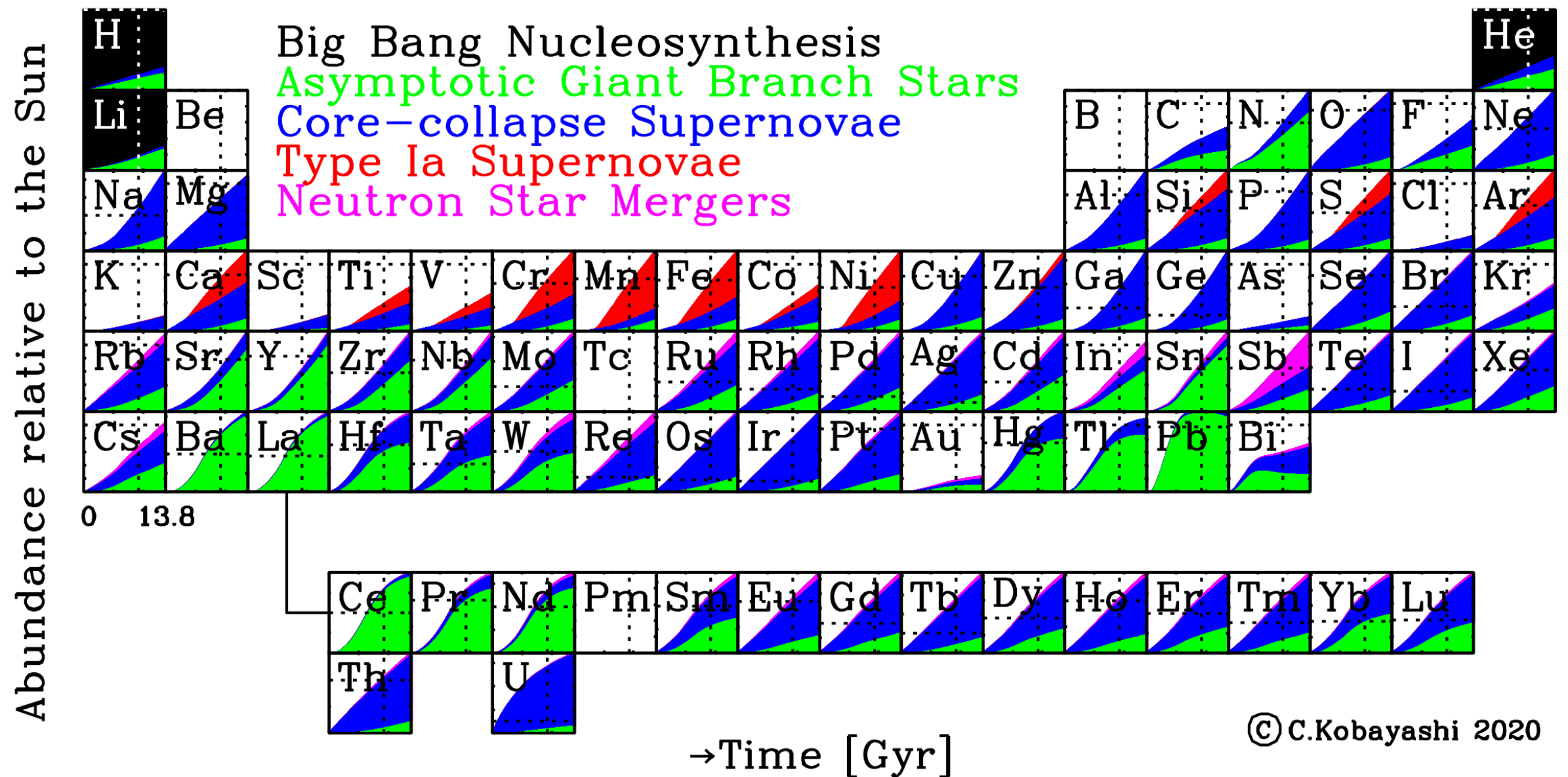
Explosive nucleosynthesis of white dwarfs

The nucleosynthetic products are determined primarily by the density of the fuel.

The CO WD incinerates to produce ^{56}Ni



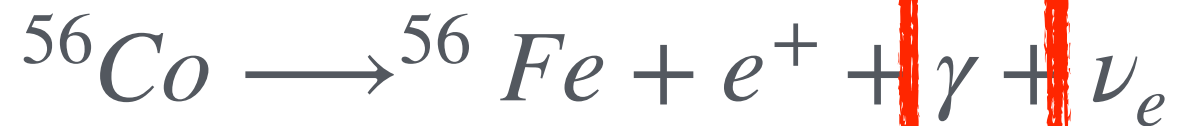
Enrichment of Fe from SNe Ia



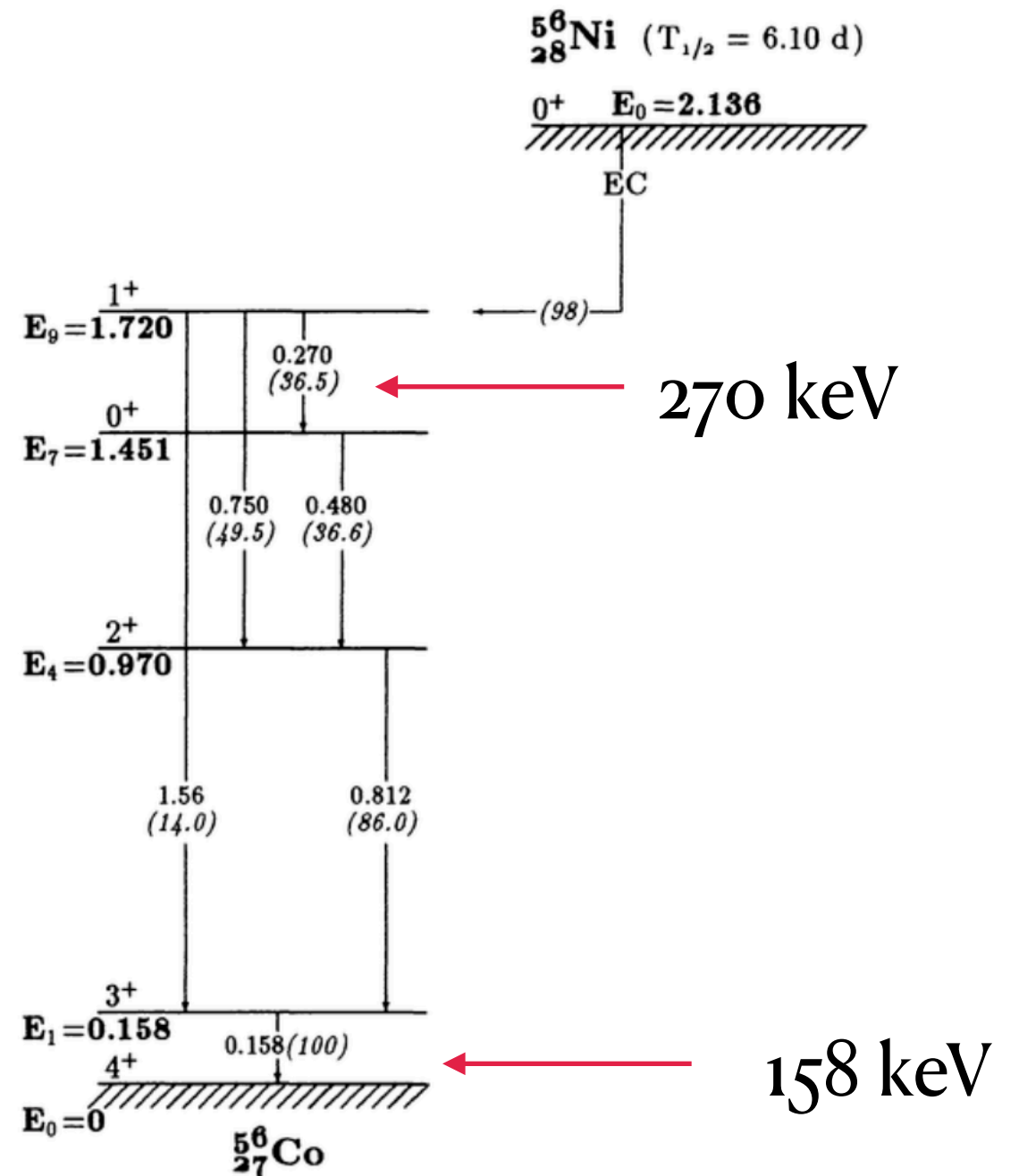
^{56}Ni decay in SNe Ia



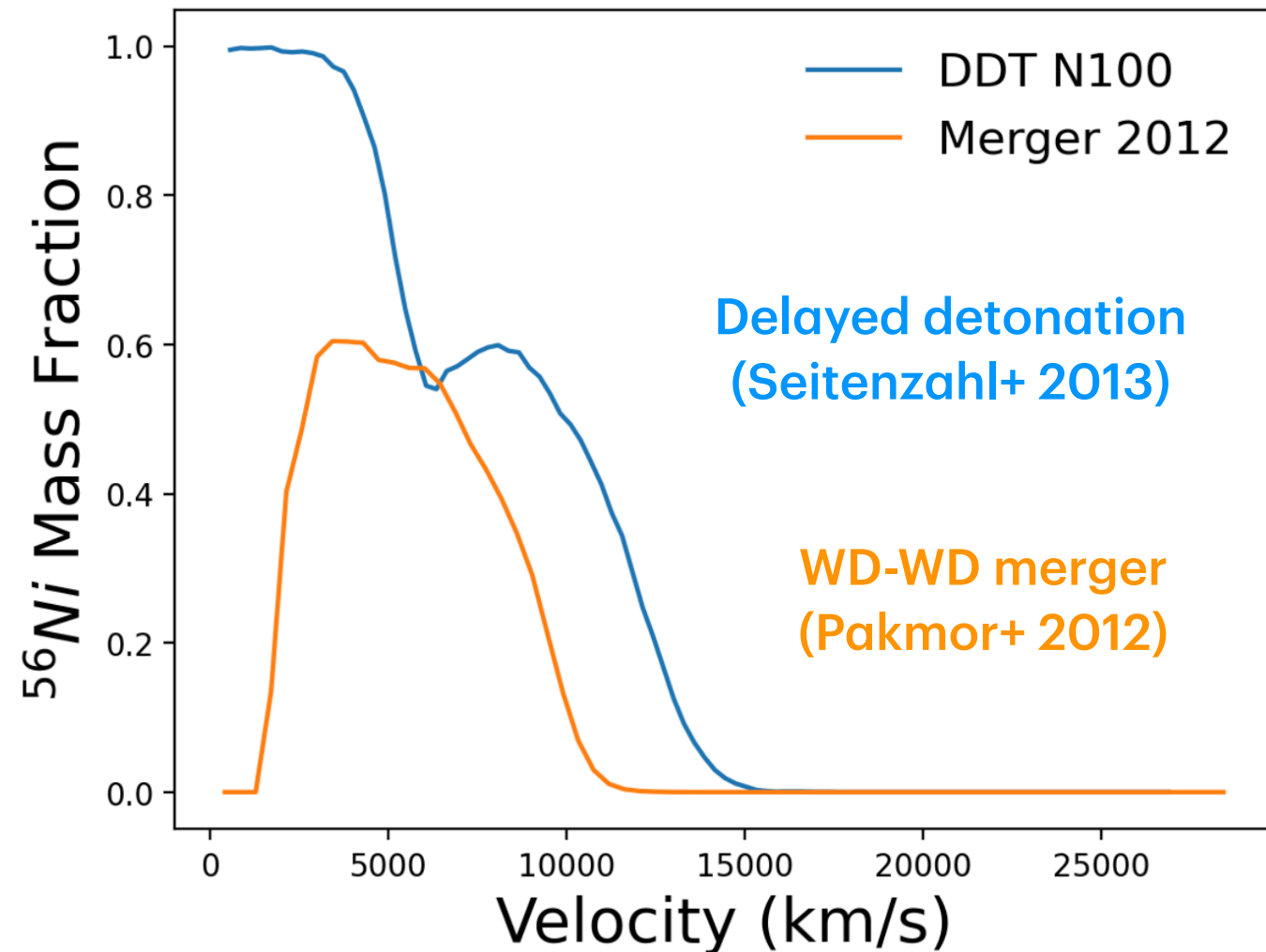
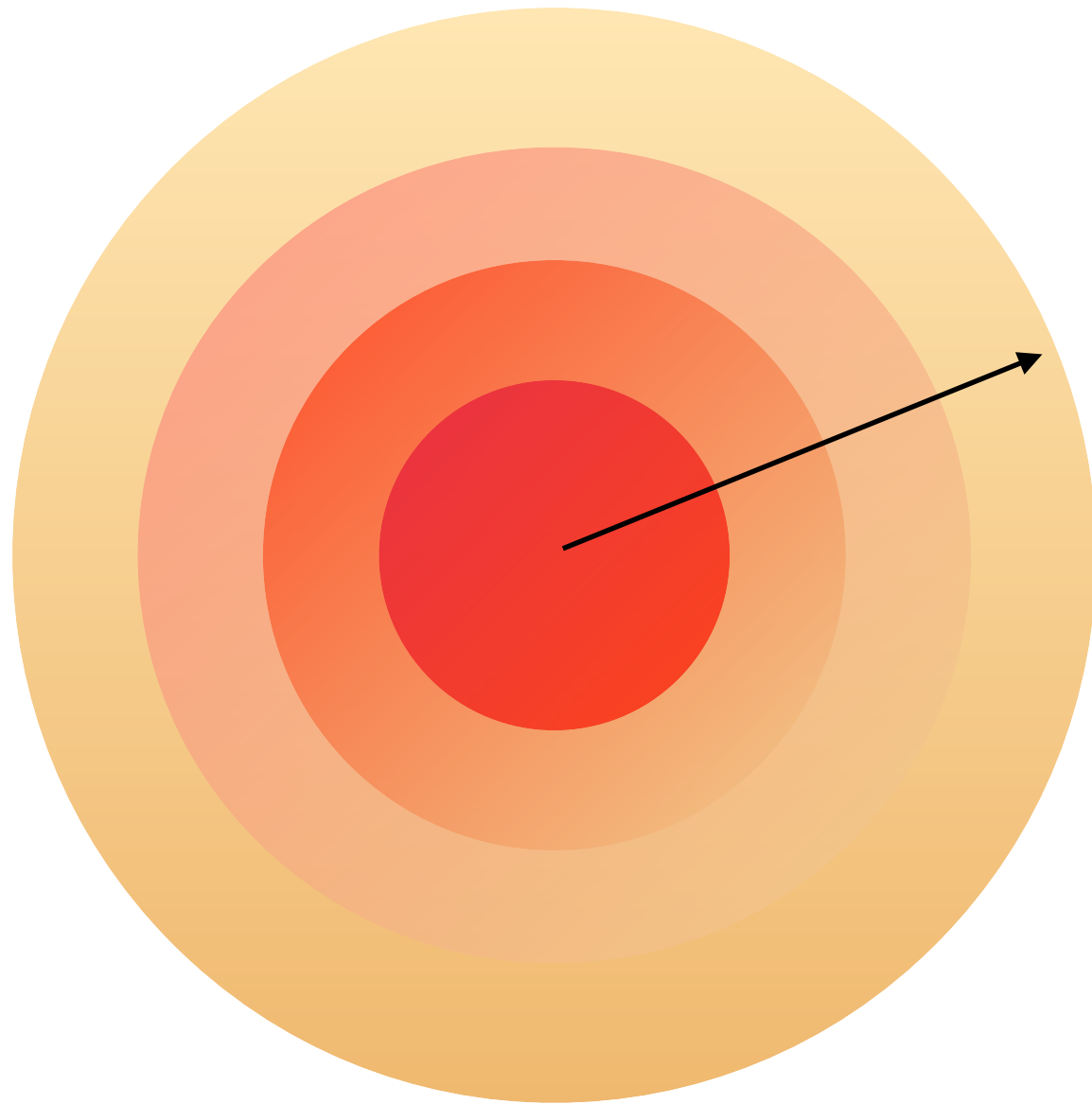
$$t_{1/2} = 6.10 \text{ day}$$



$$t_{1/2} = 77.12 \text{ day}$$

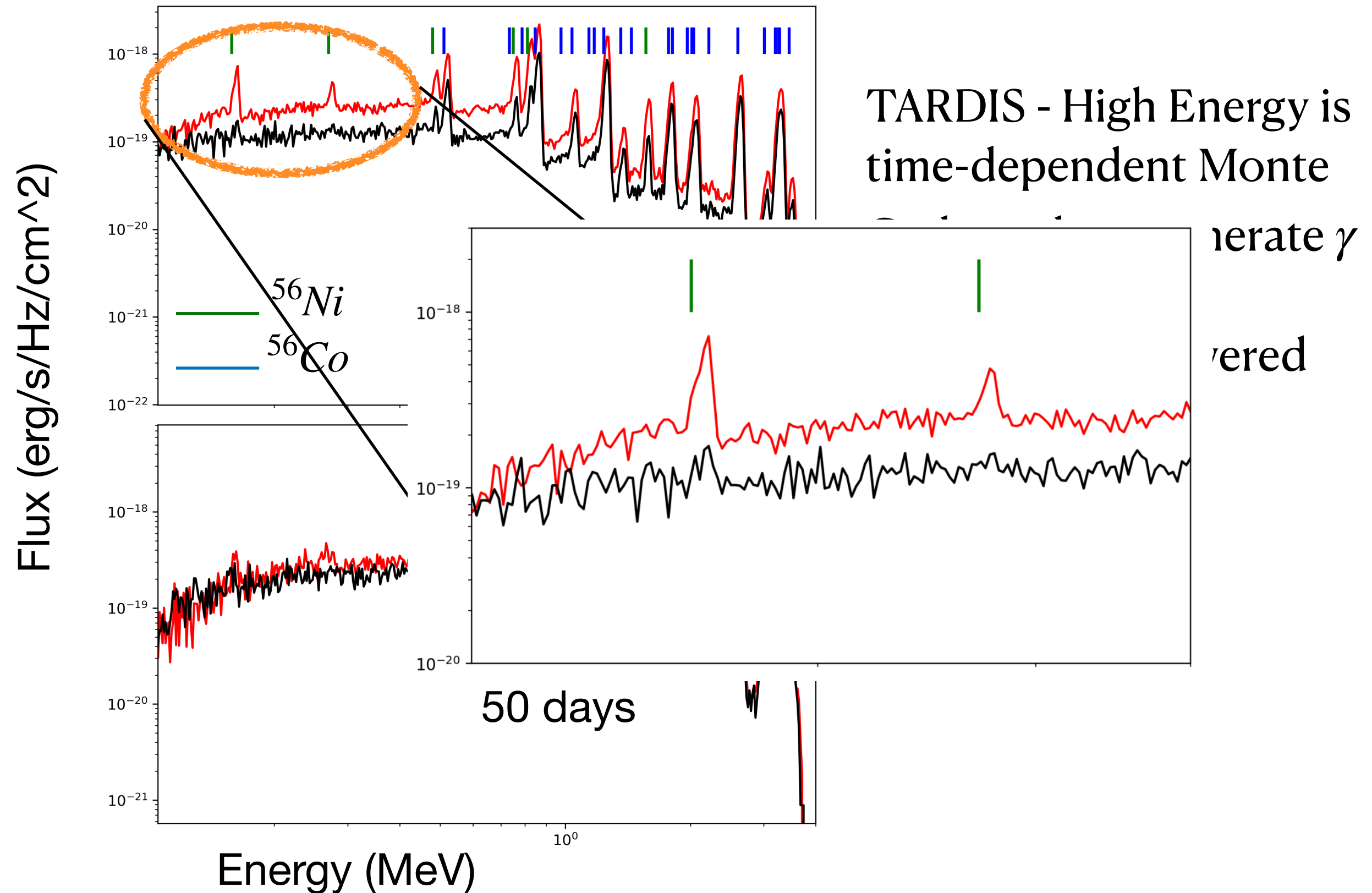


Distribution of ^{56}Ni



*Angle averaged ^{56}Ni mass fractions
from HEidelberg Supernova Model
Archive (HESMA)*

γ -ray lines as diagnostic of explosion models

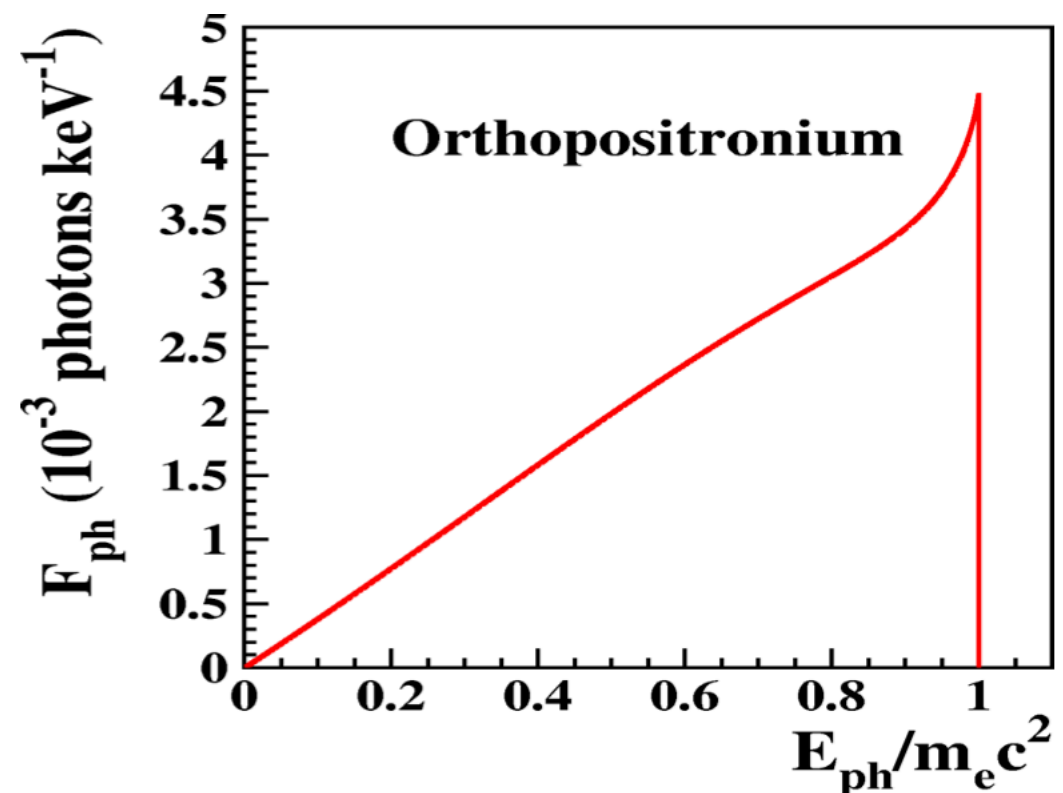
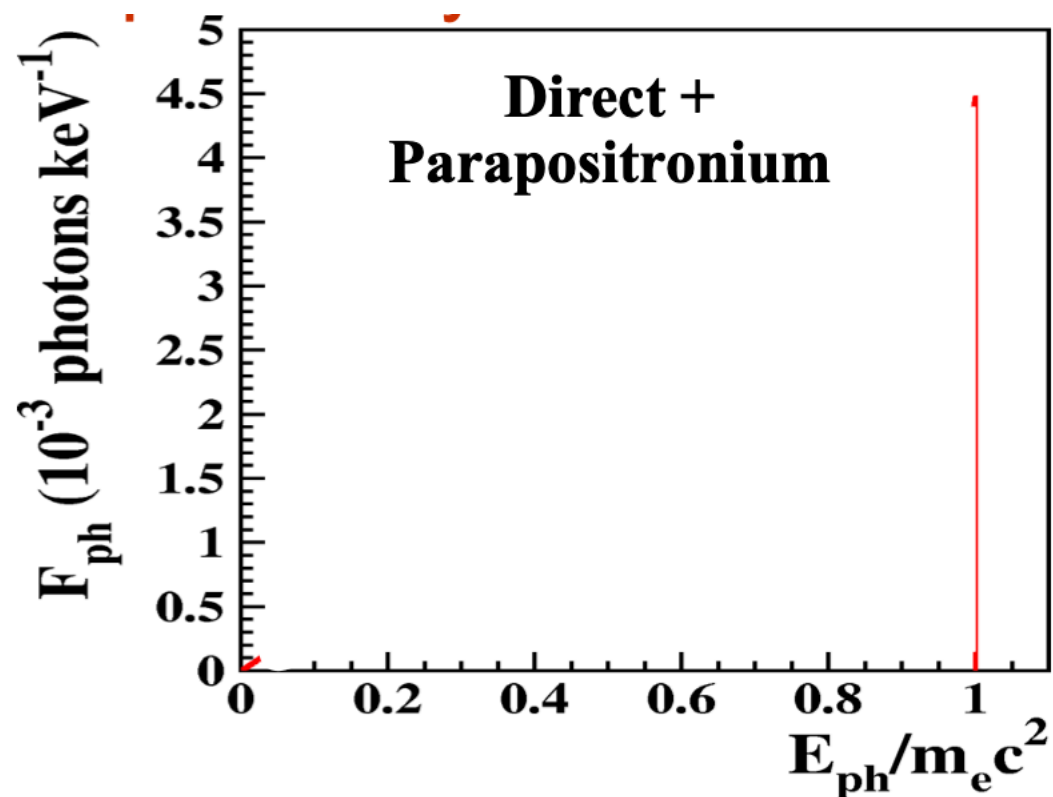


Effect of positronium on the γ -ray spectra

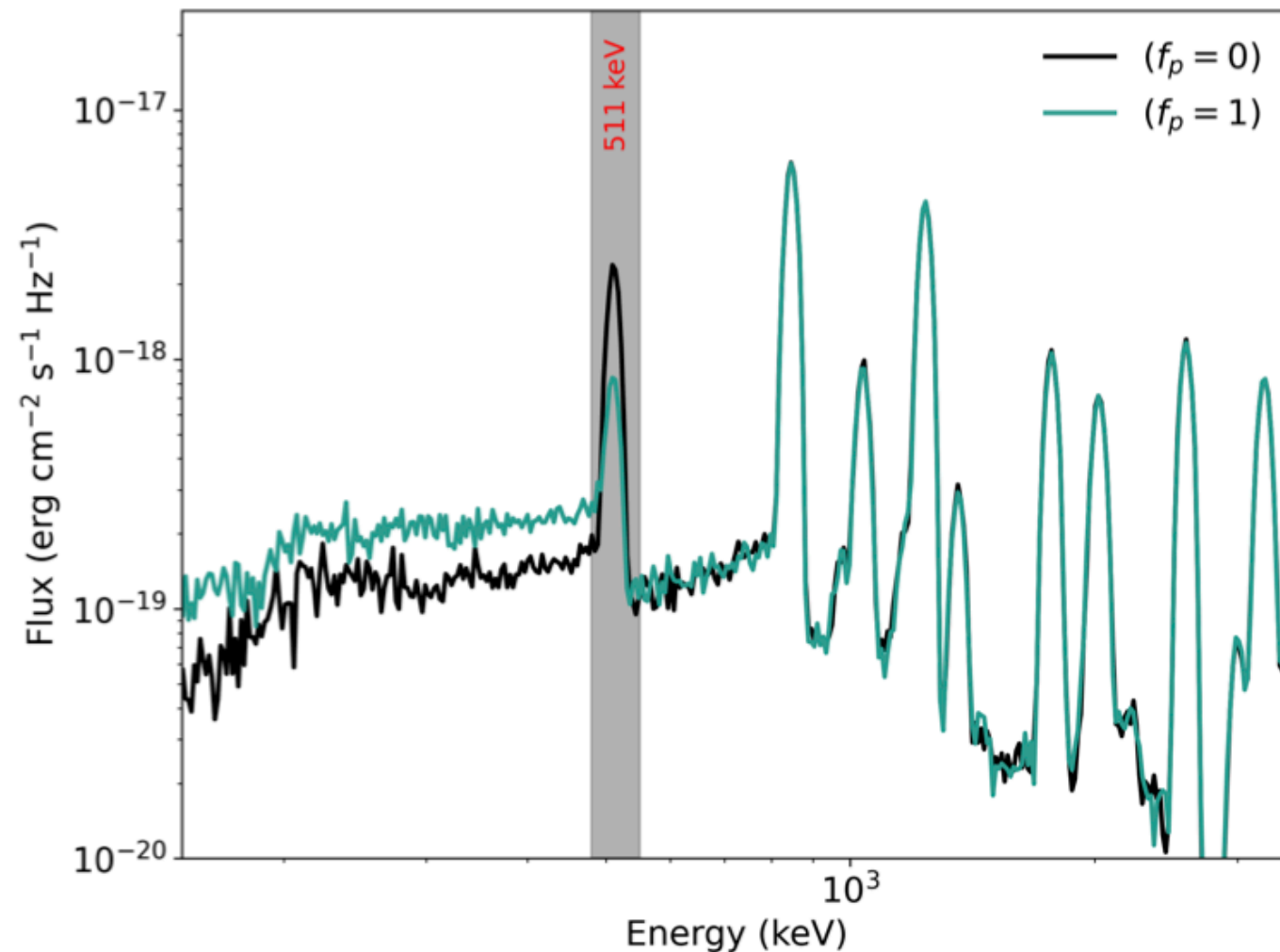
An e^-e^+ pair annihilates directly or after production of a bound state called positronium

Para-positronium - two γ -rays of 511 keV each

ortho-positronium - three γ -rays share the 1022 keV annihilation energy and forms a continuum upto 511 keV



Effect of positronium on the γ -ray spectra



The effect of forming positronium is the shifting of the line flux to the continuum assuming an ortho-para ratio.

Accepted for publication with minor comments in ApJ

The Compton Spectrometer and Imager

COSI is a NASA small explorer satellite with a planned launch of 2027.

It will scan the entire sky for 0.2 - 5 MeV γ -rays everyday.

Studies of γ -rays from unstable radioactive elements and annihilation line at 511 keV.

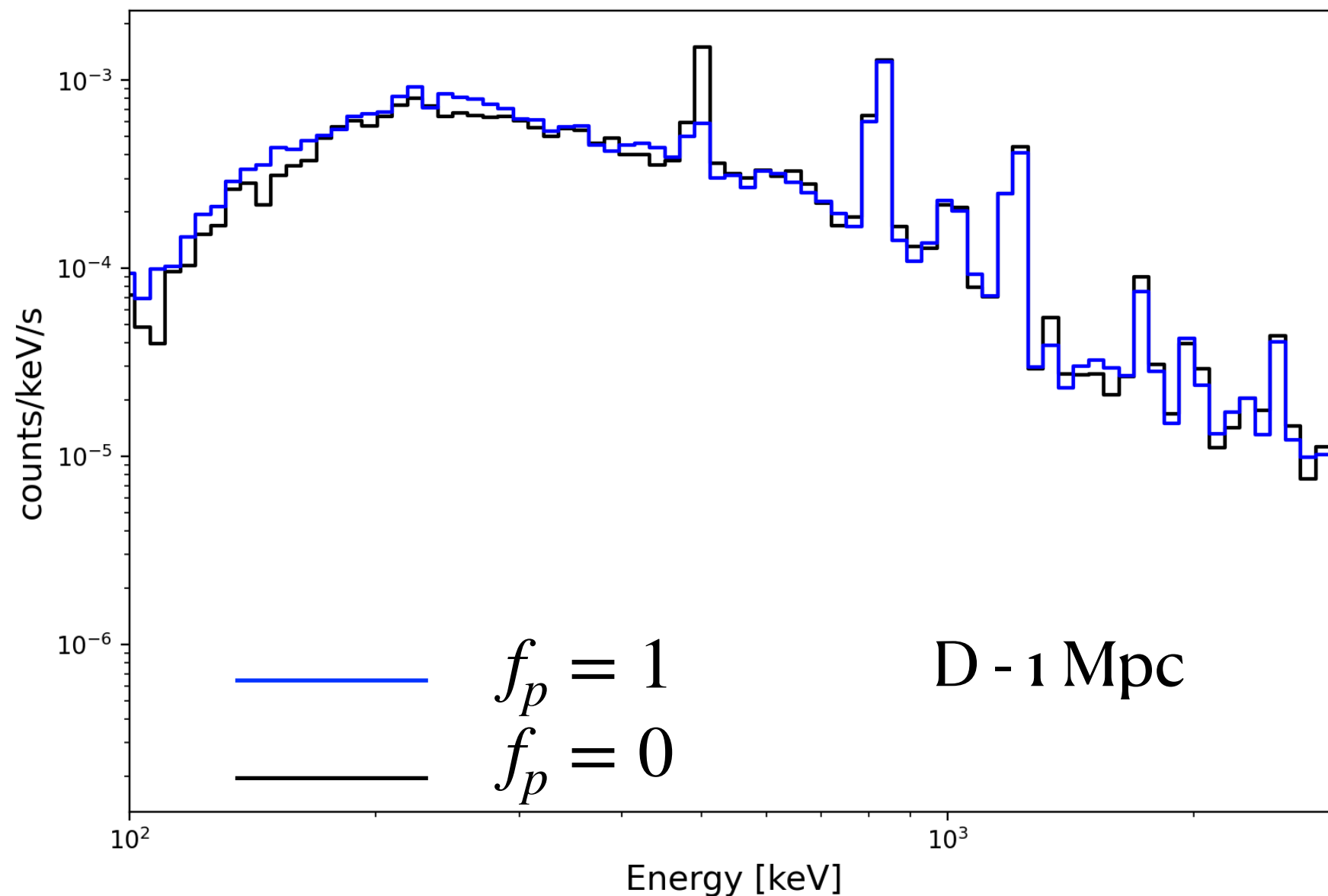
Transient astronomy - classical novae, thermonuclear supernovae, gamma-ray bursts.

Excerpts taken from Tomsick+ 2023



Simulations of γ -ray spectra of Type Ia supernovae as observed by COSI

Early results not including backgrounds !



Simulations performed with MEGAlib (Zoglauer+ 2006)

Conclusion

Optical spectra of supernovae typically collected during maximum are less conclusive of the explosion mechanism.

γ -ray spectra offers advantage in constraining the explosion models.

For a more careful interpretation of the 511 keV annihilation line positronium fraction needs to be constrained.

The sensitivity of COSI at 511keV, 847 keV, 1238 keV will be useful for thermonuclear SN studies.