ASTR 5590 - Supernovae

★ Cartoon Slide

Baade + Zwicky suggested new class of novae, or that it was 2 distinct ones

Zwicky began systematic search w/ 3.25" camera on Caltech roof, then 18" → 48" Schmidt telescopes @ Palomar

→ 20 SNe per year

→ few week outburst (rise, peak) exponential decline, half-life ~60d

★ what does decline suggest?

Classified into 2 Types, w/ various subtypes

Types slide

hundreds/blends

I broad emission bands (Fe^{+} + Fe^{++} lines)
- no H lines
- spectral + L evolution identical
- found in all types of galaxies (Ia)

II Balmer series of H lines soon after max
- wider range of properties

- spirals, usually arms

SN rate per $L(B) = 10^{10} L_\odot(B)$ [MW size]

Ia → 0.2 / century (but these brighter)

II → 0.6 / century

Ia C-O core (from remnant of low mass star: WD) burns explosively, everything burns to natural endpoint

$^{56}Ni \rightarrow ^{56}Co \rightarrow ^{56}Fe$

6.1d (half life) → 77.1d

per decay: 1.72 MeV 3.5 MeV

@ max, ^{56}Ni decay E deposited into expanding envelope, heated so glows

exp. decay of light curve from ^{56}Co

$^{56}Ni \rightarrow 0.1 - 1\ M_\odot$ produced, ends up as Fe

↳ most important source is ISM

Explosion not well understood, odd so uniform

Acc. from MS or giant companion?

Double degenerate (WD-WD) merger?

No object left

C-O burning sensitive: $\dot{S} \propto T^{12}$ → sens. to instabilities

→ sens. to imperfect burning?

- subsonic deflagration
- supersonic shock compression (detonation?)
  ↳ get Fe, no good

LCs all very similar, empirically scalable
↳ can use as distance indicators
for cosmology

Tycho → light echos slow spectrum of Ia
1572, observed by Tycho Brahe
in Cassiopeia

★ Show slides & video

II likely source of γ-ray bursts

After He burning, core hot enough
to produce e^-, e^+ pairs
↳ annihilations produce $\nu_e, \bar{\nu}_e$ pairs
that escape easily, so P support
lost faster w/each new element

★ 15 $M_\odot$ star burning stages

Produce Fe core ~1.5 $M_\odot$:
- $p + e^- \rightarrow n + \nu_e$ (inverse β decay)

- thermal γ-rays disintegrate Fe

$$^{56}Fe + \gamma \rightarrow 14\ ^4He$$

10% of rest mass is converted to ν_e

$\sim 3 \times 10^{53}$ erg

w/ $\sim 10^{51}$ ergs going into ejecta

Classic bounce of outer stellar layers on newly formed NS likely not right

→ shock forms before hitting that stalls, produced by rad., e^-, e^+ bubble

Explosion may create heavier elements

r-process (rapid)

→ need to make things before they can β decay

– in ~10s, produce elements thru

$Fe + n \rightarrow$ ↑ elmnt $+ n \rightarrow \ldots$

Cas A light echoes consistent w/ IIb

– seemingly unobserved historically, although may have been recorded by Flamsteed on Aug 16th, 1680 (~300 yr ago)

↳ if ejected outer shells before explosion, much of emission could have been absorbed

One of the first discrete radio sources

$^{44}Ti \rightarrow {}^{44}Sc \rightarrow {}^{44}Ca$, 2% of Ca (likely only way to produce)

- Ti & Fe clumpy, not coincident
  evidence for turb. or asymmetry explosion, bipolar?