AST 296LB

Astronomy with Python

Why do stars explode?

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About 160,000 Years ago:

The Earth was experiencing an Ice Age

Homo sapiens were arriving on the scene n Africa

And in a very nearby galaxy to Earth:

A star explodes!!

A star explodes!!

And in February 1987, the light finally arrives on Earth.

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Brighter
Older
3 x 10^13
10^4
250
200
150
100
50
0
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
ν's
23 February 1987
7:35 am (UT)
Core collapse: ν-burst
UV
≈10 am (UT)
Shock breakout
(hard UV burst)
Pluto's orbit
Jupiter's orbit
20 May
13 April
4 July
31 October
X-rays
γ-rays
24 Feb.
26 March
25 Feb.
13 March
1 March
Sk -69 202
(0.1)
2300 AD?
(Cas A supernova remnant 300 years after explosion)
12 light years

"The nitrogen in our DNA, the calcium in our teeth, the iron in our blood, the carbon in our apple pies were made in the interiors of collapsing stars. We are made of starstuff." —Carl Sagan

The life cycle of stars

Low mass stars are needed for Type Ia SN

High mass stars create Core collapse SN

The sizes of stars

https://www.youtube.co /c 7hTGA

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How are the masses distributed?

Way more low mass stars, but high mass stars can be brighter than thousands of low mass stars combined

Lifetime of stars

Mass (solar masses)	Time (years)	Spectral type
60	3 million	O3
30	11 million	O7
10	32 million	B4
3	370 million	A5
1.5	3 billion	F5
1	10 billion	G2 (Sun)
0.1	1000s billions	M7

The more massive a star, the shorter its lifetime.

The Two Types of SNe

Type Ia
Thermonuclear

Type II
Core Collapse

Massive star evolution

Massive star evolution

As the star evolves, constant battle between photons produced by nuclear fusion supporting the star and gravity wanting to pull it down

Radiation Pressure

Gravity

What do the explosions leave behind?

Cas A
Exploded around 1670
Wasn’t seen on earth (dust?)

SN 1987A
Still observing changes in real time

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Neutrinos

Neutrinos carry away energy and mass ($E=mc^2$) - 99% of a SN explosion

They can also travel straight through the Earth without being detected

Fig. 2a : The supernova signal of the KAMIOKANDE-II experiment. It is a part of the laser printer output of the low energy raw data.Nhit is the number of hit photomultipliers.

Neutrinos

Neutrinos

Neutrino Detector
Cerenkov photon
positron
phototube
detector
computer
neutron
neutrino
H_2O
proton

Pulsars

beamed
radiation
magnetic
field
neutron
star
beamed
radiation
rotation axis

Type Ia

The progenitor of a Type Ia supernova
Two normal stars are in a binary pair.
The more massive star becomes a giant...
...which spills gas onto the secondary star, causing it to expand and become engulfed.
The secondary, lighter star and the core of the giant star spiral inward within a common envelope.
The common envelope is ejected, while the separation between the core and the secondary star decreases.
The remaining core of the giant collapses and becomes a white dwarf.
The aging companion star starts swelling, spilling gas onto the white dwarf.
The white dwarf's mass increases until it reaches a critical mass and explodes...
...causing the companion star to be ejected away.

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Supernova light curve

Supernova light curve

Type Ia as standard candles

The maximum brightness of a Ia is correlated with the rate at which it dims. The slower it dims, the brighter it is. This can be used to figure out its absolute brightness and therefore a distance to the host galaxy.

Historical Supernova in Milky Way

Chaco Canyon NM
SN1054

Keplers SN
1602

Tychos SN
1572

Will we see a SN in our galaxy?

Betelgeuse

<u>If it exploded today:</u>

- Would be as bright as the full moon
- Could be seen in the daytime for a few months
- Would have exploded around AD 1400