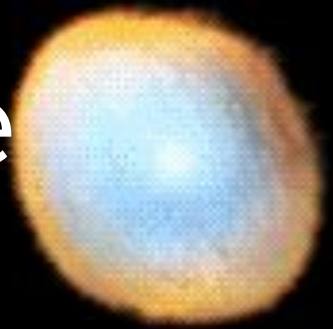
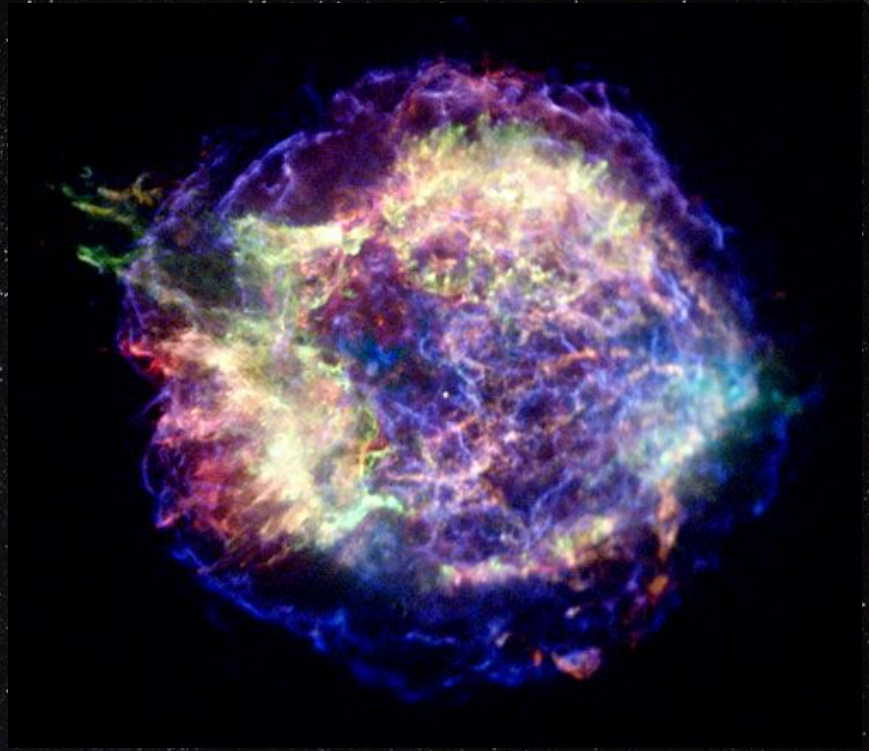
Supernovae



Type I

Supernovae

- *What are supernovae*
- *Types of supernovae*
- *Why study supernovae*
- *How do we find them*
- *History of sightings*



Chandra X-ray photograph of Cassiopeia A; the youngest supernova remnant in the Milky Way. (Image: © NASA/CXC/MIT/UMass Amherst/M.D.Stage et al

What are Supernovae?

Explosive stellar death that unleashes a burst of light throughout the cosmos [NASA, 2018]

- 30,000 km/s [Schawinski, 2008]

Crab Nebula

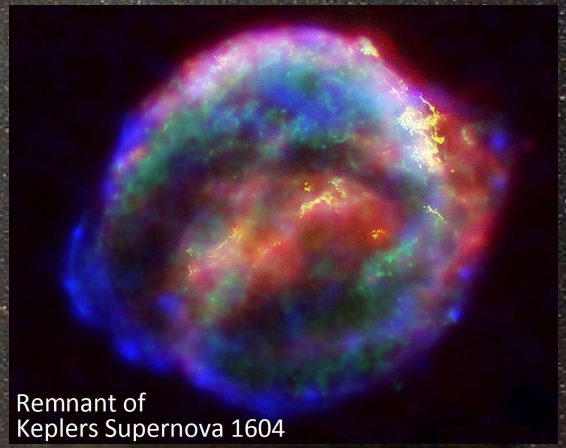
- Remnants of supernova [Freedman, 2015]

1987A ***Credits: NASA***

Crab Nebulae SN 1054 Remnant; Image Credit: NASA, ESA, J. Hester, A. Loll (ASU)

Supernovae; overview

- Occur about once per century in a galaxy (Wheeler, 2007)
- First recorded SN 185 (Wheeler, 2007)
- Most recent supernova in Milky Way in 1604 (NASA, 2013)
- Astronomers have been finding several hundreds of supernovae each year (ASASSN, 2019)
- 54 have been discovered so far in 2019! (ASASSN, 2019)



Remnant of
Keplers Supernova 1604

Photo Credit: 21 July 2007, taken by ESO astronomer Yuri Beletsky

Kepler Remnant Image Credit: Spitzer space telescope

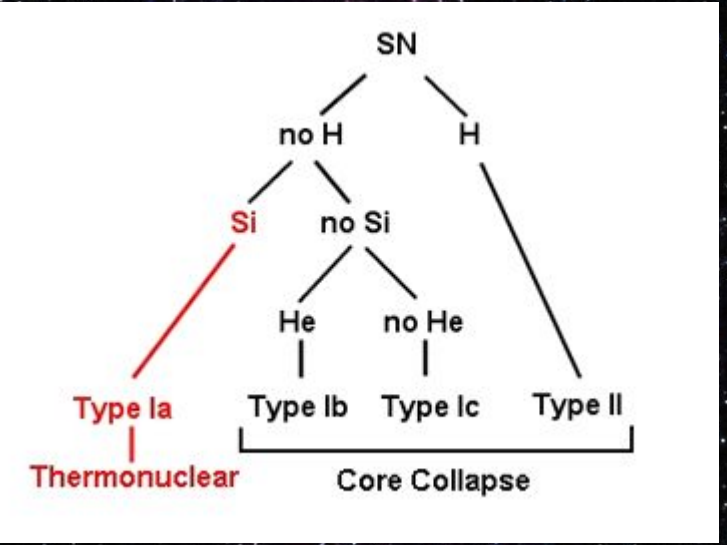
Supernovae Types

Type I (no Hydrogen)

- Ia
- Ib
- Ic

Type II (Hydrogen)

(Wheeler, 2007)



Ring NEbula Image Credit, NASA, ESA

SN classification;t http://astronomy.swin.edu.au/cosmos/S/Supernova+Classifica

How does a Supernova occur?

Supernovas happen in two different ways:

1. Massive stars run out of Hydrogen
    - Not enough pressure to sustain self against own mass
    - Central part of such a star collapses
    - Outer layers of the star fall into the core [NASA, 2018]

How does a Supernova occur?

2. **Type Ia; Binary System** [NASA, 2018]

- White dwarf and star orbiting each other
- White dwarf slowly absorbs mass of star
- Reaches critical mass (1.4 solar masses) (Chandrasekhar limit)
- Collapses and explodes

Type Ib and Ic

- Lost outer Hydrogen layers (companion star or strong winds)
- Otherwise undergo core collapse similar to Type II
- Absence of Silicon in Type Ib and Ic
- Type Ib have strong helium emission lines (spectra)
- Type Ic do not

(Strobel, 2018)

What happens after a supernova?

- Depends on size of original star
- Intermediate sized (mass > 1.4 $\mathbf{M}_\odot$ but < 3 $\mathbf{M}_\odot$)
  - ➔ Electrons + protons form neutrons
  - ➔ Prevent further collapse, form neutron star

- Massive sized (mass > 3 $\mathbf{M}_\odot$)
  - ➔ Gravity wins, nothing prevents collapse
  - ➔ Black hole

(Strobel, 2018)

Photo credit: Event Horizon Telescope Collaboration

Why study supernovae?

Provides evidence for theory of expanding and accelerating universe (Nasa, 2013)

Supernovae distribute elements throughout our universe
Gamma radiation blasts or GRB are huge blasts of radiation

observed in the universe and their source was mostly unknown until studying supernovae

(University of Chicago, 2017)

Image retrieved from: https://www.theatlantic.com/science/archive/2016/01/rare-supernova-crab-nebula/424125/

Expanding and Accelerating Universe

Researchers from University of Chicago and Wayne University won the 2011 nobel prize for physics for this discovery

Theories must be tested

Observing all type 1a supernovae moving away from each other provides evidence for expanding universe theory

Space is constantly expanding and accelerating

(University of Chicago, 2017)

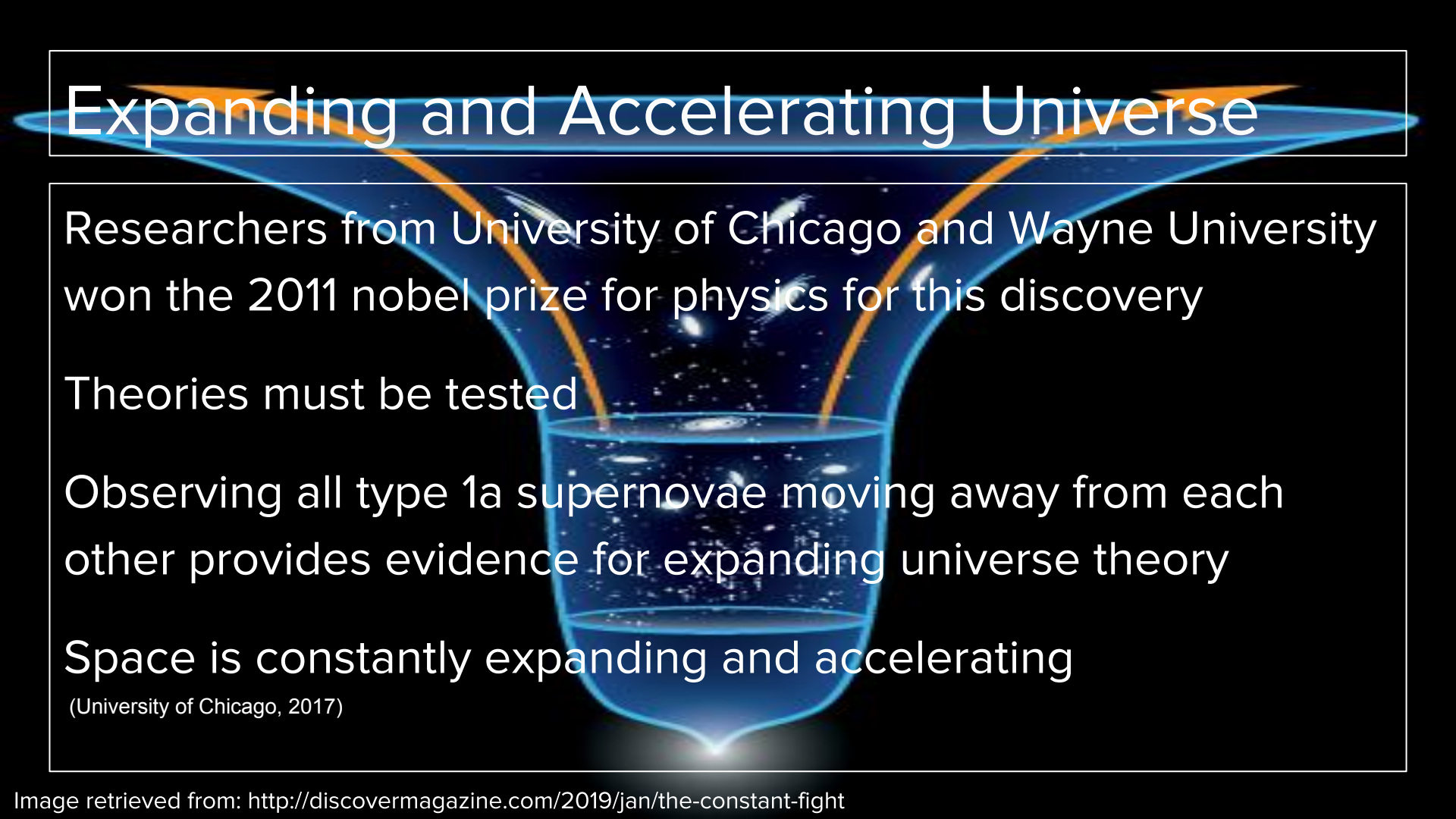


Image retrieved from: http://discovermagazine.com/2019/jan/the-constant-fight

Supernovae Distribute Matter

After the big bang there was H and He

All other elements are created within stars and distributed through star death

Elements are created in the core of the star and distributed upon explosion

We are stardust! (Newman, 2017)

Image retrieved from:
https://www.geek.com/news/nearby-supernova-will-light-up-the-sky-for-week-grant-insight-into-dark-energy-1583165/

Gamma Ray Blast (GRB)

Originally thought to be only generate when matter crosses event horizon of a black hole

Gamma rays are a huge source of energy but their source was unknown

Scientists detected gamma rays and found the source

Creates energy cocoon to penetrate star (explains why not all supernovae produce GRB) (Jorgenson, 2019)

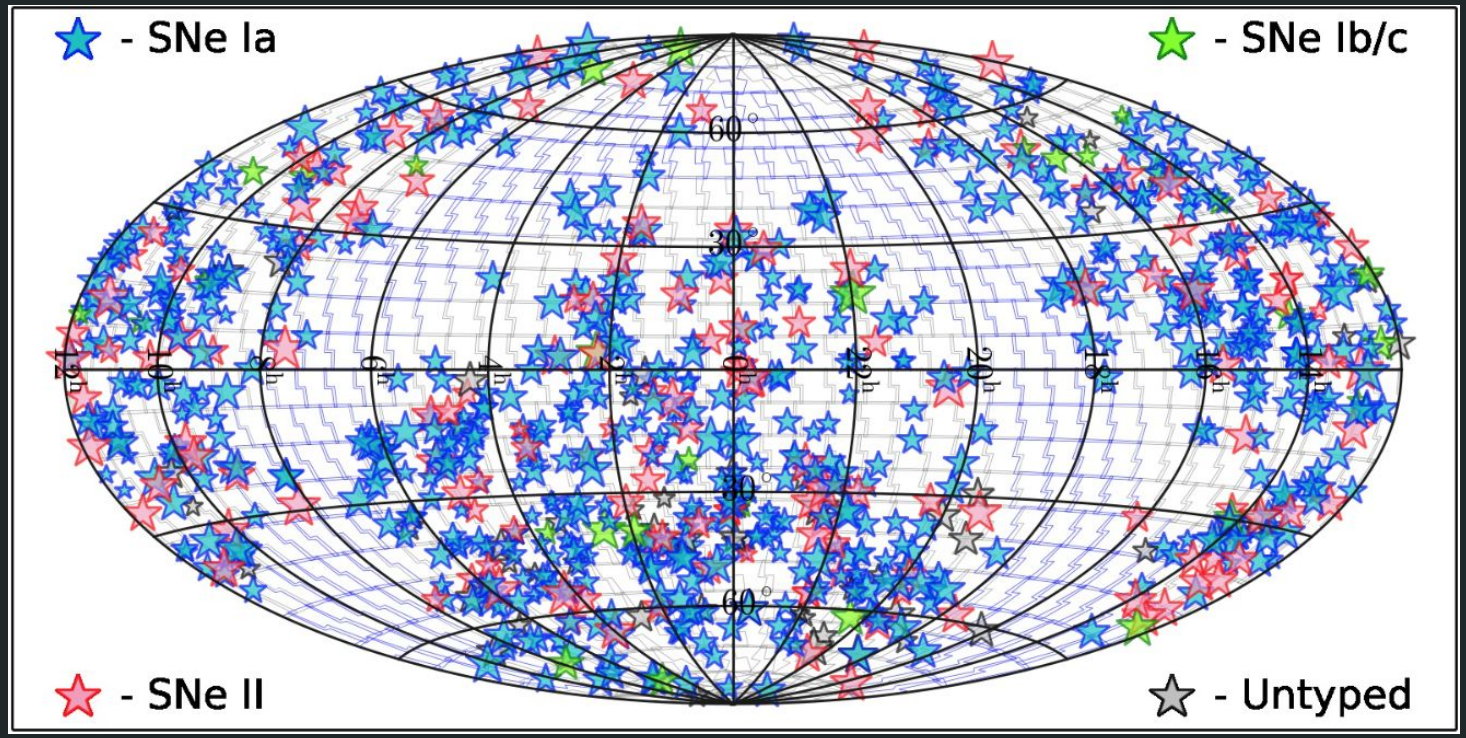
Image Credit. Gamma Ray Blast http://en.minghui.org/emh/article_images/2003-3-25-gammaexplo.jpg

ind SN?

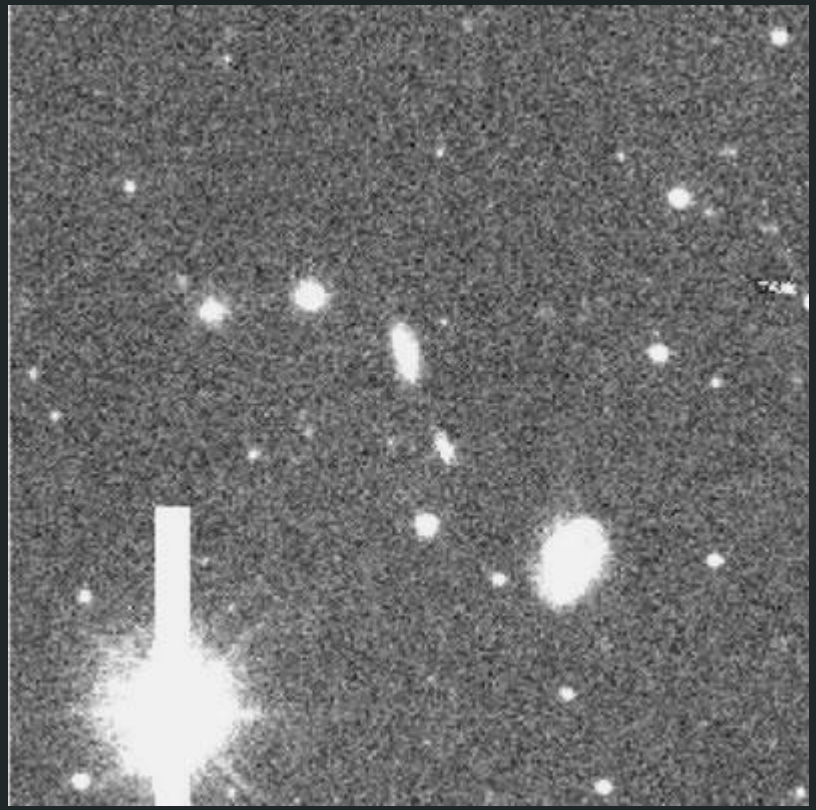
- Impossible for astronomers to know beforehand
- Some telescopes observe visible light from the event, others record data from X-rays and gamma rays that are produced
- Visible: compare two images (a ‘template’ and the new image), subtract the difference

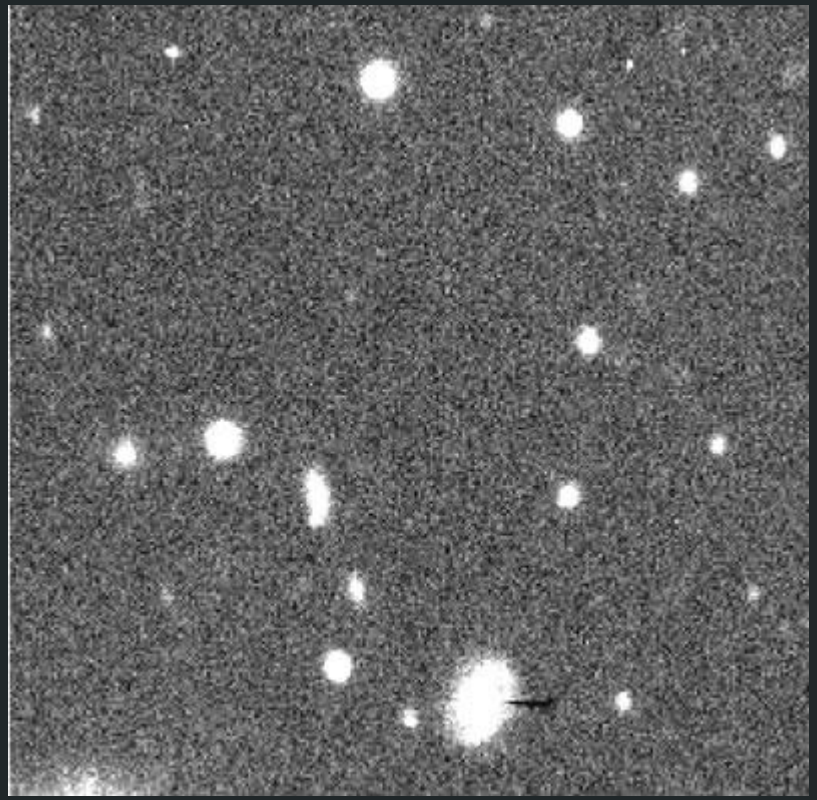
(“Supernova Search”, n.d.)

All Sky Automated Survey for SuperNovae (ASASSN)

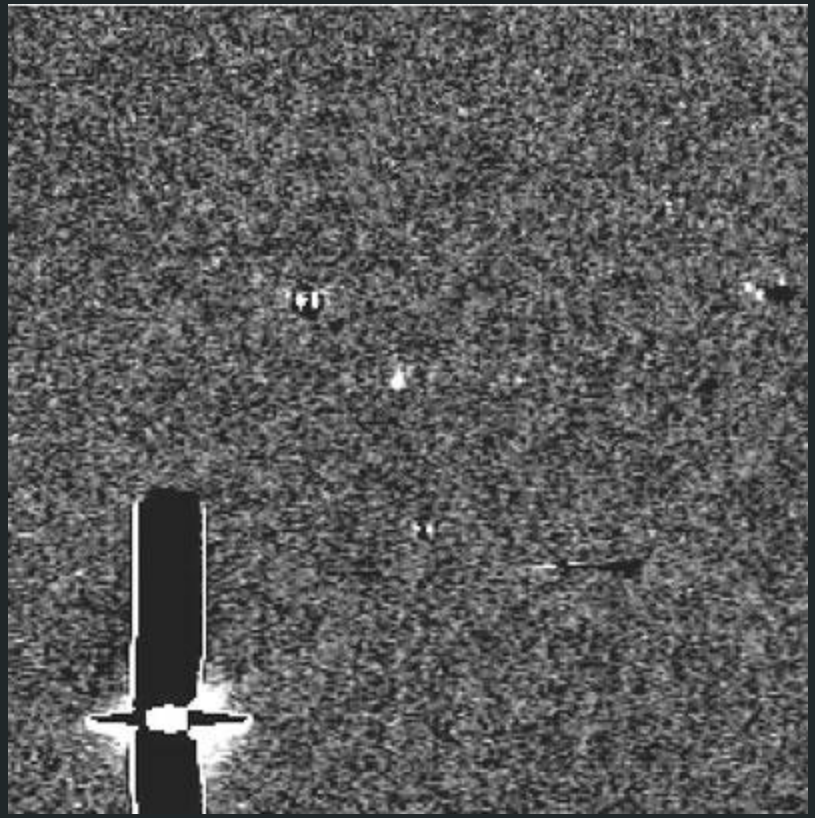


Credit: ASAS-SN Homepage





Credit: Supernova Search - The SAO Encyclopedia of Astronomy



Credit: Supernova Search - The SAO Encyclopedia of Astronomy

History of Sightings (Our Galaxy)

- Seven or eight supernovae over last 2000 years in *our Galaxy*
- Earliest recorded in 185 AD and 393 AD (unconfirmed)
- 1006 was the brightest on record (Type Ia)
- 1572 Tycho Brahe (Type Ia)
- Most recent 1604 Johannes Kepler (Type Ia)

(Wheeler, 2007)

Modern Observations

"There's something satisfying, I think, about the idea of light travelling for millions of years through space and *just* at the right moment as it reaches Earth, someone looks at the right bit of sky and sees it. It just seems right that an event of that magnitude should be witnessed." - Robert Evans

Credit: Roger Ressmeyer/Corbis. (ca. 1988)

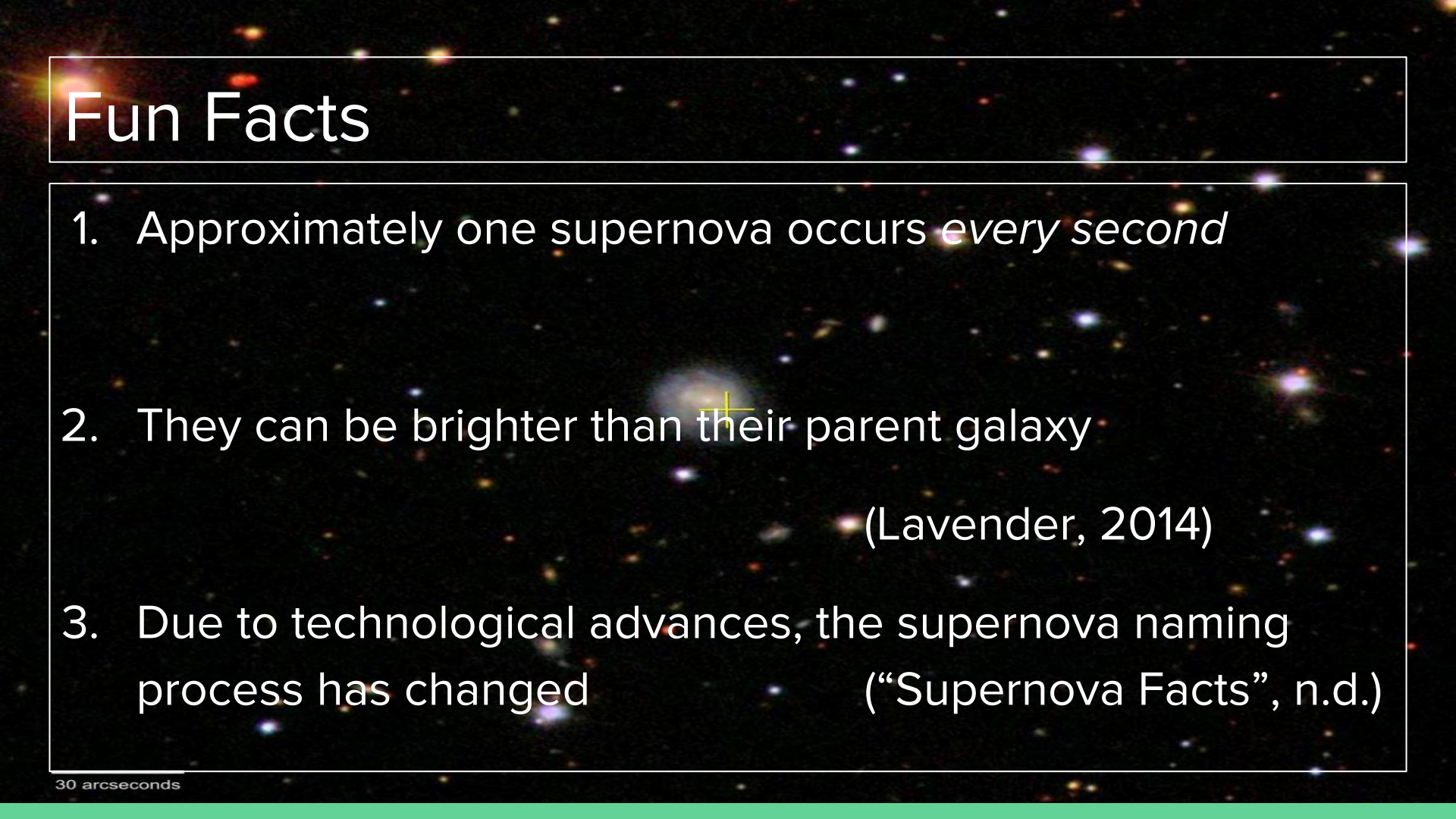
Fun Facts

1. Approximately one supernova occurs *every second*

2. They can be brighter than their parent galaxy

(Lavender, 2014)

3. Due to technological advances, the supernova naming process has changed ("Supernova Facts", n.d.)



Bibliography

ASAS-SN's Homepage. (2019). Retrieved from http://www.astronomy.ohio-state.edu/~assassin/index.shtml

Freedman, Roger A. Geller Robert M. Kaufmann III, William J. Universe Stars and Galaxies (2015) fifth edition. W H Freedman & Co

Hubble Site 2019: Dark Energy and More; Type 1a Supernovae. http://hubblesite.org/hubble_discoveries/dark_energy/de-type_ia_supernovae.php

Jorgenson, A. (2019, January 21). Astronomers may have finally connected supernovae and gamma ray bursts. Retrieved April 5, 019, from http://www.astronomy.com/news/2019/01/astronomers-may-have-finally-connected-supernovae-and-gamma-ray-bursts

Kastner, J., & Evans, R. (2004). CABINET // Are the Stars Out Tonight?: An Interview with Robert Evans. Retrieved from http://www.cabinetmagazine.org/issues/15/kastner2.php

Lavender, G. (2014). Five amazing facts about supernovae | Space Facts – Astronomy, the Solar System & Outer Space | All About Space Magazine. Retrieved from https://www.spaceanswers.com/deep-space/five-amazing-facts-about-supernovae/

May, Sandra (2018) What is a Supernova? NASA. https://www.nasa.gov/audience/forstudents/5-8/features/nasa-knows/what-is-a-supernova.html

NASA's HEASARC: Education and public information (2011) https://heasarc.gsfc.nasa.gov/docs/objects/snrs/snrstext.html

Newman, P. (2017, March 08). The Dispersion of Elements. Retrieved April 07, 2019, from https://imagine.gsfc.nasa.gov/educators/lessons/xray_spectra/background-elements.html

30 arcseconds

Bibliogprahy (Cont'd)

Schawinski, K. et al. (2008). "Supernova Shock Breakout from a Red Supergiant". Science. 321 (5886): 223–226.

SciShow Space. (2015). *Robert Evans, Supernova Superstar* [Video]. Retrieved from https://www.youtube.com/watch?v=1TfUDiCA_gI

Smith, K. (2018). The Brightest Supernova Ever Recorded Lit Up The Sky On This Day in 1006. Retrieved from https://www.forbes.com/sites/kionasmith/2018/04/30/the-brightest-supernova-ever-recorded-lit-up-the-sky-on-this-day-in-1006/#62bfdd26230a

Supernova Facts. Retrieved from http://www.softschools.com/facts/space/supernova_facts/2237/

Supernova Search. Retrieved from http://astronomy.swin.edu.au/cosmos/S/Supernova+Search

Strobel, N. (2018). Lives and Deaths of Stars. Retrieved from https://www.astronomynotes.com/evolutn/s11.htm

University of Chicago. (2017, January 04). Role of supernovae in clocking the universe. Retrieved April 07, 2019, from https://www.sciencedaily.com/releases/2017/01/170104143607.htm

Wheeler Craig J. Cosmic Catastrophes (2007) Exploding Stars Black Holes, and Mapping the Universe 2nd edition. Cambridge University Press.

30 arcseconds

Image and Video Bibliography

All Sky Automated Survey for SuperNovae (ASASSN) *Credit: ASAS-SN Homepage*

Black Hole; Photo credit: Event Horizon Telescope Collaboration

Crab Nebula; Image retrieved from: https://www.theatlantic.com/science/archive/2016/01/rare-supernova-crab-nebula/424125/

Crab Nebulae SN 1054 Remnant; Image Credit: NASA, ESA, J. Hester, A. Loll (ASU)

Gamma Ray Blast; retreived from http://en.minghui.org/emh/article_images/2003-3-25-gammaexplo.jpg

Kepler SN Remnant Image Credit: Spitzer space telescope

M.D. Stage et al. (2005) Chandra X-ray photograph of Cassiopeia A. NASA, CXC, MIT, UMass Amherst.

Milky Way and Observatory; Photo Credit: 21 July 2007, taken by ESO astronomer Yuri Beletsky

Ring Nebula Image Credit, NASA, ESA

Spot the Supernova; occurrence; *Credit: Supernova Search - The SAO Encyclopedia of Astronomy*

Supernova 1987A ***Credits: NASA***

Supernova Classification Chart; http://astronomy.swin.edu.au/cosmos/S/Supernova+Classification

Supernova Explosion; "Distribute MAtter" Image retrieved from:

-https://www.geek.com/news/nearby-supernova-will-light-up-the-sky-for-week-grant-insight-into-dark-energy-1583165/

Supernova Gif. Retrieved from Giphy.com; https://gph.is/2yomp1k

Type 1a Supernova; https://www.youtube.com/watch?v=5YZkAoR3WLE

Universe: Artists Interpretation; Image retrieved from: http://discovermagazine.com/2019/jan/the-constant-fight

30 arcseconds