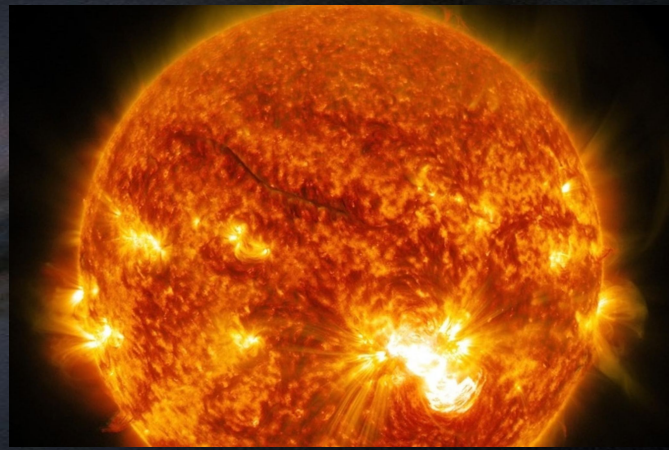
Study of the Nearest* Hydrogen-Rich Core-Collapse Supernova: SN 2023ixf

SN 1994D (bright spot on the lower left), a type Ia supernova within its host galaxy, NGC 4526

The Basics: What is a star?

- Stars are giant balls of gas – mostly hydrogen, with some helium and small amounts of other elements.
- Because of the immense pressure and temperature in their core, they fuse hydrogen into helium (for most of their life), releasing energy (and neutrinos) that prevents a gravitational collapse and keeps them stable.
- Their rate of fusion and hence their luminosity (and colour) depend on their mass.



Our sun, currently living a normal life

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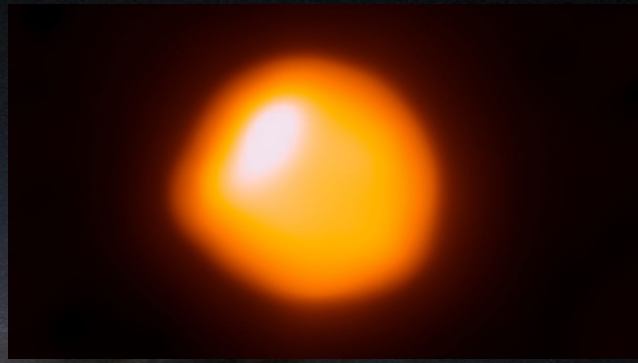
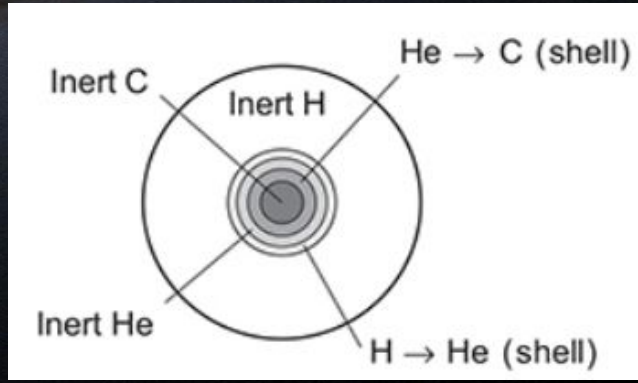
The Basics: Evolution of a Star

- Eventually, the Hydrogen in the core gets converted to *inert* Helium (inert because much more extreme conditions are required to start Helium fusion), causing the start contract.
- This causes hydrogen *burning* to start in a shell surrounding the core, causing the outer layers to expand.
- The conditions in the core may get extreme enough (due to the contraction) to start Helium fusion into Carbon and just like before, eventually, all the Helium in the core gets converted to inert Carbon and Helium burning begins in a shell.



Betelgeuse living a not so normal life



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The Basics: Death of a Low Mass Star

- Now low mass stars don't have the mass needed to start carbon fusion, so no more fusion.
- The outer layers are radiated away forming what are known as *planetary nebulae* leaving behind a *white dwarf* made mostly of inert carbon ash.
- If you're wondering why the Carbon core doesn't collapse, it's saved by something called the *electron degeneracy pressure* – which arises because two electrons don't want to be in the same place

NGC 7293, the Helix Nebula

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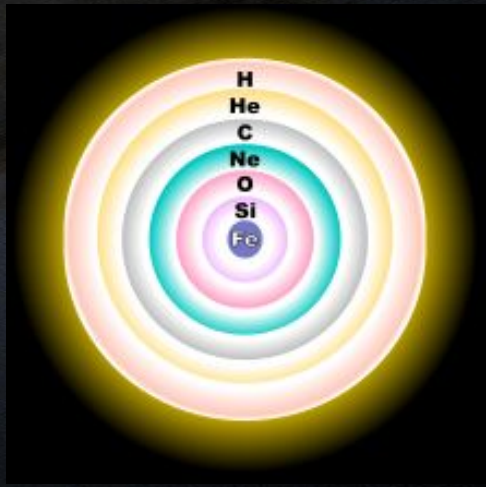
The Basics: Death of a Massive Star & Supernova

- The death of a massive star is much more dramatic and ends with one of the most energetic and violent explosions known to humans.
- The fusion of heavier elements continues in the core till iron is formed. Fusion of iron releases no more energy.
- Once the mass of the iron core goes above the Chandrasekhar mass, the core collapses and the outer layers are expelled in a violent explosion called **supernova.**
- A neutron star or black hole is formed depending on the mass of the star.



The layers of a massive, evolved star just before core collapse

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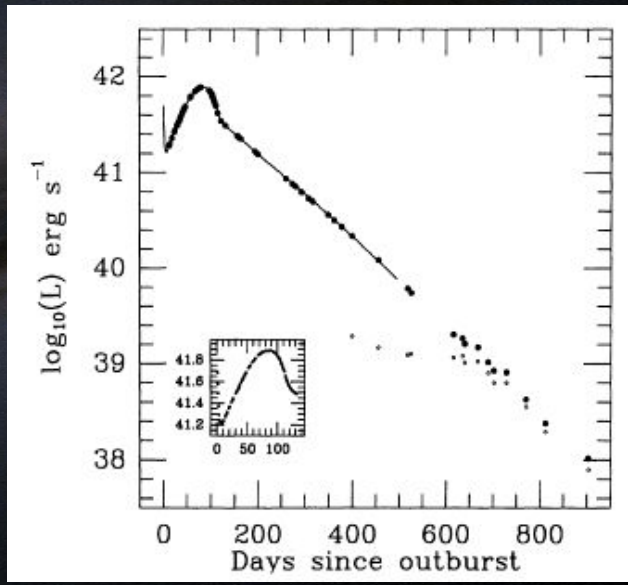
About the Project (Finally!)

- You'll be extracting the lightcurve of SN 2023ixf (i.e. the variation of the *brightness* of that supernova with time) and modelling it.
- The kind of data you'll be using is the same kind of data astronomers used/use to deduce what you read in textbooks about our universe. In astronomy you need data, and a little ingenuity and you're free to play around.
- What you're going to be doing is a very cool, extremely non trivial and creative work.



Lightcurve of SN 1987A

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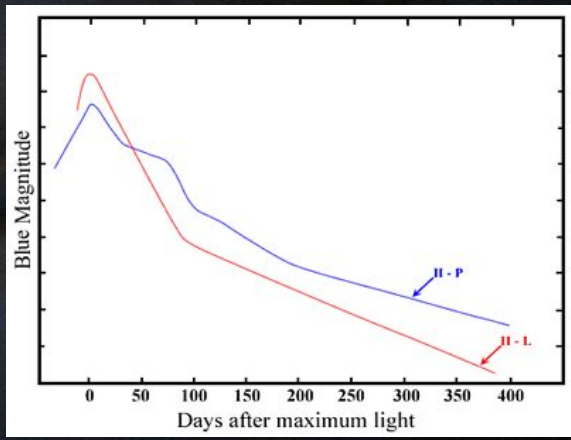
About the Project

- Initially you'll learn about the how the images are collected and processed. Each wavelength has its own challenges. This is the engineering part.
- Once you have the processed data for all the observations, you plot the magnitude as a function of time.
- The final step is modeling i.e. explaining what you see or the Physics part. This is where you can go crazy and say whatever comes to your mind as long as you're able to explain the observations in a generalised way (won't be ideal to have 100 models for 10 supernovae).



Typical lightcurve of type II supernovae

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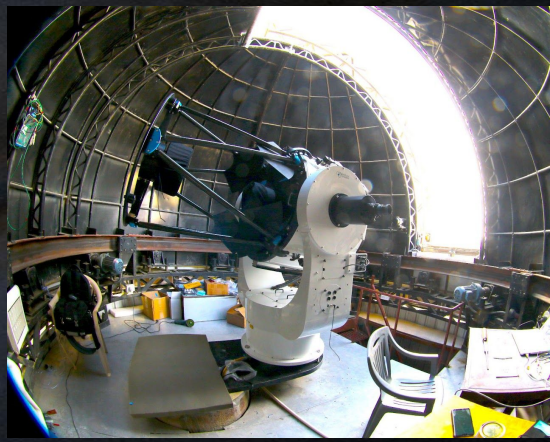
GROWTH Collaboration and GIT

- A sudden change of gears, now we'll return back from stars to the Earth, where the magic of observation happens.
- GROWTH stands for Global Relay of Observatories Watching Transients Happen. It is an international collaborative project studying the physics of fast-changing events in the cosmos.
- GROWTH jointly operates 18 observatories, enabling them to gather continuous data on transients as they "pass on the baton" (of observation) continuously westward, thus "beating sunrise".



GROWTH India telescope

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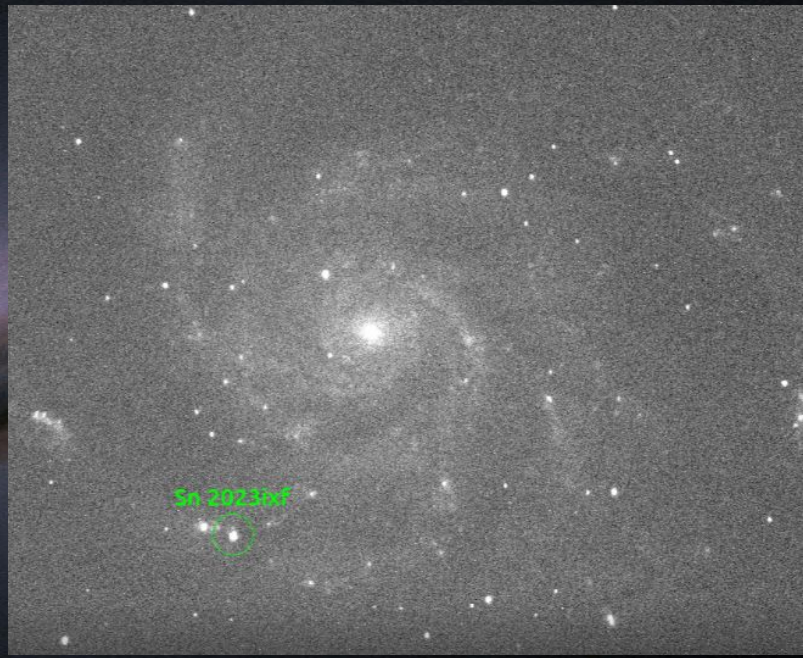
GROWTH Collaboration and GIT

- You'll be using GIT's raw (data as recorded in the detector) data for this project.
- GIT is India's first fully robotic optical research telescope (you can give commands for operating it from IIT Bombay – your other mentor does that)
- Located at the Indian Astronomical Observatory site at Hanle, Ladakh.
- The GROWTH-India project has a focus on time domain astrophysics (fast transients, supernovae and novae, and solar system objects like asteroids)



An image of SN2023ixf taken with GIT

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The Coolness of Supernovae

- Supernovae can outshine entire galaxies. A supernova in Milky Way will be visible even during daytime.
- Supernovae are responsible for heavy element synthesis (they're responsible for creating gold among other elements).
- Supernovae enrich the ISM with elements, paving the way for formation of new stars, planets and life.
- SN 2023ixf (your supernova) was discovered by an amateur astronomer. It is the closest type II supernova in the last 25 years, located in the Pinwheel galaxy.

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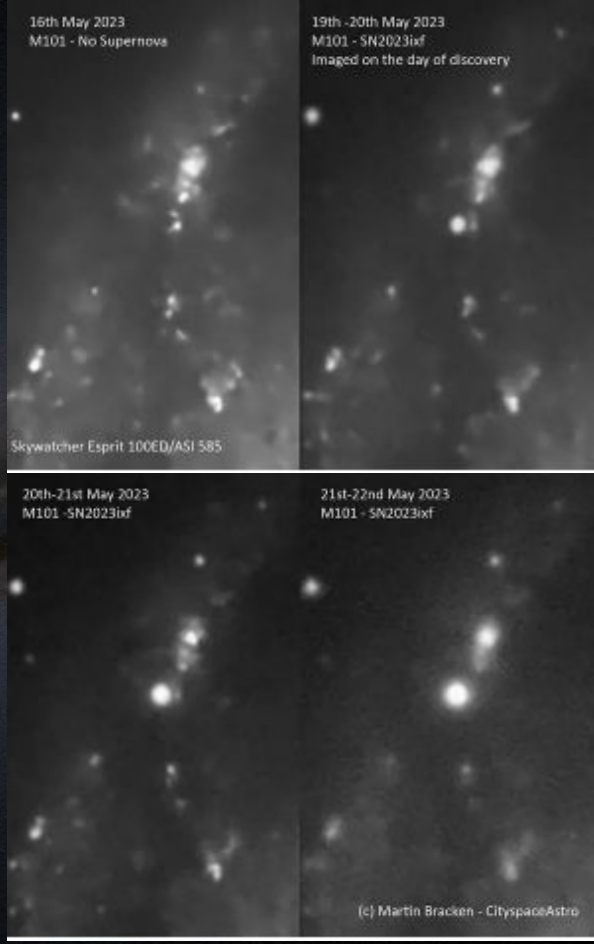

A collage showing the appearance of SN 2023ixf

Your Tasks

- Read about the magnitude system. This is what I meant when I used *brightness* in slide 6. Understand the difference between *apparent* and *absolute* magnitude.
- Read about luminosity and see how it's directly related to magnitude.
- Understand *bolometric* luminosity and magnitude.
- Read briefly the astronomical coordinate systems, and understand thoroughly the equatorial coordinate system (only the spherical one). Read about right ascension and declination.
- I've given brief installation instructions. Try to get VS code running and all these packages installed.

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