Explosions in the Sky: Supernovae Type Ia

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Introduction

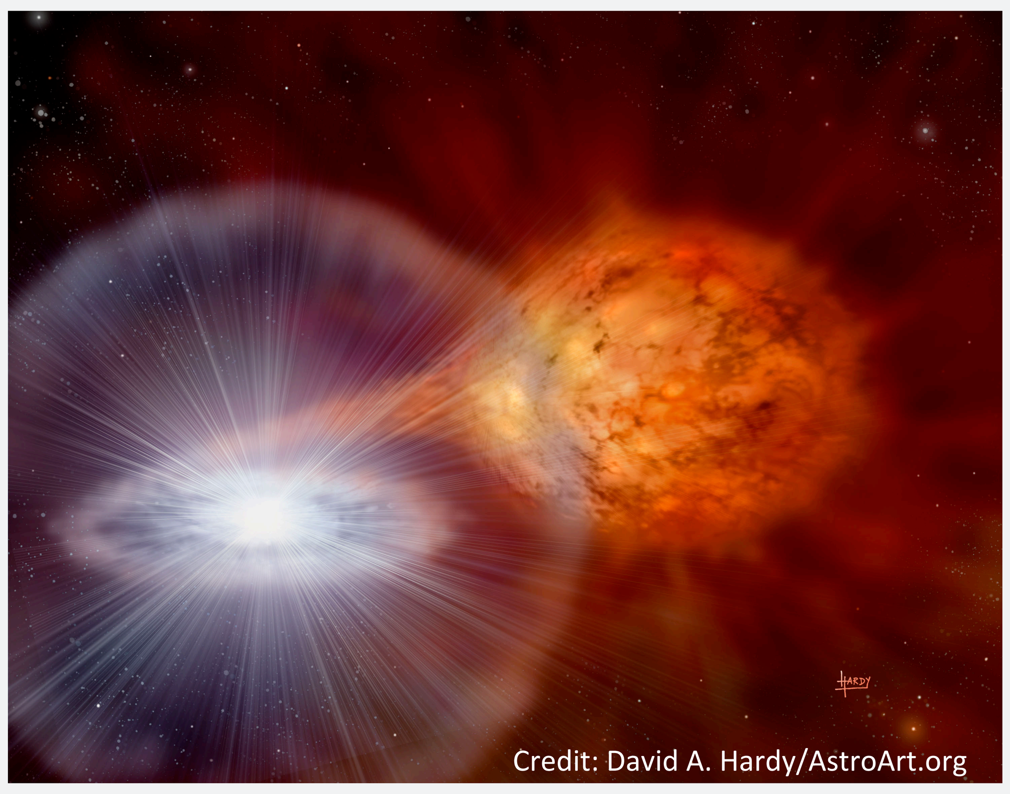
Supernovae Type Ia (SNe Ia) are massive **thermonuclear explosions** of an Earth-sized star called a **white dwarf (WD)**. They occur as the WD gains material from a **neighbouring companion star**, until it cannot longer support itself against gravity, at which point it explodes. The SNe Ia explosions are always **uniformly bright** and of the same magnitude. This reliability allows astronomers to calculate accurate **distances** from the earth to the supernovae even when they occur in distant galaxies.

Combining this information with an independent distance measurement called **redshift**, we are able to investigate the composition of the Universe, since different **cosmological models** predict different behaviours of redshift vs. distance.

In 2011, S. Perlmutter, B. Schmidt and A. Riess were awarded the **Nobel Prize in Physics**, following work in this scientific area, proving the existence of **Dark Energy**, a previously unknown but significant (~70%) component of our Universe.

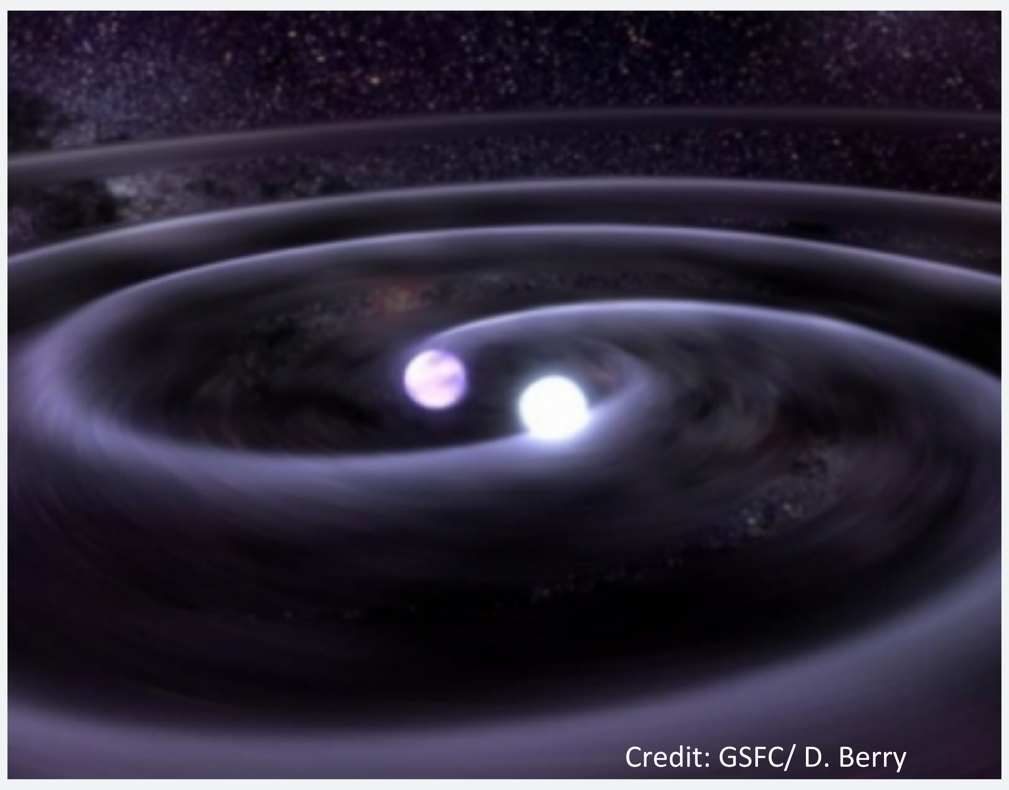
Before the explosion: The Progenitor Problem of Supernovae Type Ia

While SNe Ia are a widely used astronomical tool, little is known about the configuration of the double star system that leads to the explosion. This is known in the scientific community as the **Progenitor Problem**. The main question is about the **nature of the companion star**, that provides the extra material, gained by the exploding white dwarf.



Single Degenerate Scenario

vs.



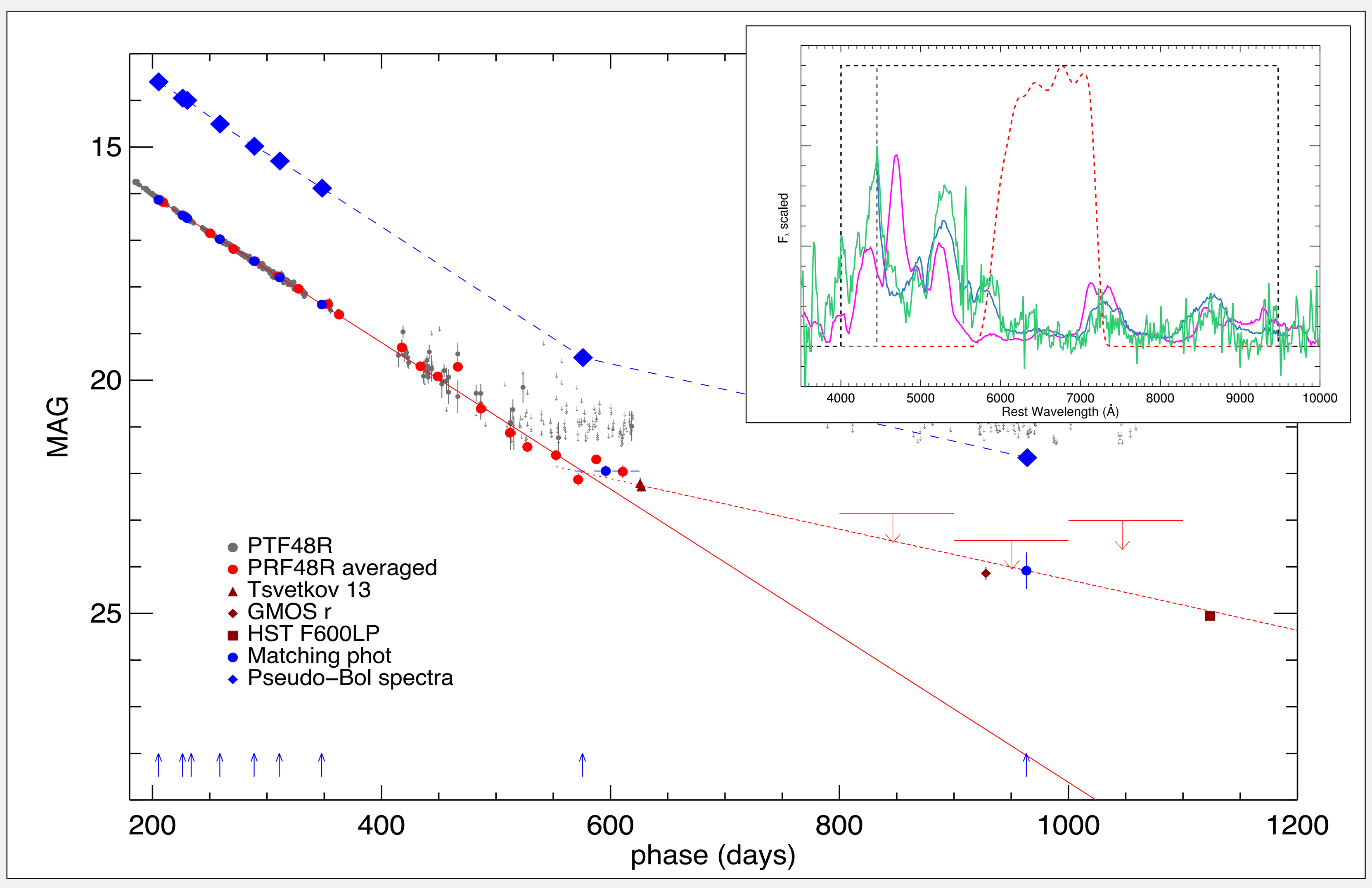
Double Degenerate Scenario

Two main suggestions have been proposed:

- The **Single Degenerate Scenario** (SD), in which the companion is a **common star**, just like our Sun.
- The **Double Degenerate Scenario** (DD), in which the companion is **another white dwarf**.

Astronomers use various scientific tools to examine this longstanding astrophysical problem. From the theoretical perspective, we create **mathematical models** that describe different stages of the phenomenon. Meanwhile, large **observational programs** are dedicated to find dozens of new SNe Ia each day. After being discovered, we **continuously** observe them for a long period of time.

When all the available data are collected, we can compare the actual observations with different explosion models to investigate: **What was there, before the explosion in the sky?**



Late time observations of SNe Ia

My work focuses on the **observational signatures** of SNe Ia at the later times of the phenomenon, almost **1-3 years after the explosion** itself. At this time, the dominant energy source is **radioactive decay**. Heavy and unstable elements, such as Nickel (**^{56}Ni**) and Cobalt (**^{56}Co**), produced at the explosion, break apart and release high energy that **heats** the expanding debris. This heated material, called **ejecta**, is what I actually observe with telescopes.

By studying the **shape** of the **light curve** – brightness plotted against time – or the **colour** of the light that reaches us, I am able to **test predictions** of various theoretical models and **measure** important **quantities** that these models suggest.

At the left-hand side, the **late time light curve** of SN2011fe is plotted, where the data come from various telescopes. I also show a collection of **spectra** (**amount of light** plotted against **colour of light**) from different epochs. While the spectra don't seem to change, the **light curve changes** at around 600 days after the explosion.

My work shows that, for some of the SNe Ia, **new elements** or other mechanisms, such as **interaction with material around the explosion**, should be considered, in order to explain the behaviour of the light curve.

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