

Type Ia Supernovae: Explosions and Progenitors

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Disclaimer

I hereby declare that the work in this thesis is that of the candidate alone, except where indicated below or in the text of the thesis.

Chapter 2:

The candidate was not involved in the acquisition of Subaru data for Tycho-G. The theoretical calculations for the expected rotation were carried out by Philipp Podsiadlowski. The surface gravity was measured by Anna Frebel.

Chapter 3:

The candidate was not involved in the acquisition of Keck data for the donor star candidates. The effective temperature, surface gravity and metallicity measurements were conducted by David Yong (except Tycho-B). The analysis of the Tycho-B HIRES spectrum was partly performed by Simon Jeffery. All other parameters and the LRIS spectrum were analyzed by the candidate.

Chapter 4:

All work (including data acquisition) was performed by the candidate, except rotation which was measured by John Laird (but confirmed by the candidate).

Chapter 5:

The spectrum synthesis code was written by Paolo Mazzali and his group. All other work was performed by the candidate.



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Abstract

Supernovae are the brightest explosions in the universe. Supernovae in our Galaxy, rare and happening only every few centuries, have probably been observed since the beginnings of mankind. At first they were interpreted as religious omens but in the last half millennium they have increasingly been used to study the cosmos and our place in it. Tycho Brahe deduced from his observations of the famous supernova in 1572, that the stars, in contrast to the widely believe Aristotelian doctrine, were not immutable. More than 400 years after Tycho made his paradigm changing discovery using SN 1572, and some 60 years after supernovae had been identified as distant dying stars, two teams changed the view of the world again using supernovae. They found that the Universe was accelerating in its expansion, a conclusion that could most easily be explained if more than 70% of the Universe was some previously un-identified form of matter now often referred to as 'Dark Energy'.

Beyond their prominent role as tools to gauge our place in the Universe, supernovae themselves have been studied well over the past 75 years. We now know that there are two main physical causes of these cataclysmic events. One of these channels is the collapse of the core of a massive star. The observationally motivated classes Type II, Type Ib and Type Ic have been attributed to these events. This thesis, however is dedicated to the second group of supernovae, the thermonuclear explosions of degenerate carbon and oxygen rich material and lacking hydrogen - called Type Ia supernovae (SNe Ia).

White dwarf stars are formed at the end of a typical star's life when nuclear burning ceases in the core, the outer envelope is ejected, with the degenerate core typically cooling for eternity. Theory predicts that such stars will self ignite when close to $1.38 M_{\odot}$ (called the Chandrasekhar Mass). Most stars however leave white dwarfs with $0.6 M_{\odot}$ and no star leaves a remnant as heavy as $1.38 M_{\odot}$, which suggests that they somehow need to acquire mass if they are to explode as SN Ia. Currently there are two major scenarios for this mass acquisition. In the favoured single degenerate scenario the white dwarf accretes matter from a companion star which is much younger in its evolutionary state. The less favoured double degenerate scenario sees the merger of two white dwarfs (with a total combined mass of more than $1.38 M_{\odot}$).

This thesis has tried to answer the question about the mass acquisition in two ways. First the single degenerate scenario predicts a surviving companion post-explosion. We undertook an observational campaign to find this companion in two ancient supernovae (SN 1572 and SN 1006). Secondly, we have extended an existing code to extract the elemental and energy yields of SNe Ia spectra by automating spectra fitting to specific SNe Ia. This type of analysis, in turn, help diagnose to which of the two major progenitor scenarios is right.

Understanding the progenitors of SN Ia has wide ranging applications. Not only would we better be able to calibrate SNe Ia for use as distance probes, but we could also dramatically improve our understanding of the chemical history of the universe, which SNe Ia play a seminal role in.

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