Identifying Hypernovae Candidates

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Abstract

Hypernovae are possibly the largest explosions in our universe since its beginnings. It may be possible to predict hypernova candidates before they explode. We have conducted research to support our hypothesis that hypernovae remnants and candidates should have similar spectrum, and to find a prediction method. We obtained stellar spectra from emulsion plates at Pisgah Astronomical Research Institute and other textual sources to obtain spectra of candidates to compare. We discuss in particular Zeta-1 Scorpii, Eta Carinae, and HD188001. These stars are some of the top candidates for possible hypernovae in their futures. We also discuss other possibilities than spectra as an identifier for hypernovae candidates.

Introduction

Once a massive star has ended its life cycle, its death is marked by a series of violent changes in its density, temperature, and size. First, the gases and material that compose the star rapidly expand until it has reached a critical size. Once it reaches this size, it will no longer be able to support its structure and collapse upon itself as a supernova. A hypernova is a supernova at least 100 times more powerful as the average supernova, and consequently has more devastating effects. Dr. Daniel Wang (Ph. D) labels hypernovae as ". . . possibly the most powerful explosions in our universe since the Big Bang," and they are the largest explosions that we have observed directly as of yet. They do not, however, occur like normal supernovae. In order for a hypernova to occur, the core of a star must collapse into a black hole before the entire star collapses. This black hole then excites the remaining stellar material to create a massive explosion. This most often occurs in special cases, such as pair-instability stars and stars in nebulae, where there is more stellar material to excite. We believe that an examination of hypernovae remnants' spectra and a comparison to the visible spectra of other super-massive stars will help identify possible candidates for future hypernovae. An analysis of the spectra will identify the elements present in the stars and remnants, which will help show a correlation between them.

Hypernovae Remnants

The first step in finding our prediction method was to locate hypernovae remnants. There are several remnants, and one galaxy in particular is a concentration point of hypernovae. Messier 101, 27 million light years away, has two hypernovae remnants within its borders, SN1998bw and SN2006gy. At the time of their explosions, they were the most luminous objects in M101, and affected a large portion of the galaxy. Some other suspected hypernova remnants are Nova Scorpii, a large supernova in Scorpius, Il Lupi, a galactic black hole binary, and XTE J1550-564. The remnants of these hypernovae are extragalactic, however, and unfortunately we were unable to obtain the spectra of these remnants due to the fact that our resources were not sensitive enough to capture such faint objects. While the hypernovae remnants were not used in our spectral analysis, they did provide us with a better understanding of hypernova, and were very important in our research.

Hypernovae Candidates

A more conclusive branch of our research was on the present hypernova candidates. Because most of the candidates of which we know are in our own galaxy, they were relatively bright and our instruments were able to capture their spectra. Most of the stars we suspected are O-class LBV's, due to their size and temperature. An example of these would be Zeta

Orionis, a large O-type star. There are some candidates, however, that are not O-type stars. P Cygni and Zeta-1 Scorpii, two B-class stars, are two of the top candidates for a hypernova, so candidacy is not limited to O-type stars. Another level of spectral classification is needed to determine good candidates to investigate. In addition to the letter class, a number in Roman numerals is added to the end of the spectral type. The only types of stars that are able to go hypernova are Ia and Ib types, which stand for super-massive luminous and super-massive non-luminous, respectively. All of the candidates we selected for study were of one of these types. We also have mentioned before LBV's or Luminous Blue Variable stars. These stars are very hot and large, and vary in luminosity periodically. This makes them excellent stars to become hypernovae, due to the fact that they are less stable but have a very large mass which is required for a hypernova.

Spectral Analysis

As mentioned above, we were unable to find spectra of hypernovae remnants to compare with the hypernovae candidates', so in order to continue our research we had to pursue a different path Perhaps the top candidate for a hypernova is Eta Carinae, a binary star. This star has been researched many times and it is almost certain that it will become a hypernova. Because of this we decided to compare our spectra to Eta Carinae instead of comparing them to hypernova remnants, assuming that it is definitely exploding in a hypernova.

Due to several technical malfunctions within our time constraints, we were only able to obtain 2 candidates, in addition to the spectra of Eta Carinae. The spectra we obtained were of Zeta-1 Scorpii (Fig. 1. 1 and 1.4) and HD188001 (Fig. 1. 2 and 1.5), another major possibility for a hypernova. We acquired the spectra for Eta Carinae (Fig. 1.3 and 1.6) from an article in the Astronomical Journal, “The Early Spectra of Eta Carinae” in order to compare the spectra, we used a program called Visual Spec, which interpreted the spectra and constructed graphs. Using the same parameters, we overlapped the spectra (Fig. 1.7) and found the similar peaks in the graphs. We found many common lines between the graphs, and manually identified the elements that the lines corresponded to. The strongest correlation we found were the elements hydrogen and helium, which was to be expected knowing that all of the spectra came from stars that fuse hydrogen to helium. We did find neon and nitrogen present in two of the stars, but not Eta Carinae due to lack sufficient spectral data.

Error Analysis

Despite the fact that there were some definitive commonalities between our spectra, our evidence was unable to conclude that spectra was the defining factor when deciding hypernovae candidates. While some lines were similar between the stars, the spectral analysis showed peaks in Eta Carinae that were not replicated in the other two stars we tested. Perhaps the most prominent reason, however, that our experiment was inconclusive is the accuracy of our instruments and the resources available to us. Several times we were unable to use our spectrometer, due to several technical malfunctions, so that several stars that we would have included in our research had to be left out. In addition to this, there is some possible error in the spectra we acquired from the plates. Especially in the case of Zeta-1 Scorpii, there were other sources of spectra that were near to the star and may have corrupted the spectra. We also ran into problems with the use of the program Visual Spec. Because we were unable to calibrate the spectra with the program and calibrated the data by hand. While this worked fairly well, there were some instances where the lines were a few nanometers off from each other, which made it difficult to find elements that matched the spectra. In addition, although the spectra we obtained for Eta Carinae was very accurate, it only spanned from 390nm to 520nm, so any spectral data beyond those parameters could not be compared to Eta Carinae, but only to each other.

Conclusions/Discussion

Upon discussion of possible reasons that some stars are better hypernovae candidates than others, we reached the conclusion that whether a star ends its life in a hypernova or a regular supernova depends mostly on its size and environment, and not necessarily the elements contained within the star. It was still important to perform this experiment, however, in order to obtain a better understanding of hypernovae. In the future more research needs to be done, and it is possible that a correlation could be established between hypernova spectra and candidate spectra. This research would need to include clear and accurate spectra of both the candidates and the remnants, but if this is accomplished it should be obvious whether our hypothesis was correct.

In conclusion, we were unable to support our hypothesis that the spectra of a star is a factor in whether it is a candidate for a hypernova. This was due in part to several sources of error that were out of our control. Also, the spectra we were able to obtain was not in its most desirable quality, and the differences among our spectrum were the reason we could not support our hypothesis.

Sources

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Visual Spec – Spectrum Analysis Program

Stellarium – Star Location and Information Program

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Appendices

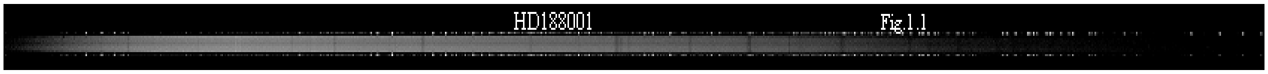

Figure 1.1: The spectrum of HD188001

Figure 1.2: The spectrum of Zeta-1 Scorpii

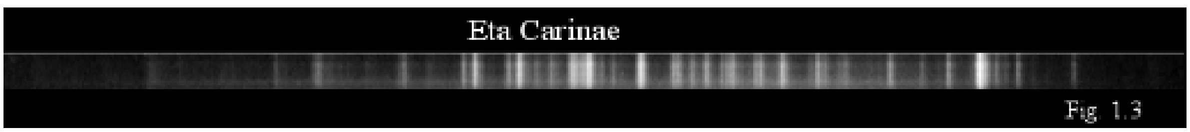

Figure 1.3: The spectrum of Eta Carinae

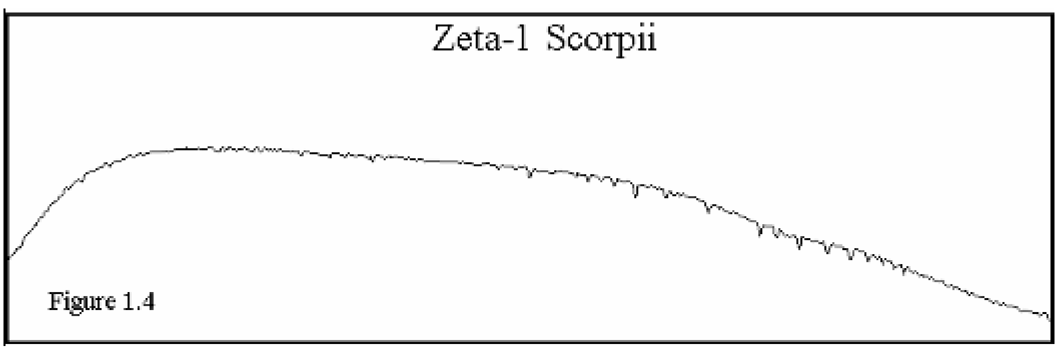

Figure 1.4: A graph of the spectrum of Zeta-1 Scorpii

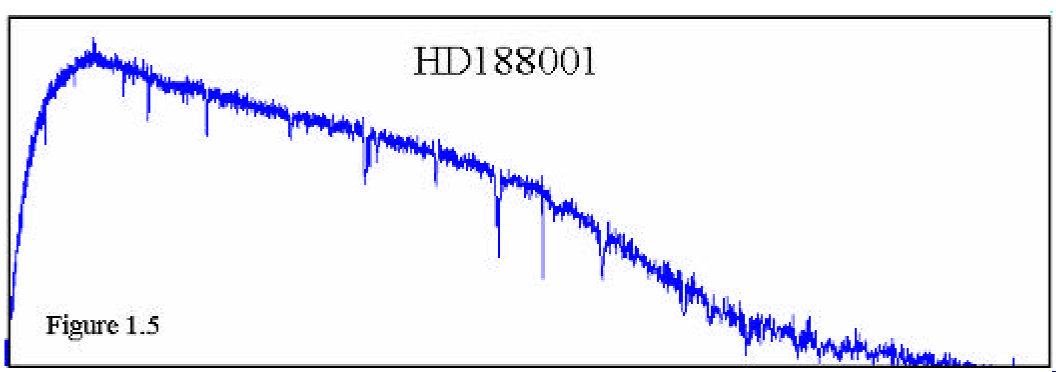

Figure 1.5: A graph of the spectrum of HD188001

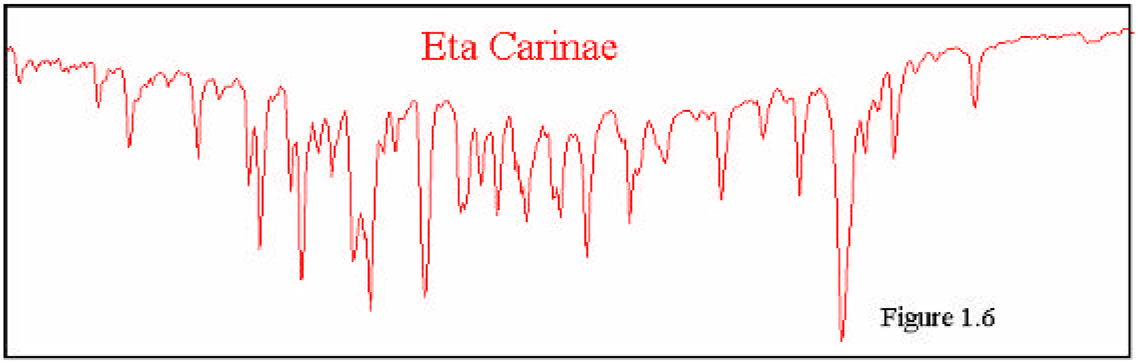

Figure 1.6: A graph of the spectrum of Eta Carinae.

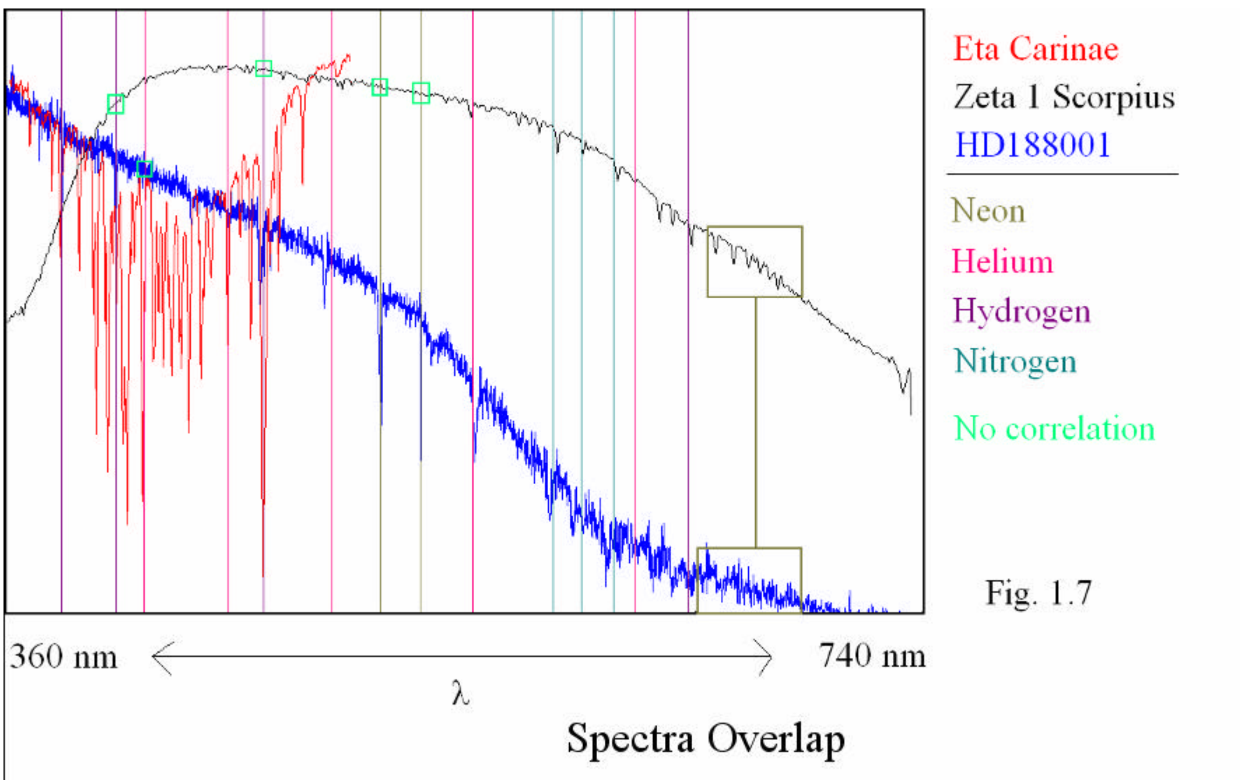

Figure 1.7: A spectral comparison of Eta Carinae, Zeta 1 Scorpius, and HD188001. The vertical lines represent common elements found amongst the stellar objects.