Letter to the Editor

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Peer Review 2

This peer review was very helpful for understanding where clarifications could be made for the reader that were less obvious to the author. One of the main issues brought up by the reviewer was to add more explanation about the supernova classifications, which I think was a good suggestion and will give the reader sufficient background information to understand the research presented. Also, some places where citations could have been added that I did not pick up on were also helpful suggestions.

Addressing Concerns:

Major Points:

The author should include the definition of each supernova types mentioned in the paper (II-P, IIb, II-L, IIn, and IIn-P)

I added a paragraph in the introduction explaining each of the supernova classifications. This helps for clarification later on when the supernova classifications are discussed.

"Photometric data were obtained...and II-L": Even though there are 11 light curves, there is only 1 for type II-b and 1 for type II-L? The author should discuss how this inequality does not create biases in the comparison.

This does not create bias because SN 1054 is established to not be a type IIb or II-L. I added explanation for this in the Observations section.

"...to calculate a linear trend between $\log P_{642}$ *and* $\log M_{prog}$*.": the author should explain how do we know that the relationship between the two variables are linear? (or if it is an assumption, the author should also state it).*

Added this sentence: "The relationship between the explosion energy and the ejecta mass (and therefore the progenitor mass) is established to be a power law, making the log-log relationship between the energy and the progenitor mass linear (see Prejcha & Prieto 2015; Müller et al. 2016, and references therein)."

"Using P_{642} *of SN 2004dj...an approximate progenitor mass for SN 1054.": the author should explain why we don't use the known mass of SN 2004 but have to the linear trend?*

By using the linear trend, this avoids the assumption that similar-looking light curves are physically the same. This sentence was added: "Using this estimated progenitor mass for 2004dj, rather than the value from Vinkó et al. (2006), as the value for SN 1054 avoids the assumption that similar SN light curves are physically identical and that their progenitors have the same mass."

"Since the progenitor mass reported in this paper, 20 solar mass,...SN 1054 most likely has a higher irradiated energy than expected...": is the value of 20 solar mass a conclusion for the progenitor mass, or it just suggests a higher irradiated energy? The author should make it clearer.

I added more explanation in this section to clarify: "Since the progenitor mass suggested for SN 1054 in this study, $20.7 \pm 9.7\ M_{\odot}$, is approximately twice the accepted value, SN 1054 most likely has a higher irradiated energy than expected according to the $\log P_{642} - \log M_{prog}$ relationship. This would explain the discrepancy between the estimated M_{prog} in this paper and the value reported by other studies."

Minor Points:

"...to be 2 mag and 20 days...": justifications for choosing this error range.

Changed to "Following Nomoto et al. (2014), error bars were assumed to be 2 mag and 20 days. The error bars on the magnitudes were doubled from Nomoto et al. (2014) to better account for uncertainties in the measurements."

"Correcting for a distance of 2 kpc and visual extinction of A_V = 1.6 mag...": needs citation or justifications.

Citations were added.

"These SN light curves as well as the SN 1054 historical light curve are displayed in Figure 1": it might be better if the author includes the magnitude of these historical data points in a table. This makes it easier for further studies to collect the data.

I decided that a table for only 3 data points seems unnecessary and might take up space in the paper. Instead, I added a sentence in the text and listed them: "The resulting data points are: -17.3 ± 2 mag at 0 ± 20 days since maximum light, -16.1 ± 2 mag at 23 ± 20 days since maximum light, and -7.1 ± 2 mag at 642 ± 20 days since maximum light."

"To determine which light curve best fit the SN 1054 historical light curve...": the author should state that the reduced Chi-square is used for comparison (instead of just using the notation of Chi-square), and that the best match will have the reduced Chi-square approximately to 1.

Changed to: "To determine which light curve best fit the SN 1054 historical light curve, reduced χ^2, or χ^2_ν, was calculated between each light curve and the observations...The best fitting light curve will result in $\chi^2_\nu \approx 1$."

"The resulting linear trend is...is shown in Figure 3.": are there any other linear fits of the same relationship in the literature? If yes, the author should mention and compare them here.

This issue was addressed in the Major Points.

"...which is comparable to the known progenitor mass of SN 2007dj...": I think the author miswrote it from SN 2004dj to SN 2007dj.

Yes, this was a typo. I corrected it.

Error bars for Figure 3 should be included, at least for the mass (x axis).

Figure 3 was updated to give error bars for the masses as they are presented in Table 1. The figure caption was also added to: "The error bars on correspond to the progenitor mass uncertainties presented in Table 1."

"The SN 1054 progenitor mass is established from the literature to be 8-10 solar masses": the author should explain how this number was determined in literature? Also, are there any points that can help explain the difference between this value with the reported value of 20 solar mass?

Added: "The SN 1054 progenitor mass is known to be $\sim 8 - 10\ M_\odot$ from evolutionary models and comparisons to the elemental abundances in the Crab (Nomoto et al. 1982; Nomoto 1985)." This method was mentioned in Nomoto (1985).

"The low kinetic energy of the Crab ejecta (~7e42 J)...": needs citation for this value.

Citations were added.

"...it is worth noting that all of the type IIn light curves..(excluding SN 1988Z)": according to Table 1, SN 1988Z is a type II-P supernova, why does it appear in the argument about type IIn light curves?

This was a mistake that I did not catch. The part in parentheses should not be there. This was corrected.

"The main complication with adopting an FeCSN model, however, is the low Ni56 abundance in the Crab, which is typical for ESCNe.": need citation.

A citation was added.

"Smith (2013) suggested that SN 1054 is a type IIn-P...": the author introduces a new type here (in addition to the 4 types that are already discussed) but does not explain clearly what it is.

This was explained briefly, but the explanation was moved to the Introduction and expanded upon with the other supernova classifications.

"such as the high neutron star kick of 160 km/s.": needs citation.

A citation was added.

"...than expected for the known progenitor mass of ∼8 to 10 solar masses. In comparison with the light curve of SN 2008S, a type...": the author should have a transition between the two sentences and rephrase the second sentence. The readers may not understand why the author wants to compare the light curve of SN 2008S while reading. For example, the transition can begin with the fact that SN 1054 was classified as type IIn ECSN in literature, and then states that it does not match the light curve of SN 2008, an example of such type.

Added transition: "Because of the high peak brightness of the event and low kinetic energy of the Crab filaments, it has been suggested in past studies that SN 1054 is an ECSN, and interactions with circumstellar material suggest a type IIn classification (Nomoto et al. 1982; Hillebrandt 1982; Kitaura et al. 2006). However, in comparison with..."

"However, by acquiring sufficient data...": if the author means the data for SN 1994W, SN 2009kn, and SN 2011ht, how can we have more data if those events already happened? If that is not what the author mean, the author should rephrase the sentences to make it clearer what data is mentioned.

Changed to: "However, by extending the light curves of SN 1994W, SN 2009kn, and SN 2011ht to at least 642 days, possibly through models and simulations,,..."

Peer Review 3

I do not agree with many of the concerns brought up by the reviewer. Once this paper will be published in an academic setting, the readers, who are experts in astronomy, will understand many of the terms used, such as K-correction (and how it is defined in terms of redshift), zero-point luminosity, and reduced χ^2. However, these corrections were received and added to better communicate the methodology.

Addressing Concerns:

Major Points:

The selected supernova, SN 2004dj does not have the lowest χ^2 value. Why was this supernova chosen over SN 1993J and SN 2004et which have the lowest χ^2 values? Through inspection of Figure 1, SN 1993J and SN 2004et meet all three error ranges while SN 2004dj does not meet the final error range. It is unclear why SN 2004dj was selected when two other supernovae seem like better selections.

This was because reduced χ^2 should be close to 1, not necessarily the lowest value. A sentence was added about this (see Peer Review 2). 2004dj does not go through all the error bar ranges but still gives the best reduced χ^2 because the ratio of the difference between the data and the expected values to the variances should be close to 1. The equation for reduced χ^2 was added for clarification.

Minor Points:

Introduction, second paragraph: The sentence starting with "Despite ongoing observations and investigations..." is hard to parse and should be re-written or broken into two sentences.

A sentence was added earlier: "Core-collapse for a $\lesssim 100\ M_\odot$ progenitor can be instigated by either the electron capture process (electron capture supernova, ECSN), resulting from a $\sim 8-9\ M_\odot$ progenitor with an O-Ne-Mg core, or the Fe-core process (Fe-core supernova, FeCSN), resulting from a $\sim 9-100\ M_\odot$ progenitor (See Wanajo et al. 2011; Janka 2012)." This introduces these concepts earlier so the sentence later on can be changed to: "Despite ongoing observations and investigations which have lasted for nearly

1000 years, we have not yet been able to determine the core-collapse mechanism or the classification of SN 1054."

In the introduction, page 2, is ECSNe and FeCSNe different types of supernovae or is the added 'e' at the end a mistake? This appears multiple times throughout the paper.

These are plural forms, and SNe is an abbreviation for supernovae. This is now clarified in the first sentence of the introduction: "supernova (SN, plural SNe)".

In equation 1, in the formula for the K-correction, is the z term redshift?

Yes, this is now clarified after Equation 1.

In section 3, where does the value for L_0 come from? Is this a universal constant or specific to the supernova?

This is the zero-point luminosity, defined such that the absolute magnitude of the Sun will be 4.74 according to Equation 2. Clarification was not provided since, once published, this paper will be read by astronomy experts who know what the zero-point luminosity is.

Peer Review 4

This peer review was very helpful in providing extra clarifications in the paper.

Addressing Concerns:

Some of the concerns mentioned in this peer review were already addressed in other reviews, so they were not mentioned again below.

Minor Points:
Section 2: "...had an apparent brightness comparable to Venus in the night sky..."

- *Perhaps worth addressing whether or not things like light pollution and other important factors which would have changed perception of brightness 1000 years ago were taken into account with these data points*
- *"...suggesting an apparent magnitude of $m_V \sim 6$ mag." → would this standard have been true that long ago?*

This is a very rough approximation. I think the paper I referenced for this is assuming that these were the standards 1000 years ago, and absolute magnitude and K-corrections are used to mitigate the effects of other factors as much as possible. I do not think that this needs to be addressed in the paper because again, this is all very approximate in the first place. No changes were made.

Section 2: "(2) a well-established progenitor mass..."

- *What constitutes "well-established"? Especially if you are proposing challenging this progenitor mass to be 20 solar masses instead of 8-10 solar masses*

Changed to "a progenitor mass established in literature"

Peer Review 5

I did not agree with all of the suggestions made in this peer review because I felt that changes to address them were unnecessary, either because they were already clarified in the paper or redundant changes. However, the reviewer also brought up some important points for clarification that were helpful and well-received.

Addressing Concerns:

Some of the concerns mentioned in this peer review were already addressed in other reviews, so they were not mentioned again below.

Major Points:
Mass value does not have error bars or an appropriate mass range.

An uncertainty was calculated using propagation of error from the 2 mag and 20 day error bars assumed for the data. The uncertainty turned out to be large, 9.7 $M_{\odot}$, so further discussion about the uncertainty was added in the Discussion section.

Minor Points:
For the 3rd inference in Section 2, an explanation of why magnitude 6 is considered invisible would be beneficial

I disagree with the reviewer because I think that saying "SN 1054 was no longer visible at night, suggesting an apparent magnitude of $m_V \sim 6$ mag" implies that $m_V \sim 6$ mag is at magnitude at which objects are no longer visible at night because of how dim the object would need to be (since magnitudes are logarithmic). No changes were made.

Figure 1: the black data points get lost in the other light curves

While this may be true, this is why Figure 2 is also in the paper, to more clearly show the SN 1054 data points and the SN 2004dj light curve. Because of this, I disagree with the reviewer, so no changes were made.

Section 3 paragraph 2 could have the linear trend separated into its own equation for clarity

The equation was separated from the text and given an equation number.

Peer Review 6

A lot of the points addressed in this peer review overlapped with other reviewers, which I looked at before this review, so the suggestions were not too helpful. However, the ones that did not overlap provided necessary clarifications and formatting issues that other reviewers did not point out. these comments were well-received.

Addressing Concerns:

Some of the concerns mentioned in this peer review were already addressed in other reviews, so they were not mentioned again below.

Major Points:
The data for SN 1054 from medieval records gets compared to data from the Open Supernova Catalog. The Open Supernova Catalog is, therefore, a major component of the study even though it does not provide the data for the target itself. The author does not explain where the data from this catalog originates or any overview of the catalog itself.

Added: "Photometric data for 11 CCSNe were obtained from the *Open Supernova Catalog* (*OSC*), an open-source catalog of data and metadata for SNe and SN candidates (OSC, Guillochon et al. 2017)."

SN 2008S represents a low-energy ECSN with a type IIn classification. In section 4, the author states that its "low brightness demonstrates why this might not be a suitable framework for SN 1054." It is unclear how the author jumps to this conclusion. An additional sentence or two would help with understanding this method.

Changed to: "In addition, SN 2008S is an ECSN and a type IIn event (Botticella et al. 2009; Stanishev et al. 2008). However, it demonstrates a low peak brightness (see Figure 1) compared to SN 1054 as well as the other SNe analyzed. SN 2008S thus serves as an example of a ECSN with a type IIn classification, but it does not achieve a high irradiated energy like SN 1054. A type IIn ECSN, therefore, might not be

a suitable framework for SN 1054 because of the low peak brightness of SN 2008S. Therefore, it is more likely that SN 1054 was an FeCSN with the low observed kinetic energy explained by a freely expanding envelope containing excess kinetic energy not measured in the Crab filaments, as proposed by Chevalier (1977)"

Minor Points:
A single sentence stands alone with tables and graphs on page four. This is a small formatting suggestion, but it would help the reader follow the text of the paper.

This was corrected.

Peer Review 7

This review brought up some interesting points that were not mentioned in other reviews, so these suggestions were very helpful, especially in terms of better communicating the intellectual merit of this research.

Addressing Concerns:

Some of the concerns mentioned in this peer review were already addressed in other reviews, so they were not mentioned again below.

Major Points:
The acknowledgement section of the paper should be taken more seriously, assuming the author is thinking of submitting to a journal.

The acknowledgements were fixed.

The author should include a couple sentences of how this study could affect any other work done in astronomy. There seems to be a bubble on the impact this study could potentially have and should be expanded upon.

Sentence added in conclusion: "The analysis presented in this paper provides a better understanding of SN 1054 and clearer insight on its nature, contributing to a solution to the ongoing debate about the core-collapse mechanism and classification of the explosion."

Minor Points:
The author should provide a time stamp as to when the results from this study will be made public so that further analysis can be conducted.

The results of the study are already made public through the paper, and the numerical results are tabulated, so I disagree with this suggestions and no changes were made.

Peer Review 8

This peer review was the last one that I read. I was surprised that it brought up issues and concerns that were not addressed by other reviewers. Therefore, I consider this review to be one of the most helpful in revisions.

Addressing Concerns:

Some of the concerns mentioned in this peer review were already addressed in other reviews, so they were not mentioned again below.

Minor Points:
There is one sentence in the abstract: "Using this trend, I estimate the progenitor mass of SN 1054 from the irradiated power of SN 2004dj to be 20 Msun while the progenitor mass is well established to be ∼8-10 Msun." I was initially confused by the wording and I think it could be rephrased so that the reader understands better.

Changed to: "Using this relationship and the irradiated power of SN 2004dj, I estimate the progenitor mass to be $20.7 \pm 9.7\ M_{\odot}$. This estimate is approximately twice the known value of $\sim 8 - 10\ M_{\odot}$, which indicates..."

There are a few grammatical errors which should be fixed with some more proofreading.

Any errors that I noticed upon revision are now corrected.

In the last sentence in the abstract, maybe it would be beneficial for the author to explain why the statement is the case. It is kind of just left wide open and as the reader I do wish there were a few more words of explanation.

Changed to: "Although, this result is uncertain, and further analyses may confirm that SN 1054 is a low-energy electron-capture supernova due to the low ^{56}Ni yield measured in the Crab Nebula."

The author refers to a neutron star kick twice in the paper. I know that this is meant for experts in the field, but I do not know what that means.

The neutron star kick is the kinetic energy transferred to the neutron star after the SN explosion. I added the word "natal" before "kick" in both places to better indicate that this is the initial (or natal) velocity of the neutron star.

At the end of the introduction, I would have liked to see a brief outline of the paper describing what is to be talked about in each section.

This was added to the paper.

In the beginning of Observations, the author states that "observations were inferred..." Who were they inferred by? The author of this paper or Nomoto et al 2014?

Changed to: "Observations of SN 1054 were inferred by Nomoto et al. (2014) from medieval records"

In the paragraph before the discussion, the author states that the progenitor masses were obtained from literature, but I would like to know the literature they came from in the text of the paper. I see they are also listed in Table 1. Another option is to say that the masses plus the references are available in Table 1.

Added "progenitor masses (with respective literature)" before first reference to Table 1.

The author says that the classification for the supernova "might not be surprising." It would be better to reword this so that it sounds more professional.

This sentence was deleted.

Additional Changes

Introduction

"It is widely accepted that SN 1054 was a type II SN (and therefore a CCSN) because of the bright hydrogen emission lines in the nebula's spectrum (Filippenko 1997). The presence of the Crab Pulsar has also established SN 1054 as a CCSN since neutron stars originate from such events (Janka 2012; Smith 2013)."

This sentence was moved to a later paragraph to introduce the problem with SN 1054 before talking about the discrepancies in its properties. This sentence seemed out of place in the first paragraph.

"which is much brighter than the typical peak magnitude""

This was changed to because saying "greater" for magnitudes, which is a reverse scale, can be confusing.

"lower peak brightness""

Changed from magnitude for same reason as above.

"lower production of Fe-group elements compared to FeCSNe (Kitaura et al. 2006). While a low ^{56}Ni yield is indeed observed in the spectrum of the Crab (Kitaura et al. 2006), the peak brightness of SN 1054 is exceedingly high compared to what is expected for an ECSN. Thus, the ECSN model does not explain the nature of this event in its entirety."

This section was reworded for clarify and because some of the sentences were redundant or confusing.

Observations

Citation added after "the absolute magnitudes presented are approximate"

This was to reference the OSC because they made the same approximation that I made.

All instances of OSC were italicized because this is still the name of a catalog, even if it is abbreviated.

All instances of "plotted" were changed to "shown" or "demonstrated" to sound more professional.

Methodology

"For progenitor masses reported with uncertainties (see Table 1), the central values were adopted for determining this trend."

This was originally in the table caption, but was moved into the text of the paper to make sure this was clearly stated and explained for the reader.

In Table 1 caption: "For each SN, the classification (as listed in the OSC),"

This was changed to make sure that the reader knows where the SN classifications came from because the references for masses are included but not for the classifications.

I realized that I had a typo in my code and had incorrect results. This did not affect the results drastically, but the chi-squared and power values changed slightly. These, and the figures, were updated.

In Table 1, the classification for SN 1988Z was incorrect, and this was updated.

In Table 1, the citation for SN 2005ip was not in parentheses. This was updated.

Discussion

"...interactions with circumstellar material (Chugai & Utrobin 2000; Smith 2013). This could point to a type IIn classification (Smartt 2009)."

This was changed to be clearer with my discussion. These references do not really mention type IIn, but talk about circumstellar interactions, which suggest a type IIn. This was changed to better reflect this.

All other changes not mentioned were for purposes of correcting grammar or to improve the flow of sentences or wording.