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Young Supernovae Detector

Introduction

Supernovae (SNe), or star explosions, are heavily studied phenomena within the fields of Astrophysics/Astronomy. The primary data used to classify supernovae is the plotted magnitudes of observations in different bands. ‘Bands’ refers to CCD filters that limit the observed light to certain wavelengths. The magnitudes recorded in these bands are used to create a scatter plot referred to as a Light Curve plot. Supernovae can be broken into types, the main two being Type I and Type II. The primary differences between these two types are that Type I supernovae can potentially be three times as bright as a Type II, their spectra contain no hydrogen lines, and they expand about twice as rapidly. Within the Type I classification also exists subclassifications, such as Type Ia and Type Ibc.

Our project was based on a proposed correlation between the difference in magnitudes of a supernova and the age of that supernova (SN). This correlation was proposed in a paper based on the Young Supernova Experiment (YSE)[1]. YSE, as stated on the UCSC webpage for the Experiment, “is a survey on the Pan-STARRS telescopes that will soon be surveying 1500 square degrees of sky every three days. YSE will discover thousands of new cosmic explosions and other astrophysical transients, dozens of them just days or hours after the explosion”.[2]

Background

Our simulation data was supplied to us by a secondary author of the aforementioned paper and P.h.D candidate in U of I’s Astronomy Program, Patrick D. Aleo. The simulations we received and used in this project were of improved quality from those used in the original paper. While numerous light filters exist for recording observations in the UV/EUV, X-Ray, and visible light spectrums, the relevant bands for the purposes of our project were red (r), green (g), and infrared (i).

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[1] Jones et al., “The Young Supernova Experiment.”
[2] “The Young Supernova Experiment – Time-Domain Astrophysics with the Pan-STARRS Telescopes.”

As previously mentioned, our project was based on a proposed correlation between the difference in magnitudes (in the r, g, and i bands) of a supernova and the age of that SN. This implies that there exists a “path” for which a supernova might take in terms of color-specific brightness during its lifetime. The original paper chose to focus on type Ia (SNIa) and type II (SNII) supernovae and plot them in a color-color space of ‘$g - r$’ as a function of ‘$r - i$’, using ‘days since first detection’ as the color marker for each point on the plot. The figure from the article is displayed below with its original caption.

‘Days since first detection’ represents the best estimate of a supernova’s age in our dataset and it is calculated by subtracting the day of the observation from the day of first detection (both of which are columns in the raw dataset). That is why in figure 1 the points are labeled as “Days from Explosion.” From now on in this report, ‘days since first detection’,

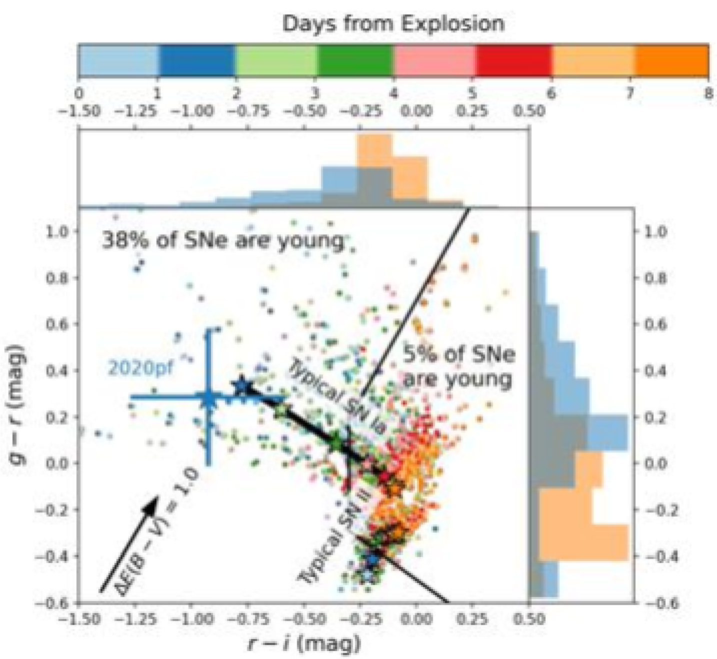

Figure 1: Color–color diagram for "noise-free" YSE SNe as simulated by SNANA, with colored points representing the time since explosion as described by the above color bar. The black arrow indicates the direction and magnitude an object would experience if its dust reddening were increased by 1 mag with R_V = 3.1. The black line defines a relatively simple cut that adequately identifies SNe within 3 days of explosion, with 38% of all objects to the left of the line being young, while only 5% of those to the right of the line are young. We highlight the path a typical SN Ia and SN II (star symbols) travel as they evolve from explosion. We note that the $g - r$ and $r - i$ colors are particularly useful for selecting young SNe II and SNe Ia from the entire population, respectively. SN 2020pf at an epoch of ~2 days after explosion from YSE and ZTF data is displayed as a star with error bars; it is consistent with the simulations and in the defined "early" region. To the top and right are histograms of the $g - r$ and $r - i$ colors for SNe before +3 days from explosion (blue) and after +3 days from explosion (orange).

supernova age and days since explosion refer to the same measurement extracted from our data. We set out to explore this proposed “path” and relationship between an SN’s age, roughly estimated by the date of first detection, and its magnitude in the r, g, and i light bands.

Data and Approach

Our data was broken down into 5 different simulation models representing supernova types/subtypes, each with about 100 ‘HEAD.FITS/PHOT.FITS’ file pairs which included all the necessary metadata to complete this project. Within one file pair is between 400 and 800 light curves of simulated SNe. This supplied us with over 5 billion SN observations. We then masked the observations to only those which included all three r, g, and i bands recorded within one or two days of one another. Since there was the possibility of this occurring multiple times for a supernova, we grouped the dataframe by SN and then took the average of observation times from all 3 band observations for each SN instance.

This process, using the one and two day ranges, cut down the number of usable observations from over 5 billion to just over 30,000 and 36,000, respectively (0.5% and 0.7% of total). The total time for running the scripts to process this data was 11.45 hrs for the one day range on a 2020 M1 MacBook Pro. The most computationally demanding portion of our data processing was reading and organizing the data, meaning it should take around the same time for a two day range processing. We opted to use the one day range because the tradeoff in precision wasn’t worth the marginal improvement in the size of our working dataset. The following graph shows what fraction of the raw data ended up in our processed dataset:

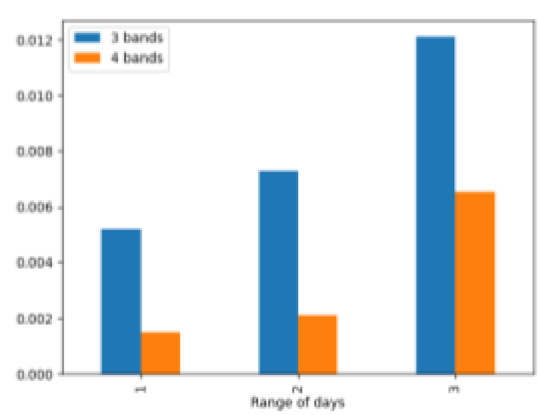

Figure 2: Percentage of usable data from processing full dataset with varying criteria

We then decided to run the data processing script for the one day range again for the purpose of separating our final results by SN type, as we recognized that potential patterns could become clearer if we distinguished each type of supernova. We eventually chose to create three supernova type-specific plots that kept the x-axis equal to $r - i$ and the y-axis as $g - r$, rather than one plot that uses annotations to differentiate the patterns by type. In addition, we created a 3-dimensional plot of g vs r vs i for each type.

Our main goal from this point was to determine if there is a correlation between the 'days since first detection' parameter and clusters created using a clustering algorithm based on band magnitudes. The following scatterplots are the scatterplots created for each type of SN with point color representing 'days since first detection'.

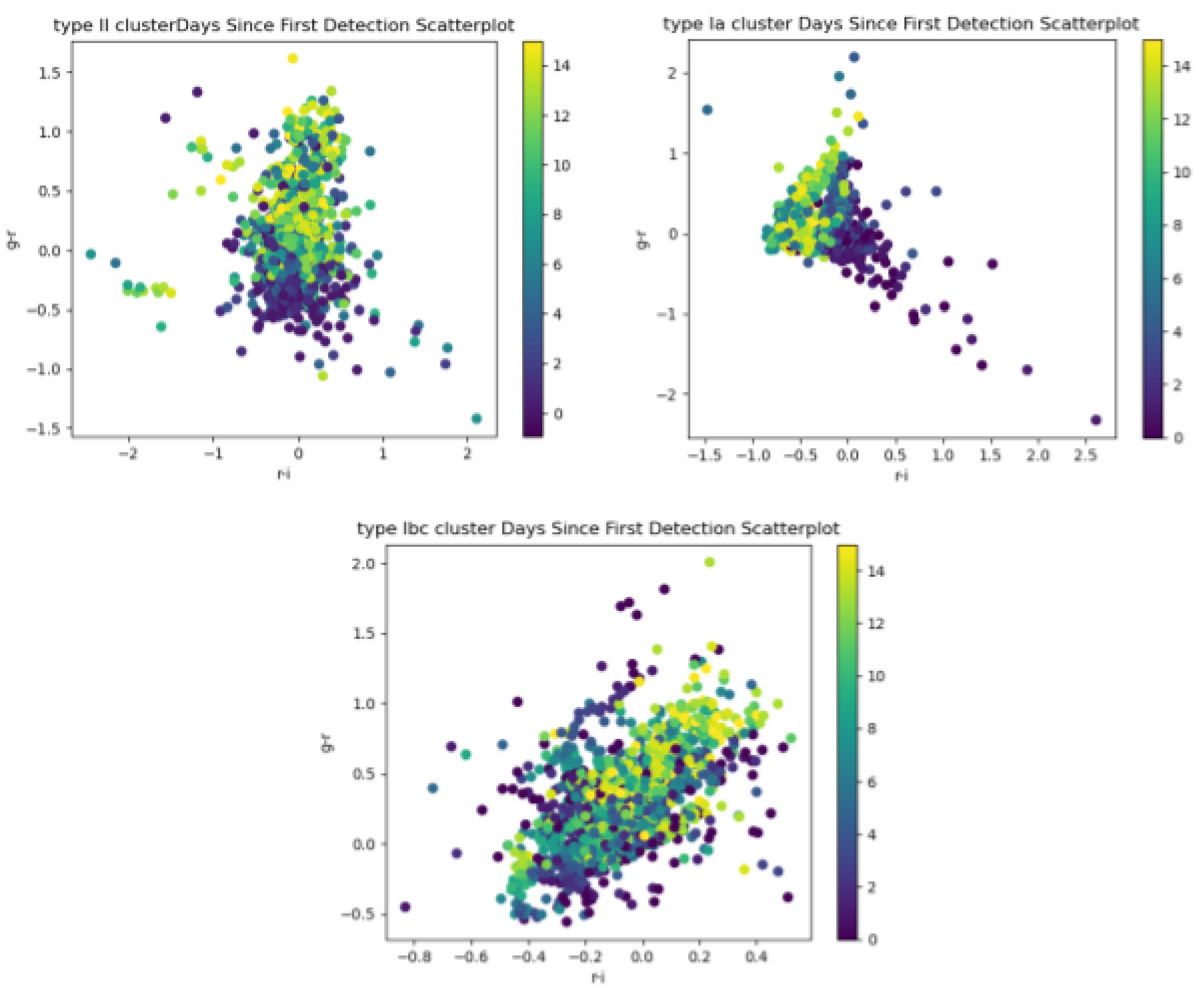

Figure 3: Days since first detection represented by color on a color-color space plot of g-r as a function of r-i.

For each clustering algorithm we explored, we had numerous assessment criteria. The points used to analyze our data were chosen by randomly sampling 15,000 points from the processed dataframe. We began by creating scatterplots in an attempt to recreate the original correlation displayed in Figure 1. Then we created heatmaps broken down into clusters and 'days since first detection' ranges between 0 and 15 days, separated into a number of ranges equal to the number of clusters we were using (e.g. 5 clusters -> 5 ranges: [0,3), (3,6), (6,9), (9,12), and (12,15]). If a correlation is present, we would expect to see linear independence in a matrix representation of the heatmap.

Our two next correlation analysis measure are: the percentage of points in a range that are in a certain cluster (e.g. 80% of SNe of age 0-3 days are in cluster 0) and if this is unique to that age range (no significant percentage of other age ranges appear in cluster 0). We also calculated the percentage of points in a cluster that are in a specific age range (e.g. 80% of points in cluster 0 are of age 0-3).

Essentially, we want to determine if SNe of a particular age concentrate in the same cluster or if clusters tend to have a concentration of supernovae with a specific age. If we were to see that most clusters have a similar age range representation, we could infer that there might not be a correlation between age and the bands we are analyzing.

Results

For every clustering algorithm we utilized, we attempted clustering based on 2 sets of criteria. The first set of criteria clustered the relevant dataframe based on the values in the color-color space ($r - i$, $g - r$). We refer to this as “Difference in Bands”. The second clustering method was based only on the magnitudes of the three bands, $r, g,$ and i. This will, from here on out, be referred to as “Bands”. In addition to two clustering methods, we also employed three to four cluster sizes/minimum samples and 3 clustering algorithms: Spectral Clustering; OPTICS/DBSCAN; and BIRCH.

Minimum samples refers to the number of samples in a neighborhood for a point to be considered a core point and it is the parameter we tweaked for the OPTICS algorithm. We have used minimum samples values of 10, 15 and 20. For the BIRCH algorithm, we used a threshold of 0.06 and the number of clusters 3, 5, 7 and 10. The same number of clusters were used for the Spectral clustering algorithm.

Our experiments generated over 198 plots. Not all of which present significant findings but, for the sake of completeness, we chose to include them all in this report. In the following analysis of results, we will describe the most significant results that we found, highlighting them in green in the tables. Some less significant results are highlighted in yellow.

Inside the tables, we have links to Markdown files that contain three plots created using the data specified. For instance, the link inside [Ia, 3] of the *Spectral Clustering by Difference in Bands* table leads to the plots created by using data from SN type Ia inserted into the spectral clustering algorithm with 3 clusters as a parameter.

The first plot in one of our Markdown files is a scatter plot based on the Band Difference, colored by the respective clustering algorithm's cluster denominations using a "tab20" colormap. The second plot is a heatmap of the range of days for how old our supernova is vs which cluster it is in, colored by the total number of SN in the cell. For example, in *Spectral Clustering - Difference in Bands* [Ia, 3], we have that there are 453 SNe in cluster 0 with age 0-5 days old (young SNe). Finally, our third plot is a bar graph showing the quantity by cluster, with each bar representing a range of days.

Spectral Clustering

Spectral Clustering - Difference in Bands			
Number of Clusters	Type		
	II	Ia	Ibc
3	https://github.com/ro	https://github.com/ro	https://github.com/ro

	digu/supernova-age/blob/main/spectral/diff/3/typeII.md	digu/supernova-age/blob/main/spectral/diff/3/typeIa.md	digu/supernova-age/blob/main/spectral/diff/3/typeIbc.md
5	https://github.com/rodigu/supernova-age/blob/main/spectral/diff/5/typeII.md	https://github.com/rodigu/supernova-age/blob/main/spectral/diff/5/typeIa.md	https://github.com/rodigu/supernova-age/blob/main/spectral/diff/5/typeIbc.md
7	https://github.com/rodigu/supernova-age/blob/main/spectral/diff/7/typeII.md	https://github.com/rodigu/supernova-age/blob/main/spectral/diff/7/typeIa.md	https://github.com/rodigu/supernova-age/blob/main/spectral/diff/7/typeIbc.md
10	https://github.com/rodigu/supernova-age/blob/main/spectral/diff/10/typeII.md	https://github.com/rodigu/supernova-age/blob/main/spectral/diff/10/typeIa.md	https://github.com/rodigu/supernova-age/blob/main/spectral/diff/10/typeIbc.md

Only one of the plots linked in the preceding table points to a significant correlation between an SN's age and its color magnitudes. The sole result from this experiment, that borders on noteworthy, is the Type Ibc plots created using 7 clusters[3]. Even this, however, shows minimal promise in a larger context. The clusters which seem to imply significance are 0, 1, 3, 4, and 5. Cluster 0 is fairly stable across values in the young to medium-aged (0.00-8.57 days) supernovae but has a much greater volume of older SNe. The number of supernovae in cluster zero with ages ranging between 8.57 and 15.00 days is 255, compared to the 177 in the remaining part of the cluster. This means that there is a 59% chance that a randomly selected point from cluster 0 is in the range of 8.57 to 15.00. Cluster 1 has the highest density of mid-aged SNe and approximately equivalent SNe in the younger and older ranges. The number of supernovae in the range of 4.29 days and 10.71 days is 417 while the young (0 to 4.29 days) and old (10.71 to 15.00 days) have, respectively, 198 SNe and 229 SNe. In other words, 49% of supernovae in this cluster are mid-aged. Cluster 3 is comprised of 59% young SNe of ages 0.00 days to 4.29 days. Cluster 4 has 54% of all of its supernovae belonging in the age range of

[3] Moving forward, results will be referred to in the following manner: [Ibc, 7] for Type Ibc plots created using 7 clusters.

12.86 days to 15.00 days . Cluster 5 contains only 24% young supernovae, ranging from ages 0 days to 2.14 days, but it is the only range in this cluster that exceeds 15%.

Spectral Clustering - Bands			
Number of Clusters	Type		
	II	Ia	Ibc
3	https://github.com/rodigu/supernova-age/blob/main/spectral/band/3/typeII.md	https://github.com/rodigu/supernova-age/blob/main/spectral/band/3/typeIa.md	https://github.com/rodigu/supernova-age/blob/main/spectral/band/3/typeIbc.md
5	https://github.com/rodigu/supernova-age/blob/main/spectral/band/5/typeII.md	https://github.com/rodigu/supernova-age/blob/main/spectral/band/5/typeIa.md	https://github.com/rodigu/supernova-age/blob/main/spectral/band/5/typeIbc.md
7	https://github.com/rodigu/supernova-age/blob/main/spectral/band/7/typeII.md	https://github.com/rodigu/supernova-age/blob/main/spectral/band/7/typeIa.md	https://github.com/rodigu/supernova-age/blob/main/spectral/band/7/typeIbc.md
10	https://github.com/rodigu/supernova-age/blob/main/spectral/band/10/typeII.md	https://github.com/rodigu/supernova-age/blob/main/spectral/band/10/typeIa.md	https://github.com/rodigu/supernova-age/blob/main/spectral/band/10/typeIbc.md

Spectral clustering by band demonstrated quite promising for labeling type Ia supernovae. This algorithm applied to the three color bands was able to consistently cluster the old supernovae together. With [Ia, 3], 49% of SNe in cluster 0 are old (10-15 days) and 93% are old or mid-range (5-10 days). Young SNe concentrate in clusters 1 and 2.

In [Ia, 7], over 79% of cluster 0's SNe are older than 8.57 days. Mid-range supernovae concentrate in cluster 1. Young supernovae are spread throughout the other clusters.

[Ia, 10] is particularly promising. Cluster 0 has the greatest concentration of old supernovae, and, different from the other cluster numbers, clusters 2 and 7 have a significant concentration of young SNe. Cluster 2 has 88% of its supernova younger than 7.5 days, while cluster 7 has 85% younger than 6 days.

Types II and Ibc didn't show much promise. For type Ibc, we only saw [Ibc, 7] show an interesting pattern. Clusters 1, 2 and 4 combined have 60% of supernovas in them being younger than 6.43 days.

OPTICS/DBSCAN Clustering

OPTICS/DBSCAN Clustering - Difference in Bands			
Minimum Samples	Type		
	II	Ia	Ibc
10	https://github.com/rodigu/supernova-age/blob/main/optics/diff/10/typeII.md	https://github.com/rodigu/supernova-age/blob/main/optics/diff/10/typeIa.md	https://github.com/rodigu/supernova-age/blob/main/optics/diff/10/typeII.md
15	https://github.com/rodigu/supernova-age/blob/main/optics/diff/15/typeII.md	https://github.com/rodigu/supernova-age/blob/main/optics/diff/15/typeIa.md	https://github.com/rodigu/supernova-age/blob/main/optics/diff/15/typeIbc.md
20	https://github.com/rodigu/supernova-age/blob/main/optics/diff/20/typeII.md	https://github.com/rodigu/supernova-age/blob/main/optics/diff/20/typeIa.md	https://github.com/rodigu/supernova-age/blob/main/optics/diff/20/typeIbc.md
Too Many Clusters	Inconclusive	Only 2 clusters	Promising

There was very little promise amongst our results created using the OPTICS/DBSCAN algorithm. Difference plots from [II, 10] and [Ibc, 10] both suffered from being overly dense as a result of too low of a "minimum samples" value. They are unintelligible and therefore give minimal insight. Plots for [II, 15] and [Ia, 10], while cramped, contain some patterns. For example, [Ia, 10] contains a majority of mid-aged SNe in clusters 0-14, young supernovae in clusters 18 and 26, and old in 16, 17, and 20-25. Suffering from the opposite problem of too few clusters (2 clusters) is [Ia, 20]. Since this specific clustering algorithm doesn't require a prespecified number of clusters, our results tended to skew towards nonsense with no realistic implications. In addition to not requiring an input number of clusters, the OPTICS/DBSCAN algorithm also discards data points for the purpose of reducing noise.

One set of plots provided relatively feasible results, however compared to the rest of the plots in the same row, we are inclined to say that this was merely a coincidence and ultimately lacks integrity. Regardless, [Ia, 15] provides a heatmap that would be promising, had the algorithm not scrapped the majority of data. Despite this, cluster 0 holds the majority of mid-aged supernovae with 53% in range 5 to 10 days, while cluster 1 is composed of 81% young SNe in the range of 0 to 5 days. Clusters 2, 3, and 4 are, respectively, composed of 50%, 38%, and 62% old supernovae ages 12.5 to 15 days.

OPTICS/DBSCAN Clustering - Bands			
Minimum Samples	Type		
	II	Ia	Ibc
10	https://github.com/rodigu/supernova-age/blob/main/optics/band/10/typeII.md	https://github.com/rodigu/supernova-age/blob/main/optics/band/10/typeIa.md	https://github.com/rodigu/supernova-age/blob/main/optics/band/10/typeIbc.md
15	https://github.com/rodigu/supernova-age/blob/main/optics/band/15/typeII.md	https://github.com/rodigu/supernova-age/blob/main/optics/band/15/typeIa.md	https://github.com/rodigu/supernova-age/blob/main/optics/band/15/typeIbc.md
20	https://github.com/rodigu/supernova-age/blob/main/optics/band/20/typeII.md	https://github.com/rodigu/supernova-age/blob/main/optics/band/20/typeIa.md	https://github.com/rodigu/supernova-age/blob/main/optics/band/20/typeIbc.md

As previously mentioned, the band OPTICS clustering dropped most of our data points. For [Ia, 15], older SNe are very clearly concentrated in clusters 0, 1 and 2, while younger supernovae are in clusters 3 and 4. [Ia, 20] was even better at clustering young SNe together, with clusters 3, 4 and 5 holding almost all of them. Nevertheless, because of the loss in our dataset, we believe that it is not possible to draw proper conclusions on the effectiveness of OPTICS for our use-case.

BIRCH Clustering

BIRCH Clustering - Difference in Bands			
Number of Clusters	Type		
	II	Ia	Ibc
3	https://github.com/rodigu/supernova-age/blob/main/birch/diff/3/typeII.md	https://github.com/rodigu/supernova-age/blob/main/birch/diff/3/typeIa.md	https://github.com/rodigu/supernova-age/blob/main/birch/diff/3/typeIbc.md
5	https://github.com/rodigu/supernova-age/blob/main/birch/diff/5/typeII.md	https://github.com/rodigu/supernova-age/blob/main/birch/diff/5/typeIa.md	https://github.com/rodigu/supernova-age/blob/main/birch/diff/5/typeIbc.md
7	https://github.com/rodigu/supernova-age/blob/main/birch/diff/7/typeII.md	https://github.com/rodigu/supernova-age/blob/main/birch/diff/7/typeIa.md	https://github.com/rodigu/supernova-age/blob/main/birch/diff/7/typeIbc.md
10	https://github.com/rodigu/supernova-age/blob/main/birch/diff/10/typeII.md	https://github.com/rodigu/supernova-age/blob/main/birch/diff/10/typeIa.md	https://github.com/rodigu/supernova-age/blob/main/birch/diff/10/typeIbc.md

Birch clustering provided the most promising result of all the experiments, both for the band clustering and the difference in bands clustering. [II, 3] contains 1187 young (0-5 days) supernovae out of a total 2466 SNe to make up 48% cluster 0. 1184 old (10-15 days) SNe appear in cluster 2 out of a total 2415 supernovae, comprising 49% of the cluster.

[Ia, 3], [II, 5], and [II, 7] are notable for the same rationales. They both contain what seem to be inverted results between clusters. That is to say that for [II, 5] for example, cluster 0 contains 234 SNe in the range of 0-3 days, while cluster 1 contains 244 supernovae in the range of 12-15 days. Cluster 0 has 301 SNe aged 3-6 days while cluster 1 has 372 supernovae aged 9-12 days. At age 6-9 days, clusters 0 and 1 have 468 and 447 SNe, respectively. This pattern continues for the remaining two age ranges for each of the two clusters.

In [Ia, 5], cluster 0 contains only 12 supernovae, but 100% of them are ages 0-3 days old. 38% of the supernovae in cluster 4 are aged 12-15 days but the number of supernovae in each range ranges between 15 to 101, with an average value of 53.4 SNe per range. The ranges in clusters 1 and 2 contain lows of 71 and 87 supernovae and highs of 162 and 161 SNe. As with many of the entries in the above table, there are quite a few heatmaps that repeat this pattern, such as [Ia, 10] and [Ibc, 10]. Clusters 0, 5, and 7 contain 5, 7 and 25 supernovae, respectively but 100% of them are in the age range of 0-4.5 days. 54% of cluster 9 is made of SNe ages 10.5-15 days. However, clusters 1 and 3 follow a similar pattern to the cluster 1 and 2 of [Ia, 5] in that the ranges have lows of 24 and 23 SNe and highs of 91 and 86 supernovae. Ultimately, clusters with distributions such as these don't relay any meaningful information for the purpose of this project.

Birch Clustering - Bands			
Number of Clusters	Type		
	II	Ia	Ibc
3	https://github.com/rodigu/supernova-age/blob/main/birch/band/3/typeII.md	https://github.com/rodigu/supernova-age/blob/main/birch/band/3/typeIa.md	https://github.com/rodigu/supernova-age/blob/main/birch/band/3/typeIbc.md
5	https://github.com/rodigu/supernova-age/blob/main/birch/band/5/typeII.md	https://github.com/rodigu/supernova-age/blob/main/birch/band/5/typeIa.md	https://github.com/rodigu/supernova-age/blob/main/birch/band/5/typeIbc.md
7	https://github.com/rodigu/supernova-age/blob/main/birch/band/7/typeII.md	https://github.com/rodigu/supernova-age/blob/main/birch/band/7/typeIa.md	https://github.com/rodigu/supernova-age/blob/main/birch/band/7/typeIbc.md
10	https://github.com/rodigu/supernova-age/blob/main/birch/band	https://github.com/rodigu/supernova-age/blob/main/birch/band	https://github.com/rodigu/supernova-age/blob/main/birch/band

	/10/typeII.md	/10/typeIa.md	/10/typeIbc.md

The Birch algorithm is the most promising for type Ia. For all of the cluster sizes we have attempted, it was able to consistently cluster together old supernovae. [Ia, 3] was able to get 88% of SNe in cluster 1 as older than 5 days, with 78% of all SNe younger than 5 days staying outside of that cluster.

[Ia, 5] had cluster 2 with a concentration of over 90% of supernovae older than 6 days. This could mean that if we find a new SN that can be clustered into cluster 2, we could have a 90% confidence that it is older than 6 days. In [Ia, 7], cluster 2 also had a significant concentration of older SNe: 88% older than 6.43 days

In [Ia, 10], clusters 7 and 8 together had a concentration of 81% of supernovae older than 7.5 days.

Type Ibc also had interesting distributions of young and old SNe in each cluster. In [Ibc, 3], we can observe that each cluster either has a higher concentration of old, or a higher concentration of young supernovae. Still, older SNe seem to more easily cluster together, as cluster 1 has 44% of its SNe as older than 10 days, while cluster 0 has 39% of its SNe as younger than 5 days. Cluster 2 is interesting because, although there aren't many SNe in total there, it has a 59% concentration of SNe younger than 5 days. So it might be rare that we find a SN type Ibc that clusters in 2, but when we do find one, we can have at least some confidence in it being young.

Plotting BIRCH Clusters in 3D

While exploring our data, we discovered that there was a pattern being obscured by the dimensionality of our plots. When clustering by band in 2D, our scatterplots looked chaotic and without reason. So, in a last ditch effort, we decided to use a 3D scatterplot which plotted the difference in bands as the x- and y-axes, clusters as the z-axis, and 'days since first detection' mapped to color. The first plot we chose to revisualize, which led to our discovery, was [7, Ia] clustered by band using the BIRCH algorithm. Figure 4 features 2 views of this plot.

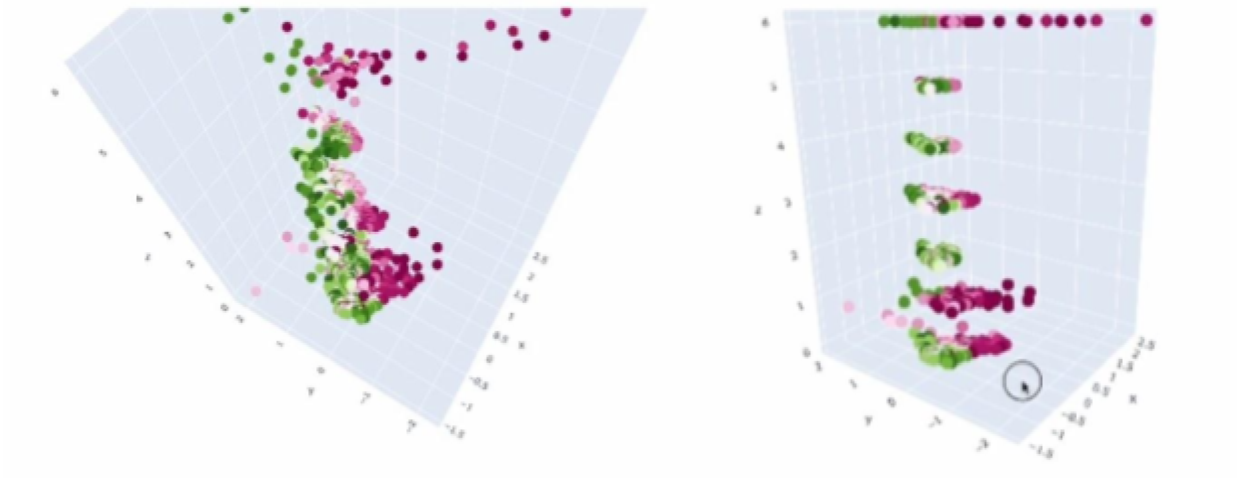

Figure 4: 2 views of BIRCH [Ia, 7] clustered by band; g-r as a function of r-i separated on z-axis by cluster; colored by days since detection.

As made clear by Figure 4, the pink points (young supernovae) congregate to one side of each cluster and the green (older) SNe are densely clustered adjacent to the pink subsection of each cluster. This could have been a coincidence, so we began testing this out with other Birch datasets clustered by band.

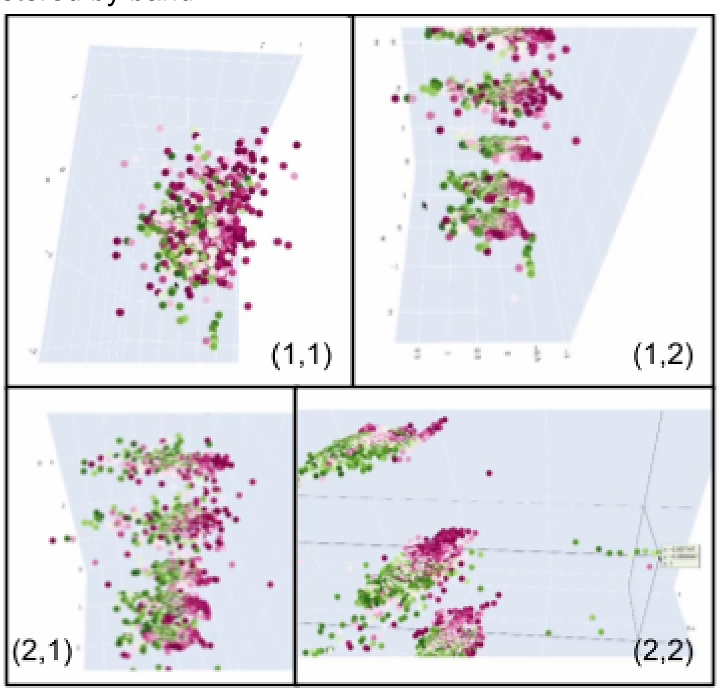

Figure 5: 4 views of BIRCH [II, 5] clustered by band; g-r as a function of r-i separated on z-axis by cluster; colored by days since detection.

Figure 5 is broken down into 4 views of the plot created using BIRCH clustering by band for type II. Figure $5_{(1,1)}$ is a birdseye view of the 3D plot, which is identical to Figure 3's 2D plot of type II SNe. The same pattern that is present in Figure 4 can also be seen in Figure 5. In addition to these subsets (Birch, clustered by band: [Ia, 7] and [II, 5]), we tested this technique with the similarly clustered [II, 3] and [Ibc, 3] and found the same pattern emerging. We did discover, however, that the results are not similar when clustered by difference in bands instead of bands.

Despite the intriguing nature of these results, we were unfortunately unable to explore further due to time constraints. However, we believe that there exists a way to further cluster our clusters, potentially by the values of the difference in bands, to show that there does, indeed, exist a correlation between the age of a SNe and its band-varying magnitudes.

Conclusion

We believe a proper supernovae age detection algorithm would involve an eclectic approach to clustering algorithms. Despite numerous experiments, we found few clusters that accurately organized SNe by the 'days since first detection'. When we did find clusters that were promising, the algorithm (with relevant specifications) was typically useless for the other types of supernovae.

If we found a real SN that could be placed in cluster 0 of [Ia, 3] in the 3-band spectral clustering, it is highly likely that that supernova is older than 5 days (as 93% of SNe in that cluster are). However, that specific algorithm can't say much about whether an explosion is young or old if we find it located in cluster 1 instead. We could then check if the real supernova in cluster 1 of [Ia, 3] could be properly clustered using a different algorithm, preferably one with a high confidence rating.

Ultimately, we believe that there is a way to properly organize SNe magnitudes in a way that aligns with its age. The algorithm may need to be multi-stepped, as implied in our analysis of Figures 4 and 5. Regardless, we did discover a definitive correlation between position in a color-color space plot and 'days since first detection' when clustered by band, as displayed in Figures 4 and 5.