Rare APO research: using a type 1A Supernova as standard candle

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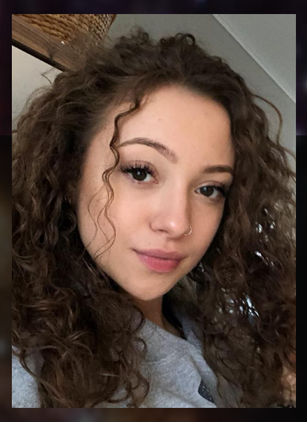

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Type Ia supernovae are the brightest and most common type of supernova. A type Ia supernova occurs when a white dwarf's mass in a binary system exceeds the Chandrasekar limit, either due to accretion or the merging of stars.
Because the mass of such a white dwarf is exactly at the Chandrasekar limit when it goes supernova, these types of supernovae have an identical light curve and thus can be used as a 'standard candle' [1]. This makes type Ia supernovae very interesting for cosmic distance calculations. Using this property, we will determine the distance to SN2019np. With the found distance we want to determine if SN2019np lays in the galaxy NGC3254 (figure [1]). With our research we want to contribute to increasing the accuracy of cosmic distance calculations.

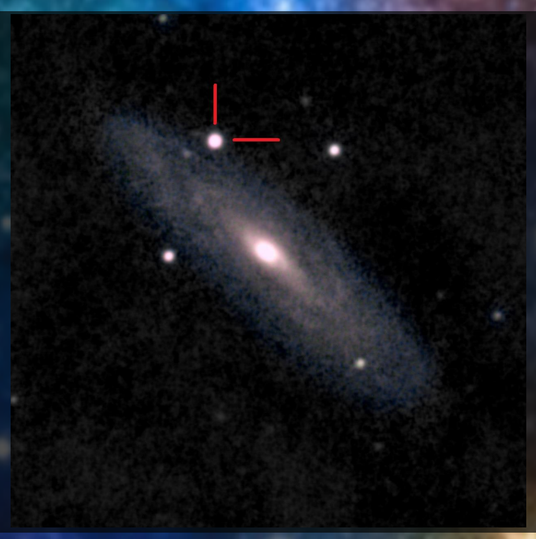

Figure 1: NGC3254 pictured with SN2019np. Stacked. Total exposure time: 20 min. Filter: L, V, R, B. Scale: 0.602 arcsec/pixel. Diameter telescope: 508 mm. F/8.2. Edited using GIMP

Method

The distance to SN2019np can be calculated using

$$d = 10^{\frac{m-M+5}{5}}, \qquad [1]$$

with m the peak apparent magnitude and M the peak absolute magnitude. Because of its 'standard candle' property, type 1a supernovae have a typical peak absolute magnitude of -19.25 ± 0.20 [2].

SN2019np was observed on five days over the time span of one month. Photometric data was collected in the B and V filter. Using photometry, the apparent magnitude of SN2019np was determined for each photo. To calculate the peak apparent magnitude of the supernova, the data was fitted to a typical type Ia supernova curve.

Using the known apparent magnitude of reference stars in their respective filters, the apparent magnitude of the supernova was calculated for each photo (figure [2]). First the instrumental flux of the reference stars and the supernova was calculated for each date using aperture and annulus photometry in Python. From this the instrumental magnitude could be calculated directly with the formula

$$m = -2.5\, log_{10}(flux). \qquad [2]$$

Figure 2: NGC3254 pictured with SN2019np and reference stars: 1 = GEN# +7.00540194, 2 = GSC 01976-00429, 3 = GSC 01976-01199. Stacked. Total exposure time: 20 min. Filter: L, V, R, B. Scale: 0.431 arcsec/pixel. Diameter telescope: 508 mm. F/8.2.

Using the instrumental and apparent magnitude of the reference stars, the instrumental magnitude of the supernova could be scaled to its apparent magnitude.

The data obtained from SN2019np was then fitted to a typical type Ia supernova light-curve with a variable vertical and horizontal translation. The peak apparent magnitude was calculated using the fitted light-curve (figure [3]).

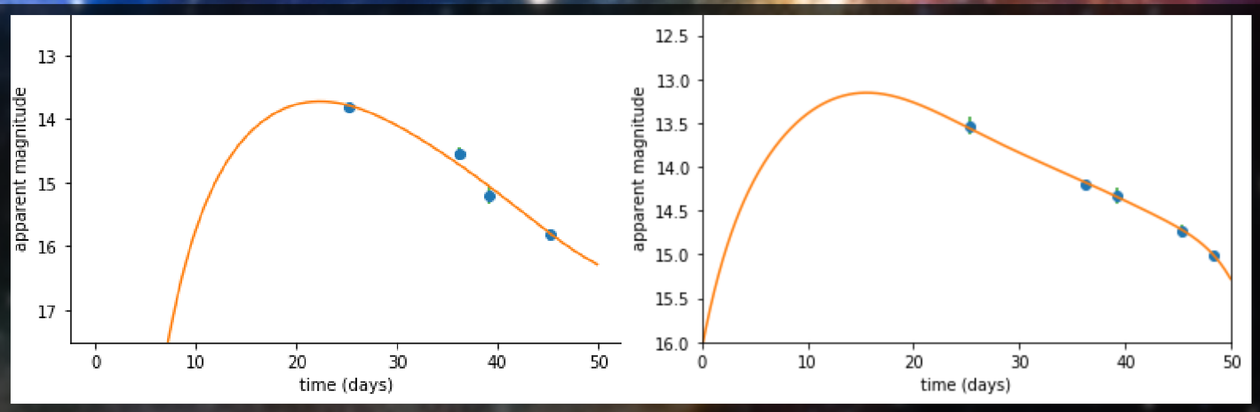

Figure 3: the apparent magnitudes of SN2019np in the B-filter (left) and V-filter (right) fitted to a polynomial of degree 10 with a vertical and horizontal translation variable using SciPy in Python.
Peak apparent magnitude B-filter: 13.72 ± 0.25. Reduced chi-squared: 1.28.
Peak apparent magnitude V-filter: 13.56 ± 0.04. Reduced chi-squared: 1.16.

Finally, the distance was calculated using formula [1], the calculated peak apparent magnitude and the typical peak absolute magnitude. This was then compared to the distance of NGC3254 (D = 33 ± 5 Mpc) [3] to determine if SN2019np lays in NGC3254
To verify that SN2019np is a type Ia supernova the data was also fitted to another type of supernova (type II).

Results

The peak apparent magnitude in the B- and V- filter are, respectively, 13.72 ± 0.25 and 13.56 ± 0.04. The corresponding distance calculated with the peak apparent magnitude and the typical absolute magnitude is 39.34 ± 5.83 Mpc in the B-filter and 36.47 ± 3.44 Mpc in the V-filter.
For the type II template the reduced chi-squared in B-filter was 21.39 and in the V-filter 57.26.

Discussion

Since the reduced chi-squared for the type Ia template was much closer to 1, we concluded that SN2019np is indeed a type Ia supernova.
It is important to keep in mind that type Ia supernovae are not as standard as once thought. Variations in the peak absolute magnitude lay between -18.25 and -20.25 [2]. As a result, the actual distance to the supernova (and its host galaxy) can differ to the calculations.
There was a limited amount of data to work with, five observations for the V-filter and four for the B-filter. The errors are, however, quite small.
At last, the type Ia template used to fit the data of SN2019np is a fit of the data from another supernova (SN2011fe) from The Open Supernova Catalog, so it is not a general template [4][5]. The data of SN2011fe was, however, sufficient to use as a template, because it has 3391 photometric detections spanning 680 days.

Conclusion

In conclusion, it can be said with great certainty that the supernova lays in the host galaxy NGC3254.

References
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[4] An open Catalog for Supernova Data, Photometry data of SN2011fe, available from : https://sne.space/sne/SN2011fe/

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