
Bjorn Jasper R. Raquel*a, Agnes C. Bantaculob, Shane Carlo B. Llemit, Eldrin P. Custodio and Ryan Manuel D. Guidoc

Center for Astronomy Research and Development, Department of Earth and Space Sciences, Rizal Technological University, Mandaluyong City, Philippines
*braquel@rtu.edu.ph, babantaculo@rtu.edu.ph, crmguido@rtu.edu.ph

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Abstract. This paper presents the spectroscopic graphs of recently discovered Supernova Remnants (AT2019fya, SN2019fjp, SN2019fcc, SN2019fbv & SN2019ffi) for the determination of elements present. The researchers use the spectral plot analysis to analyze the presence of certain elements of the individual supernova remnants (SNR) for the assimilation, differentiation and classification of these SNR. Redshift and velocities of these SNR were also found using the observed wavelength and the rest wavelength ratio. Comparison suggests that AT2019fya is a Type II supernova remnant and some of the SNRs in this study exhibits an existence of krypton (Kr) on their composition which is recently discovered by M. Barlow (2013) to be present at the Crab Nebula. This might suggest that AT2019fya, SN2019fbv, SN2019fce, and SN2019ffi have a pulsar at their center.

Introduction

Supernova (SPN) is the huge explosion that occurs at the end of the life of a star. It is caused by the change in the core of a star and this change can happen in two ways: the first type of SPN (Type Ia) happens when the orbit of the binary stars on of which is a white dwarf are at the same point and the second type (Type II) takes place when a massive star collapses rapidly and explodes [3]. When the explosion occurs, tremendous amount of energy from SPN affects the interstellar materials, pushing and compressing it until the supernova remnant remains [5]. Supernova remnant is defined as the dispersed nebula left from a supernova explosion wherein most of the mass of star ejects in expanding clouds of debris [2]. There are three types of SPN remnants based on their morphology: Shell type remnant (ring-like) produced when the shockwave from the explosion of supernova plows then stirs and heats up to the encountered interstellar materials; Crab-like remnant (plerions) is when the nebula is loaded up with high energy electrons from the pulsar in the center and finally the composite remnant which appears both shell-type and crab-like remnant. The composite remnant has two kinds: Thermal composites which is visibly a shell-type in the radio waveband yet appears as crab-like and the Plerionic composites that appear in both radio and x-ray waveband as crab-like yet have shells [7].

Supernova (SPN) remnants produces magnetic turbulence and magnetic shock that heats up the interstellar gas. Thus, it is one of the primary sources of heavy elements in the universe such as oxygen [2]. These elements can be determined through analyzing the spectral plot of SPN remnants. Spectrometry is about the interactions of light and matter, the measurement of intensity of radiation and wavelength. From a simple spectroscopic graph, you can obtain the wavelength that would give the chemical composition [6].

The researchers of this study aim to describe the similarity of the recently discovered SNRs i.e. AT2019fya (discovered May 24, 2019), SN2019fjp (discovered May 14, 2019), SN2019fcc (discovered May 12, 2019), SN2019fbv (discovered May 11, 2019), SN2019ffi (discovered May 11, 2019), and SN2019fce (discovered May 12, 2019) due to the fact that there is always a new SPN...
remnant discovery almost every day but there is no enough information to thoroughly study these marvels of the universe. Discovered by J. Tonry, et al (2019) and classified by M.A. Tucker (2019) the SN2019fbv is a blue, mostly featureless continuum with broad, weak Balmer series emission, young Type II supernova. The AT2019fya was discovered by Koichi Itagaki (2019) and classified by J. Zhang et al (2019) has its spectrum dominated by the P-Cyg profile of Ha. Next is the SN2019fjp, discovered by J. Tonry et al (2019) and classified by R. Cartier (2019), who also estimated the redshift using host galaxy narrow emission lines. SN2019fcc was discovered by V. Lipunov et al (2019) and classified by M. Gromadzki (2019), on which the aforementioned discovered that its spectrum shows a typical spectral signature for Supernova type II, with broad P-Cyg profile Ha and Hb lines. Additionally, Ha line contains narrow component with $z=0.0126$. Then the SN2019fge which is discovered again by J. Tonry et al (2019) and classified by M. Nicholl (2019). Lastly, the SN2019fhi which is discovered by A. Delgado (2019) and classified by R. Cartier (2019), on which the spectrum is consistent with a SN II with significant reddening, showing a very red continuum. The redshift was estimated using host galaxy narrow emission lines from the 2D frames. Furthermore, the researchers also aim to formally categorize the said AT2019fya supernova remnant on which J. Zhang and X. Yu (2019) suggest is a Type II SNR. This study will only focus on the spectra of the individual SPN remnant that is to date the only available data about these supernova remnants.

**Methodology**

Spectroscopic data obtained from The Open Supernova Catalog (TOSC) were subjected to spectral plot analysis on which the researchers compare and contrast the spectra of the individual supernova remnant. The researchers determined the presence of the different elements that can be found commonly on SNRs, those are hydrogen (H), helium (He), oxygen (O, O I, O II, [O II], [O III]), sodium (Na), magnesium (Mg, Mg II), silicon (Si II), sulfur (S II), calcium (Ca II, [Ca II]), iron (Fe II, Fe III). In addition to that the possible existence of krypton (Kr), neon (Ne), and mercury (Hg) were also checked. The catalog that served as a reference for this can be accessed through the TOSC webpage, https://sne.space. The SNRs used in this study have an average redshift value of $z < 0.03$. Meaning all of this SNRs are moving away from us. Calculations of the velocity of each SNR has also been made as described in Table 1.

**Results and Discussion**

SN2019fbv (Fig. 1), AT2019fya (Fig. 2), SN2019fjp (Fig. 3), SN2019fcc (Fig. 4), SN2019fge (Fig. 5) and SN2019fhi (Fig. 6) were discovered just recently. AT2019fya was classified to be a Type II supernova by J. Zhang and X. Yu (2019) because its optical spectrogram matches the idealized spectra for the aforementioned type of supernova but this suggestion was not universally recognized for their results was only published recently. The rest of the supernova remnants mentioned in this study were verified to be Type II supernova remnant. Comparing the trend of each spectrum, it is evident that the trend of AT2019fya is much more similar to SN2019fhi than any other SNR in this study. These two show a strong singular emission in the near infrared just like the SN2019fjp, only that SN2019fjp’s trend is much more similar to SN2019fbv, SN2019fjp, SN2019fcc, and SN2019fge. The trends of the emission of both the SN2019fhi and AT2019fya are somehow equally distributed to the different wavelength. While the emission trend of SN2019fbv, SN2019fjp, SN2019fcc, and SN2019fge show a strong emission on the near ultraviolet than the near infrared. Below are the spectra of the supernova remnants that the researchers used in this study.
Based on these spectral data, the researchers can try to deduce why AT2019fya can be considered as a Type II supernova. Looking on the spectral line of all the SNRs, it is evident that there is a high frequency of both emission and absorption from 530 nm (5300 angstrom) up to 300 nm (3000 angstrom) suggesting that this must be common for all Type II supernova remnants the researchers are discussing on this study. Analyzing the spectra of these SNP remnants the researchers have found the following:

<table>
<thead>
<tr>
<th>Supernova Remnant</th>
<th>Element(s) Present</th>
<th>Velocity (m/s)</th>
<th>Redshift</th>
</tr>
</thead>
<tbody>
<tr>
<td>AT2019fya</td>
<td>H$_2$ (line 6), H (line 6), Kr (line 6)</td>
<td>4,736,720.8364</td>
<td>0.0158</td>
</tr>
<tr>
<td>SN2019fbv</td>
<td>Kr (line 5), Ne (line 17)</td>
<td>8,394,188.824</td>
<td>0.028</td>
</tr>
<tr>
<td>SN2019fcc</td>
<td>H (line 3)</td>
<td>3,777,384.9708</td>
<td>0.0126</td>
</tr>
<tr>
<td>SN2019fce</td>
<td>Kr (line 5)</td>
<td>12,291,490.778</td>
<td>0.041</td>
</tr>
<tr>
<td>SN2019ffi</td>
<td>H (line 4, line 8), Kr (line 6)</td>
<td>11,691,905.862</td>
<td>0.039</td>
</tr>
<tr>
<td>SN2019fjp</td>
<td>H$_2$ (line 4, line 5, line 6), H (line 5, line 7), Ne (line 9), He (line 5)</td>
<td>8,693,981.282</td>
<td>0.029</td>
</tr>
</tbody>
</table>

All of these were identified to be present on these remnants by comparing the spectra of the element and the SNP remnant. These findings were very unusual given the discovery of a noble gas such as krypton in some of these newly found SNP remnants as showed from Table 1. However, as M. Barlow (2013) showed by analyzing the spectra of Crab Nebula which is a Type II supernova remnants like these remnants that were mentioned in this paper. Helium (He), argon (Ar), radon (Rd), and krypton (Kr) can be found in the Crab Nebula. This supports the claim of the researchers that the existence of krypton on these SNP remnants is not impossible. Neon on the other hand was known to be able to exist in these region of the universe as stated by T. Plotner (2013). Mercury along with other heavy metals beyond iron is a natural occurring by product of SNP as discovered recently (J.D. Myers, 2017).

Based on Table 1, these SNR moves approximately $0.03c$ ($c$ = speed of light $299,792,458$ m/s) on average. These SNRs were also redshifted or moving away from us. It is also worth noting that the SN2019fbv (Canes Venatici) along with SN2019fjp (Microscopium) and SN2019fcee (Aquila) along with SN2019ffii (Canis Major) were moving at the almost the same speed with a redshift difference of approximately $0.1\%$. Meaning that the space on these different regions of the universe must expand at the same rate. Adhering to the Einstein field equations of general relativity by A. Einstein (1915).

**Conclusion**

Following from all the findings presented the researchers support the claim of J. Zhang and X. Yu (2019) about the AT2019fya being a Type II supernova remnant. It is shown that the similarities in the spectral signatures and element composition should make a strong suggestion and serve as a profound evidence that this SNP remnant (AT2019fya) is indeed a Type II SNP remnant in comparison to the other recently discovered remnants. In addition to that, the researchers also accomplished to discover other Type II supernova remnants such as AT2019fya, SN2019fbv, SN2019fcee, and SN2019ffii contains noble gases in their composition i.e. krypton which were thought to be somehow impossible to exist in such a place. Thus, this goes to show that krypton does exists in these SNP remnants. Lastly, in this study it is discovered that given two distant region of space we
can still test if the prediction of general relativity still holds true. The researchers would like to recommend that determination of the abundance of these elements on the SPN remnants that were the subject of this study must be done to further improve this study.

Appendix

AT2019fya

![Spectra for AT2019fya](image1)

He-L5  Hg-L6

![Spectra for AT2019fya](image2)

H-L6  Kr-L6
SNN2019ffi

SN2019fjp

H-L4
H-L8
Kr-L6
Hg-L6
H-L5
References


