O CEASAR: The Optical CAtalogue of Extragalactic SupernovA Remnants

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Abstract: We present **O CAESAR**, the Optical CAtalogue of Extragalactic SupernovA Remnants. **O CAESAR** will provide the largest homogenous optical survey of extragalactic SNR candidates taken by the same telescope (Canada-France-Hawaii Telescope, CFHT), the same instrument (SITELLE), and under similar observational conditions. SITELLE, the imaging Fourier transform spectrograph at CFHT, offers a large field of view (11'x11'), complete spatial coverage, and a high spatial resolution (0.32'' limited by the seeing), which are ideal to cover the whole disk of nearby galaxies. Using three filters, we are able to measure the strong emission lines [OII]λ3727, Hβ, [OIII]λλ4959,5007, Hα, [NII]λλ6548,6583, and [SII]λλ6716,6731. The spectral resolution is variable and depends on the scientific goal. Our sample is volume limited (D ≤ 10 Mpc) and includes all the galaxies of *SIGNALS survey* (~ 40 galaxies) in addition to other galaxies that will be proposed specifically for our project to include different ranges of types, masses and metallicities. Identification of the SNR candidates will be done automatically and will be based on the emission line criterion [SII]/Hα ≥ 0.4. The shock-excited nature of SNR candidates will be confirmed using the whole set of emission lines available with our SITELLE data. This poster presents the method and the first results of this analysis on NGC 3344.

1. O CAESAR

The **O**ptical **CA**talogue of **E**xtragalactic **S**upernov**A** **R**emnants (O CAESAR) will provide the largest homogenous survey of extragalactic SNR candidates taken by the telescope (CFHT), the same instrument (SITELLE), and under similar observational conditions.

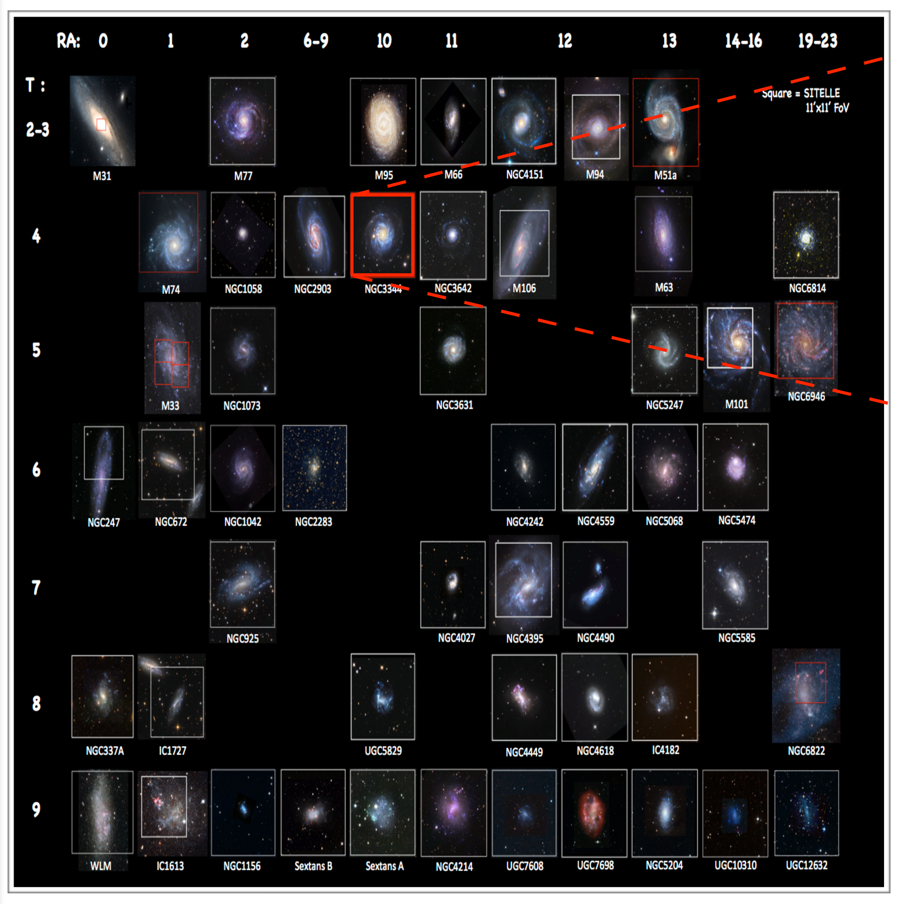
Optical CAtalog of Extragalactic SupernovA Remnants

The goal of this catalogue is to present the main parameters of each galaxy (e.g. type, mass, metallicity, SFR) and the primary characteristics of each SNR candidate, such as ID, Right Ascension and Declination of the centroid, optical size, [SII]/Hα ratio, spectroscopic confirmation using (i) Sabbadin plots*; (ii) BPT-diagrams*; and [OI]λ6300 emission line. Finally, the presence of confirmation from other wavelength ranges (near IR, radio and X-rays) will be highlighted with references.

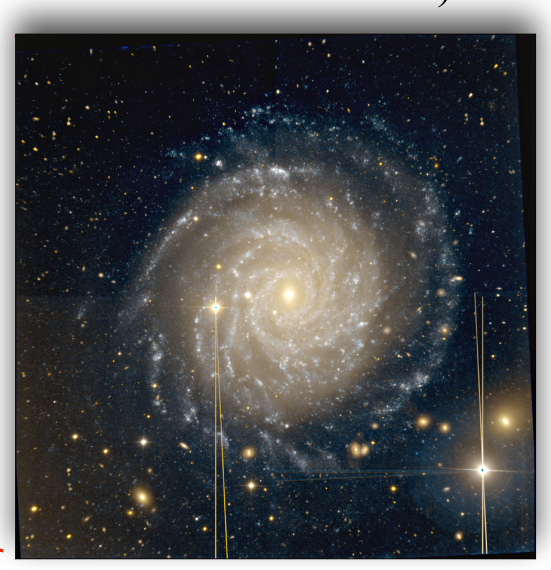
* The Sabbadin plots (Sabbadin et al. 1977) and BPT diagrams (Baldwin, Phillips & Telervich 1981) are two sets of diagrams used to identify the ionization mechanism of the nebular gas using the optical emission lines (Hβ, [OIII]λ5007, [NII]λ6548, Hα, [NII]λ6583, and [SII]λλ6716,6731).

2. The Sample

O CEASAR catalogue is volume limited (D ≤ 10 Mpc) and includes all the galaxies from the SIGNALS survey (PI. Laurie Rousseau-Nepton; http://signal-survey.org) that will be added to other galaxies that will be proposed for O CAESAR to include different ranges of morphological and physical properties of galaxies (e.g. types, masses and metallicities).



SIGNALS, the Star formation, Ionized Gas, and Nebular Abundances



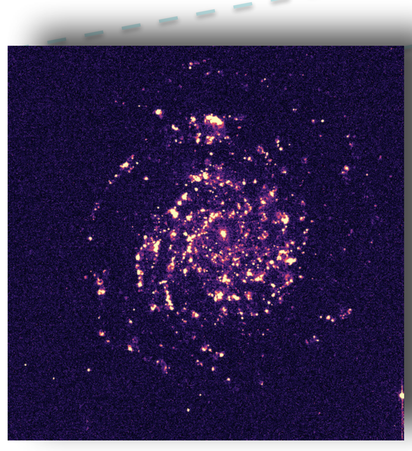
The SITELLE image of NGC 3344 obtained from the combination of the SN1 (blue) and SN3 (red) deep images.

12 of the galaxies known to host optical SNR are part of the SIGNALS survey

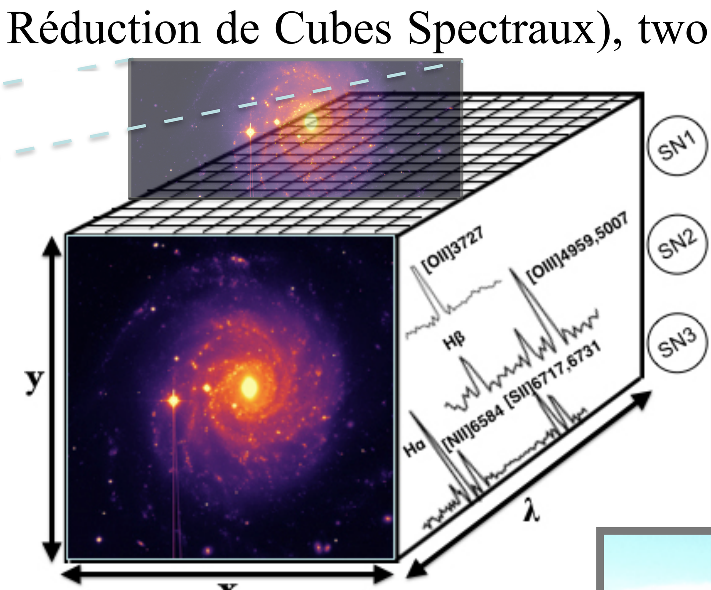
3. Observation and Data Reduction

The sample will be observed using the imaging Fourier transform spectrometer **SITELLE** (Drissen et al. 2019) installed on the 3.6-m CFHT. For each galaxy, more than 4 million spectra are obtained using the filters SN1 (365-385 nm, R≈400), SN2 (480-520 nm, R≈600), and SN3 (651-685 nm, R≈1500) with seeing limited spatial resolution of 0.8''. Only ~3 hours are needed to reach the spectral resolution requested for each filter.

Data reduction is performed with **ORBS** (Outils de Reduction Binoculaire pour SpIOMM/SITELLE) and lines are fitted using **ORCS** (Outils de Réduction de Cubes Spectraux), two softwares developed specifically for SITELLE (Martin et al. 2015).



[OII]λ3727 Flux map



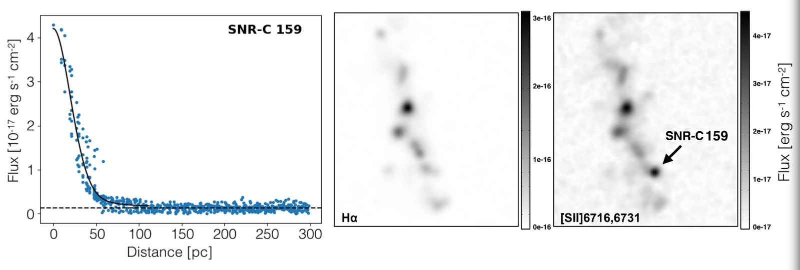
A 3D SITELLE Spectral datacube

4. SNR Identification

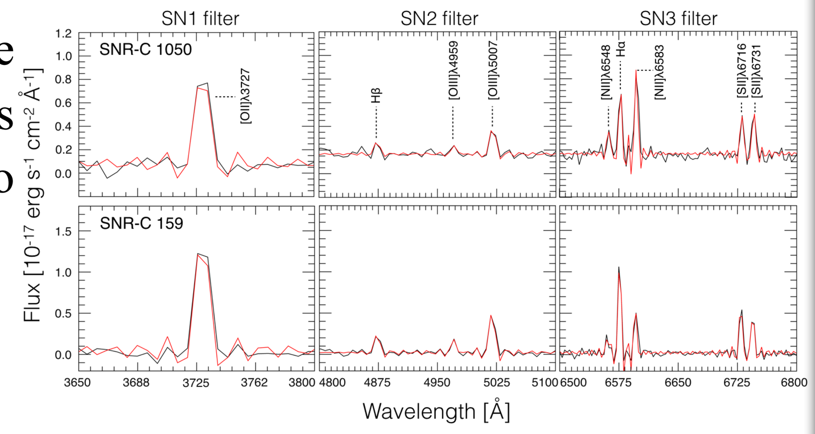
In order to identify the SNR candidates in a non-subjective way, we use the automated identification technique described by Rousseau-Nepton et al. (2018). This technique was initially created to study the star forming regions in the nearby galaxy NGC 628.

Moumen et al. (2019) have adapted this technique to identify automatically SNRs in nearby galaxies such as NGC 3344 . Four criteria were applied to select SNR candidates:

1. Line ratio [SII]/Hα ≥ 0.4
2. The signal to noise ≥ 5 for Hα and [SII] lines
3. The size of the region ≤ 120 pc
4. The correlation coefficient of the profile ≥ 0.5



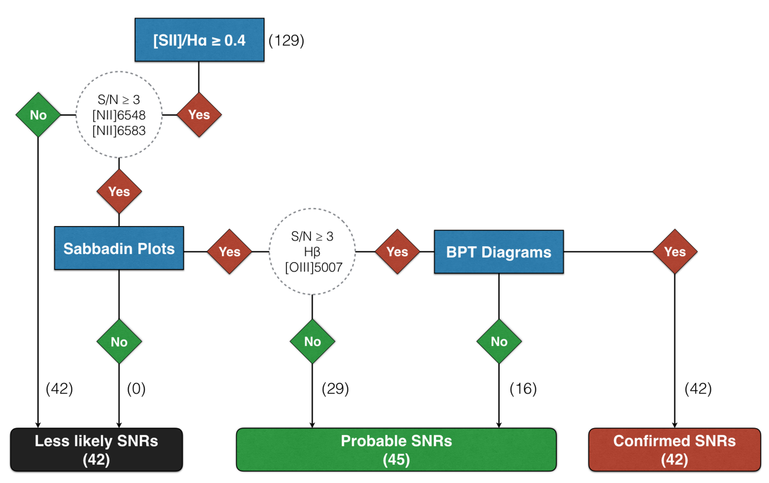
Left: Pseudo-Voight profile of SNR-C 159 in NGC 3344. Right: Hα and [S II]6716,6731 flux maps near the SNR-C 159.



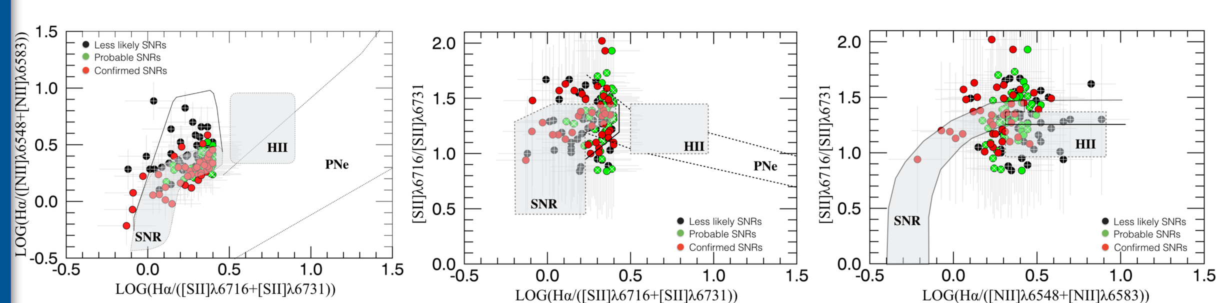
SITELLE spectra for one pixel within SNR-C 1050 and SNR-C 159. In black, the observed spectrum and in red, the fit obtained with ORCS.

5. SNR Confirmation

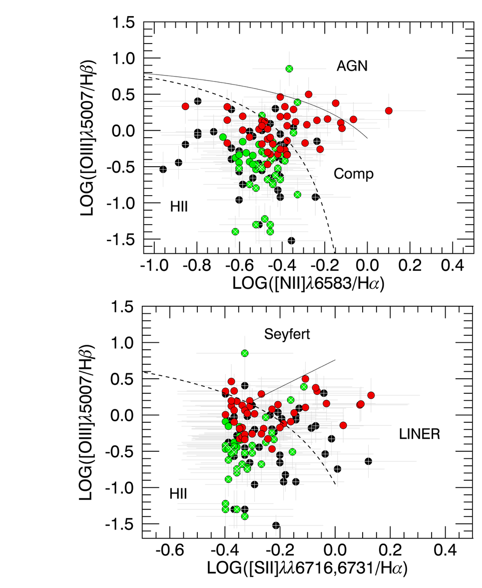
STELLE data used in this project provide important emission lines which are useful to get the gas physical parameters (e.g. [SII] Hα and [OII] for the main shock heating mechanism, [NII]/Hα and [OII] for the metallicity, [OIII]/Hβ for the shock velocity, [SII] ratio for the density, and Hα/Hβ for the extinction, etc.). In order to confirm the shock-heated nature of the SNR candidates, we adopt a self consistent analysis using Sabbadin plots (Sabbadin et al. 1977) and BPT diagrams (Baldwin et al. 1981).



Our self-consistent spectroscopic analysis revealed 129 SNR candidates in NGC 3344: 35~Confirmed SNRs, 52~Probable SNRs, and 42~Less likely SNRs



Sabbadin plots with the 129 SNR candidates found in NGC 3344. The final classification of the candidates is shown using different colors: **red** for the Confirmed SNRs, **green** for the Probable SNRs, and **black** for the Less likely SNRs. Circles with a '+' symbol indicate SNR candidates with S/N<3 for the [NII]λλ6548,6583 lines, while circles with a '×' symbol indicate candidates with S/N<3 for the Hβ or [OIII] lines.



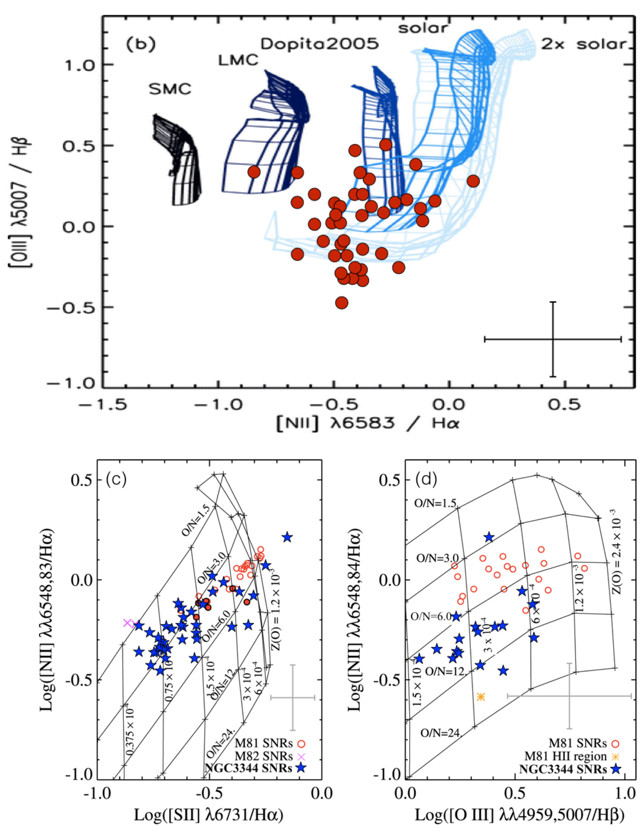
BPT-NII and BPT-SII diagrams of the 129 SNR candidates found in NGC3344. Colors and symbols are the same as presented in the Figure for Sabbadin plots.

[O I]λ6300 is another indicator, produced by shocked gas, used to confirm the shock heated nature of the SNR candidate. It can be available for SITELLE although the challenge of the strong sky line emission near of 6300Å.

6. Shock Models

Understanding emission nebulae like SNRs in various galaxies is a major issue in astrophysics, and involves a statistical approach for large samples in galactic environments of all kinds. Instruments like SITELLE at the Canada-France-Hawaii Telescope have opened a new era in the three-dimensional study of extended objects. Various sets of model of photo-ionization and shocks make it possible to connect these types of observations to the physical conditions (temperature, density, chemical composition, ionizing source) in the nebulae. But more sophisticated models including more parameters are still needed.

O CAESAR will be an excellent source of spectroscopic data for developing and testing new shock models.



Top: [O III]5007/Hβ versus [N II]6583/Hα based on the shock+precursor models of Allen et al. (2008). Bottom: Emission line ratios based on the model of Dopita et al. (1984) for a shock velocity of 106 km s^{-1}.

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