Characterization of M51's supernova remnants with the imaging spectrometer SITELLE

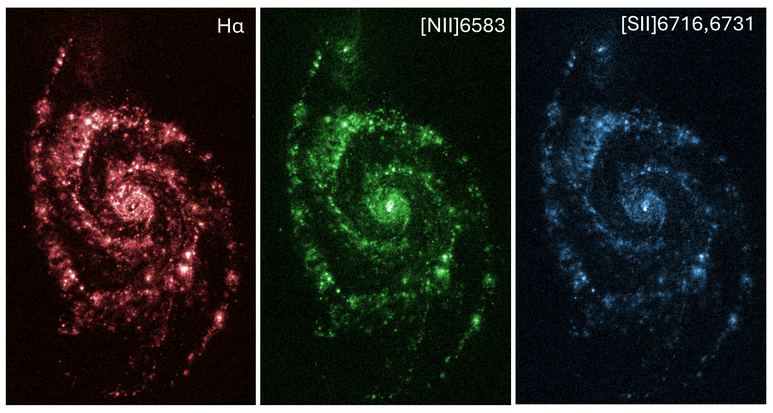
Billy Gamache[1,2], Laurent Drissen [1,2], Carmelle Robert [1,2], Mykola Posternak [1,2]
[1]Département de physique, de genie physique et d'optique, Université Laval, Québec (QC), G1V 0A6, Canada
[2]Centre de recherche en astrophysique du Québec (CRAQ)

Introduction : M51 was the subject of a supernova remnant (SNR) population study by Winkler et al. [4]. They found 179 candidates and obtained the spectrum of 66 of them. Following their lead, we made a complete analysis of all of Winkler's candidates with the imaging spectrometer SITELLE while looking for new SNRs.

SITELLE AS INSTRUMENT

SITELLE [1] is an imaging Fourier transform spectrometer attached to the Canada-France-Hawaii telescope. It produces spectral cubes with a field of view of 11'x11' (sampled at 0.32''/pixel) and can cover most of the visible part of the spectrum (350-900 nm). The spectral resolution can be adjusted up to R ~10 000.

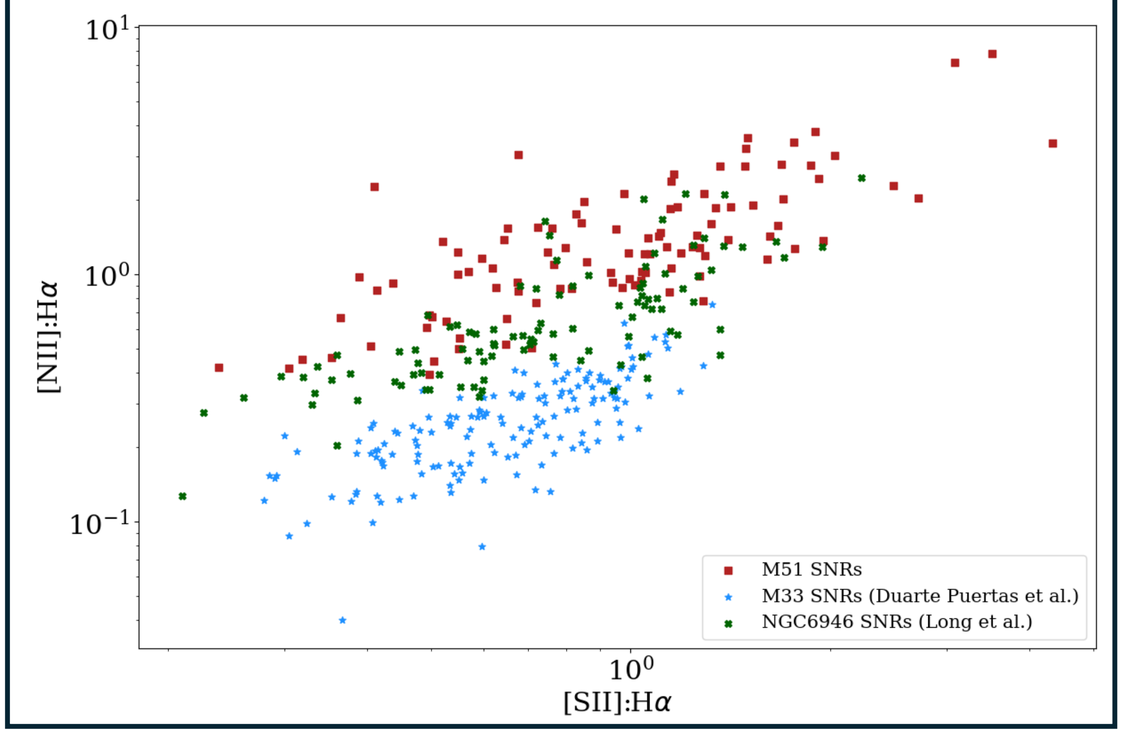
Figure 1 : SITELLE and M51 flux maps.



INTENSITY RATIO

Comparing line ratios from M51's supernova remnant population to M33's (Duarte Puertes et al. (*in prep*)) and NGC 6946's (Long et al. [3]) clearly shows a trend to higher values for M51. This is especially true for [NII]:Hα, which is an indication of high metallicity in the galaxy.

Figure 3 : Intensity ratio comparison with other spirals.

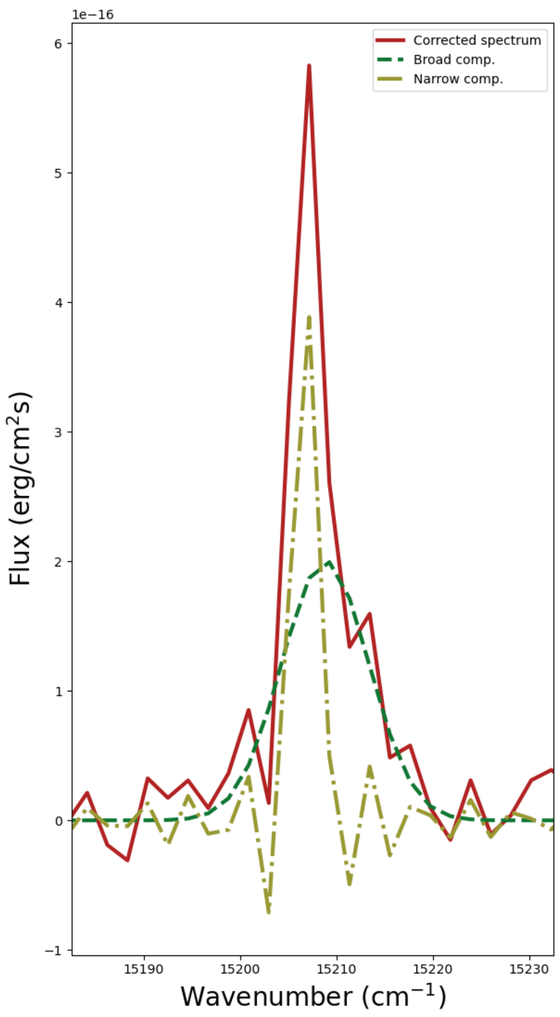


MULTI COMPONENT ANALYSIS

The difference between Hα and [NII] velocity dispersion has motivated two components fitting for Hα. We were able to fit a broad component at the base of a narrow one for 15 cases, with S/N>3. The case of GD24-234 is shown in figure 5. The velocity dispersion of the narrow line is 12 ± 8 km/s and the broad one 90 ± 11 km/s.

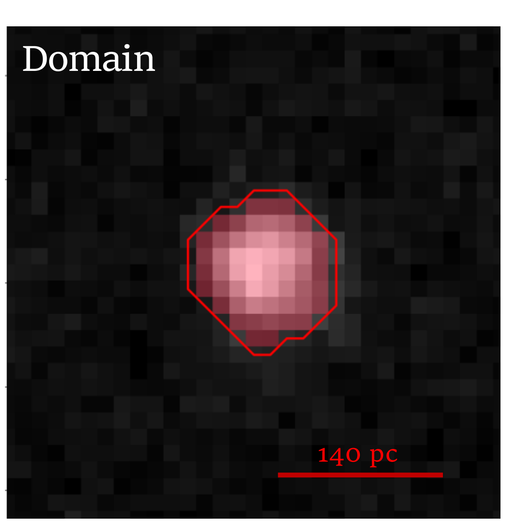
Possible reasons as to why we are seeing 2 components are background contamination or another phenomenon specific to the physics of SNRs. Among them, SRNs with shock precursors can show an intermediate component in their velocity profiles [5].

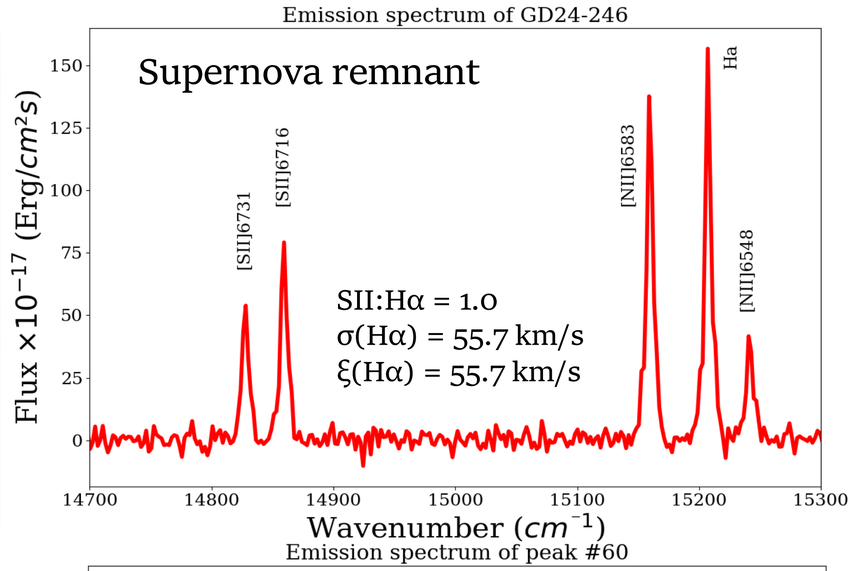
Figure 5 : The two components fitted to GD24-234 Hα

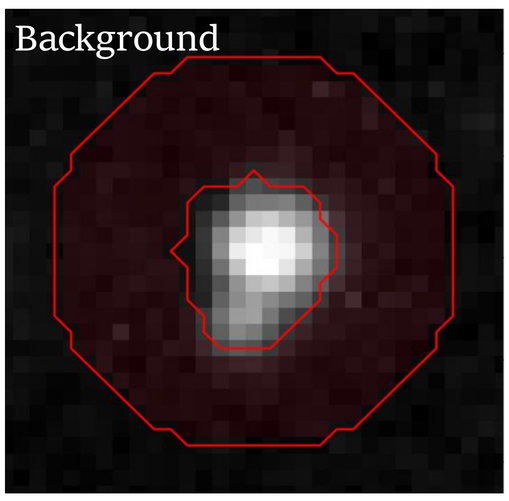


THE DATA

This study is mainly based on SITELLE's SN3 filter (648 to 685 nm). The M51 cube was obtained with a spectral resolution of ~5000 and a seeing of ~1.1". Lines are modelled with ORCS [2], a data reduction tool for SITELLE. Spectra were obtained by integrating individual pixels in a domain and subtracting a background.







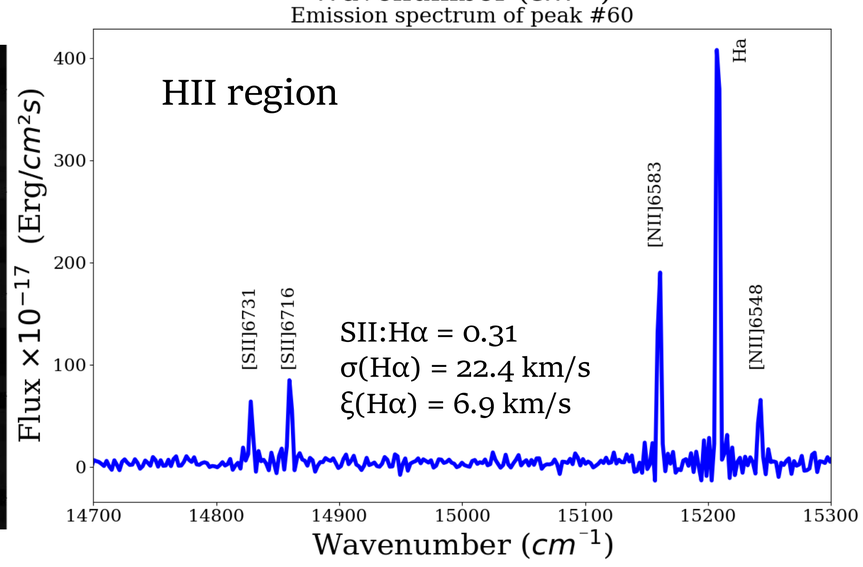


Figure 2 :Domain and background definition and SN3 spectra of an SNR and an HII region.

M51'S SNRs

Of the 283 candidates analyzed, a total of 103 SNRs have been confirmed; 83 of them were already discovered by Winkler et al. [4]. The confirmation criteria were [SII]:Hα > 0,4 and σ > 30 km/s. Along with SNRs, an emission region sample has been obtained, mostly composed of DIG and HII regions. To compare both samples, we use the parameter :

$$\xi = [SII]{:}H\alpha \times \sigma$$

The plot in Fig. 4 shows a clear separation between the two samples, with a median value of 59 km/s for SNRs and of 5 km/s for the control sample. Interestingly, the median value for SNRs drops to 30 km/s if we consider the Hα velocity dispersion.

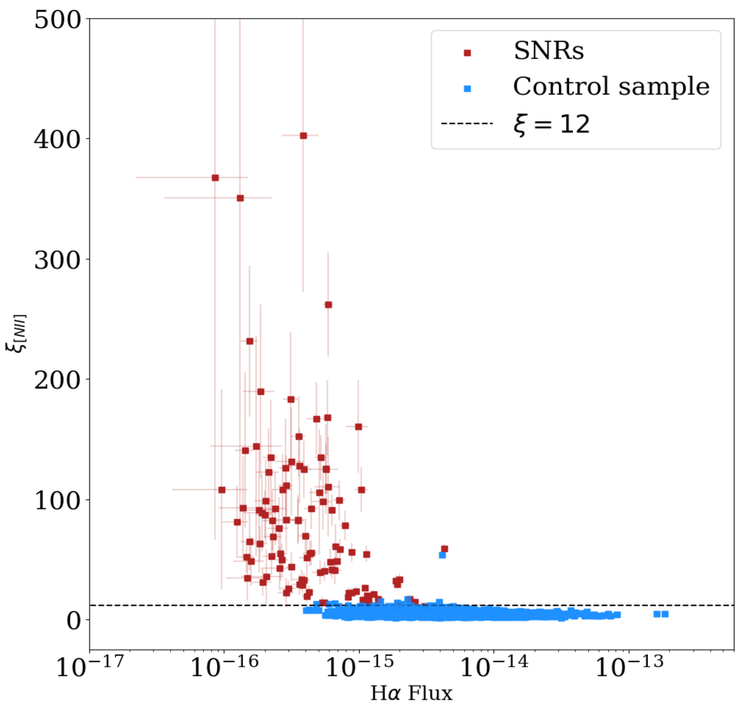


Figure 4 : Parameter ξ for the fitted [NII] velocity dispersion.

GALACTOCENTRIC GRADIENT

Figure 6 shows that the [NII]:Hα ratio for SNRs tends to be more dispersed and extends to larger values toward smaller galactic radius. Intriguingly, the inverse is observed for the control sample of HII regions, with a positive [NII]:Hα gradient.

Similarly to the ξ parameter, we can see a clear separation between SNRs and HII regions in the line ratio, except for a few overlapping SNRs.

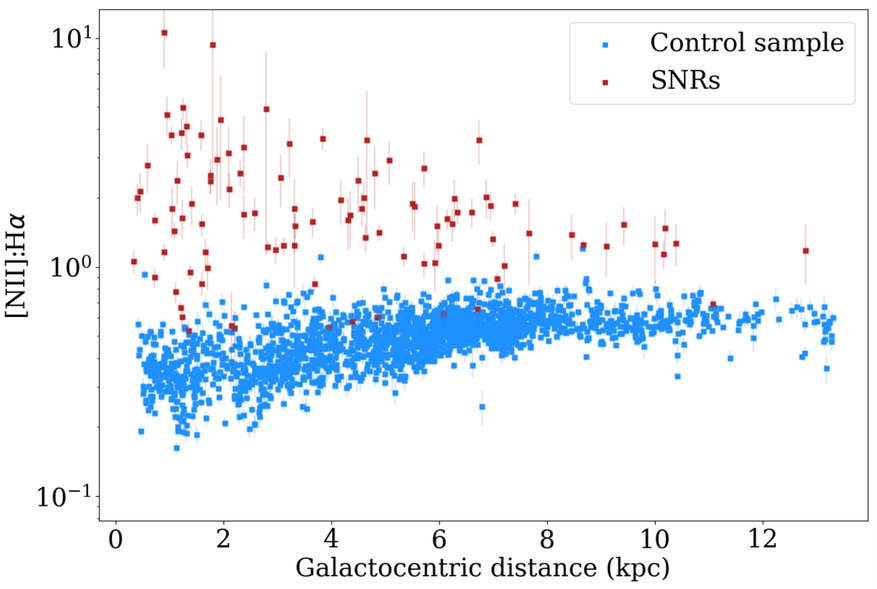


Figure 6 : [NII]:Hα ratio with galactocentric distance.

References : [1] Drissen et al., 2019, MNRAS, 485, 3930. [2] Martin et al., 2021, MNRAS, 5514-5529. [3] Long et al., 2019, ApJ, 875,85. [4] Winkler et al., 2021, ApJ, 908, 80. [5] Morlino et al., 2012, , ApJ, 760,137.

billy.gamache.1@ulaval.ca