WiFeS Spectral Studies of H-alpha Features in the Scutum Supershell blowout

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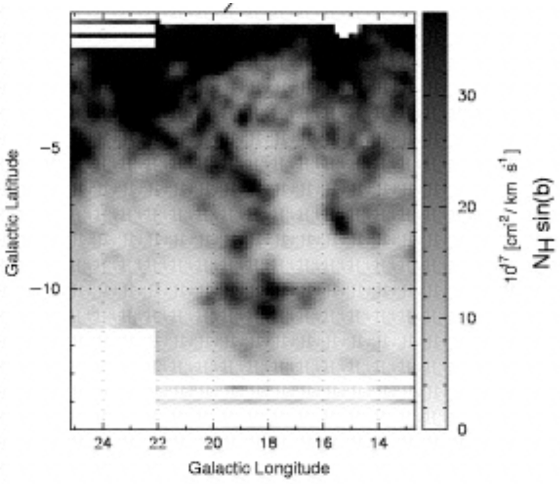
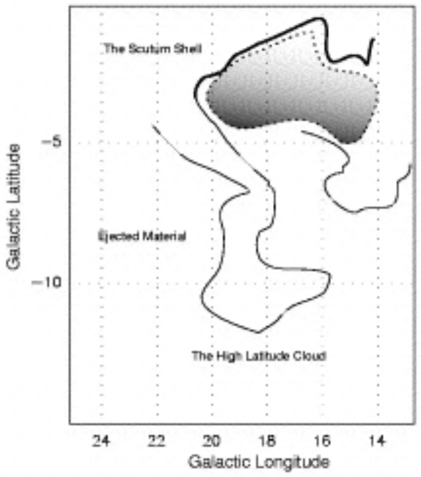
Scutum Supershell Region

- Observed HI emission points to a shell like region
- X-rays suggest some hot gas (Callaway + 2000)

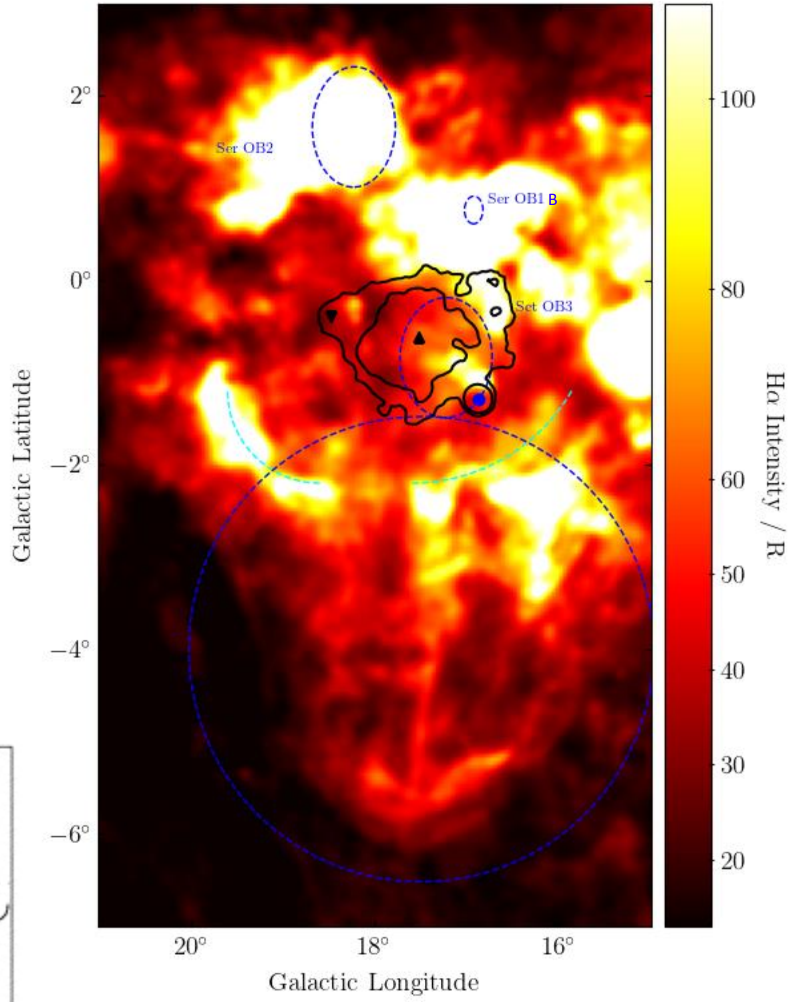
Kinematic distance 3300 (pc)	Diameter 290 (pc)	Volume 6.2×10^6 (pc^3)	H I density 4.05 (cm^{-3})
Total energy 1.14×10^{52}(ergs)	L X-ray 5×10^{36} (ergs s^{-1})	H I column 3.6×10^{20} (cm^{-2})	Mass 6.20×10^5 ($M_\odot$)

- Blowout in WHAM data and here in higher resolution
- Three Gamma-ray sources observed using H.E.S.S.
- Revisiting this region reveals larger optical features in the vicinity of the high energy gamma-ray sources
- Collisional excitation
  - Supernova remnants
  - Pulsar wind nebulae
    - HESS J1825-137
    - HESS J1826-130
  - LS 5039 (HMXB)
- Photoionisation
  - $H + h\nu \longrightarrow H^{+} + e^{-}$
  - OB associations
    - Ser OB1B
    - Ser OB2
    - Sct OB3





The Scutum Shell



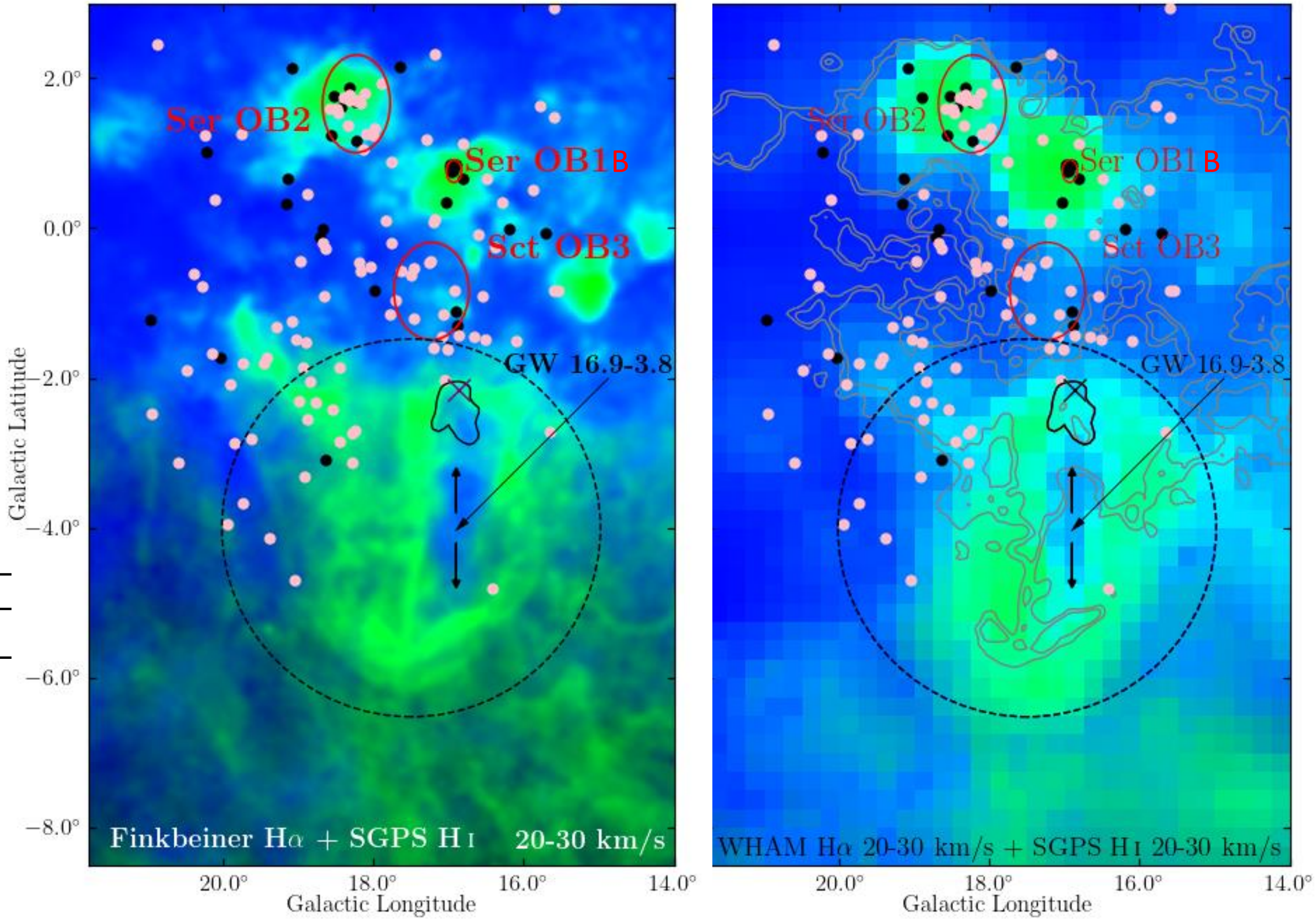
Wide view of the optical Hα emission from Finkbeiner (2003) with the TeV γ-ray significance contours in black obtained from HESS observations. HESS J1825-137 (PSR J1826–1334 ▲), HESS J1826-130 (PSR J1826–1256 ▼), LS 5039 'yellow' ● are shown. The Scutum Supershell is shown in the blue dashed circle. SNR G18.7–2.2 is shown by a dashed black arc from Stupar+(2008); Voisin+(2016). Indicated OB associations are from Mel'Nik & Efremov (1995).

Photoionisation

- OB-type stars
  - have a high ionisation rate
  - are located towards the north
- OB associations and their star clusters
- SGPS H I (blue) and Hα (green) emissions

Name	Distance	Age	O stars	Total stars	Q
	kpc	Myr			S^{-1}
Ser OB2 (NGC 6604)	1.6	6.8	~5	260	5×10^{50}
Ser OB1 –B (NGC 6611)	1.5	6.8	18	51	1×10^{51}
SCT OB3	1.3	4.5	~3	145	2×10^{50}
Ser OB1 –A (NGC6618)	1.7	7.5	8	42	4×10^{50}

- Galactic worm G16.9-3.8 provides a surface for UV

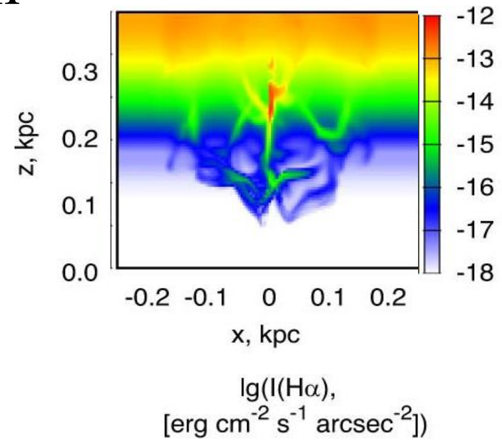


Left: Integrated 20-30 km/s composite map featuring Galactic worm GW 16.9–3.8 as a distinct HI vertical feature in blue (McClure-Griffiths et al., 2005), encircled by Hα emission in green (Finkbeiner, 2003). Black contours of CO(1–0) emission (Mizuno & Fukui, 2004) outline molecular hydrogen around water maser G016.8689–02.1552 (purple cross). Red ellipses point to Ser OB2, Ser OB1B, and Sct OB3 OB associations. Right: a similar image shows WHAM Hα emission integrated over 20-30 km/s towards this region, with Hα emission from Finkbeiner (2003) shown as gray contours.

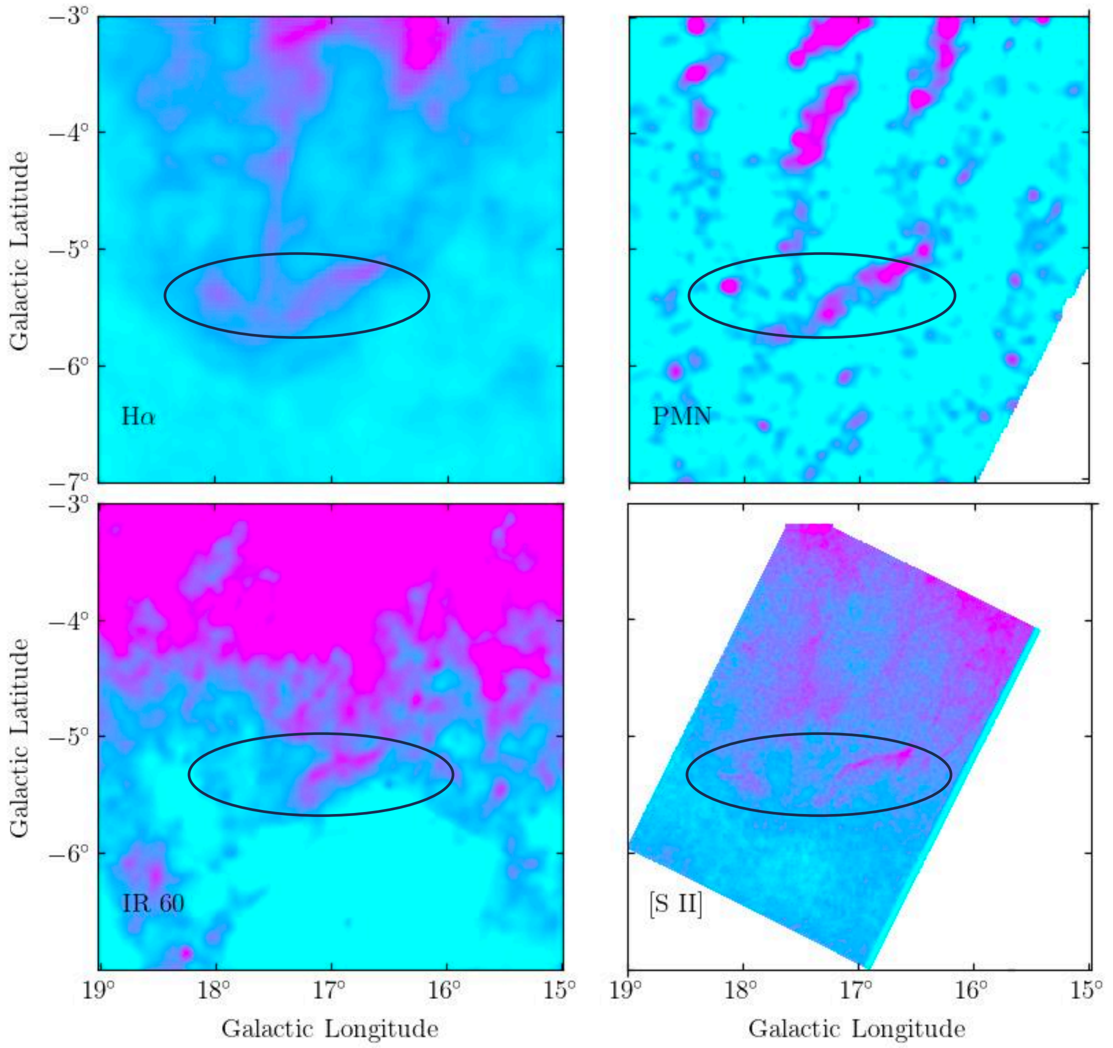
Collisional ionisation (Shock)

- The Bow shock region exhibits multi-wavelength Hα, radio continuum PMN, IR 60 μm + [S II] emissions

- Drozdov et al. (2022) present a simulation for a cluster of 10 SNe located 20 pc above the midplane at time of 16 Myr after the first explosion shows similar feature.
- A possible shock collision from SNR or Stellar wind or OB evolution



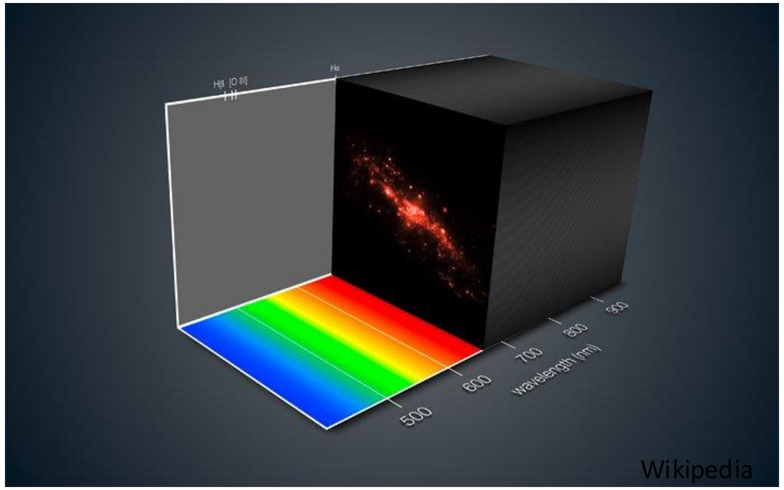
[arXiv:2410.15712](https://arxiv.org/abs/2410.15712)

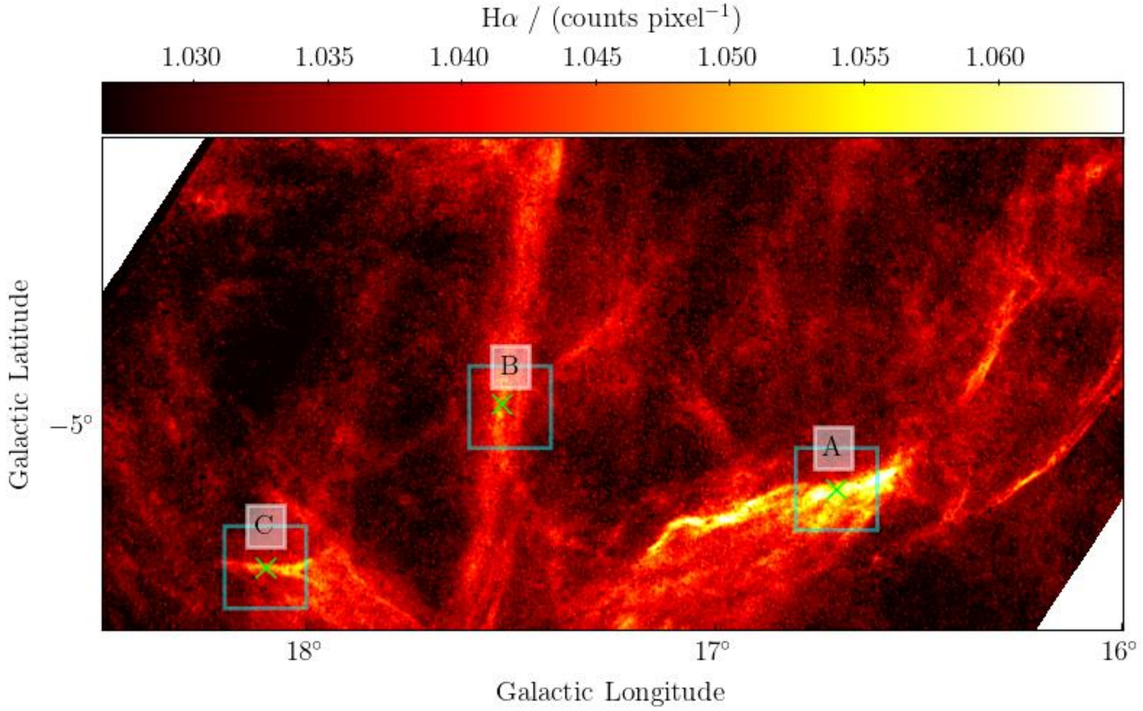


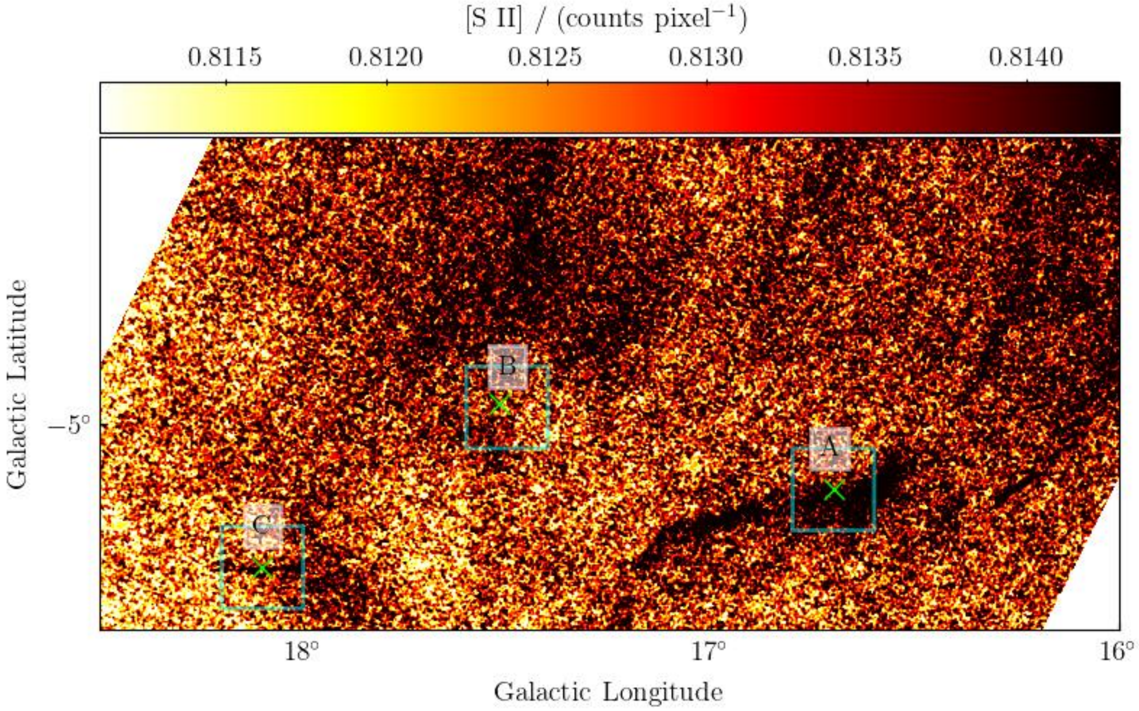
Multi-wavelength observations of the Bow shock region where the top-left panel shows Hα emissions (Finkbeiner, 2003), the top-right PMN data, the bottom-left IR emissions (IRAS), and the bottom-right our [S II] observations. Black ellipses point to the bow shock region.

WiFeS Observation Using the 2.3M T

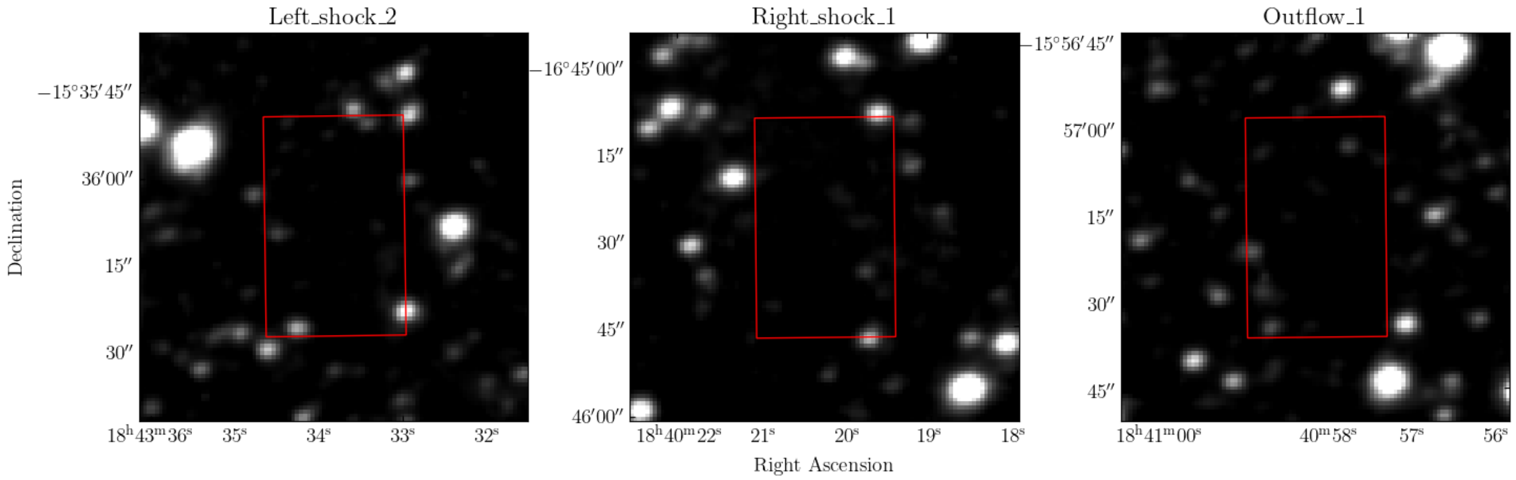
- The normal mode of WiFeS is used
- A — Right shock & B — Spine & C — Left shock
- Grating for B3000 & R3000 with resolution ~0.7 to 1.2 Å, respectively.
- Covers 3200Å to 9700Å and 50 min exposure time
- Observations were across two nights 10 and 11 Oct 2023
- Automated Pywifes pipeline was used for reduction.



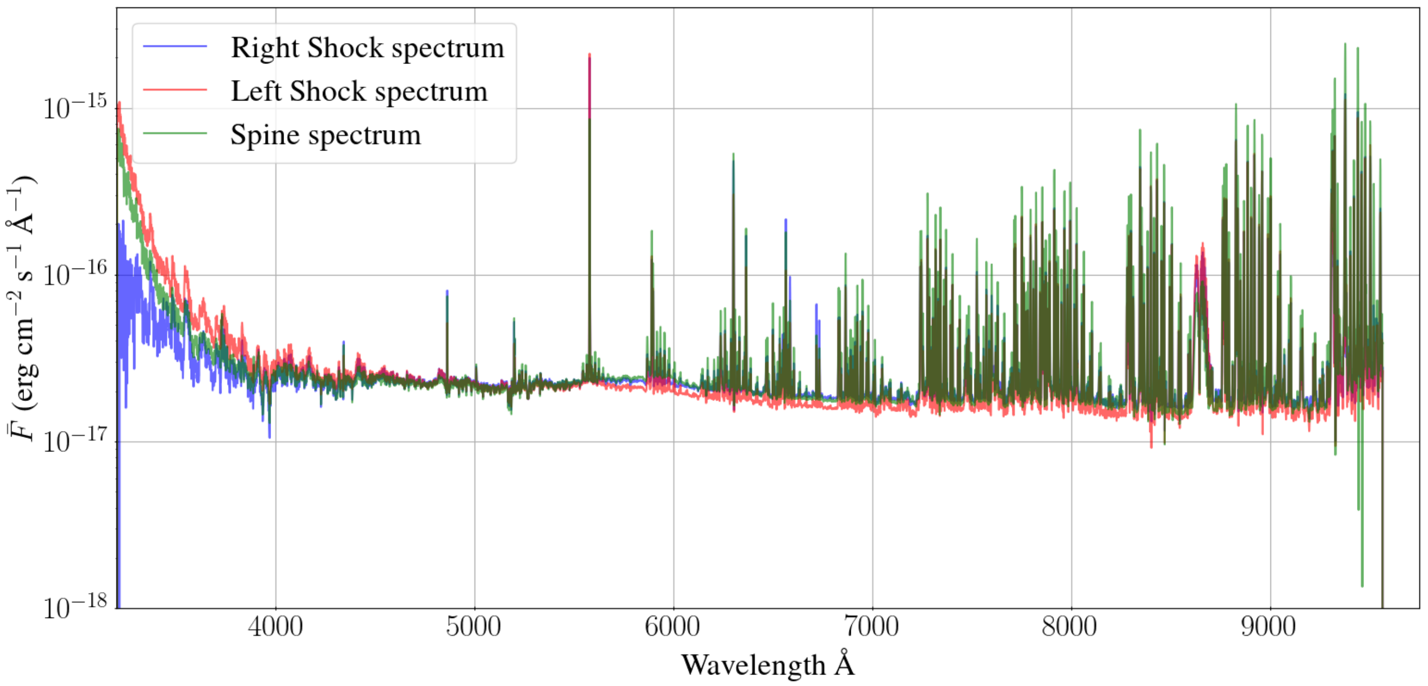




Processing the Spectra

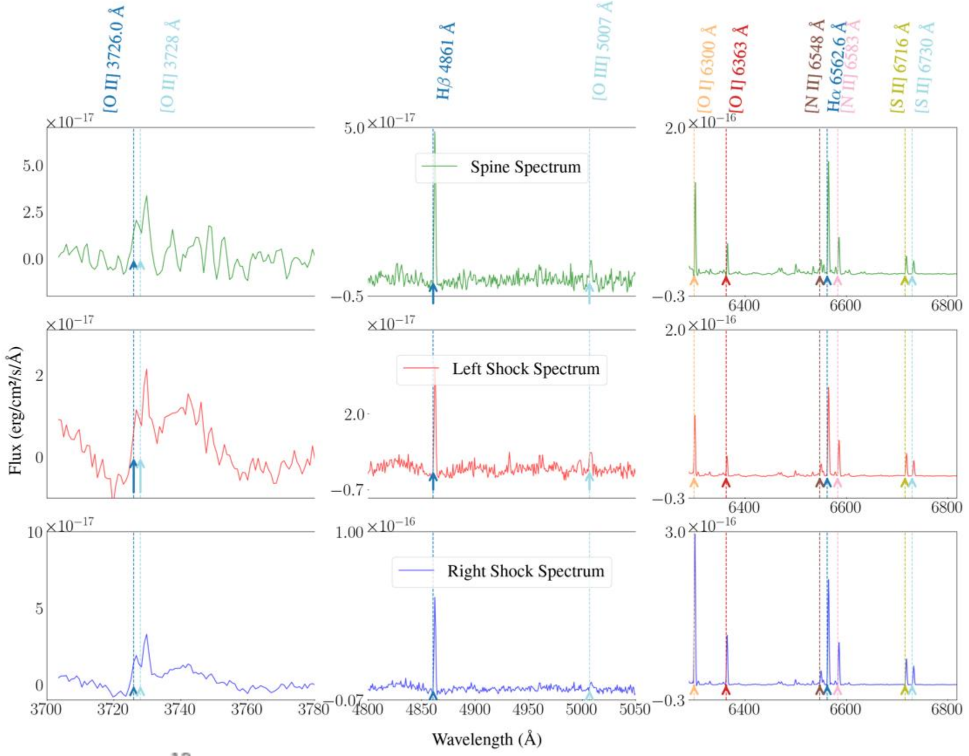


- The blue and red spectra are combined using the PyWiFeS splice function
- Contamination from other Hα sources is masked using Gaia point sources
- Continuum fits
    - Eye or IRAF are used
    - Hampel filter and B-spline
- Airglow sky line removal
    - SN 2023tra frame was utilised
    - Scaling and subtracting sky emission lines

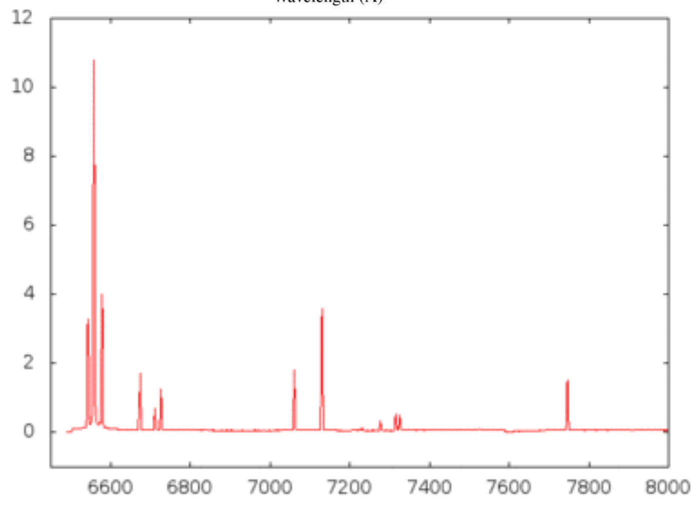


Line Fluxes of the Spectra

- **Spectral Analysis**
  - The cleaned spectra are analysed using ALFA to search for emission lines fluxes in each region.
  - Interstellar extinction c(Hβ) is determined by Hα/Hβ
  - Ratio between the emission line intensities

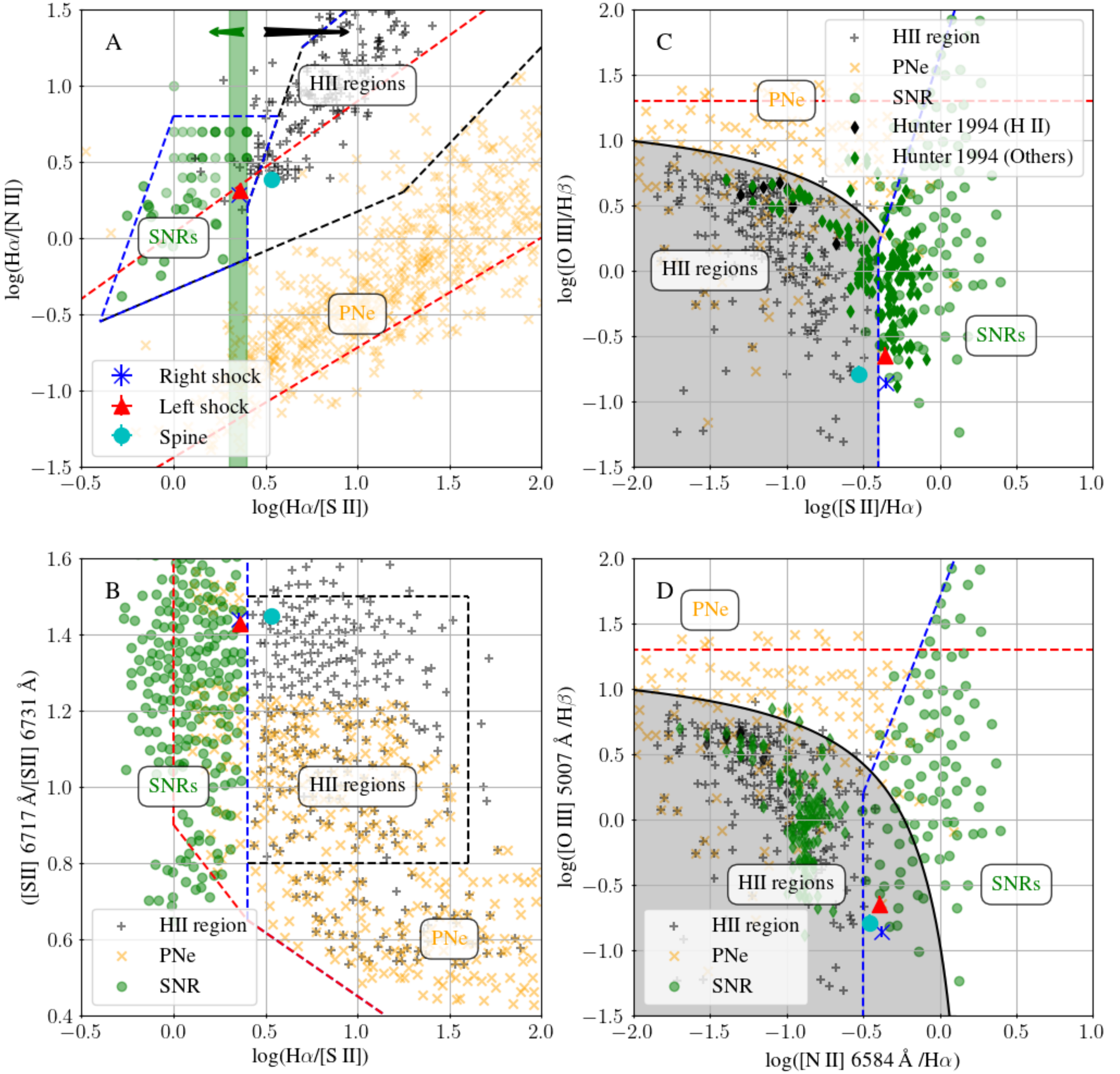


Ratio	Right Shock	Left Shock	Spine
Hα/[S II]	2.20 ± 0.01 (0.45)	2.21 ± 0.01 (0.45)	3.36 ± 0.01 (0.29)
[S II] 6717/31Å	1.43 ± 0.04	1.42 ± 0.03	1.44 ± 0.04
Ha/[N II]	1.79 ± 0.01	1.98 ± 0.01	2.17 ± 0.01
[N II]6584Å/ Ha	0.43 ± 0.01	0.38 ± 0.01	0.35 ± 0.01
[O III]5007Å/Hβ	0.12 ± 0.05	0.22 ± 0.03	0.16 ± 0.04



Diagnostic Line Ratios

- Known HII regions are dominated by photoionisation as well as PNe, where SNRs are known to be shock excitation regions.
- The population of line ratios of SNRs, HII regions, and PNe are shown
- [SII]/Hα line ratios
  - classification depends on other lines
  - generally agreed that
    - > 0.4 to 0.5 indicates shock collision region such as SNR
    - < 0.3 indicates photoionisation region such as HII region
  - bow shock ratio is ~ 0.45
  - spine ratio is ~ 0.3
- Left and Right shock ratios indicate shock excitation regions



Sources shown here include: Planetary Nebulae (PNe) represented by red dots; H II regions shown as open black squares; evolved Supernova Remnants (SNRs) as open blue triangles; young SNRs as orange triangles; and low-metallicity Magellanic Cloud SNRs as green triangles, following the classifications from Sabin et al. 2013

Conclusion & Future work

- In the case of the bow shock ionisation process, shock emission are possibly from either SNRs in the OB associations, or stellar winds, or the evolution of the OB associations.

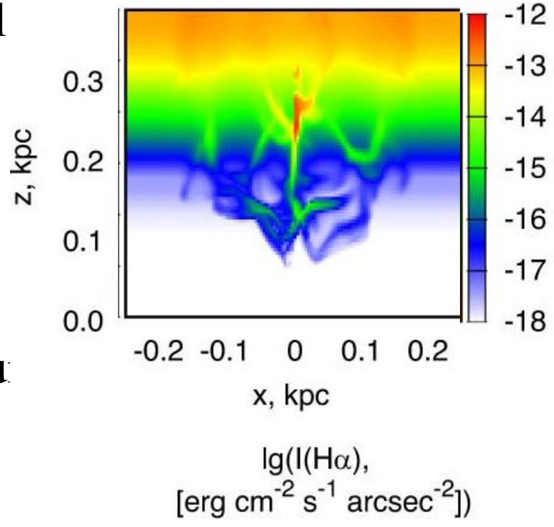
- Observations using Wide Field Spectrograph (WiFeS) spectroscopy will be in a future publication.

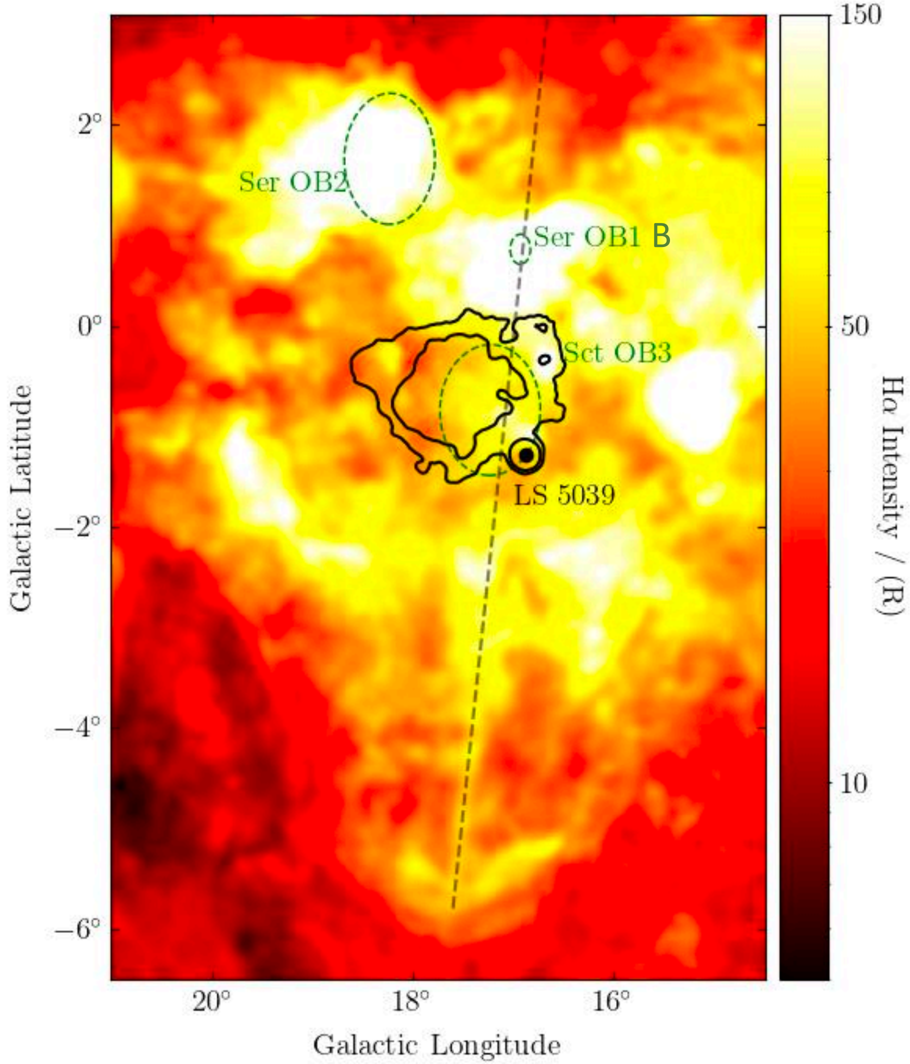
Reference:

- Abdalla, H., (H.E.S.S. Collaboration) Abramowski, A., Aharonian, F., et al. 2018, A&A, 612, A1
- Drozdov, S. A., Vasiliev, E. O., Ryabova, M. V., Shchekinov, Y. A., 945 & Nath, B. B. 2022, Open Astronomy, 31, 154
- Finkbeiner, D. P. 2003, ApJS, 146, 407
- Voisin, F., Rowell, G., Burton, M. G., et al. 2016, MNRAS, 458, 2813
- Green, D. A. 2019, Journal of Astrophysics and Astronomy, 40, 36 956
- Miville-Deschênes, M.-A., & Lagache, G. 2005, ApJS, 157, 302
- Stupar, Parker, Q. A., & Filipovic, M. D. 2008, MNRAS, 390, 1037
- Griffith, M. R., & Wright, A. E. 1993, AJ, 105, 1666 958
- ……

Hα Bow shock From OB associations

- **Study by Drozdov et al. (2022)**
  - Simulation demonstrates the potential outflows from OB associations.
- **Key Elements of the Simulation**
  - Involves a high number of stars and multiple supernovae (SNe).
  - Predicts the formation of large structu spanning kiloparsecs.
- **Emission Characteristics**
  - Structures emit in Hα and X-ray (0.7–1.2 keV) over several million years (Myr).
- **Regional Alignment**
  - Ser OB1 and Sct OB3 are well-aligned within the region.





Hα image from Finkbeiner (2003) towards this outflow, showing some energetic sources such as HESS J1825−137 and LS 5039 with gamma–ray emission (red contours of 5σ, 10σ and 50σ). The OB associations are noted by the green dashed region. LS 5039's possible birth locations (Moldon et al. 2012) . Pulsar are showed as blue x. The sources of high energy are showed HESS J1825-137 with ▲, HESS J1826-130 ▼, and LS 5039 ●.

Exploring the Complexity of This Region

- Energetic sources in the regions are
  - Supernova remnants
    - SNR G17.8-2.3
    - SNR G18.3-1.7
  - Pulsar wind nebulae
    - HESS J1825-137
    - HESS J1826-130
  - High Mass X-ray binary
    - LS 5039 (High Mass X-ray Binary)
  - OB associations
    - Ser OB1A, Ser OB1B, Ser OB2, and Sct OB3
  - Galactic worm GW 16.9-3.8 (Koo+1991)

- ~ Scutum Supershell Blowout is a mix of photoionisation and shock excitation