AGNAGN seminar

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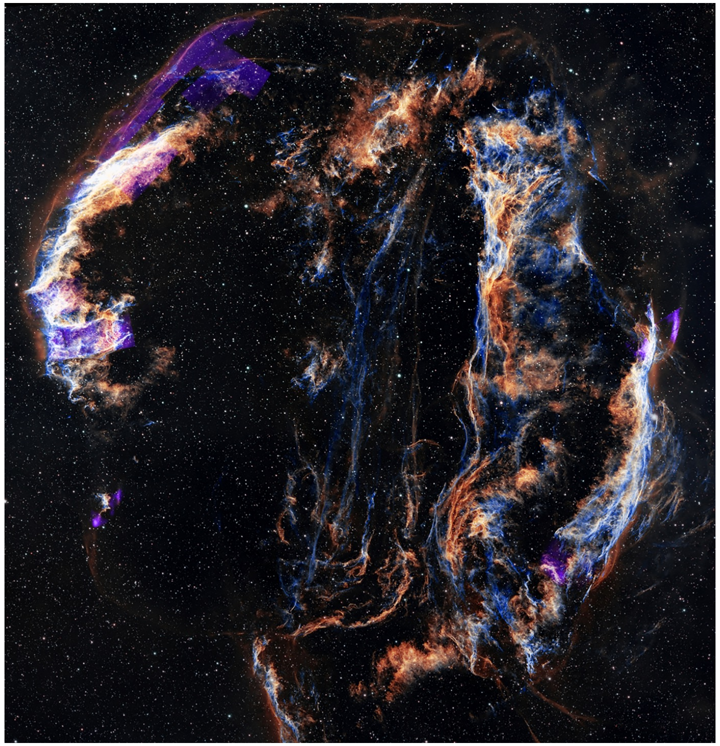
12.6 Other Supernova Remnants

- Other remnants in the Milky Way
  - Some remnants were found in radio surveys.
    - non-thermal, power-law spectra (synchrotron emission)
  - The radio emission is often strongly concentrated near the edge of the object. (Cf. Cygnus Loop)
  - They are typically not observed in optical.
    - because of strong interstellar extinction

  - They show highly filamentary structures



12.6 Other Supernova Remnants

- Other remnants in other galaxies
  - Identified by radio and optical observations
  - Strong X-ray emission is another way to identify them
  - It arises in the very hot gas left behind the shock
- Example: L/S MC
  - Direct images were taken through narrow-band filters ([SII],[Fe X])
  - Size, mean expansion velocity → lifetime → occurrence rate
  - Estimated supernova occurrence rate : 0.6 / century

12.7 Shock-Heated and Photoionized Regions

- In shock-heated and photoionized clouds, strongest emission lines are basically the same
- strongest lines : HI, He I, [OIII] (optical)
  HI, [CIII], C IV, Mg II (UV)

- But a careful analysis can usually identify the basic energy source

12.7 How to distinguish Shock-Heated and Photoionized Regions

- Utilize [OIII] line ratio
  - In shock ionization
    - gas is collisionally ionized → $kT \simeq \Delta E$
    - $O^{++}: T \simeq 0.5 - 1.0 \times 10^5$ K
  - In photoionization
    - $O^{++}: T \simeq 10^4$ K
  - Precise measurement of [OIII] enables us to distinguish between the two cases
    - most of the remnants are too faint for λ 4363 to be measured.

12.7 How to distinguish Shock-Heated and Photoionized Regions

- Utilize low-ionization lines ([OI], [SII], ⋯)
  - The front strikes → instantaneously heated, ionized
  - → cools by radiation (with Recombination lags)
  - As a result, a long, partly ionized, still heated region is created
  - In this region,
    - Recombination : $O^+ \rightarrow O^0$, $S^{++} \rightarrow S^+$ results in affluent O^0, S^+
    - Also , there are appreciable amounts of e^-(from H^+)
    - Thus , strong collisionally excited [OI], [SII] lines are emitted.

  - On the other hand, photoionization region has few O^0, S^+

12.7 How to distinguish Shock-Heated and Photoionized Regions

- Utilize lines from refractory elements (Ca, Al, Fe)
  - Shocks destroy grains
  - → the refractory elements are returned to the gas phase

  - In photoionized regions, grains survive for substantial times

  - Therefore, the gas-phase abundances of these elements can be diagnostic

12.8 η Car

- class of luminous blue variables
- some of them have $M \geq 100M_{\odot}, L \geq 10^6 L_{\odot}, \tau \leq 3\times10^6$yr
- current luminosity : $L \simeq 5\times10^6 L_{\odot}$
- Temperature : $T \simeq 30{,}000$K
- stellar radius : $\simeq 0.4$ AU
- mass loss rate : $5\times10^{-4}\ M_{\odot} yr^{-1}$

12.8 η Car

- luminous blue variables
  - only marginally stable (L/M is close to the Eddington limit)
  - leave the main sequence and evolve into giants
  - then undergo mass loss
  - finally, become Wolf-Rayet stars and supernovae

12.8 η Car

- The combined radiation of the 36 known O stars ionizes and heats the surrounding Carina nebula
- Dust extinction reddening : R ~ 4 (larger than average)
  - due to larger *grain size*
- The presence of M supergiants with age $\sim \mathbf{10^7}$ yr
  - η Car itself is much younger
- visual apparent mag : 2 ~ 4 (variable)
- The most recent major outburst
  - occurred between 1837 and 1856
  - the star reached $m_V = \mathbf{0 \sim -1}$

12.8 η Car

- The “Homunculus Nebula”
  - The two lobe(shell)-like ejecta around the η Car star
  - Expansion velocity : $650\ km/s$
  - Two lobes have diameters of roughly 0.1 pc
  - Formation process of this the bipolar flow is not well understood
    - rapid stellar rotation
    - a binary companion

12.8 η Car

- Dust
  - Dust must have formed within the Homunculus Nebula
  - Dust temperature ~ radiative energy temperature
    - $T = (U/a)^{1/4}$, a : radiation constant
  - Dust sublimation temperature ~ 1000K
    - which corresponds to 0.003 pc

12.8 η Car

- Other ejecta
    - Emission-line regions are also found outside the Homunculus Nebula
    - H II region-like spectra
    - components:
        - $He/H \sim 4(He/H)_{\odot}$
        - $C/H, O/H \sim 0.1\ (C/H, O/H\ )_{\odot}$
        - $N/O \sim 40(N/O)_{\odot}$
    - strongly affected by CNO nuclear processing → late stages of its evolution