Giant HII Regions in M 101: X-ray and Hlpha-line spectra property

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Introduction

- Massive star formation regions are excellent astrophysical laboratories to study the co-evolution of multi-phase gases;
- Giant HII regions (GHRs) are sites of active star formation and have a wide range of X-ray properties, e.g., 30 Doradus (Townsley et al. 2006), NGC 604 (Tüllmann et al. 2008) vs. IC 131 (Tüllmann et al. 2009);
- ▶ NGC 5461, NGC 5462 and NGC 5471 are three GHRs in M 101 with distinct optical morphologies (Chen et al. 2005);
- ▶ NGC 5471B has been suggested to be a "hypernova remnant" (Wang 1999).



▶ large-velocity-width source (LVWS): H α line at NGC 5471B containing an extra broad component $\gtrsim 100$ km s⁻¹;

0.01 5×10-

2×10⁻

10⁻ 5×10⁻

contours);

the B-knot

- X-rays only exist at knot-B, so do broad components of Hα-lines (solid

Extra broad components only exist at

- Prominent thermal emission of

0.18 keV, $L_{\rm X} \sim 10^{39}$ erg s⁻¹;

- E_{th} of order 10^{52} erg.

Result: NGC 5471



the re-construction of normal (dashed contours) and broad (solid contours) components of $H\alpha$ -line fitting overplotting on $H\alpha$ image



- Assuming Sedov-Taylor evolution:
 - \triangleright remnant age: $3.4 imes 10^4$ yr,
- comparable to the time PDS phase starts, so do the remnant radius; \rhd shock velocity: 340 km s^{-1},
- consistent with the extreme velocity offset of the H α -lines; \triangleright explosion energy: 1.5×10^{52} erg, comparable to $E_{\rm th}$:
- in favor of the "hypernova remnant" scenario;
- \blacktriangleright mass of the internal clusters: less than $10^5~{
 m M}_{\odot}$
- cannot launch such luminous X-ray emission according to the theoretical work (Stevens & Hartwell 2003; Oskinova 2005);
- \blacktriangleright the energy deposited in warm ionized gas ($\sim 10^{52}$ erg) is comparable to that in hot gas
 - similar to the situation in 30 Doradus.

Conclusions on NGC 5471

- ► X-rays only exist at knot B the "hypernova remnant" candidate;
- ► NGC 5471B as LVWS: extra broad components in Hα-lines only exists at NGC 5471B all across NGC 5461 and NGC 5471;
- X-ray quantitative analysis suggests and favours the "hypernova" scenario of NGC 5471B.

Major Data

- X-rays: available segments in the observations of M 101 (Kuntz & Snowden 2010) + a short exposure towards NGC 5471 (PI: Q. D. Wang)
- \blacktriangleright H α echelle spectra: taken on KPNO 4m telescope fully covering NGC 5461 and NGC 5471 (PI: Y.-H. Chu)



in favor of the cluster wind scenario.



May be a sign of past violent process;

- multi-band: red: Spitzer IRAC 3.6 μm, green: HST F656N, blue: Chandra ACIS 0.3-1.5 keV
- ► X-ray tri-color: red: 0.3-0.7 keV, green: 0.7-1.5 keV, blue: 1.5-7.0 keV
- spectral color coding: black source spectrum, red background spectrum, dotted line - fitting components