Excitation Mechanisms of Supernova Remnants in the UWIFE and UWISH2 Surveys
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Abstract
We have searched for near-infrared [Fe II] (1.64 μm) and H₂ 1-0 S(1) (2.12 μm) emission features associated with Galactic supernova remnants (SNRs) using the narrow-band imaging surveys UWIFE / UWISH2 (UKIRT Widefield Infrared Survey for [Fe II] / H₂). By this time, we have found 19 [Fe II]- and 18 H₂-emitting SNRs, and these are likely to increase in future as we inspect the images in more detail. Some of the SNRs show bright, complex, and interesting structures that have never been reported in previous studies.

Among the SNRs showing both [Fe II] and H₂ emission lines, some SNRs show the "[Fe II]-H₂ reversal" phenomenon, i.e., the H₂ emission features are detected outside the [Fe II] emission boundary. In this presentation, we show several examples of such SNRs detected in our study, and present high resolution (R~40,000) H and K-band spectra of H₂ emission features obtained by using IGRINS (Immersion Grating Infrared Spectrograph).

Introduction

1. Excitation Mechanisms of [Fe II] emission
(a) Radiative Atomic Shock
→ The radiative atomic J-shock (v < 200 km/s) make extensive partially ionized zone behind of the shock front: post-shock cooling region.
→ Strong UV ~ X-rays from the shock front can also make partially ionized zone ahead of the shock front: radiative precursor.
(b) Non-thermal Radiation
→ Strong UV ~ X-rays from non-thermal sources (e.g., pulsar wind nebula in Crab Nebula) can produce [Fe II] emission lines.

2. Excitation Mechanisms of H₂ emission
(a) Supernova Shock (Non-dissociative C-shock or Fast J-shock)
→ The slow C-shock (v < 50 km/s) can excite H₂ gas without any dissociation of the molecule.
→ Magnetic / radiative precursor; ahead of the fast J-shock front, can make warm region, where the H₂ gas can be collisionally excited.
→ H₂ lines can be arising from reformation of H₂ molecules in far downstream of the fast J-shock (v > 100 km/s).
(b) Non-thermal Radiation
→ H₂ gas can be heated by strong synchrotron radiation and/or cosmic rays (e.g., pulsar wind nebula in Crab Nebula).

3. Purpose of this Study
■ The two complementary [Fe II] / H₂ imaging surveys together with the following NIR spectroscopy, can help us understand not only the environment and evolution of the individual SNRs but also statistical properties of the Galactic SNRs.

Observations & Detection Summary

1. UKIRT Widefield Infrared Survey for [Fe II] (UWISE) / H₂ (UWISH2)
■ Coverage: 7 < l < 62°; -1.5 < b < +1.5
■ Includes 79 SNRs or 27% of the known Galactic SNRs (# = 294 in Green 2014)
■ Filter: [Fe II] (1.64μm) / H₂ 1-0 S(1) (2.12μm) narrow band, respectively

2. Observation Summary

<table>
<thead>
<tr>
<th></th>
<th>UWISH2</th>
<th>UWIFE</th>
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<tbody>
<tr>
<td>Exp. Time</td>
<td>Total per-pixel integration time ~ 720 seconds</td>
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<tr>
<td>Seeing</td>
<td>~ 0.73’in K-band</td>
<td>~ 0.80’in H-band</td>
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<tr>
<td>Detection limits (@5σ)</td>
<td>10⁻¹⁸ W m⁻² arcsec⁻²</td>
<td>8.1 x 10⁻¹⁸ W m⁻² arcsec⁻²</td>
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Results

1. Detection Summary
■ 19 [Fe II]-emitting and 18 H₂-emitting SNRs (out of 79).
→ Detection rate ~ 20% ~ 60% of newly confirmed
→ Likely to increase in future
■ More than a half of the SNRs have the both emission features.
→ Will investigate the relation in more detail.

2. "[Fe II]-H₂ reversal" in UWIFE and UWISH2

3. Follow-up NIR spectroscopy using IGRINS

| Observation Summary |
|---|---|
| Instrument | IGRINS @ McDonald 2.7-m |
| Band Coverage | H and Ks band, simultaneously |
| Resolving Power | ~40,000 (7 km/s) |
| Target | G11.2-0.3, Kes 73, and 3C 396 |
| Date | June, 2015 |

■ H₂ line ratios & line width
(1) Thermal line ratio of T ~ 3000K (See right)
(2) Broad line profile with >10 km/s
→ Excited by (SN) shock!
■ What kind of (SN) shock is exciting the circumstellar/interstellar H₂ gas?
→ Remains to be explored...

References