Supernova Remnants in the UWIFE and UWISH2 Surveys

Yong-Hyun Lee[1], Bon-Chul Koo[1], and Jae-Joon Lee[2]

[1]Department of Physics and Astronomy, Seoul National University ; yhlee@astro.snu.ac.kr, koo@astro.snu.ac.kr
[2]Korea Astronomy & Space Science Institute ; leejjoon@kasi.re.kr

Abstract

We have searched for near-infrared [Fe II] (1.64 μm) and H_2 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] / H_2). By this time, we have found 19 [Fe II]- and 18 H_2-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 H_2 emission lines, some SNRs show the "[Fe II]-H_2 reversal" phenomenon, i.e., the H_2 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 H_2 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 H_2 emission

(a) **Supernova Shock (Non-dissociative C-shock or Fast J-shock)**

=> The slow C-shock (v < 50 km/s) can excite H_2 gas without any dissociation of the molecule.

=> Magnetic / radiative precursor, ahead of the fast J-shock front, can make warm region, where the H_2 gas can be collisionally excited.

=> H_2 lines can be arising from reformation of H_2 molecules in far downstream of the fast J-shock (v > 100 km/s).

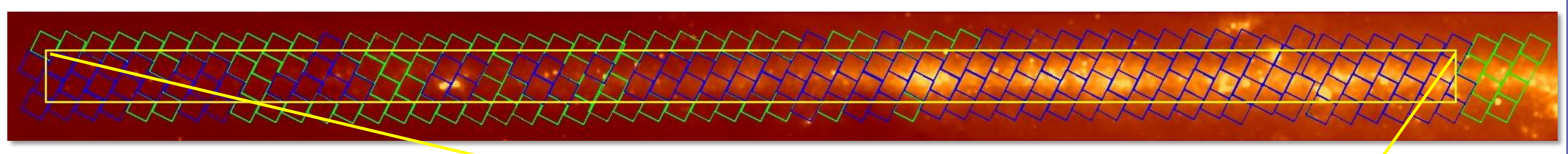
(b) **Non-thermal Radiation**

=> H_2 gas can be heated by strong synchrotron radiation and/or cosmic rays (e.g., pulsar wind nebula in Crab Nebula).

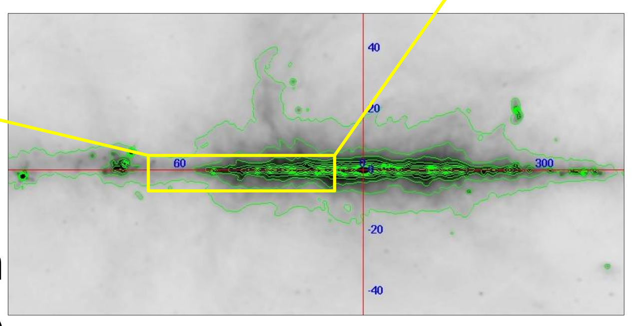
3. Purpose of this Study

■ The two complementary [Fe II] / H_2 imaging surveys together with the following NIR spectroscopy, can help us to 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] (UWIFE) / H_2 (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) / H_2 1-0S(1) (2.12μm) narrow band, respectively

2. Observation Summary

	UWISH2	UWIFE
Survey Progress	28 July 2009 ~ 17 Aug. 2011	20 June 2012 ~ Aug. 2013
Exp. Time	Total per-pixel integration time ~ 720 seconds	
Seeing	~ 0.73" in K-band	~ 0.80" in H-band
Detection limits (@ 5σ)	K ~ 18 mag 10^{-19} W m^{-2} arcsec^{-2}	H ~ 18.7 mag 8.1 x 10^{-20} W m^{-2} arcsec^{-2}
Reference	Froebrich et al. 2010	Lee, J.-J. et al. 2014

Results

1. Detection Summary

■ **19 [Fe II]-emitting** and **18 H_2-emitting** SNRs (out of 79).

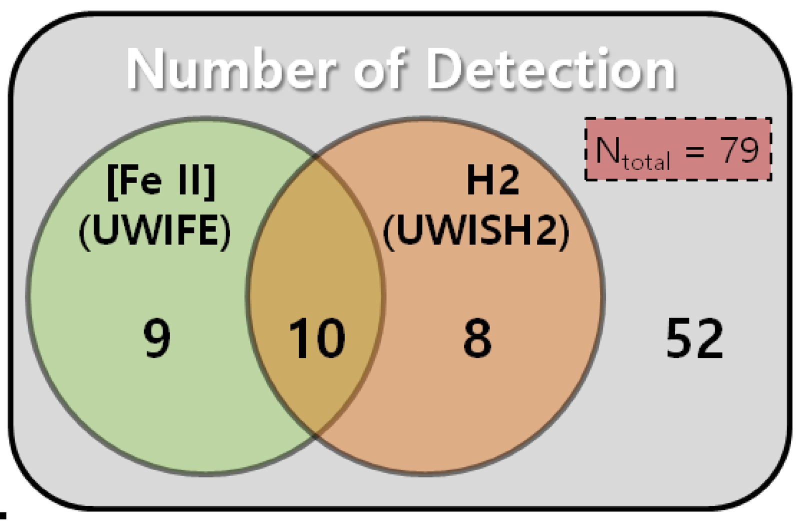
=> **detection rate ~ 20%**

=> **~ 60% of newly confirmed**

=> likely to increase in future

■ **More than a half of the SNRs have the both emission features.**

=> We will investigate the relation in more detail.



2. "[Fe II]-H_2 reversal" in UWIFE and UWISH2

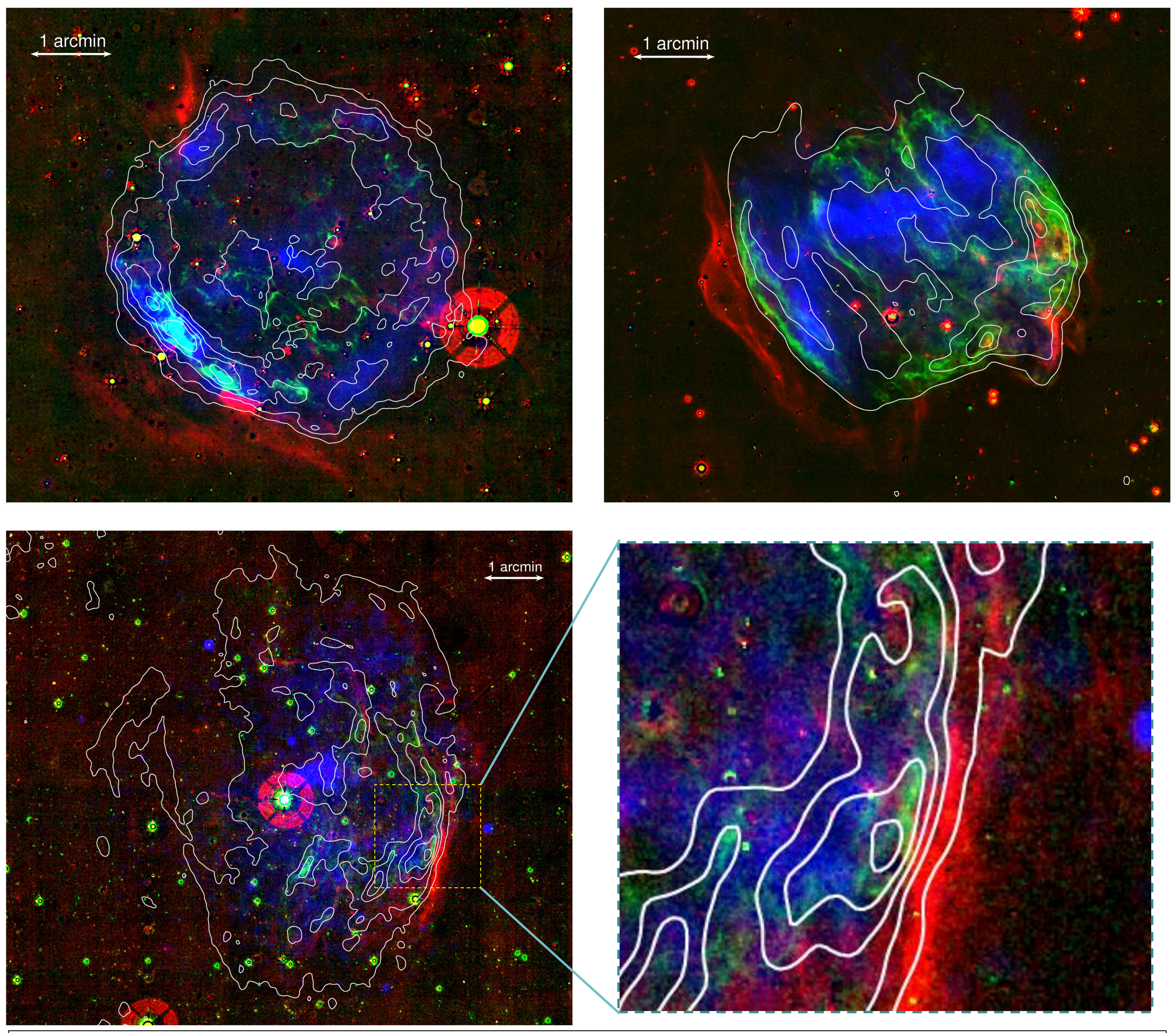


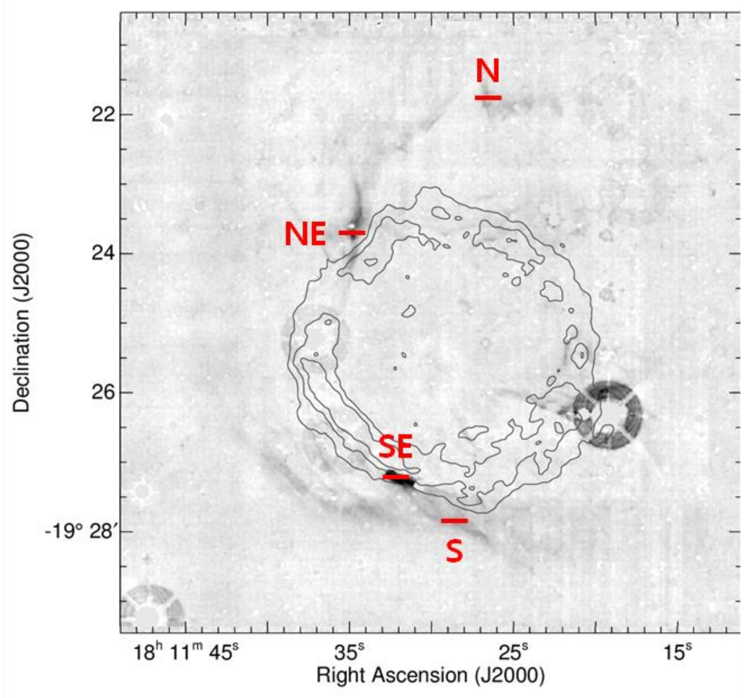
Figure 1: Color-composite images of G11.2-0.3 (top-left), W49B (top-right), and 3C 396 (bottom-left). Radio continuum (white) contours superposed on the 3-color images of H_2-K (red), [Fe II]-H (green), and X-ray (blue). Note that the reddish ring-like features are the diffraction patterns around saturated stars. North is up and east to the left in both images.

■ [Fe II] and H_2 trace fast J-shock and slow C-shocks, respectively.

=> In this scenario, **[Fe II] should be ahead of H_2**

■ In observations, **H_2 emission extends the outside of the radio and [Fe II] emission line boundary.** => **"[Fe II]-H_2 reversal"** problem ! (e.g., Koo et al. 2007, Oliva et al. 1990)

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) @ 2.12 μm
Target	G11.2-0.3, Kes 73, and 3C 396
Date	June, 2015

■ H_2 line ratios & line width

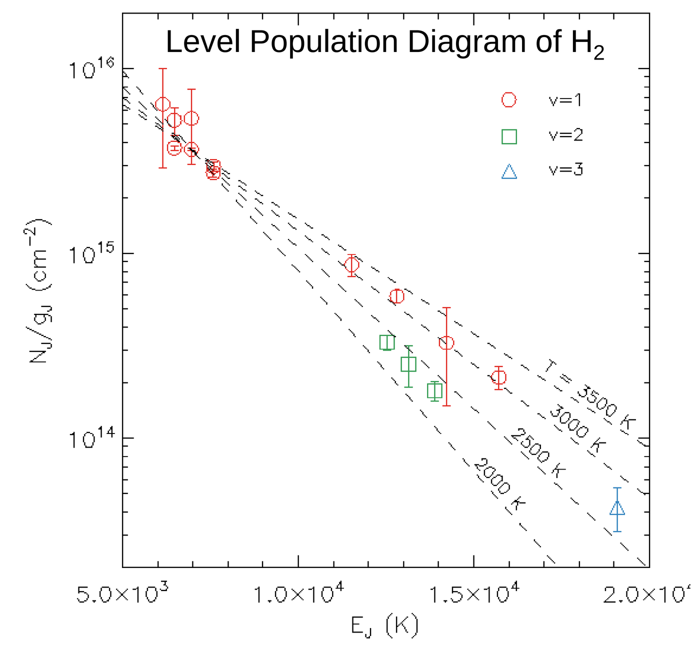
(1)Thermal line ratio of T ~ 3000K (See right)

(2) Broad line profile with >10 km/s

=> **Excited by (SN) shock !**

■ What kind of (SN) shock is exciting the circumstellar/ interstellar H_2 gas?

=> remains to be explored…



■ **References**

(1) Froebrich et al. 2011, MNRAS, 413, 480, (2) Green 2014, BASI, 42, 47, (3) Koo et al. 2007, ApJ, 657, 308, (4) Lee, J.-J. et al. 2014, MNRAS, 443, 2650, (5) Oliva et al. 1990, A&A, 240, 453