Our NIR IFU/MOS observations of SNRs and future application to SWIMS

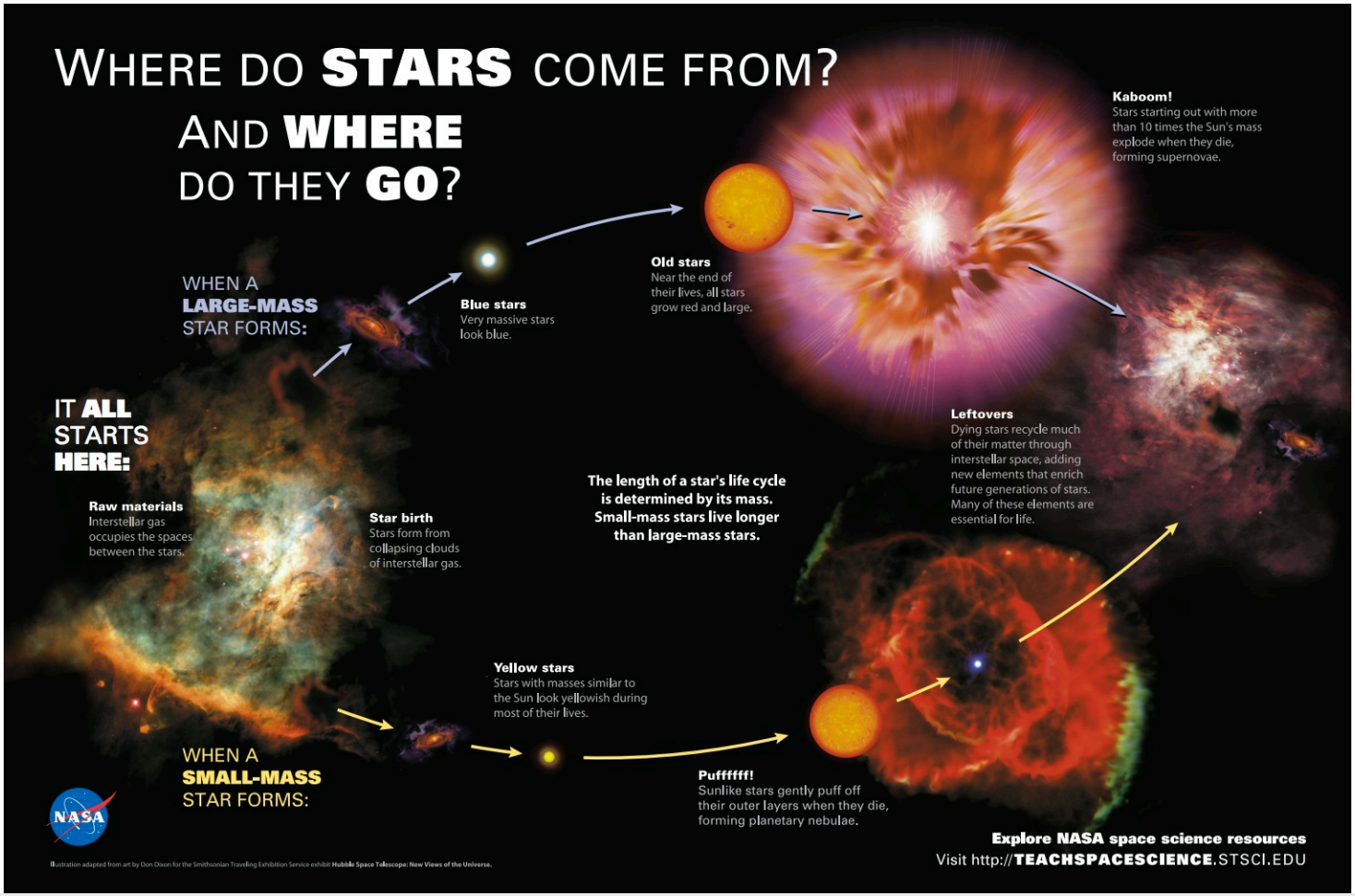
2015 September 18

SWIMS Science Workshop 2015

Ho-Gyu LEE

KASI

ISM & (massive) Stars



Single massive star

- Theoretical scenarios (Maynet et al.)
  - Mass loss!

$M > 90 M_\odot$: O - Of - WNL - (WNE) - WCL - WCE - SN(SNIbc/BH/SNIIn)? (PCSN/Hypernova low Z?)

$60 - 90\ M_\odot$: O - Of/WNL⇔LBV - WNL(H poor)- WCL-E - SN(SNIbc/BH/SNIIn)?

$40 - 60\ M_\odot$: O - BSG - LBV ⇔ WNL -(WNE) – WCL-E - SN(SNIb)
- WCL-E - WO SN (SNIc)

$30 - 40\ M_\odot$: O - BSG - RSG – WNE - WCE - SN(SNIb)
OH/IR ⇔ LBV ?

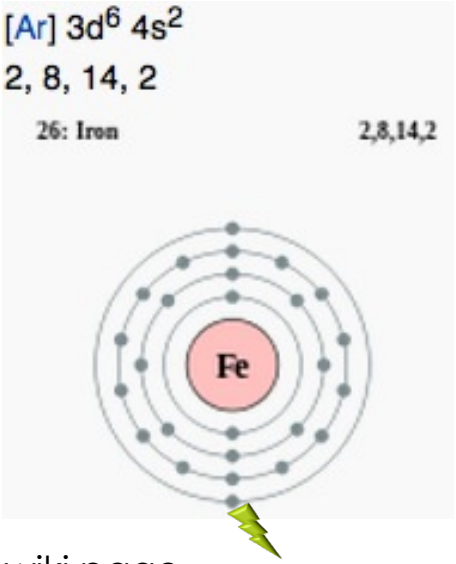
$20 - 30\ M_\odot$: O -(BSG)- RSG – BSG (blue loop) – RSG – SN(SNIIb, SNIIL)

$10 - 20\ M_\odot$: O - RSG - (Cepheid loop, $M < 15\ M_\odot$) RSG – SN (SNIIP)

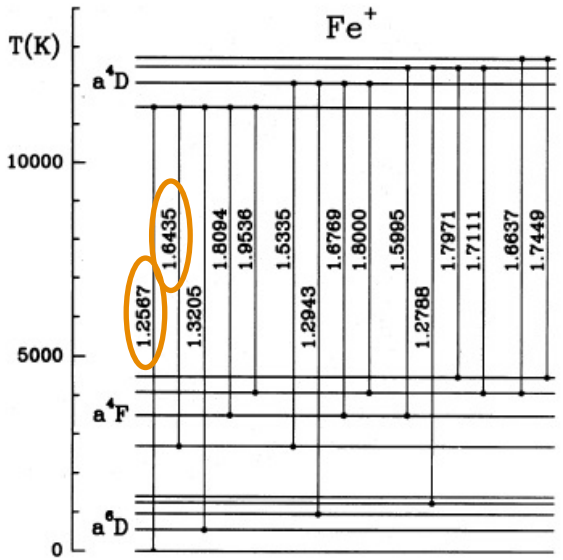
SNRs -> Shocked gas -> [Fe II] lines in NIR

- Forbidden emission from Fe+ (singly ionized Fe)
  - Partially ionized region

Ionization energy
1st : 7.9 eV
2nd: 16.2 eV
cf. H : 13.6 eV

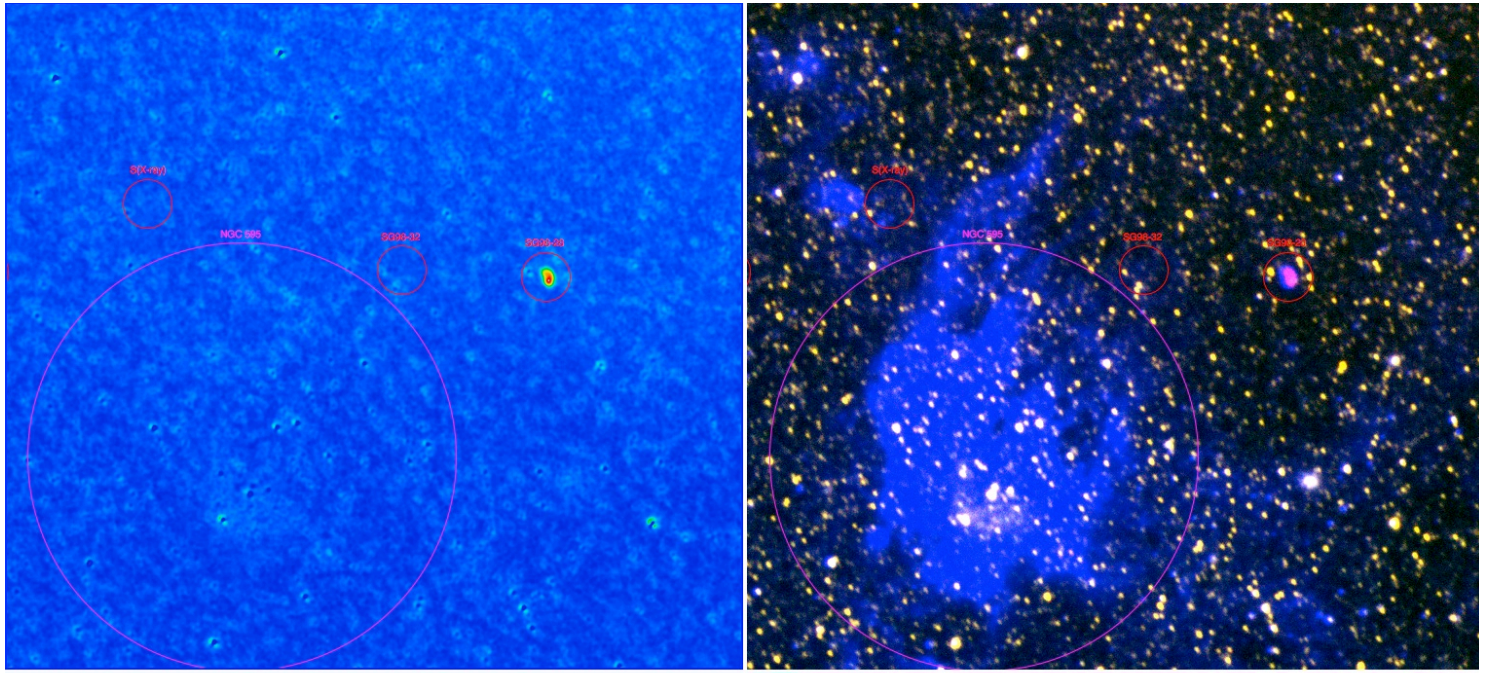


wiki page



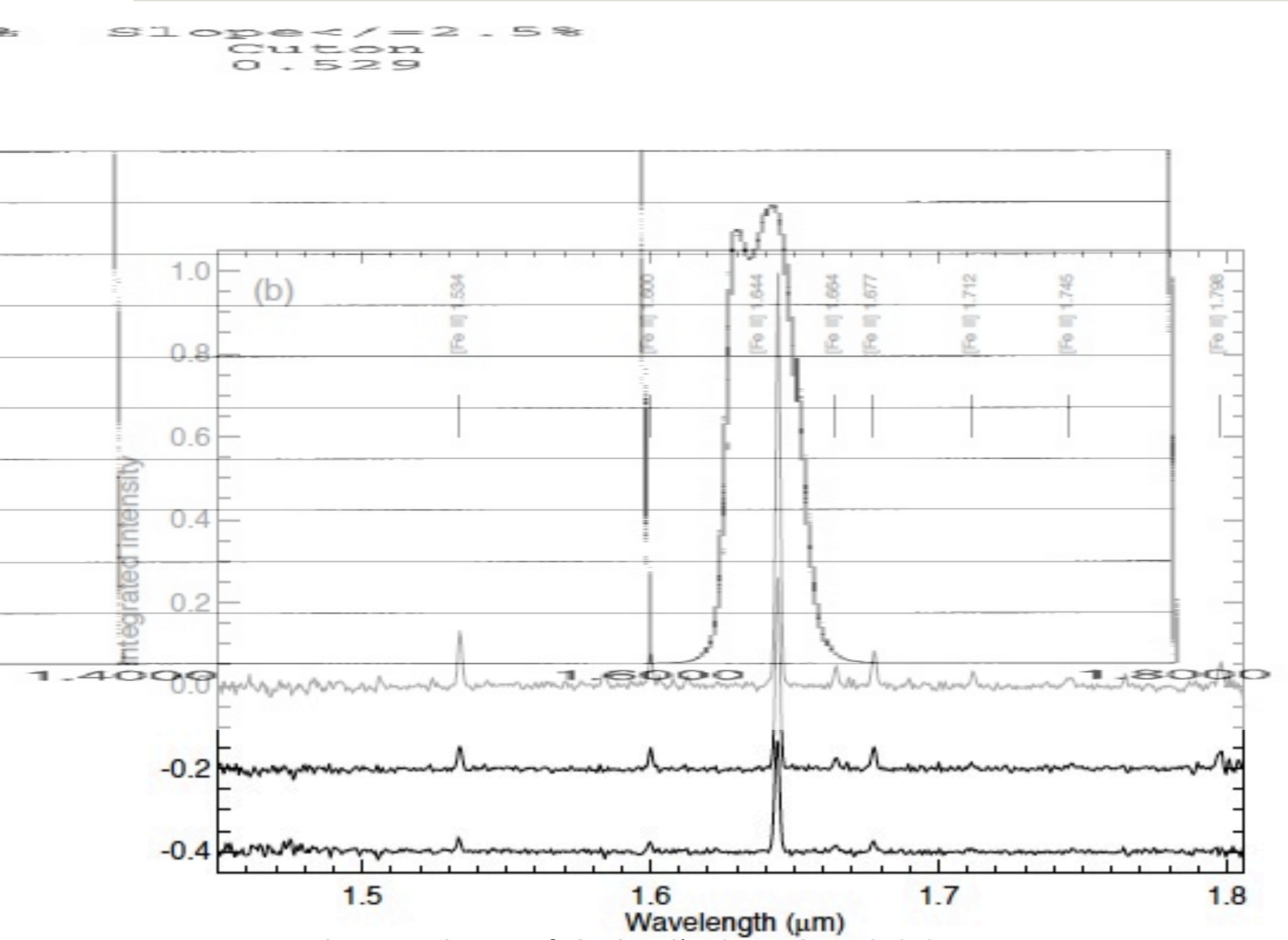
Two distinct lines at 1.26 & 1.64 um (Oliva et al. 1990)

NIR [Fe II] as a shock tracer : SNR G98-28 vs. giant H II region NGC 595 in M33



Star-subtracted [Fe II] ([Fe II]-H)

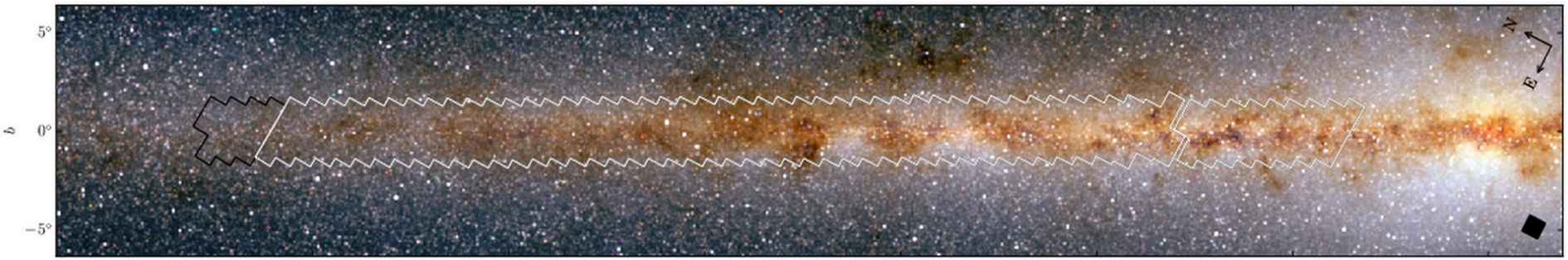
[Fe II]-H:H:Hα (R:G:B)



Example spectrum of Galactic SNR G11.2-0.3

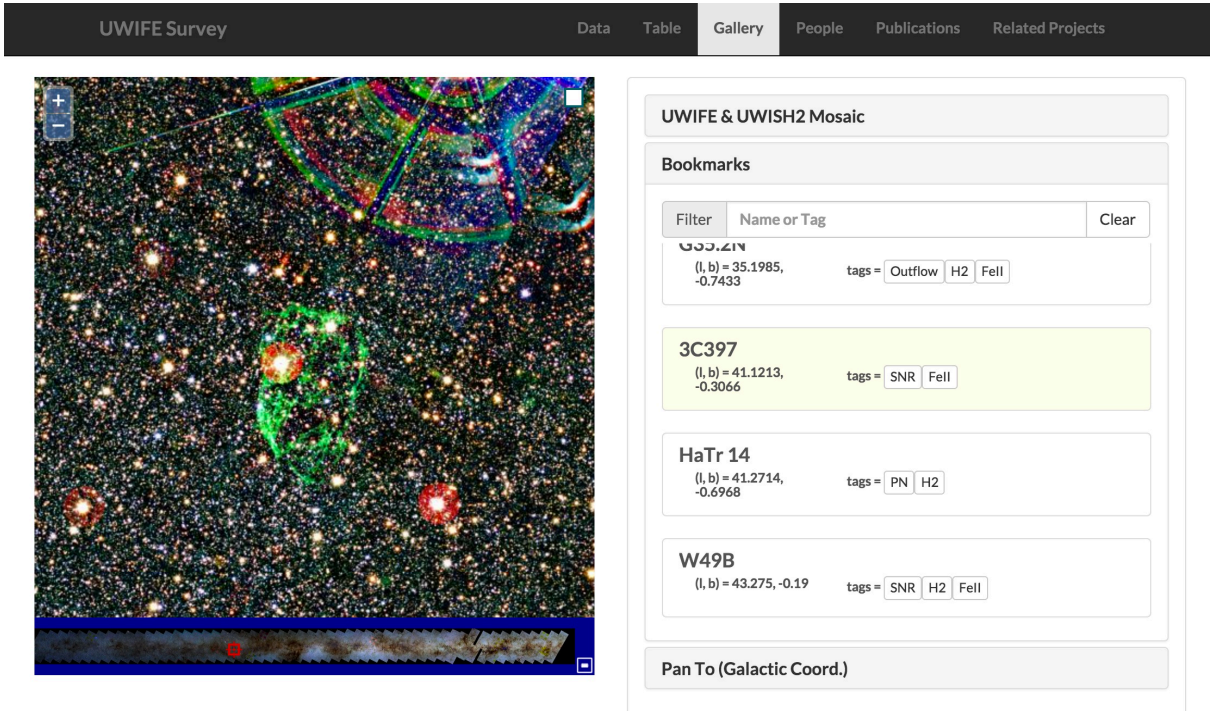
UWIFE survey (Lee, J.-J. et al. 2014)

- UKIRT Widefield Infrared survey for Fe+ (UWIFE)
  - Galactic Plane ($7^\circ < l < 62^\circ$; $-1.5^\circ < b < +1.5^\circ$)
  - WFCAM at UKIRT
  - [Fe II] 1.644 μm narrow band filter
  - Integration time of 720 s
- complement the UWISH2 survey
  - Almost same area with H2 2.12 filter

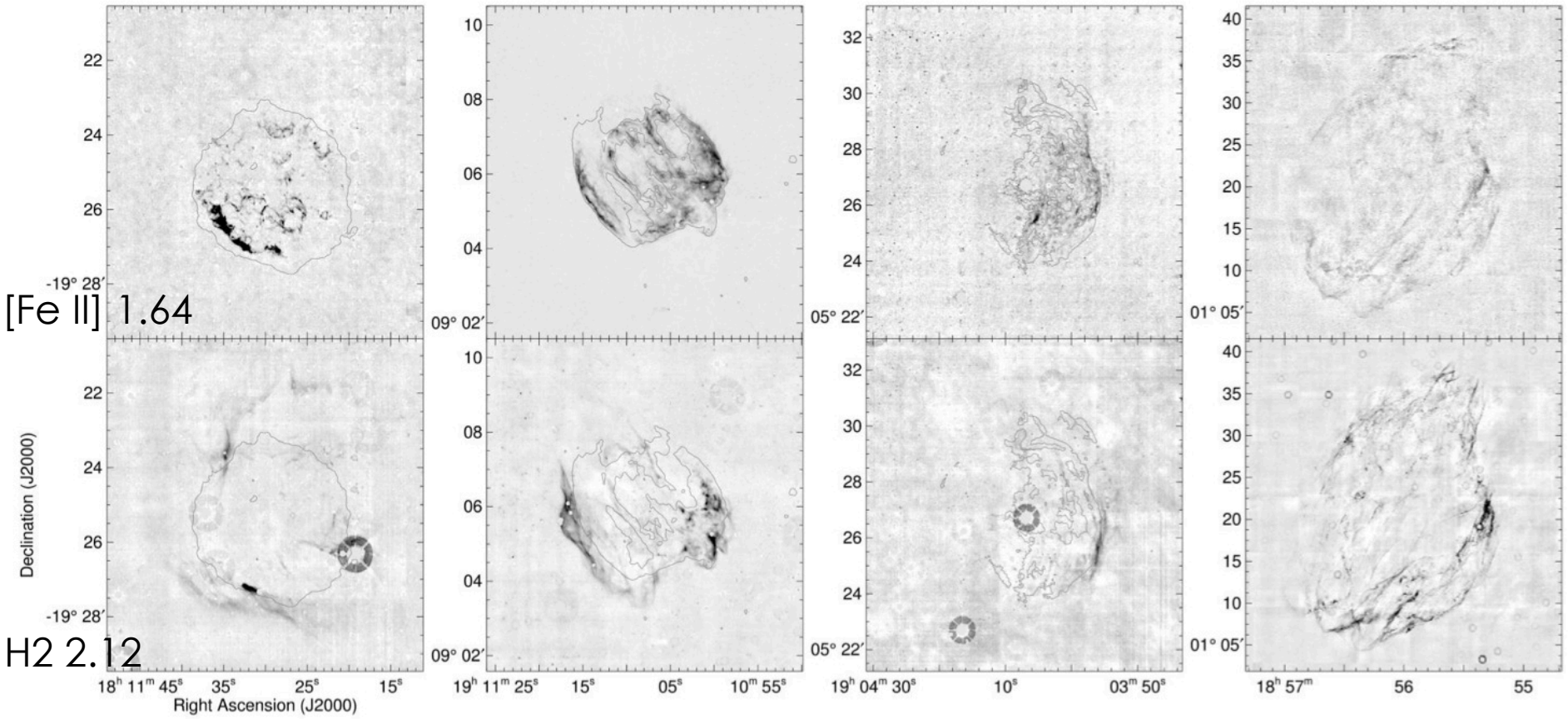


UWIFE page & gallery

- gems0.kasi.re.kr/UWIFE/



Examples of detected SNRS in UWIFE/ UWISH2 (Lee, Y.-H.)



Better than previous images

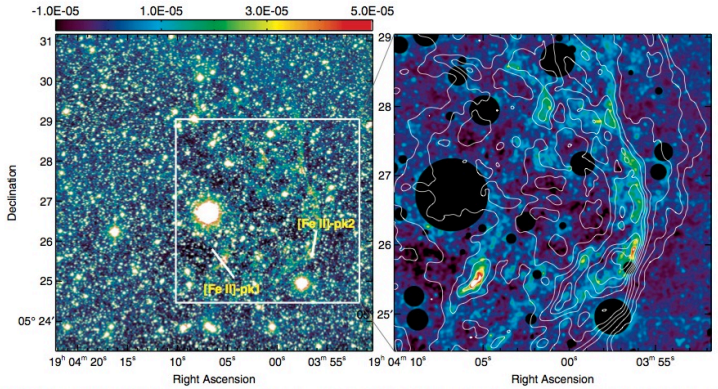


Figure 2. (Left) WIRC image of 3C 396 obtained with the [Fe II] 1.64 μm narrowband filter. The filamentary [Fe II] emission is detected in the western part of remnant distinguished from the pointlike stellar emission. The two slit positions used for the spectroscopic observations are indicated by elongated white bars in the small internal panel. The surface brightness scale range of two panel images is expressed by the color bar at the top in units of ergs cm^{-2} s^{-1} sr^{-1}. (Right) Enlarged image of the panel in the left after the subtraction of stellar emission, superimposed on radio contours. Median-box filtering and Gaussian smoothing are applied to enhance the image quality (see Section 2).

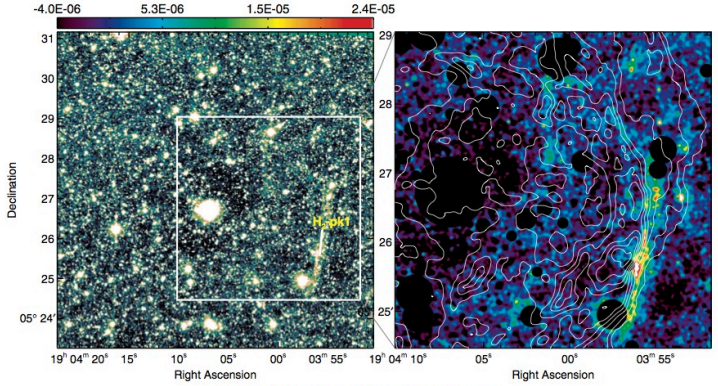


Figure 3. Same as Figure 2 but for the H_2 emission.

Quality (Lee et al. 2009)

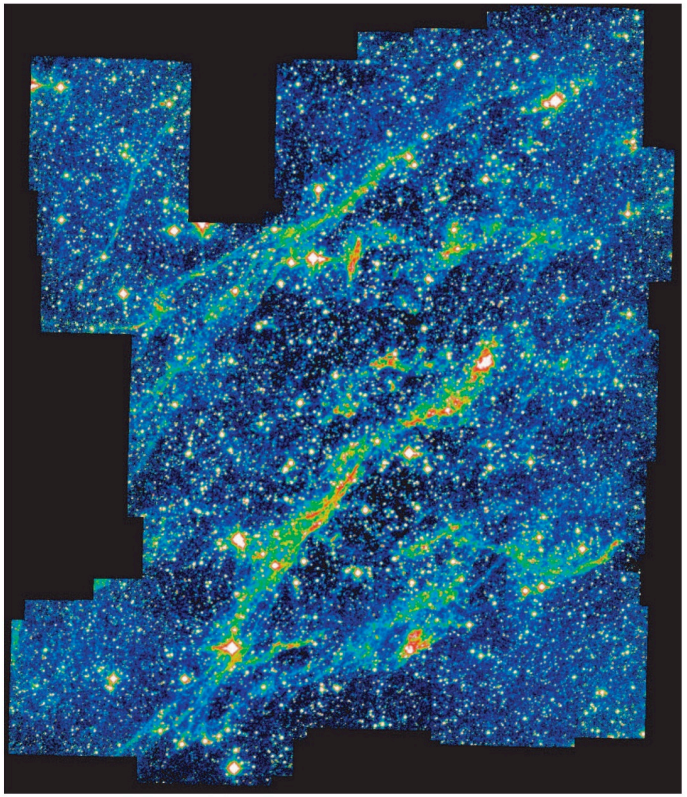
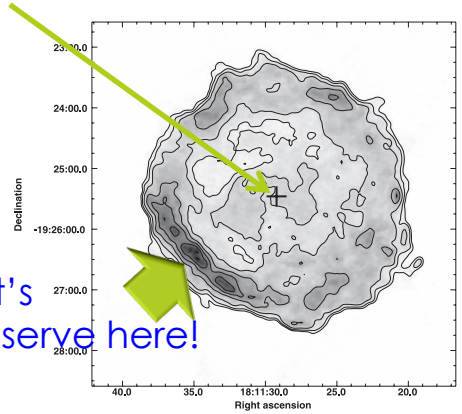


FIG. 10.—Color version of the H_2 2.12 μm image of the southern portion of W44 (Map 2).

Coverage (Reach et al. 2005)

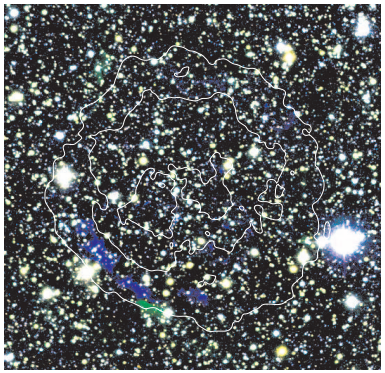
NIR Mayall/IFU observation of G11.2-0.3

Position of pulsar
SN AD386?



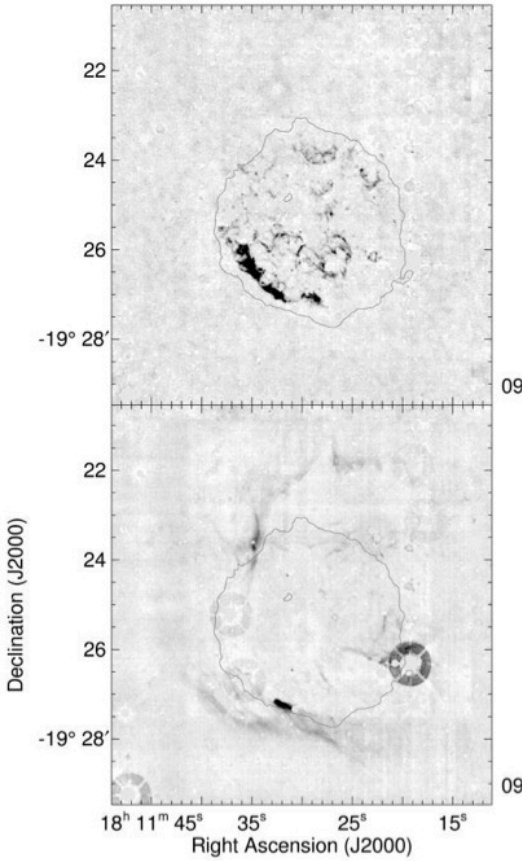
Let's observe here!

VLA 20cm;
R ~ 2' (3pc at d = 5 kpc)
(data from Green 1988)



Palomar K : H2 : [Fe II]

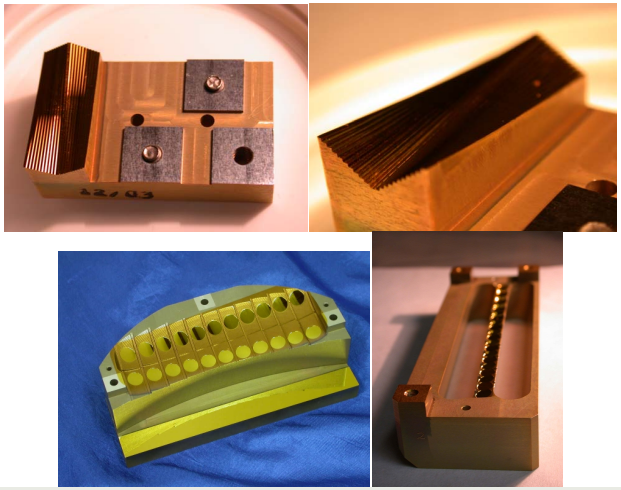
(Koo et al. 2007)



UKIRT [Fe II] & H2

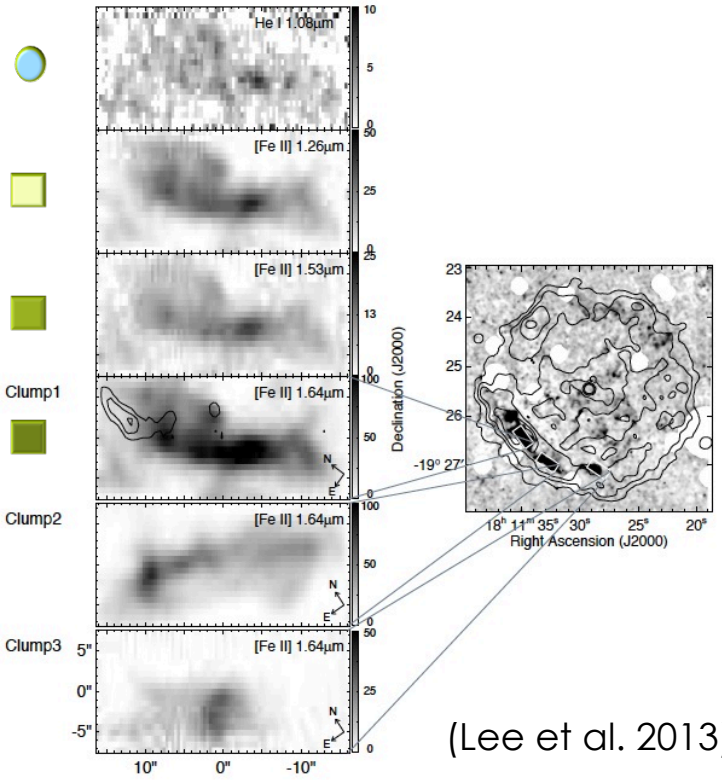
Wide-field Integral field unit (IFU)

- Wide field IFU
  - FISICA + FLAMINGOS on Kitt peak 4m telescope
  - Image slicer : FISICA
    - working like 21 long-slit spectrographs at a single exposure
  - FoV = 16″ x 33″ !

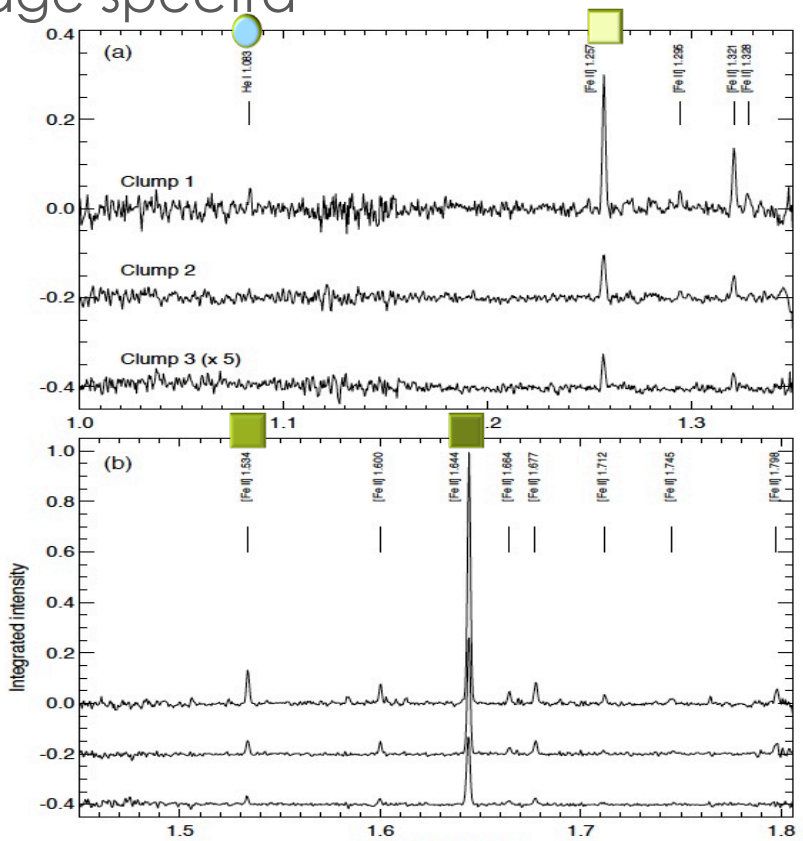


Images & spectra

- Line images and average spectra

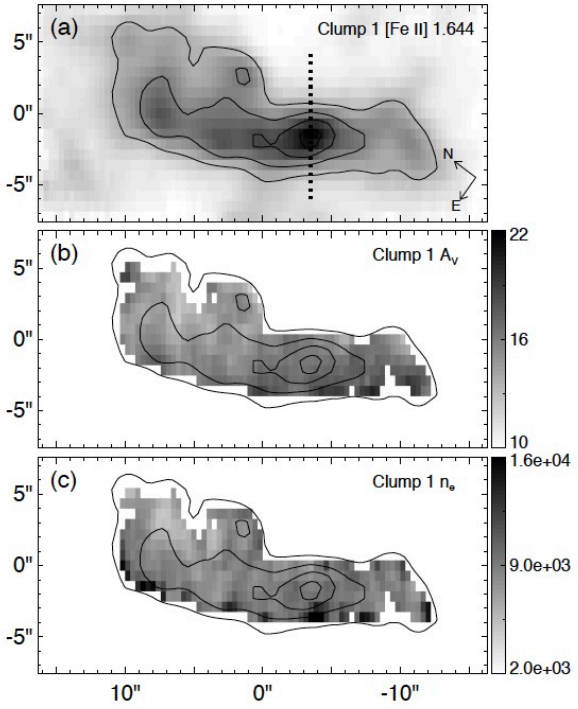


(Lee et al. 2013)

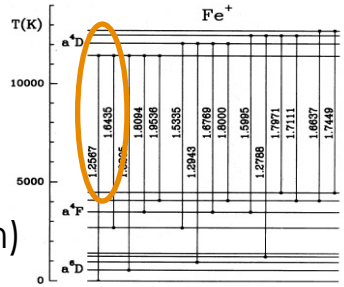


Properties of clump1

- Bright enough to provide distributions in several transitions

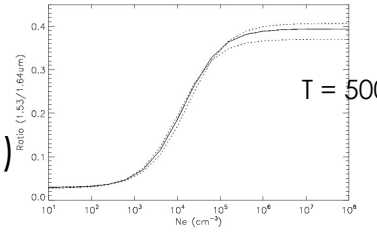


I(1.26)/I(1.64um)



(Transition diagram Oliva et al. 1990)

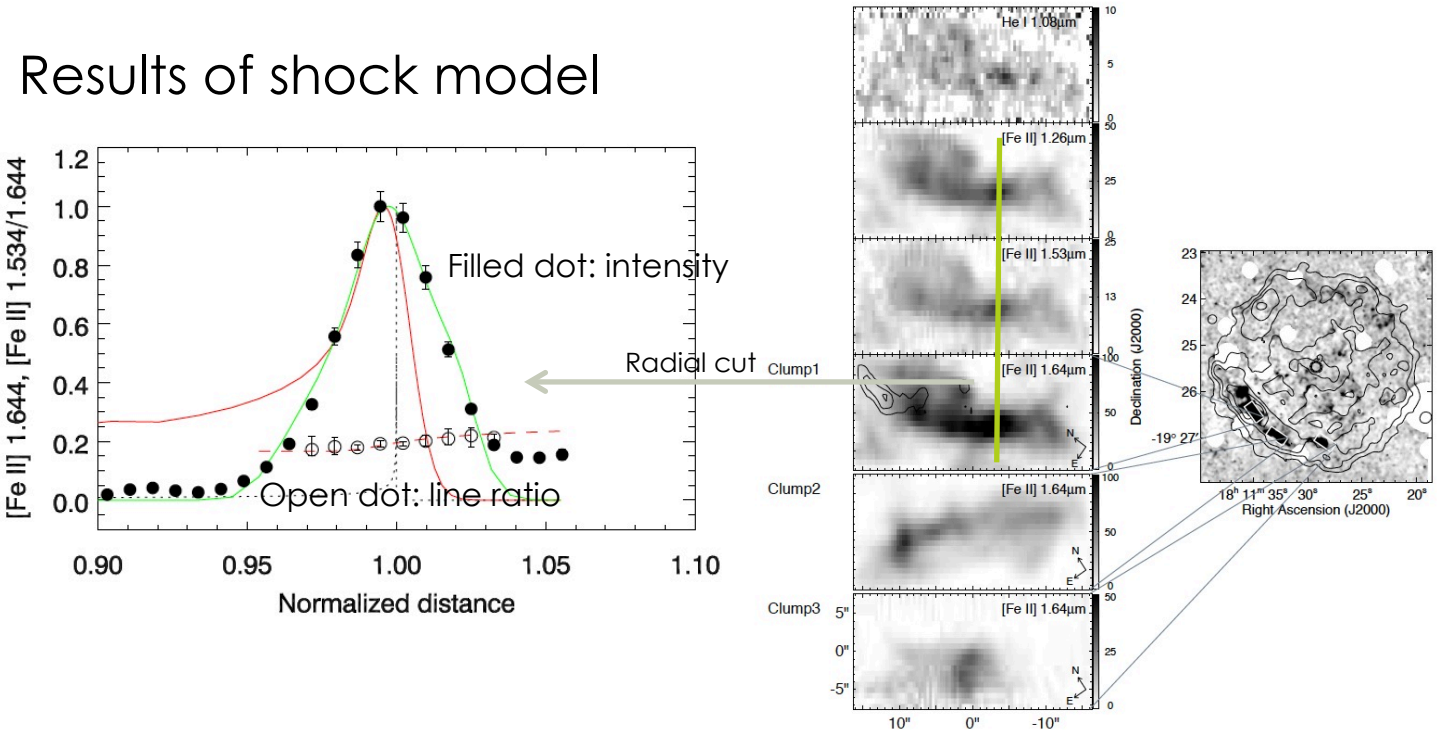
I(1.53)/I(1.64um)



T = 5000 – 10000 K

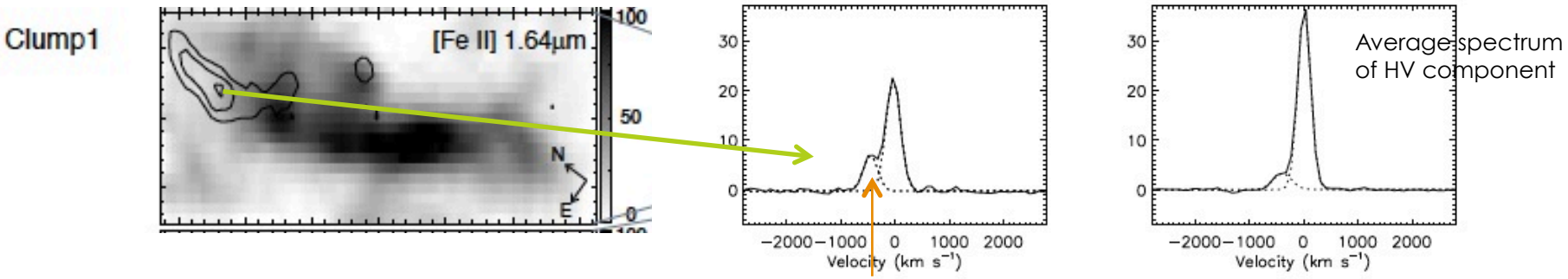
Radiative model for radial profile

- Results of shock model



High velocity component

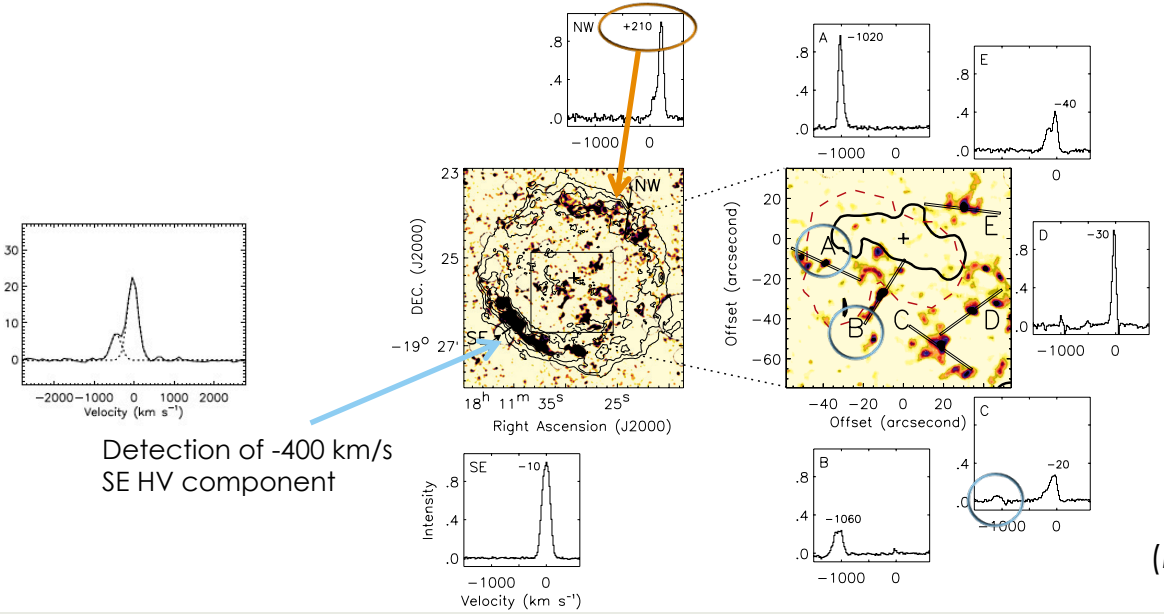
- Contribution by ejecta?
  - Flux of HV component : ~ 4 % of total flux
    - We detect only bright, fast, separated ones
    - Cannot totally exclude a possibility of CSM + ejecta
- Observed velocity ~ 400 km/s
  - Moving speed (de-projected v) can approach to 1000 km/s



Bipolar distribution?

- NW : redshifted component
- SE : blueshifted component

} Hint for bipolarity of SN explosion?



(Moon et al. 2009)

[Fe II]/H?

miniTAO Telescope
Institute of Astronomy, University of Tokyo

Semester : S

miniTAO/ANIR 観測提案書

(Page 1)

1. Title of Proposal（提案題目）

和題 :

English : Near-infrared Paschen line imaging observations of supernova remnant G11.2-0.3

2. Principal Investigator（提案者）

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Institute : The university of Tokyo

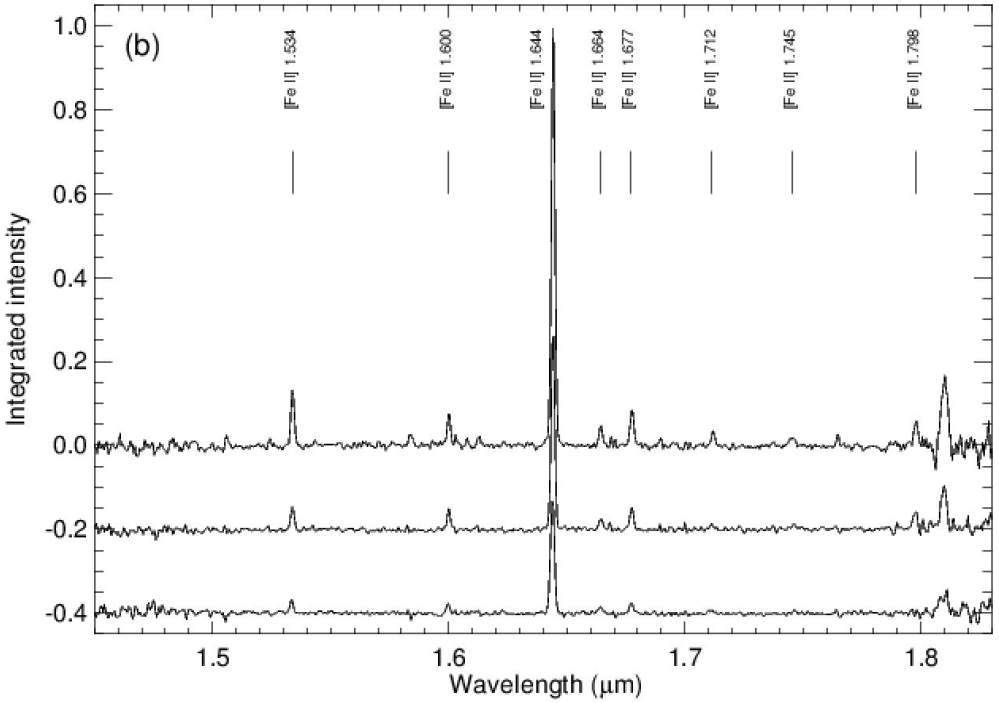
Phone : 03-5841-4268

3. Abstract（提案概要）

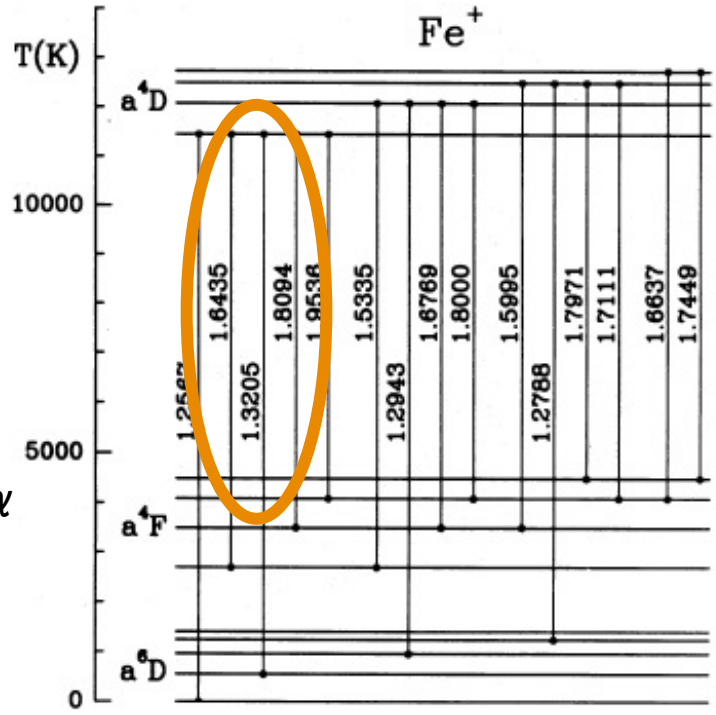
We propose to perform imaging observations of young core-collapse supernova remnant (SNR) G11.2-0.3 using the ANIR narrow-band Paschen filters aboard the miniTAO telescope. G11.2-0.3 is a composite type SNR which has a pulsar at the center as well as surrounding circular shell (radius of 2') structure. The southeastern shell is bright at radio, X-ray, and infrared wavebands. At the southeastern shell, we detected bright [Fe II] emission of which origin is uncertain. It can originate from either swept-up circumstellar medium by the supernova shock or ejected material of the supernova explosion. Comparing the [Fe II] line image with the hydrogen line image, we are to investigate the origin of the strong near-infrared emission detected at G11.2-0.3.

Av > 10

TAO/SWIM can do similar works using one band (H) only



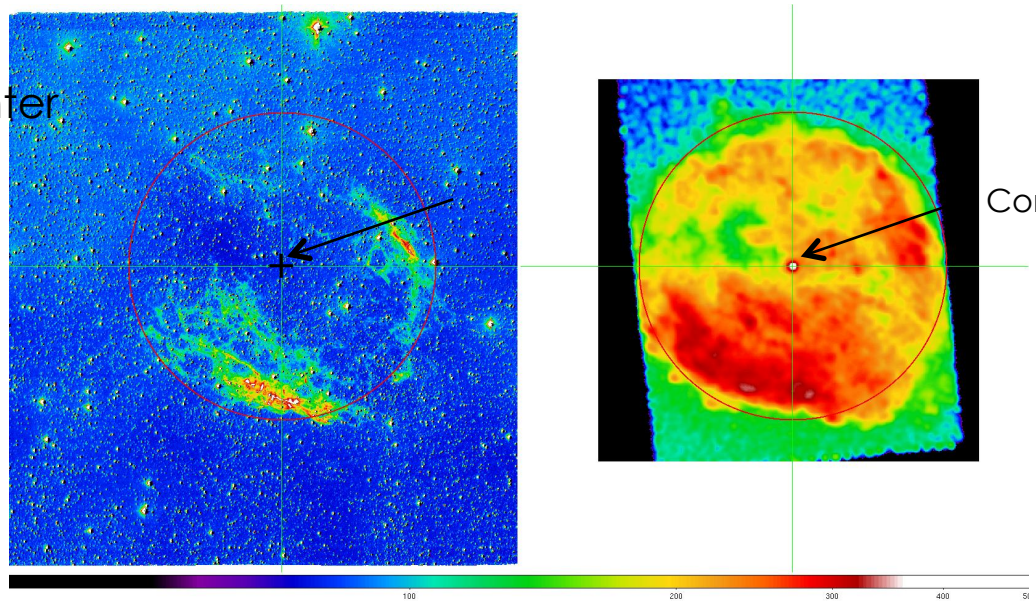
+ Pa α



NIR AAT/IRIS2-MOS observation of RCW103

- One of brightest [Fe II]-emitting SNRs

Offset between X-ray center and [Fe II] center

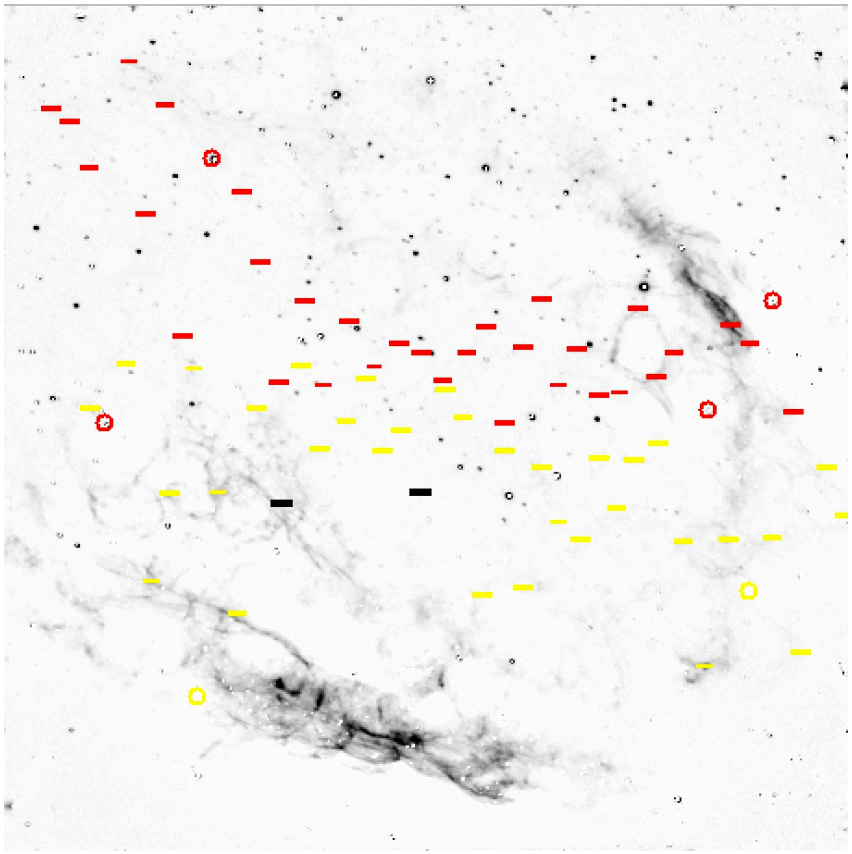


Compact Central Object

d ~ 3.3 kpc
Age < 4000 yrs

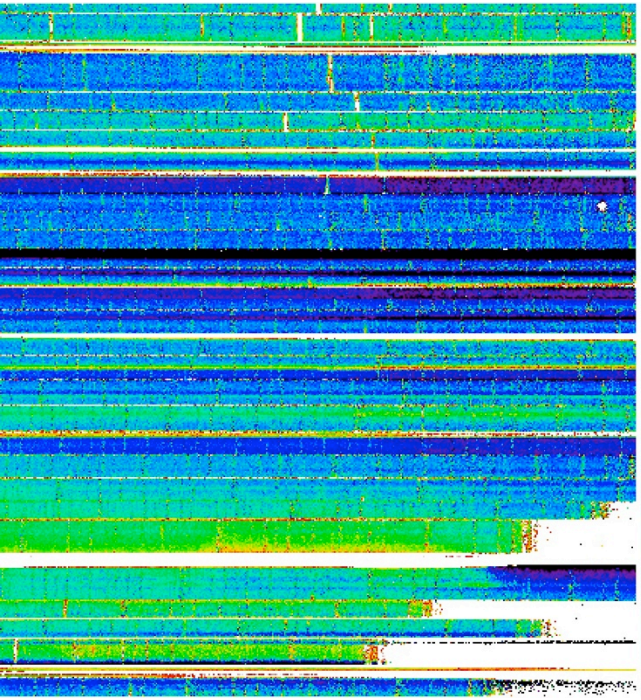
AAT [Fe II] & Chandra X-ray

MOS slit positions

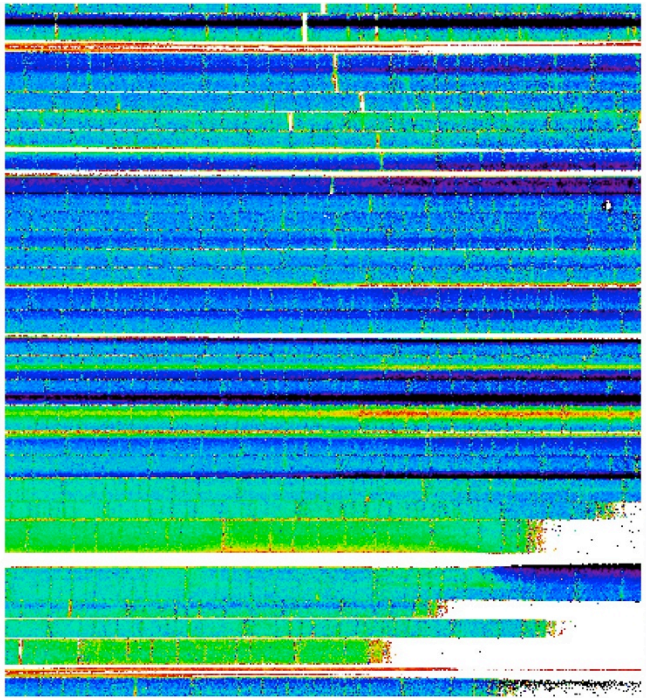


FoV~7.7'
cf. TAO/SWIMS~9.6'

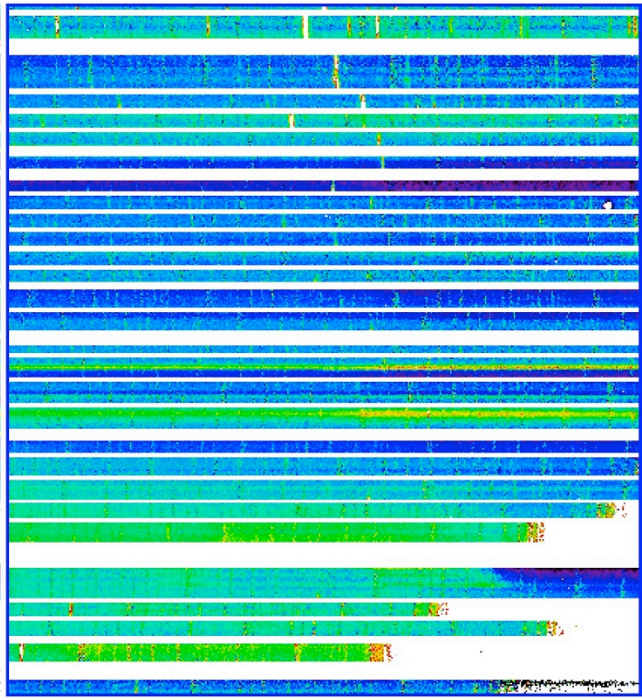
Stacking (two different sky positions)



Sky 1



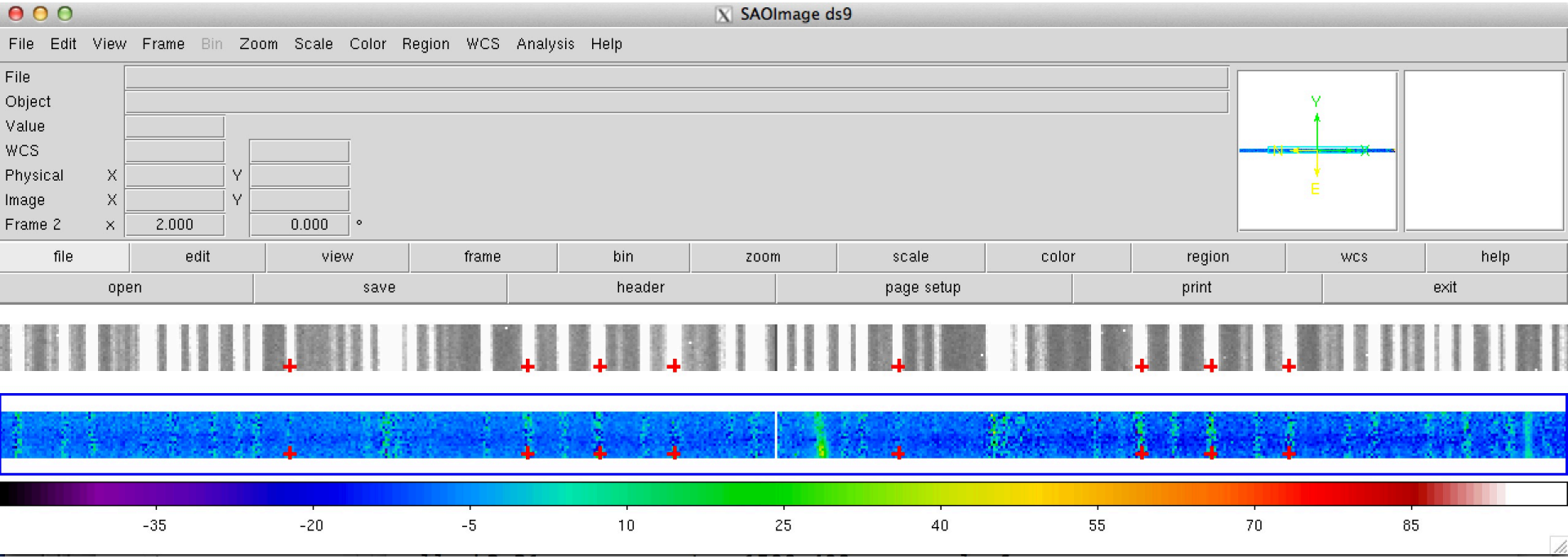
Sky 2



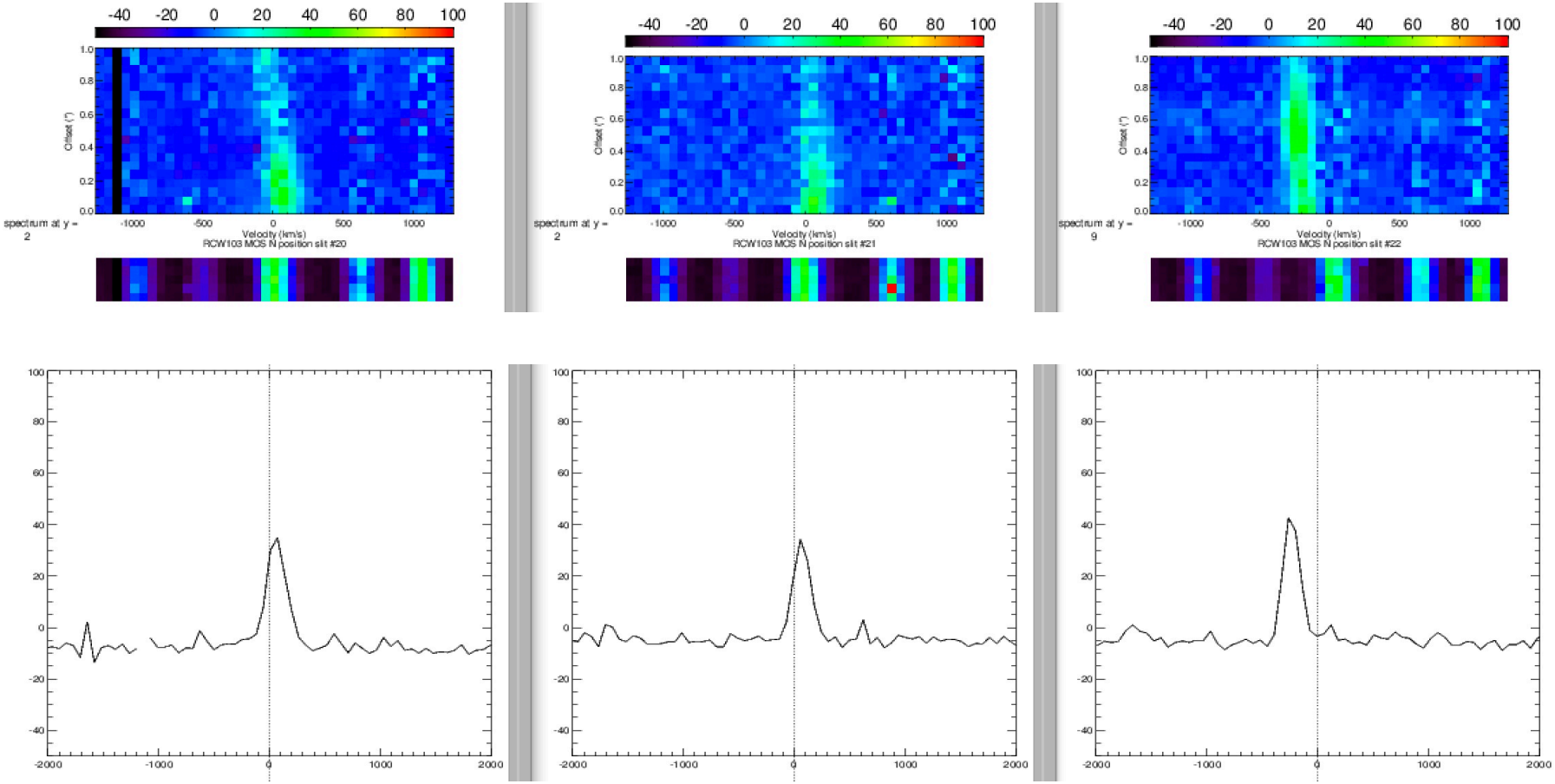
Stacking & masking

Extraction & wavelength calibration

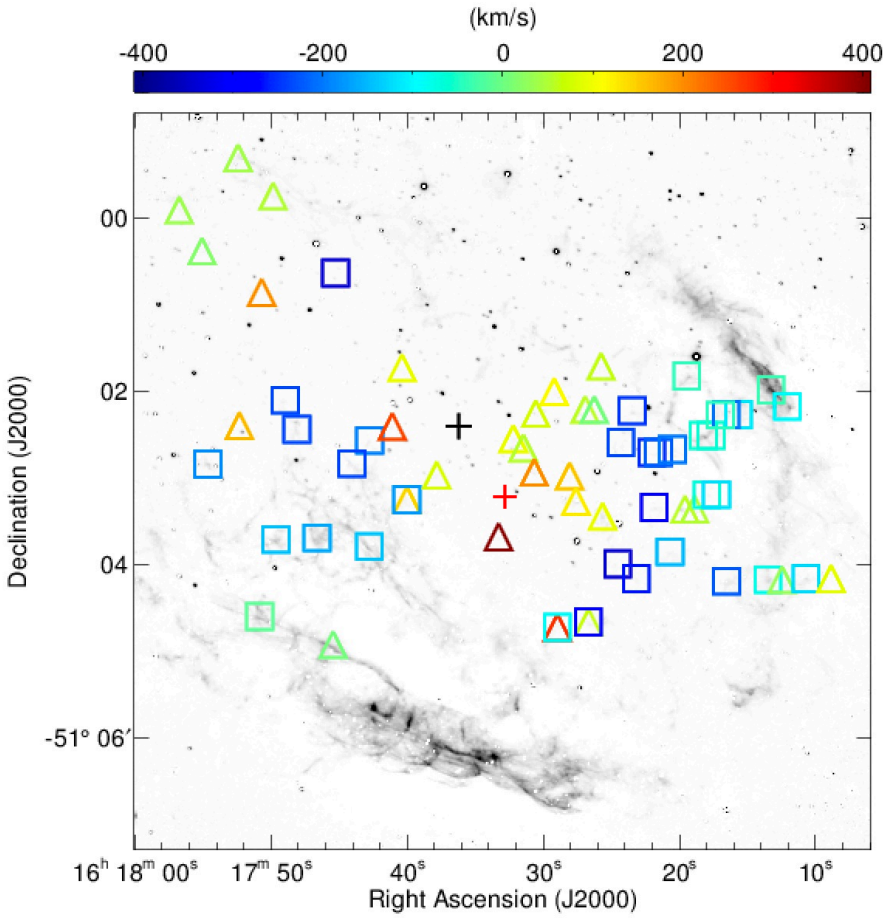
- idl + ds9



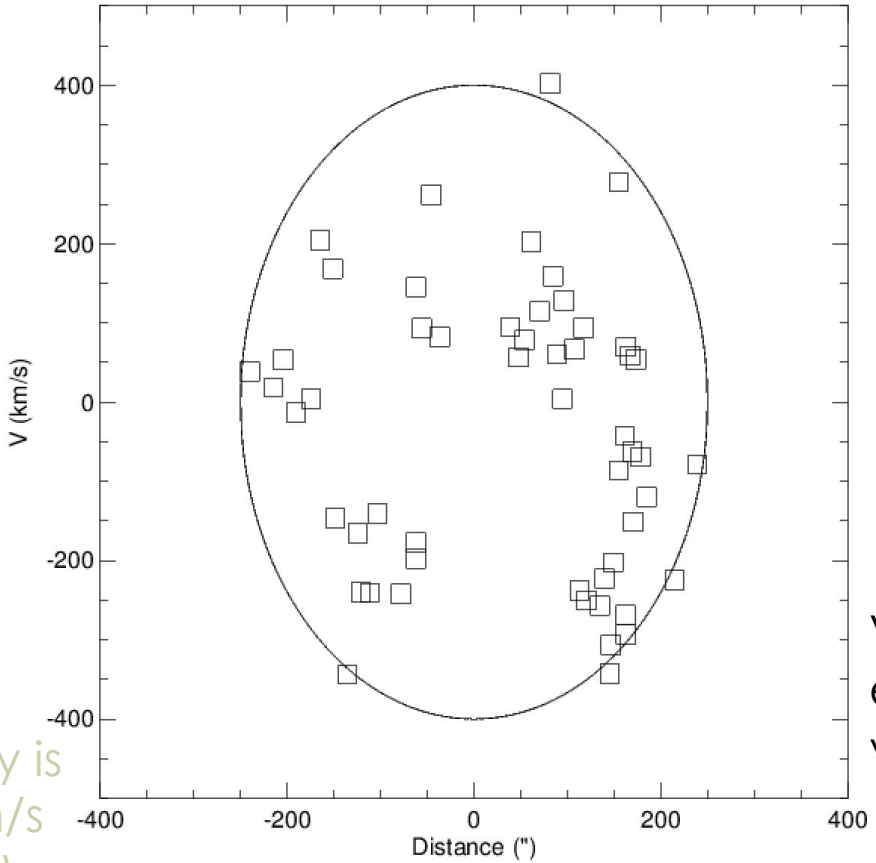
Example spectra

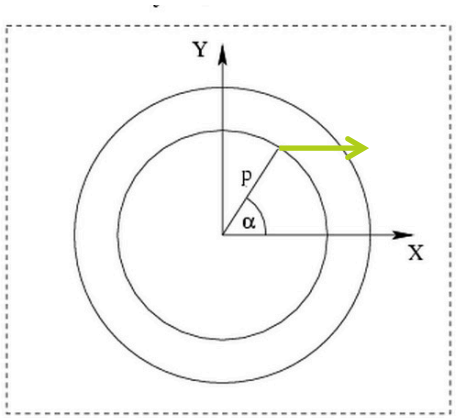


Measured [Fe II] velocity distribution



[Fe II] Velocity vs. distance from CCO E (-) and W (+)





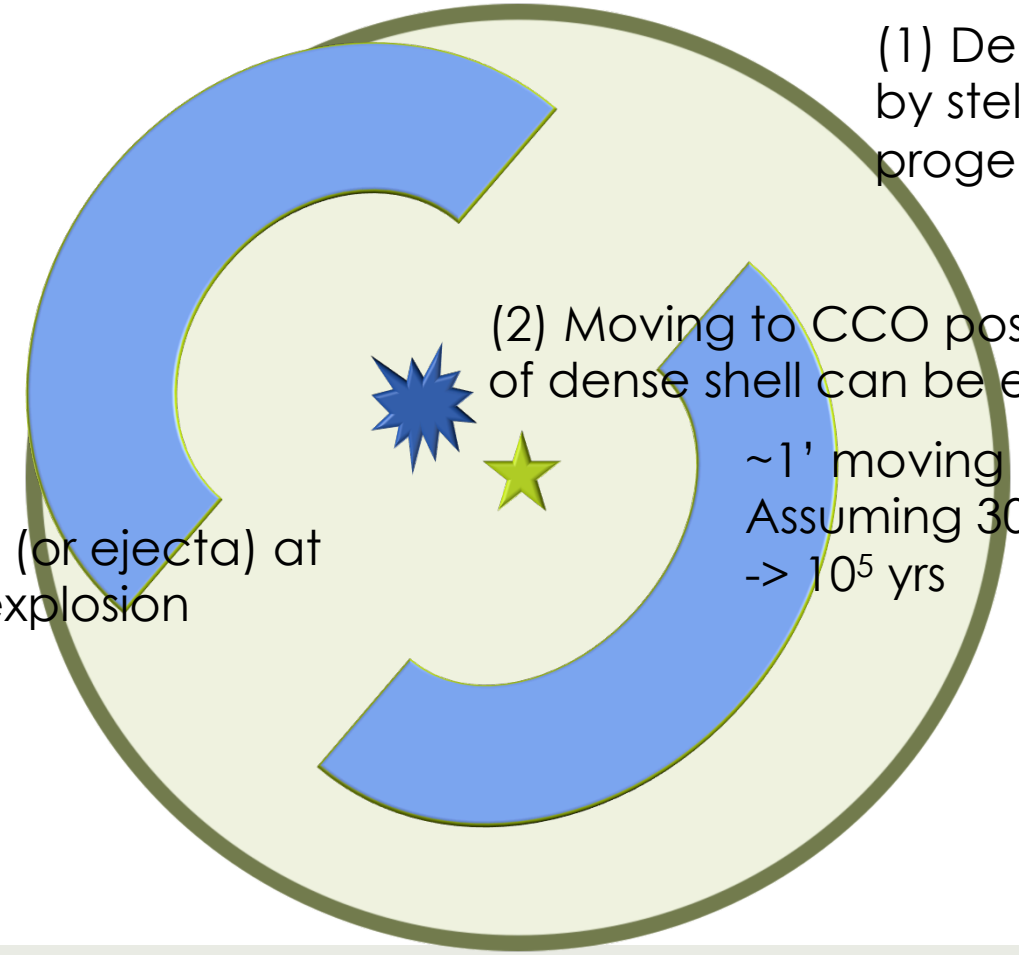
Velocity ellipse assuming expending shell of v=400km/s & r=250"

Systemic velocity is known to ~60km/s (Oliva et al 1999)

Two different [Fe II] origins?

- Fast moving (~400 km/s) [Fe II] expelled at the position of CCO
  - Either ejecta or CSM
- Slow moving dense wind from the center of [Fe II] shell
  - CSM

Possible scenario



(1) Dense shell made by stellar wind of the progenitor

(2) Moving to CCO position (shape of dense shell can be elongated)

~1' moving at 3.3kpc=1pc
Assuming 30km/s motion
-> 10^5 yrs

(3) Fast wind (or ejecta) at the time of explosion

Future plan?

- Telescopes
  - 4 m -> 6.5 - 8 m -> 25 m
- Targets
  - Our galaxy -> Magellanic Clouds, nearby galaxies
  - First priority?
    - Cas A , 1987A
- Features
  - Bright shell -> faint knots

Summary

- NIR [Fe II] is good to trace "shocking" phenomena in sky
- We are doing extensive study using NIR [Fe II]
  - Galactic plane survey (first quarter)
  - Individual imaging and spectroscopy
- Using IFU and MOS, we can find 3D view of SNR :
  - Velocity structure
  - Distribution of faint structure of SNR
- Current and past condition of SNR/SN explosion
  - Understanding for the final stage of massive stars