

SSG workshop

Gemini/GNIRS spectroscopy of SNRs

2019. 2. 22

Ho-Gyu Lee

@SSG workshop/HighOne

Gemini instruments

Gemini North Instruments

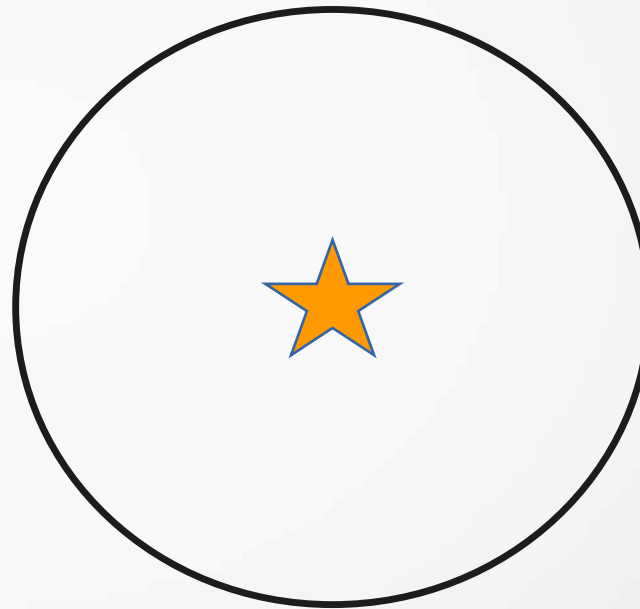
VISIBLE	NEAR-IR	MID-IR	OTHER FACILITIES
Facility Instruments			
GMOS (multi-object, long-slit and IFU spectrograph and imager) Instrument Fact Sheet	NIRI (1-5 μ m imager) Instrument Fact Sheet		GCAL (facility calibration unit)
	NIFS (1.0-2.5 μ m integral field spectrograph) Instrument Fact Sheet		ALTAIR (facility natural/laser guide star AO system)
	GNIRS (1-5 μ m long-slit and 0.9-2.5 μ m cross-dispersed spectrograph; formerly at Gemini South) Instrument Fact Sheet		
Visiting Instruments			
GRACES (0.4-1.0 μ m high resolution spectrograph)			
'Alopeke (diffraction-limited optical imager)			
POLISH2 (optical polarimeter)			
Expected to be available in 2019A. For more info on these or other Visiting Instruments, contact geminivip@gemini.edu			

Gemini South Instruments

VISIBLE	NEAR-IR	MID-IR	OTHER FACILITIES
Facility Instruments			
GMOS (multi-object, long-slit and IFU spectrograph and imager) Instrument Fact Sheet			GCAL (facility calibration unit)
	GSAOI (high-resolution imager for use with Multi-Conjugate Adaptive Optics system "GeMS") Instrument Fact Sheet		GeMS (Multi-conjugate adaptive optics system)
	GPI (adaptive-optics imaging polarimeter/integral-field spectrometer) Instrument Fact Sheet		
	FLAMINGOS-2 (long-slit spectrograph and imager) Instrument Fact Sheet		
Visiting Instruments			
DSSI (diffraction-limited optical imager)	Phoenix (high-resolution spectrograph)		
Expected to be available in 2019A. For more info on these or other Visiting Instruments, contact geminivip@gemini.edu			

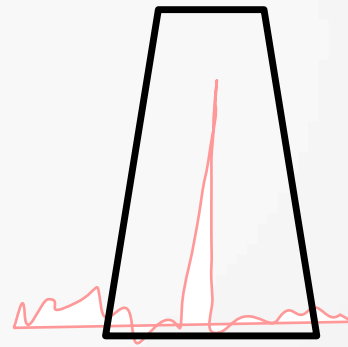
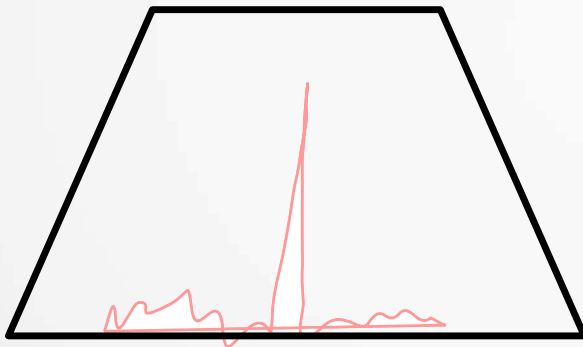
Which is brighter?

- Same source with different aperture



Which is brighter?

- Same line with different bandwidth

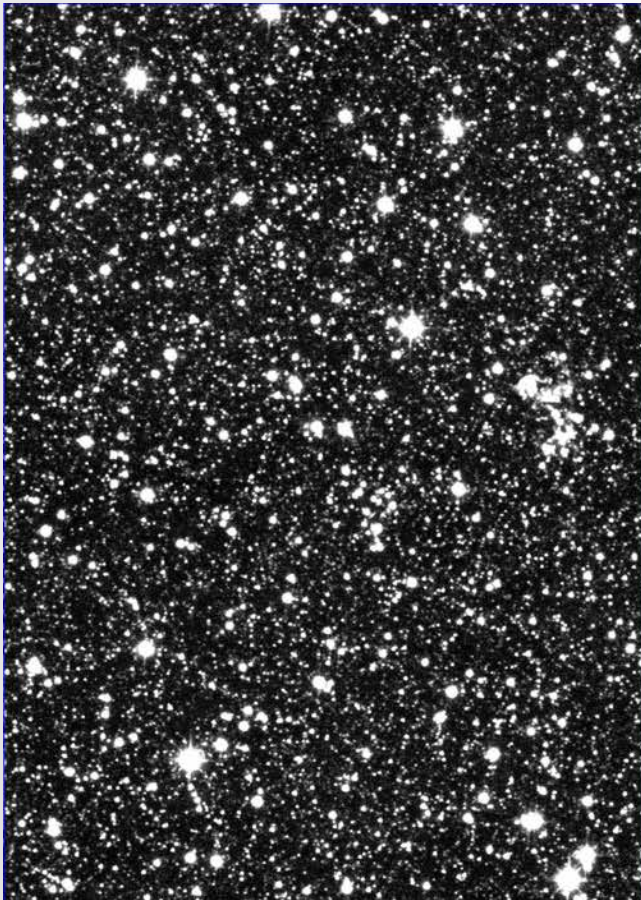


Emission line source

- Continuum : one can get more flux when increasing basket.
- Line : same flux
- Line signal gets relatively weaker as bandwidth increases and vice versa
- Spectroscopy

Finding line-emitting source in narrow band image

- Kepler's SNR

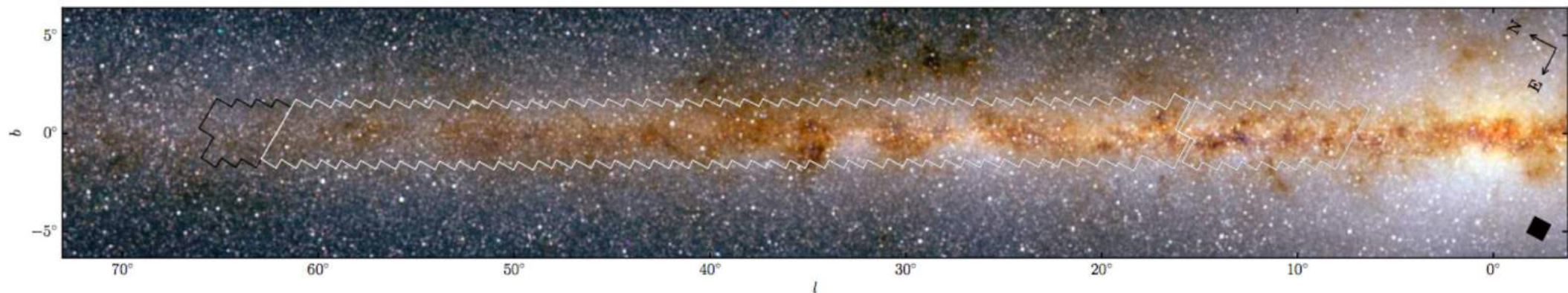


[Fe II]-band

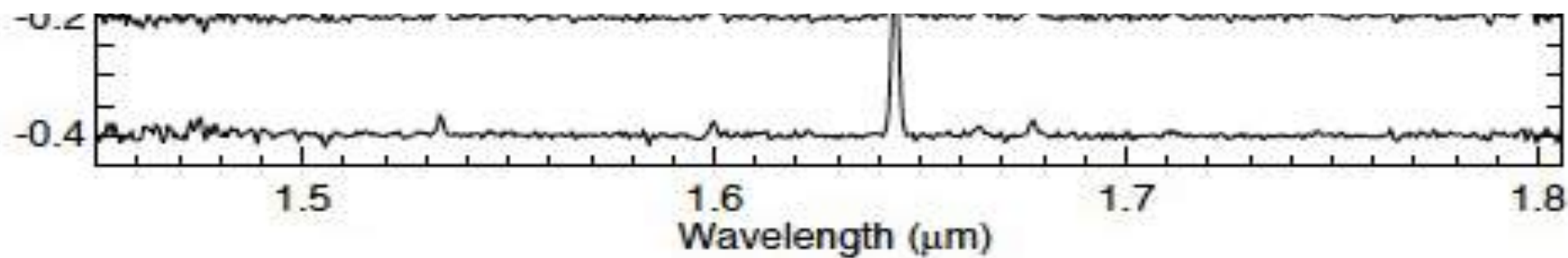
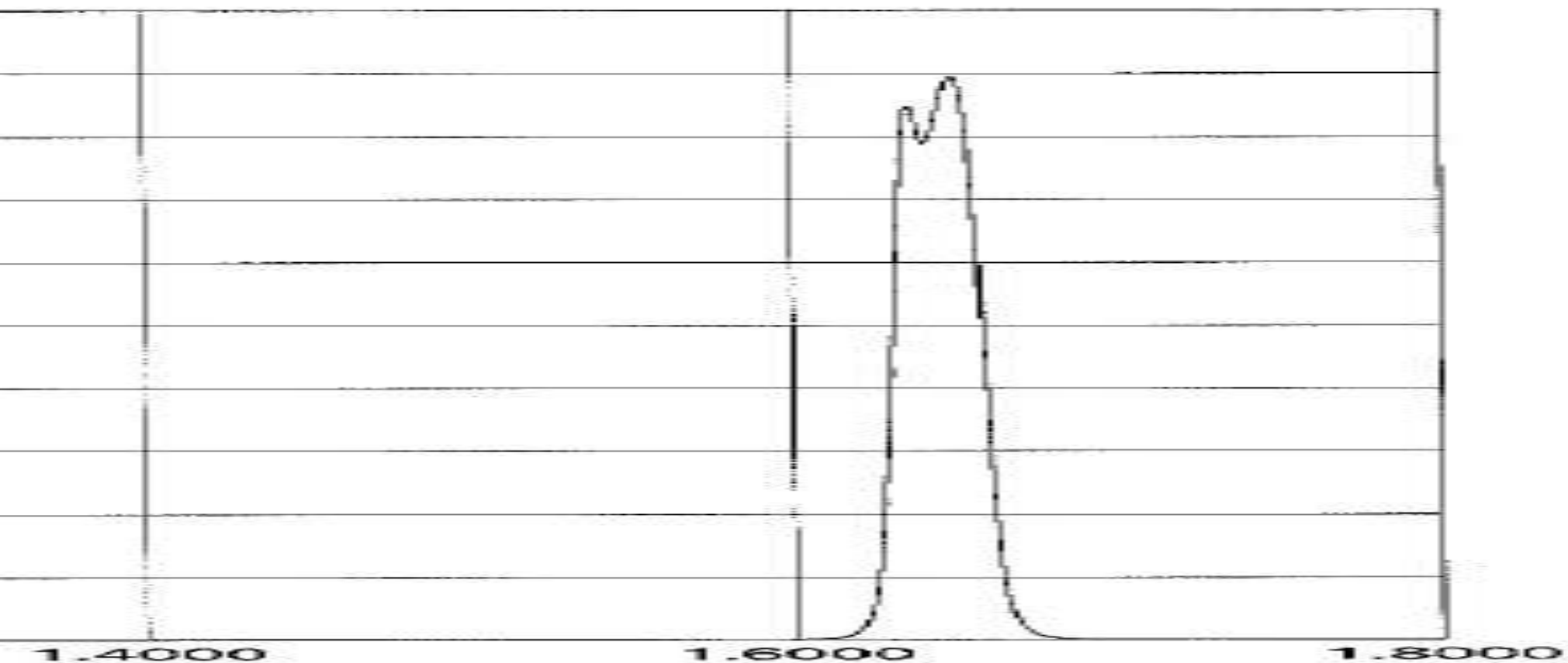
UWIFE survey

Lee, J.-J. et al. 2014, MNRAS, 443, 2650

[Fe II] imaging survey of the Milky Way
(gems0.kasi.re.kr/uwife)



Slope $\leq -2.5\%$
Cutoff
0.529



Example spectrum of shocked gas & filter response

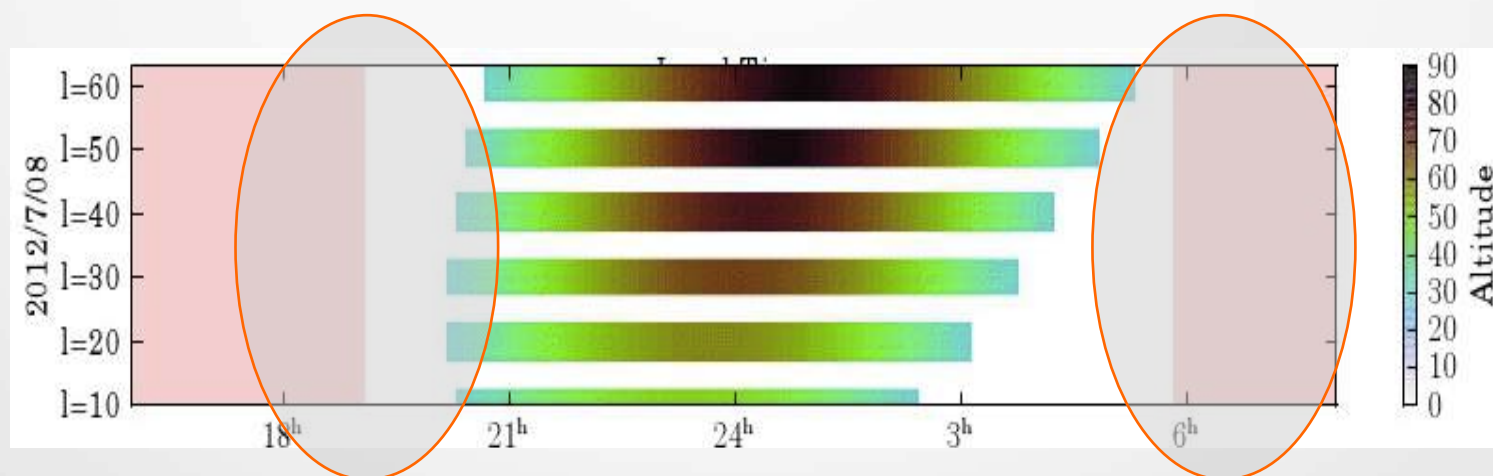
[Fe II] mini-survey of nearby galaxies

Secondary product of UWIFE project

Natural track : MW $\rightarrow$ nearby galaxies

Usage of time blocks when the MW has no/little visibility

Not always in best condition



Visibility of MW at Mauna Kea on one scheduled night

Target galaxies

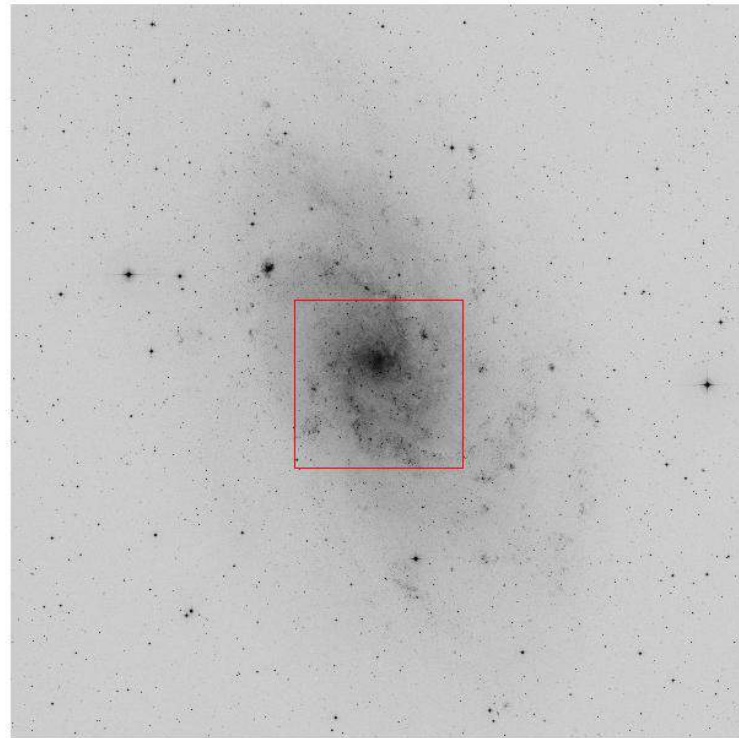
[Fe II] & H imaging : mostly 4 x 15 min. exposure

Name	RA	DEC	Size		Distance		Type
M83	13 37 00.4	-29 52 04	12.2	9.39	4.47		SBc
M101	14 03 12.6	+54 20 55	28.8	26.9	6.7		Sc
M51pair	13 29 53.4	+47 12 48	8.22	5.59	8		Sc
NGC4214	12 15 39.6	+36 19 39	4.81	3.08	2.92		I
M33	01 33 51.0	+30 37 37	29.4	23.5	0.84		Sc
M74	01 36 41.8	+15 47 00	6.78	5.83	7.3		Sc
NGC247	00 47 08.8	-20 45 38	9.75	5.36	3.65		SsD

	1	2	3	4	5	H
M82						
M83	7/6/2012	7/7/2012	7/7/2012	7/8/2012		7/9/2012
M101	6/24/2012	7/9/2012	7/10/2012	7/11/2012	7/12/2012	6/26/2012
M51	6/25/2012	7/6/2012	7/7/2012	7/8/2012		6/23/2012
NGC4214	7/13/2012					7/13/2012
M33	6/20/2012	6/21/2012	6/22/2012	6/26/2012		6/22/2012
M74	6/20/2012	6/21/2012	6/22/2012	7/6/2012	7/7/2012	6/20/2012
NGC247	6/25/2012	7/6/2012	7/6/2012	7/7/2012	7/7/2012	7/6/2012

Observed region of M33

Central 13' region

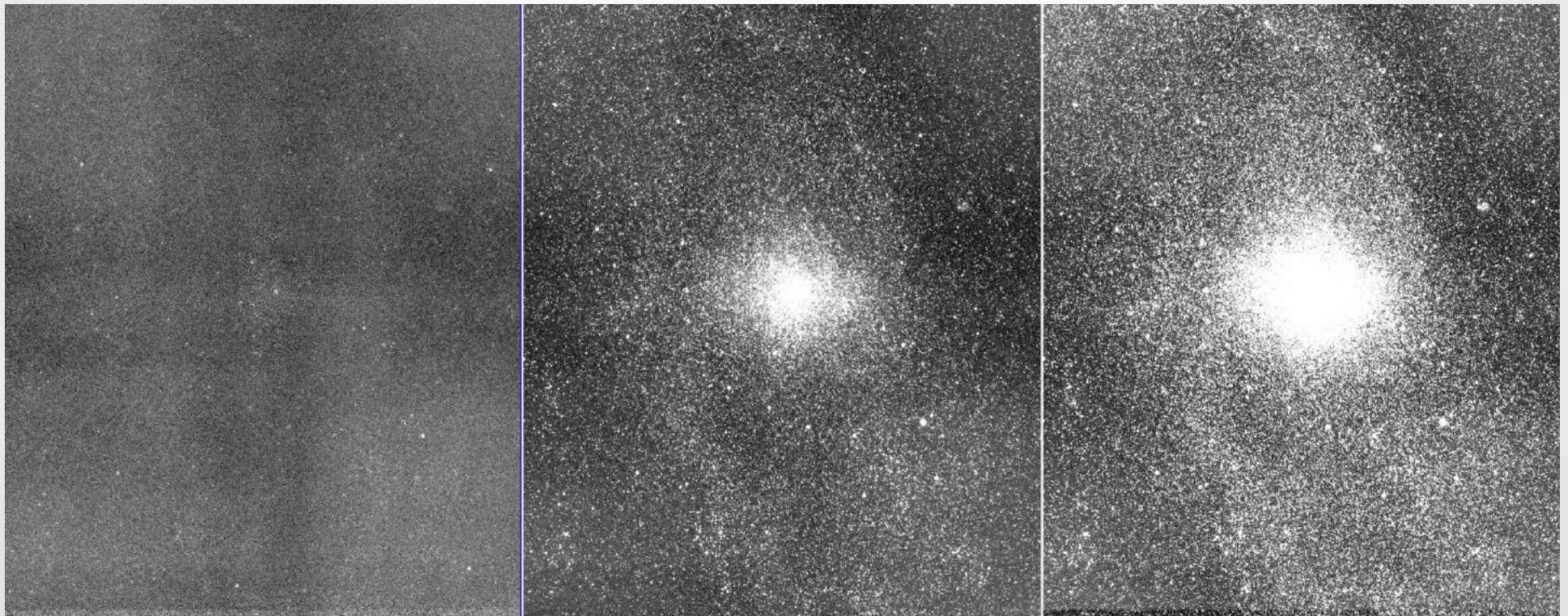


DSS 1° image
& UKIRT 13' FoV

2488 4943 7422 9877 12356 14811 17266 19745 22200

Extragalactic

- M33

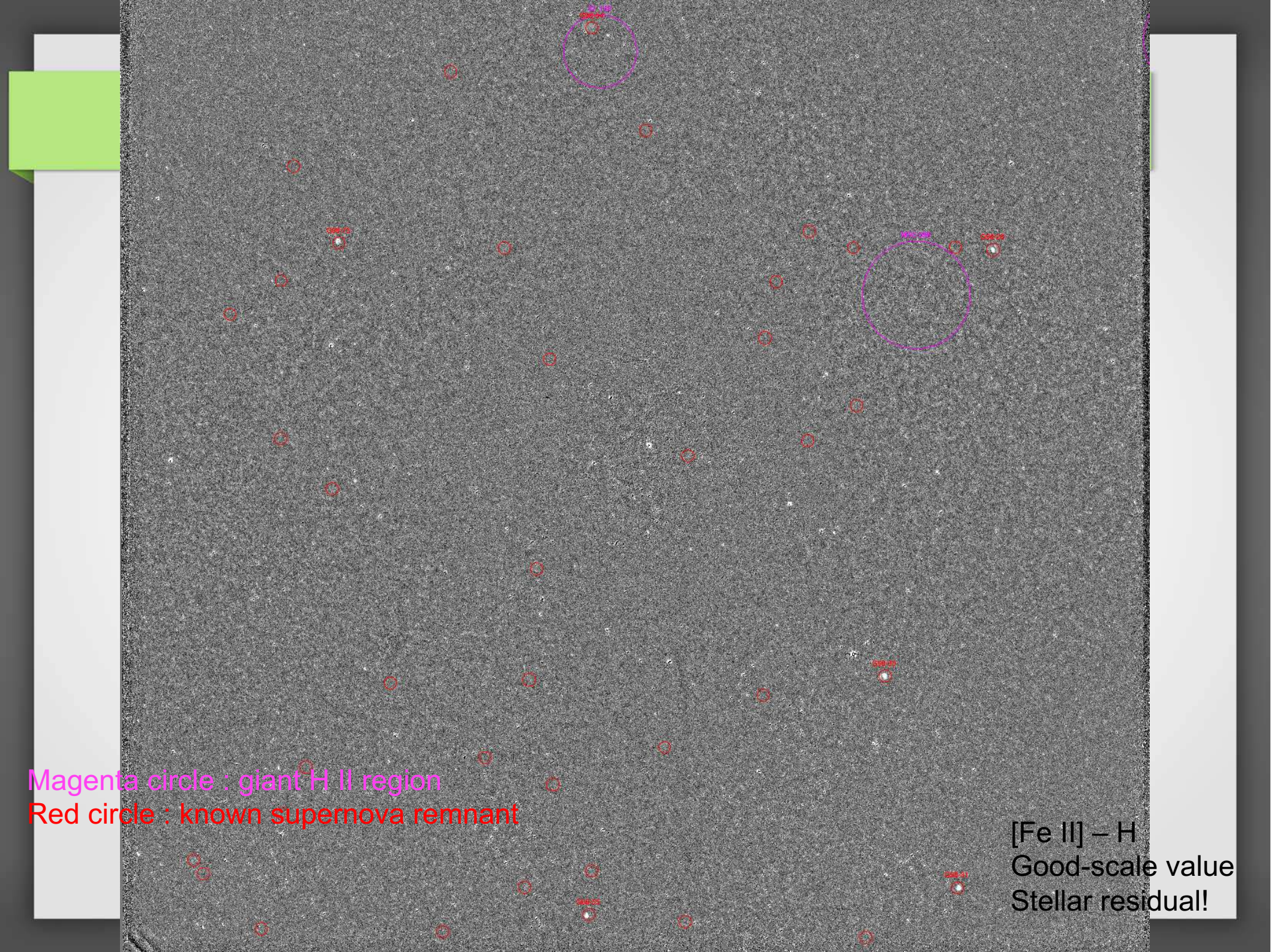


[Fe II] - H

[Fe II]

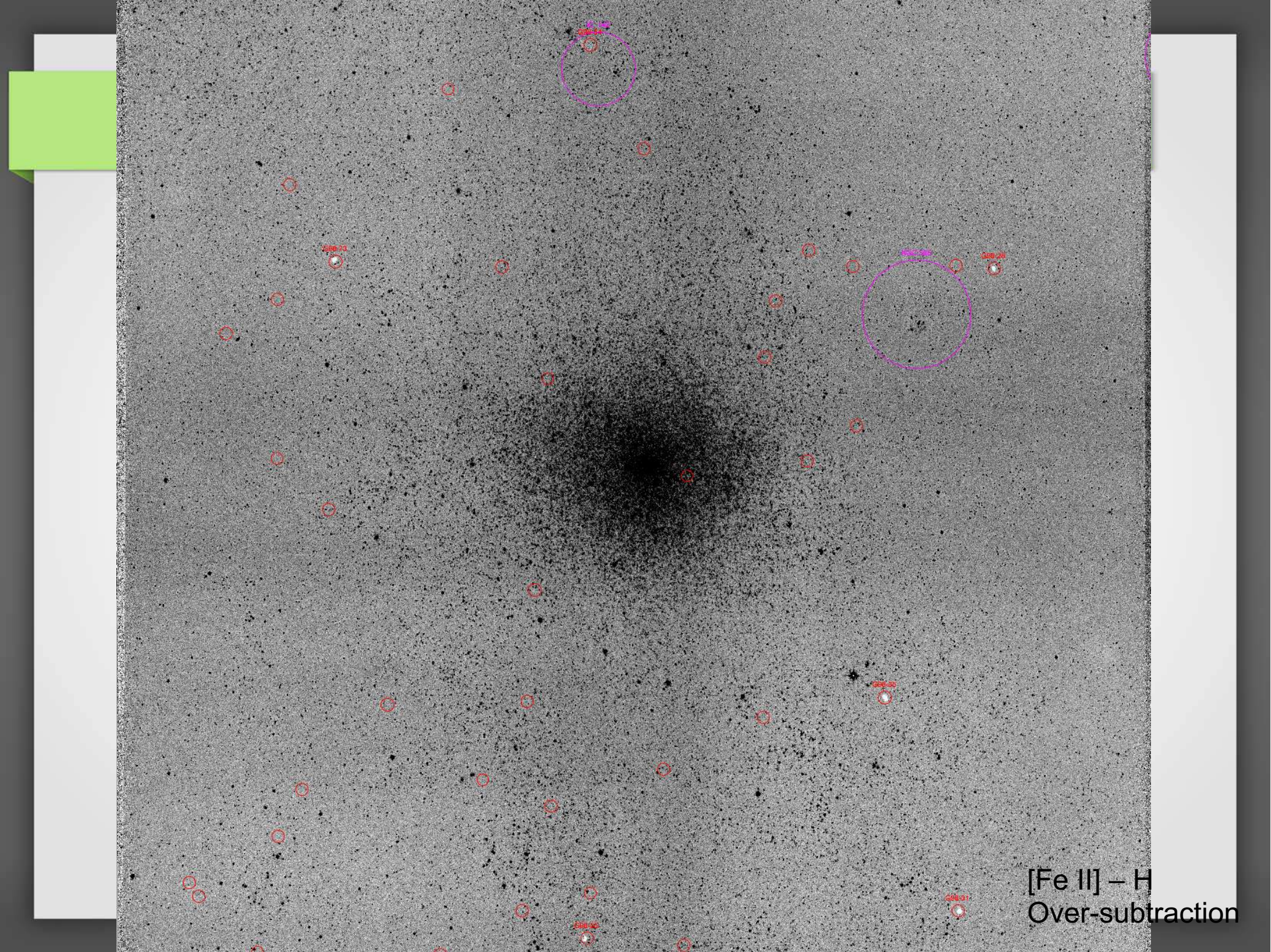
H

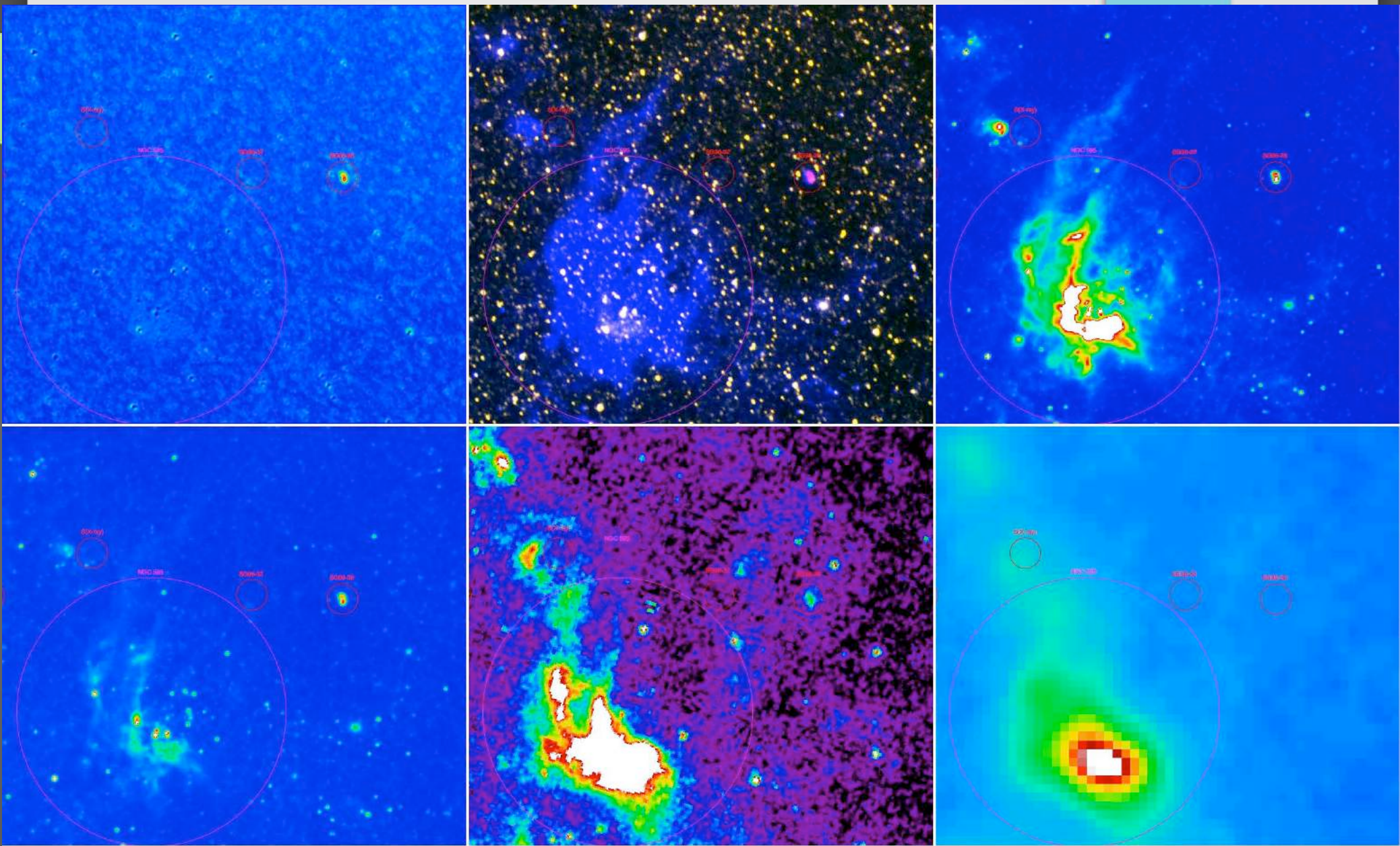
x10 bandwidth, x1/10 exposure



Magenta circle : giant H II region
Red circle : known supernova remnant

[Fe II] – H
Good-scale value
Stellar residual!





Star-subtracted [Fe II] ([Fe II]-H), [Fe II]-H:H:Hα (R:G:B), Hα, [S II], Spitzer 8 μm, and Herschel 160 μm images of SNR G98-28 and giant H II region NGC 595 in M33.

Detected [Fe II] SNRs

Positions of 6 [Fe II] SNRs

(01:33:29.0, +30:42:17), (01:33:31.2, +30:33:33)

(01:33:35.9, +30:36:28), (01:33:54.7, +30:45:19)

(01:33:54.8, +30:33:10), (01:34:10.7, +30:42:24)

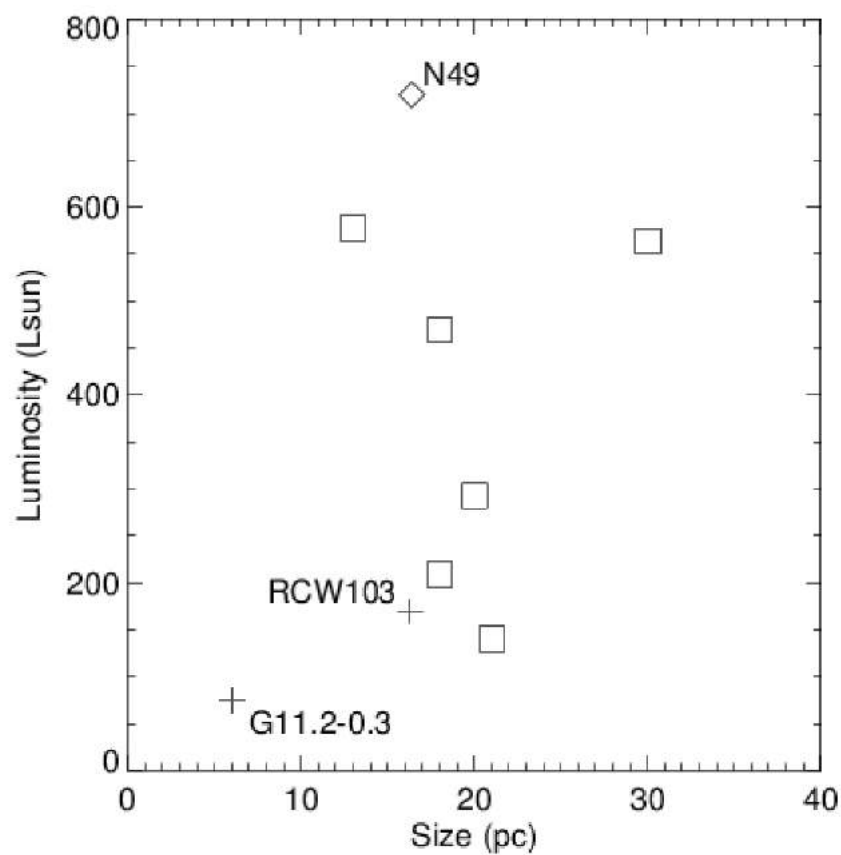
Basic data from Table 3 of Long et al. 2010

Name	Other*	R.A. (J2000)	Decl. (J2000)	Dia. (pc)	Morph.	Env.	Radio**	Sur. Bright $_{H\alpha}^{\dagger}$	$L_{H\alpha}$ (erg s $^{-1}$)	[N II]:H α	[S II]:H α	[S II]-rat.	Spec. Ref.
L10-036	G98-28	01:33:29.05	+30:42:17.0	18	A	1	c	5.0e-15	6.5e+36	0.59	1.13	1.11	S93
L10-039	G98-31	01:33:31.25	+30:33:33.4	13	A	1	c	1.5e-14	9.6e+36	0.86	0.95	0.78	MMT-BCS
L10-045	G98-35	01:33:35.90	+30:36:27.4	30	A'	2	c	5.8e-15	2.0e+37	0.57	0.82	1.10	MMT-BCS
L10-070	G98-54	01:33:54.51	+30:45:18.7	21	B	3	c	2.2e-15	3.7e+36	0.47	0.83	1.41	G98
L10-071	G98-55	01:33:54.91	+30:33:11.0	20	A	2	c	5.0e-15	8.1e+36	0.48	0.83	1.12	S93
L10-096	G98-73	01:34:10.70	+30:42:24.0	18	A	1	c	3.7e-15	5.0e+36	0.59	1.25	1.15	S93

A: well defined (A': small, bright), B: partial shell, C: poorly defined
1: isolated, 2: within nebulosity but separable, 3: confused

How bright?

[Fe II]-bright Galactic SNRs (G11.2-0.3, RCW103) & N49 in LMC

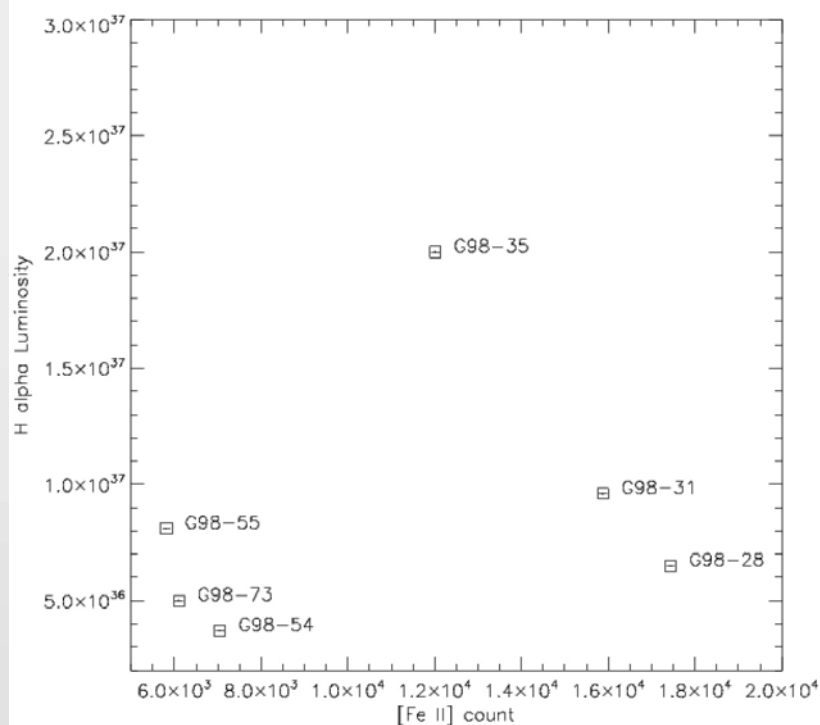


Comparison with prev. obs.

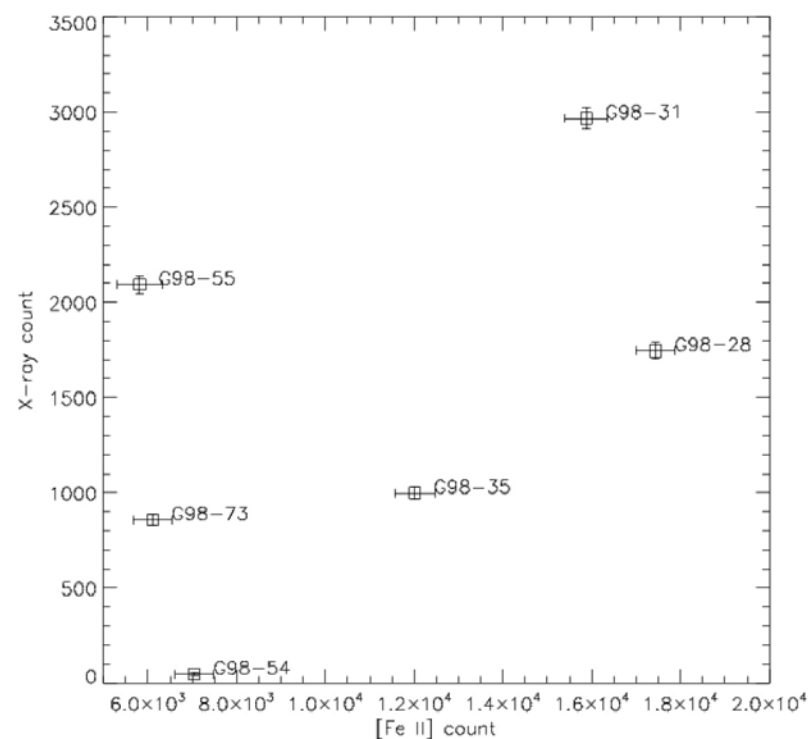
Scattered ...

Difference in emitting mechanism?

H α

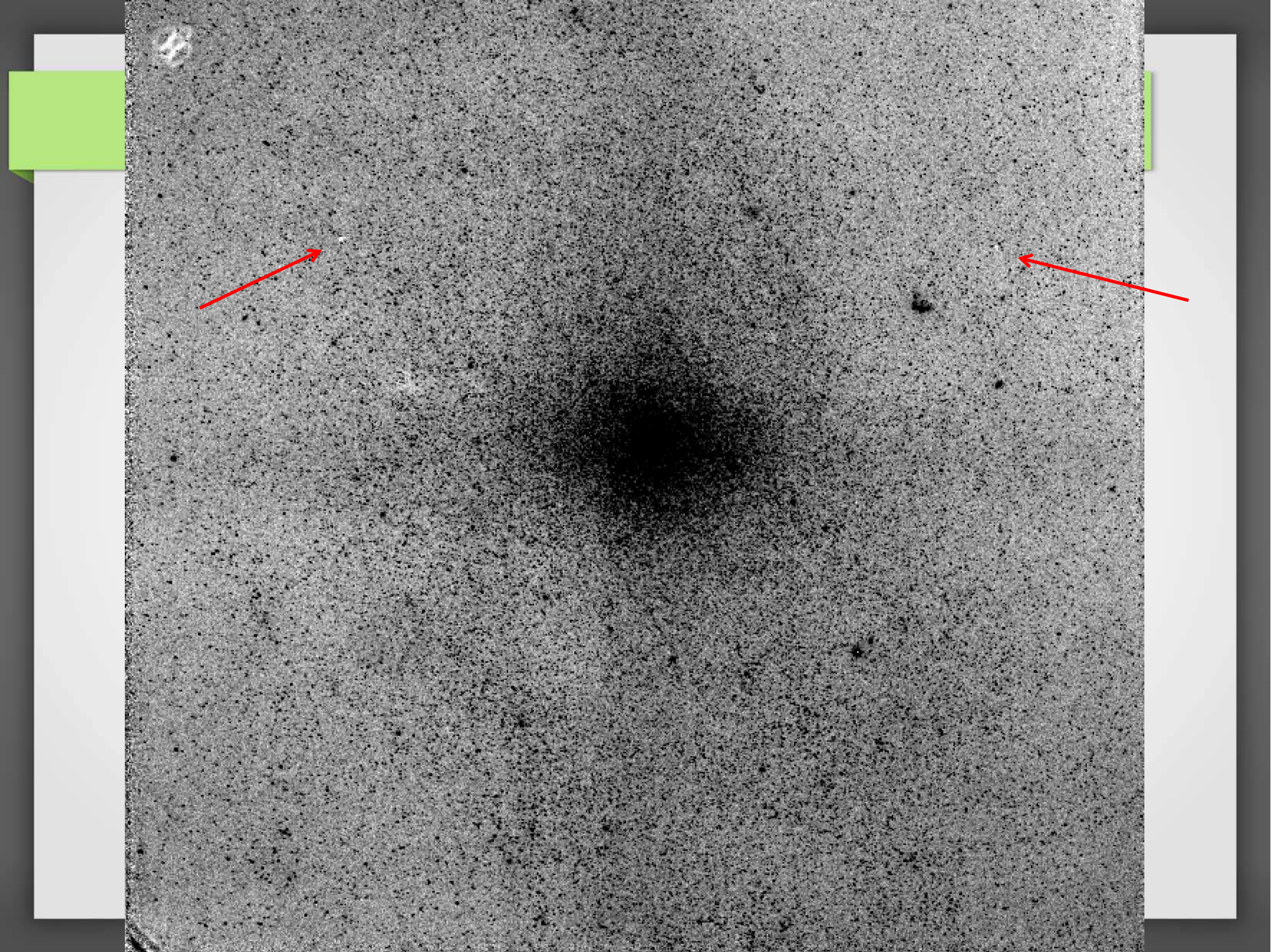


X-ray



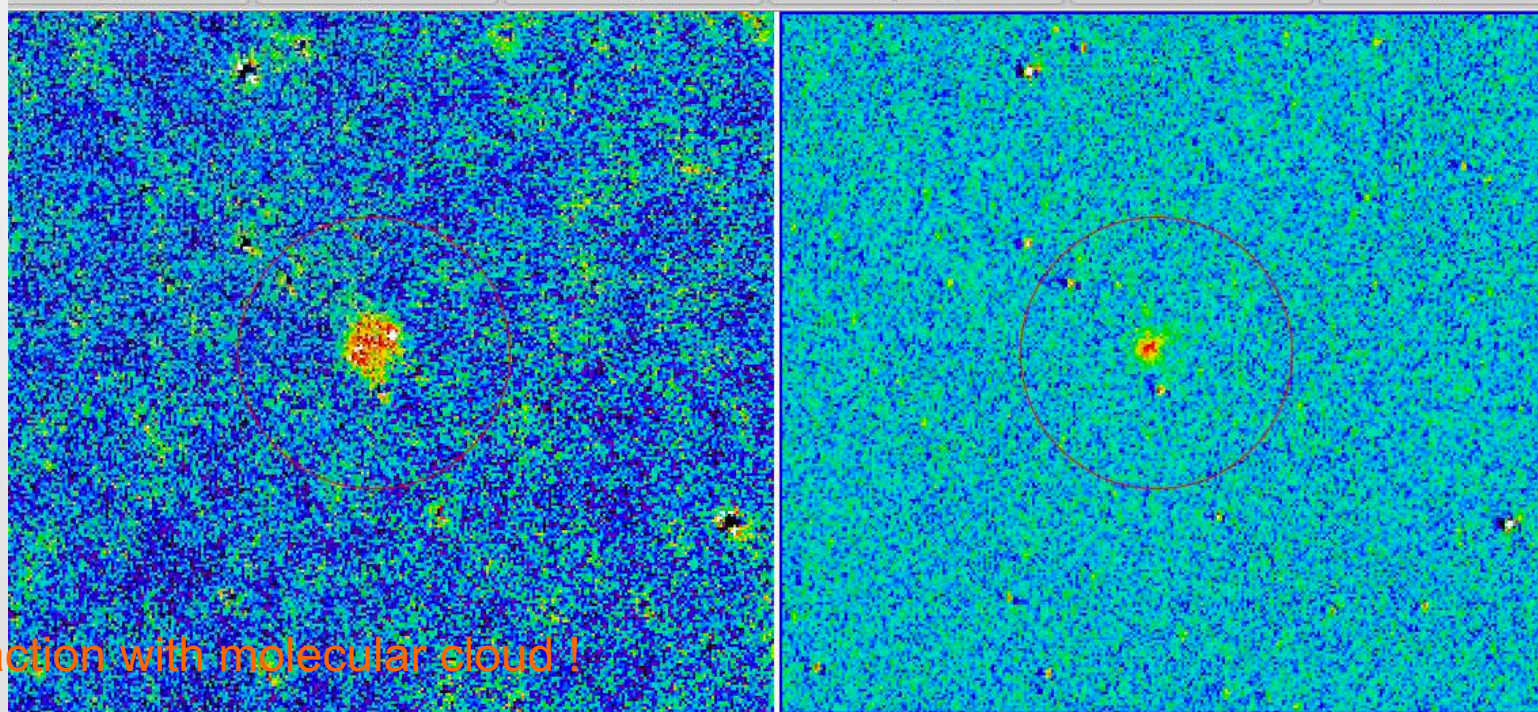
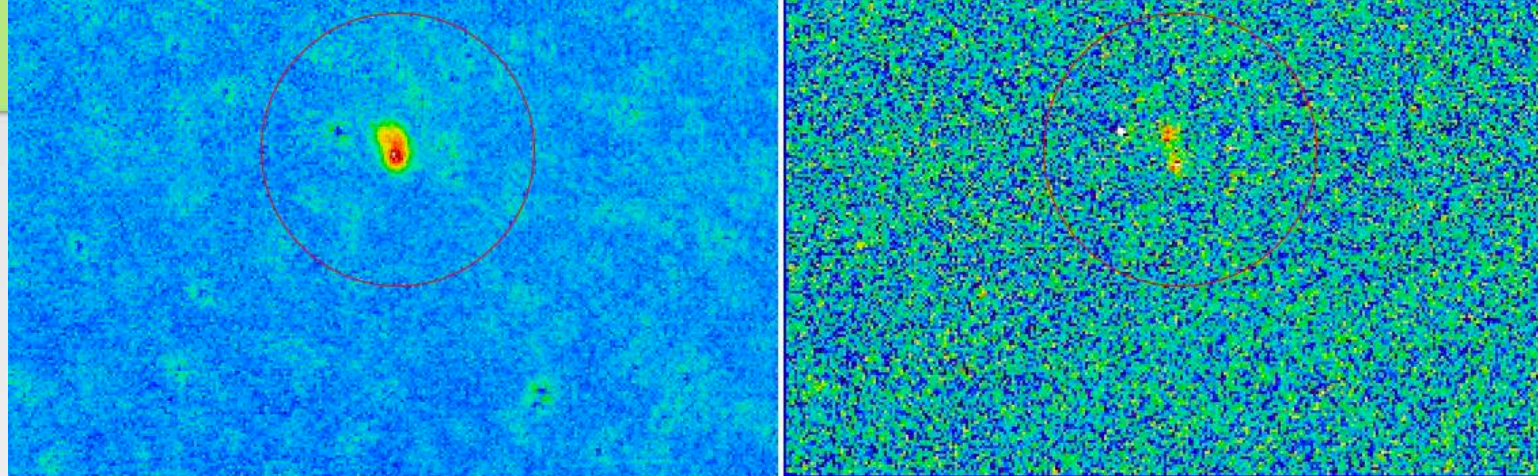
H2 image

Integration time (1/4 of [Fe II] image)



[Fe II]

H2



Peak: $6e-5$
erg/s/cm²/sr

in erg /s /cm² /sr
red circle: 10''
[Fe II] - H (-1 ~ 2e-4) , H2 -
K (-1.5 ~ 3e-5)
[Fe II] - H (-2 ~ 4e-5), H2 -
K (-3 ~ 6e-5)

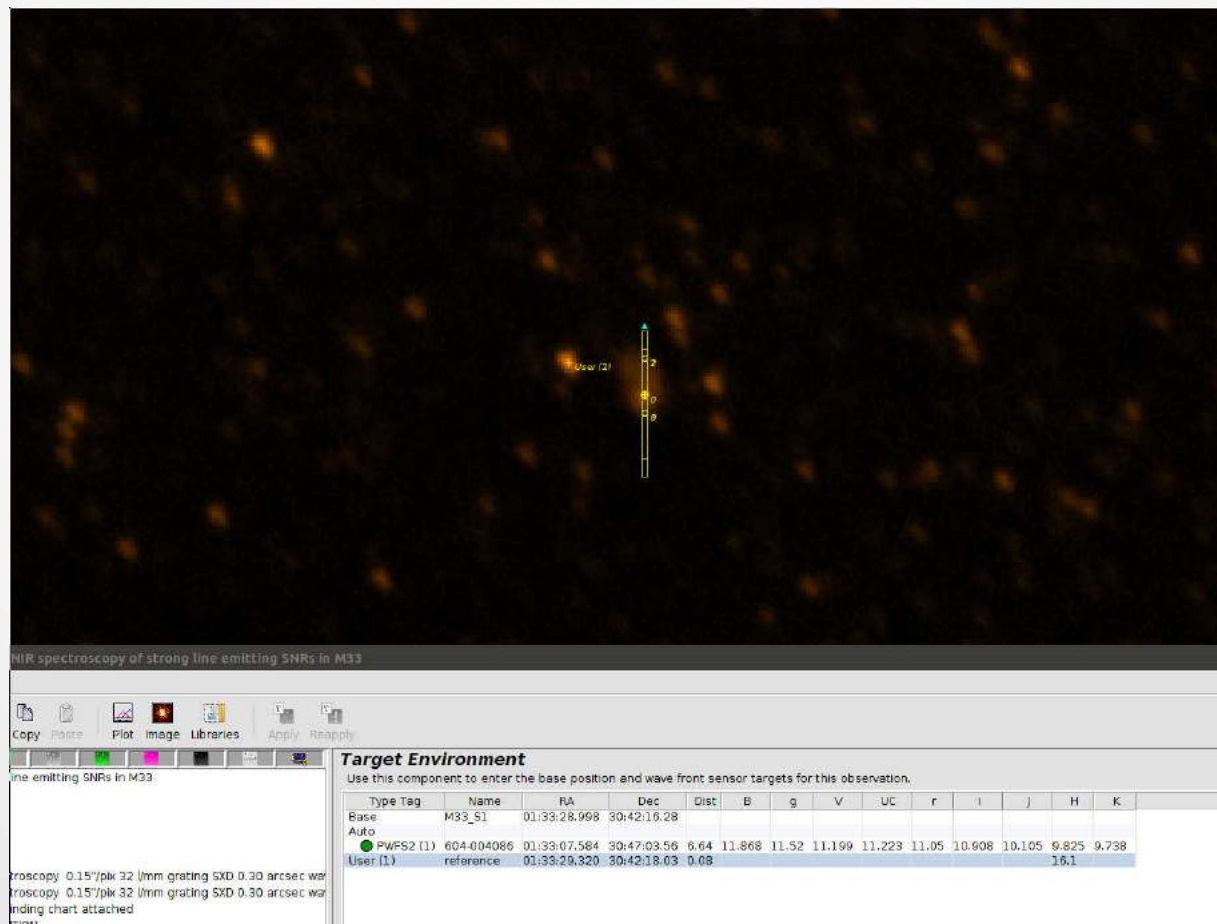
Interaction with molecular cloud !

Gemini/GNIRS spectroscopy

- JHK band
- $R \sim 1700$
- Band 3 (again)
- Blind offset

Observing reference

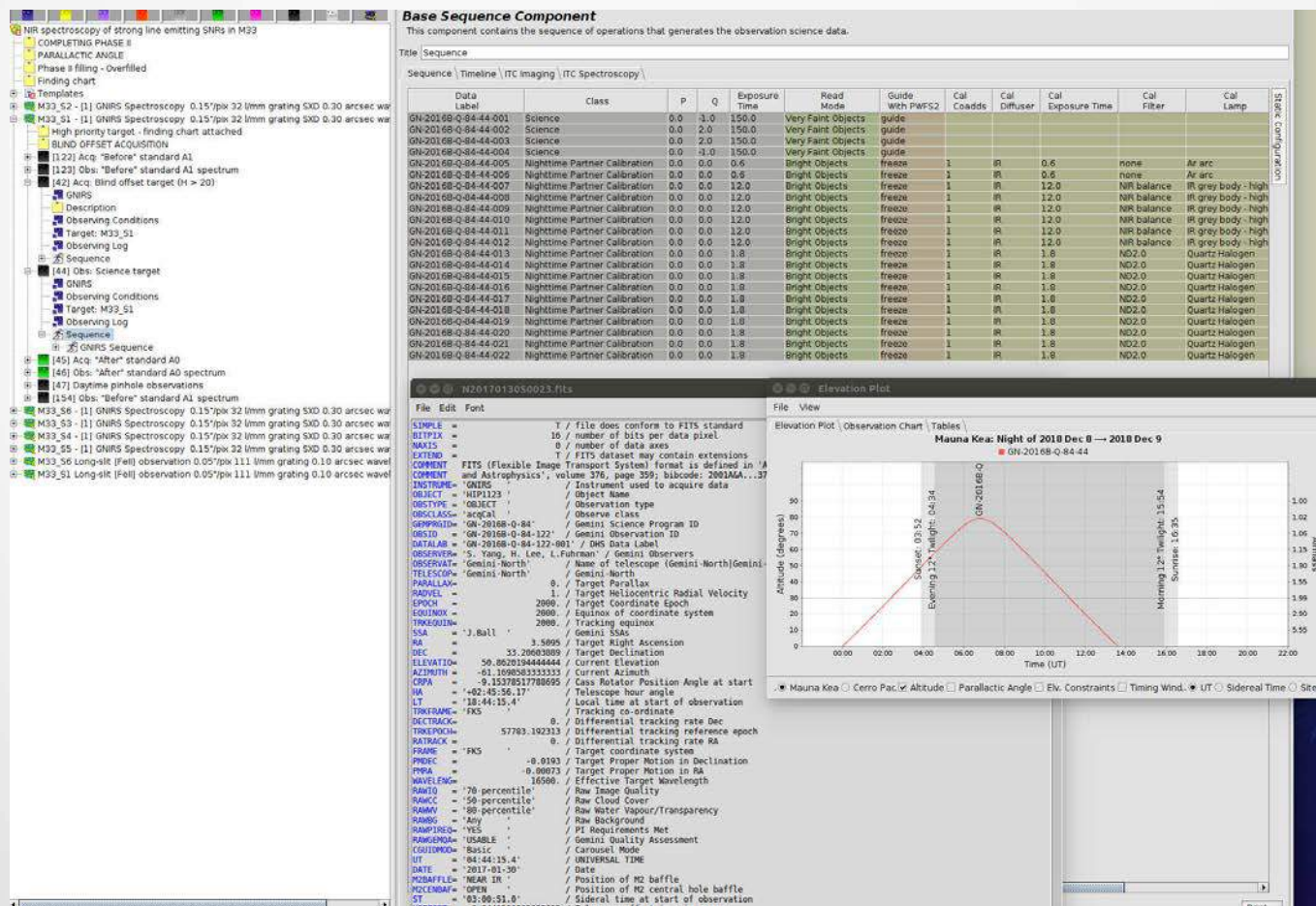
- Nearby H=16 mag star



Slit and ref. star positions on [Fe II] image. Invisible on H image.

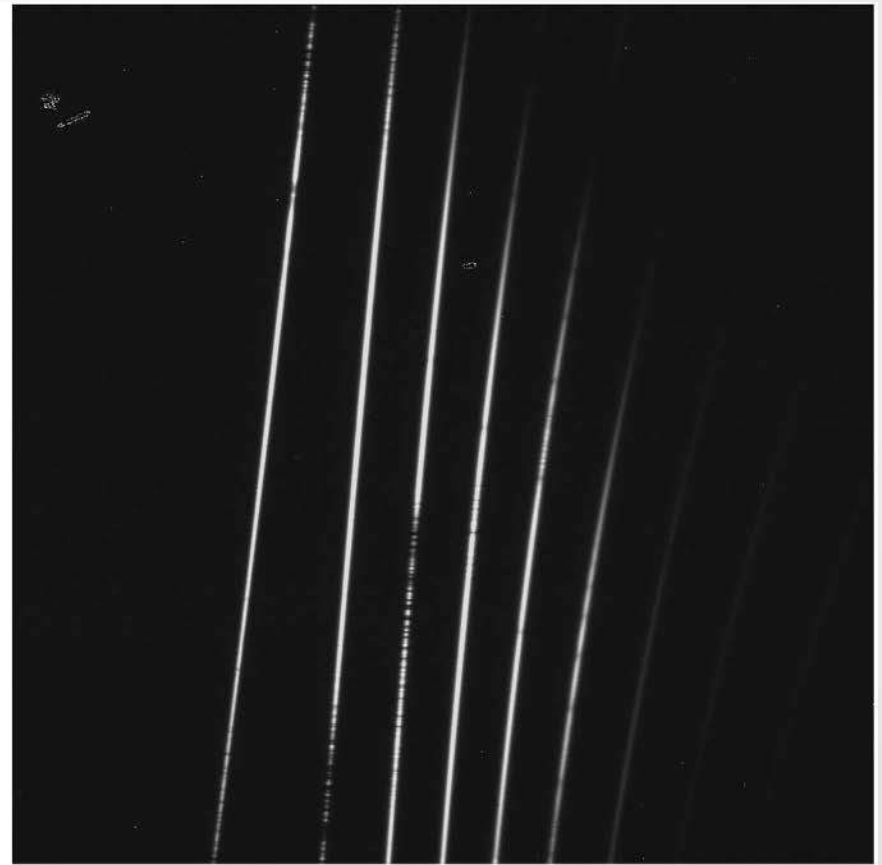
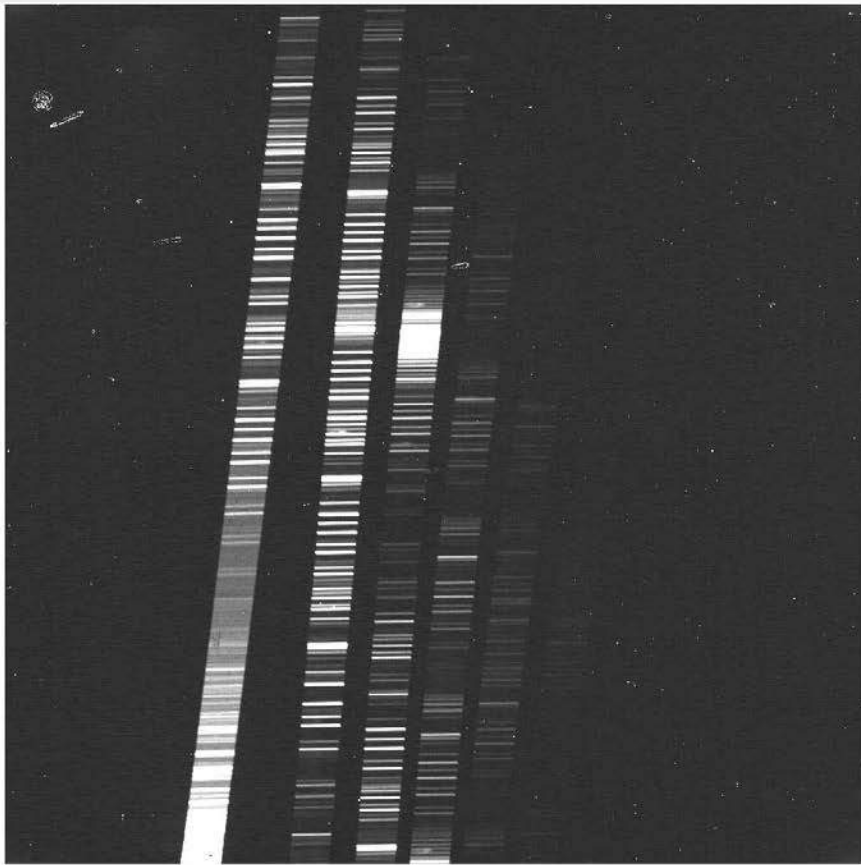
Tried in (Infrared) bright sky

- Just after twilight : first fits file at UT 04:44
- 150 s x 4

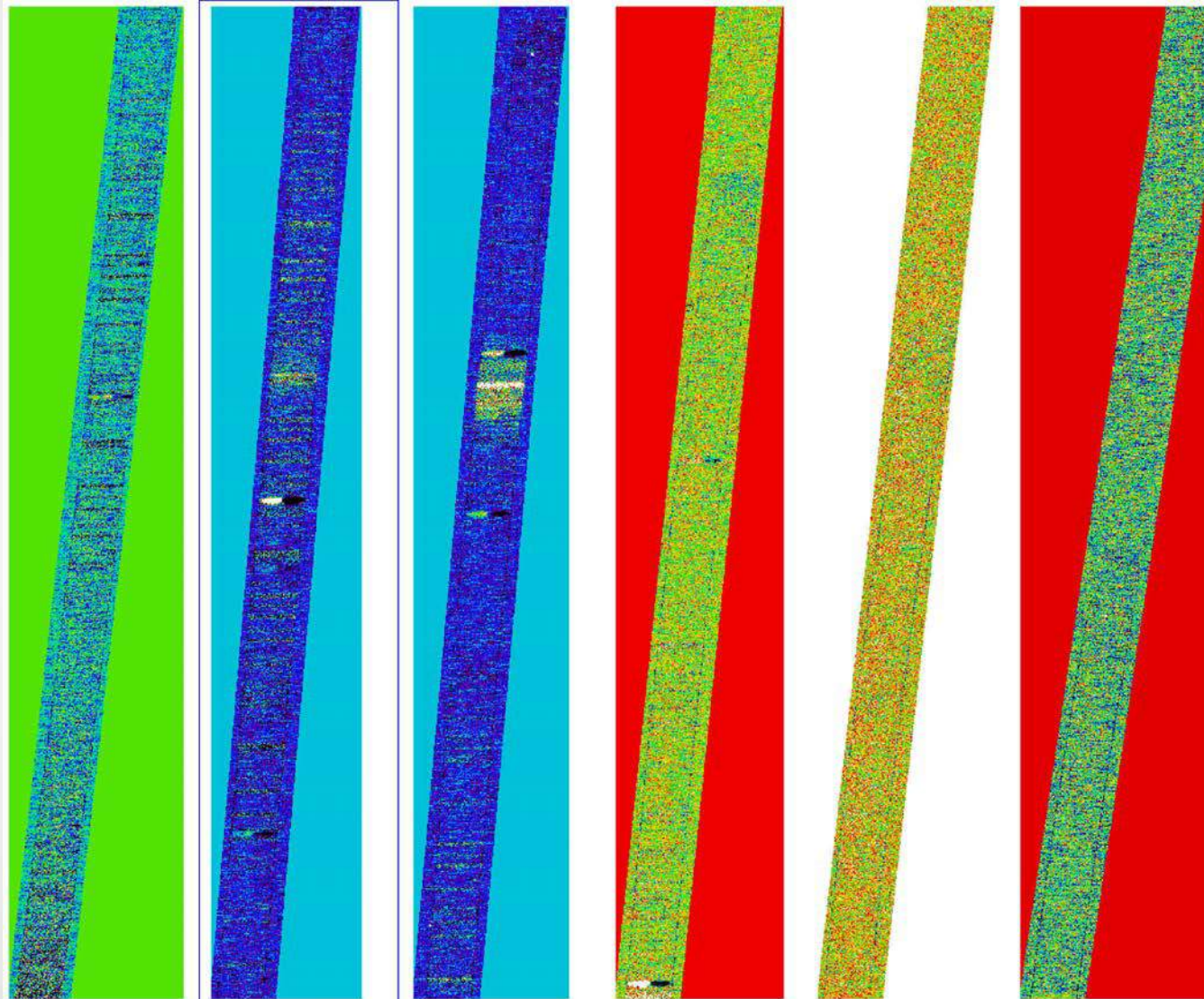


Raw spectra

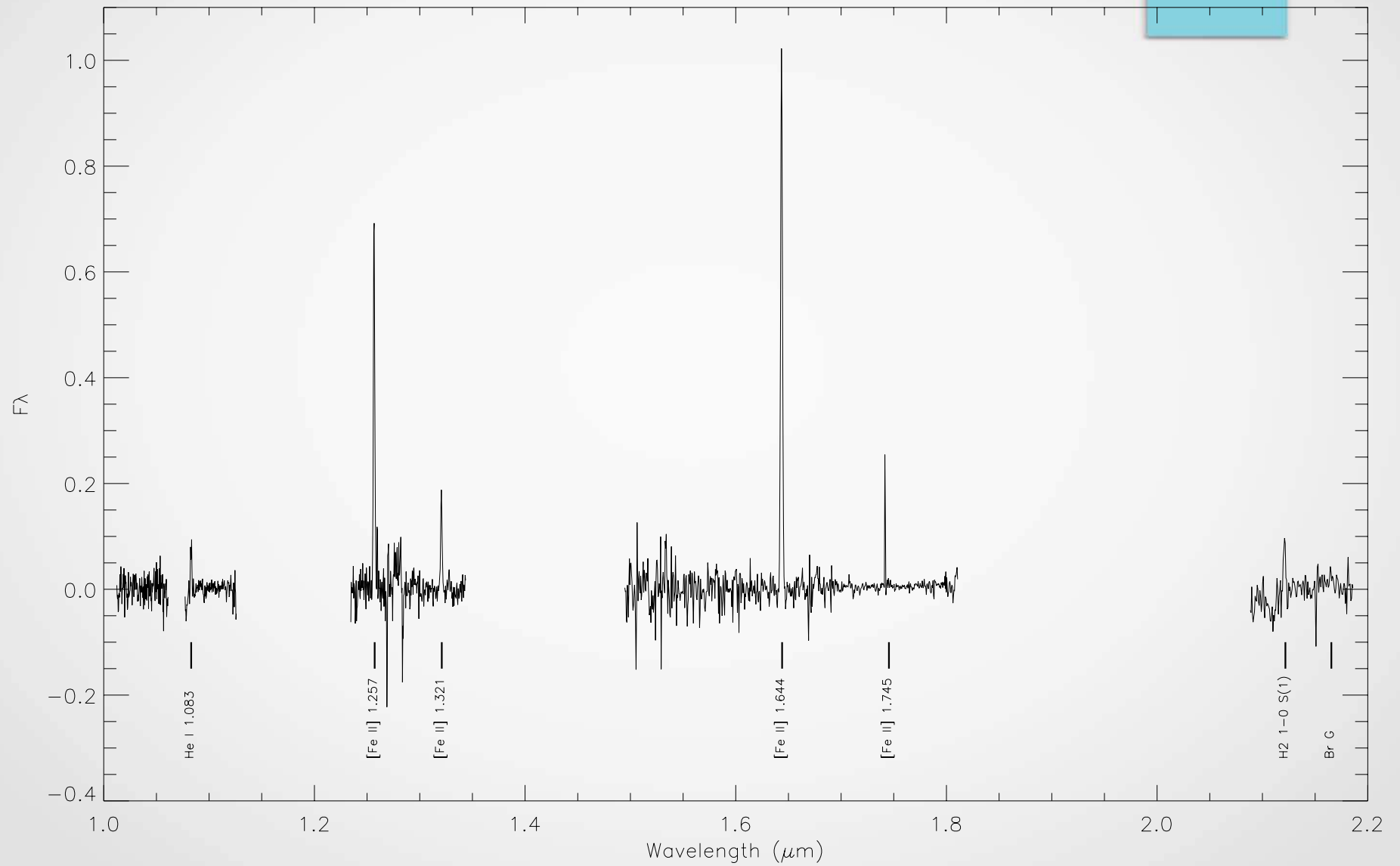
- Source & telluric



Reduced spectra



Extracted spectra



Ejecta? Swept-up?

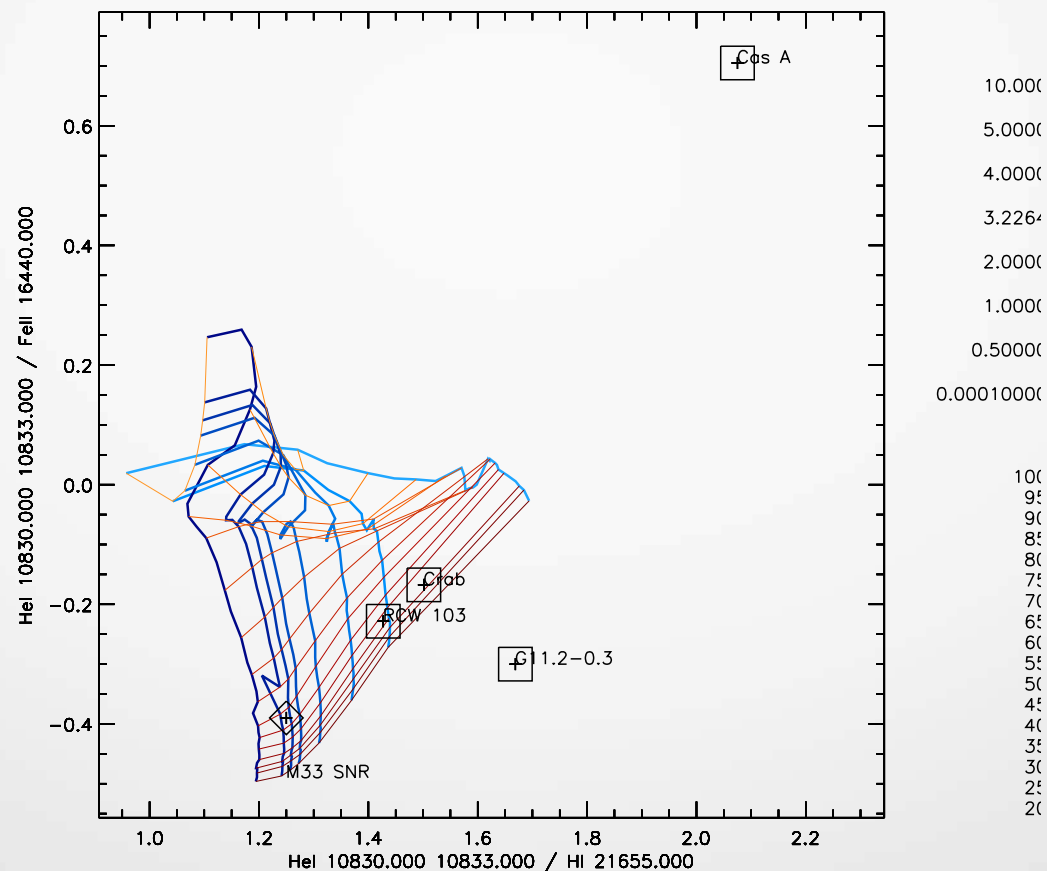
- Radial velocity
 - $R \sim 1700$, $\Delta V_r \sim 200$ km/s
 - Less likely ejecta
- Luminosity
 - A few hundreds L_{sun}

Not a simple environment

- Atomic line ([Fe II])
 - Shocked compressed gas
 - Gas density $\sim 10^2 - 10^5 \text{ cm}^{-3}$
 - Preshock density $n > 10 \text{ cm}^{-3}$
- Molecular line (H₂)
 - Molecule formation behind shock front or Interaction with molecular cloud
 - Preshock density $> 10^3 \text{ cm}^{-3}$

Radiative shock model

- Mappings III
 - $n = 1 \text{ cm}^{-3}$, solar abundance



Lesson today

- SNR in M33 is detectable
 - Only exposure of 150 s x 4
 - Bright sky
- Emission line source needs blind offset
 - Even though short exposure target
- If extended, positional tolerance can be large
 - Blind offset but no precise accuracy
- Bright, extended targets in MW
 - Candidate for band 4