

SNe/SNRs in nearby galaxies

2013 May 24

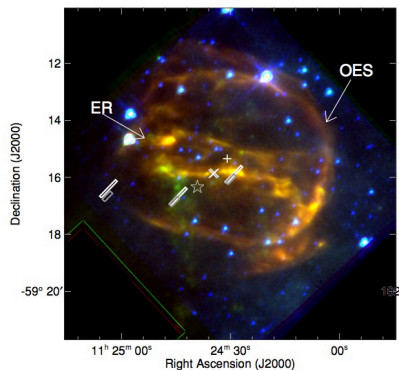
Mimizuku science workshop 2013

IoA

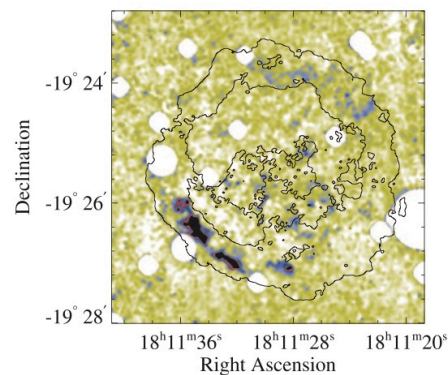
Ho-Gyu LEE

Motivation

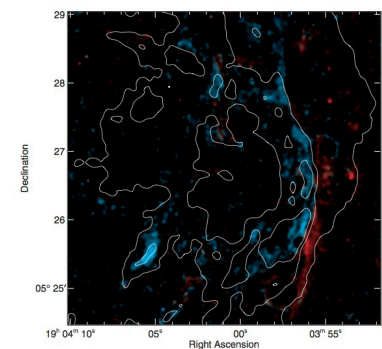
- Our recent IR observations revealed CSM in SNRs
 - Pre-existing structure before SN explosion
 - Mass-loss through stellar wind
- Diverse characteristics
 - Size, density, progenitor type ...



G292.0+1.8 AKARI 24:15:7um
(Lee et al. 2009)



G11.2-0.3 [Fe II] - H
(Koo et al. 2007)



3C396 H2:[Fe II]
(Lee et al. 2009)

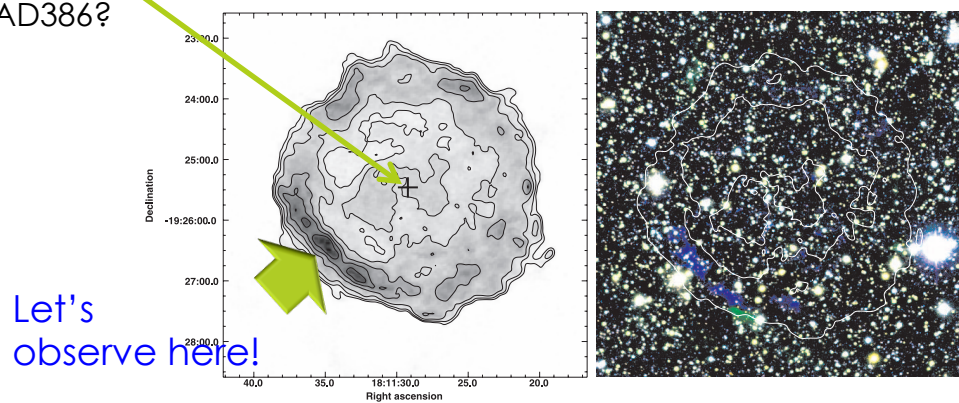
If CSM shell exists,

- Present SNR ejecta/shock
 - Interacting with CSM with velocity of 100-10,000(?) km/s
- Soon after SN explosion (SNR phase?)
 - Light moves first
 - Light echo
 - For pc scale CSM, SN light can reach in a few years
 - Peak at MIR
 - Two epochs of interaction
 - Light echo
 - Interaction by ejecta/shock

Example: G11.2-0.3

- One of the brightest [Fe II] emission in SNRs
- Southeastern shell : circumstellar materials (CSM) or ejecta

Position of pulsar
SN AD386?



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

Palomar K:H2:[Fe II]
(Koo et al. 2007)

Integral field unit (IFU) observations of G11.2-0.3

- IFU observations
 - FISICA + FLAMINGOS on Kitt peak 4m telescope
 - Image slicer : FISICA (works like 21 long-slit spectrographs at a single exposure)
 - FoV = 16" x 33" !

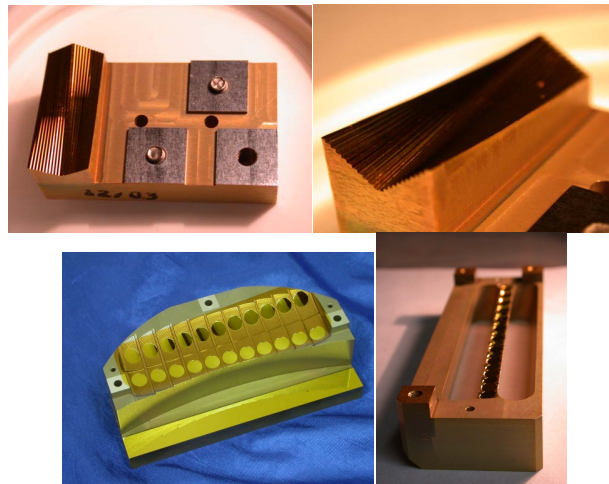


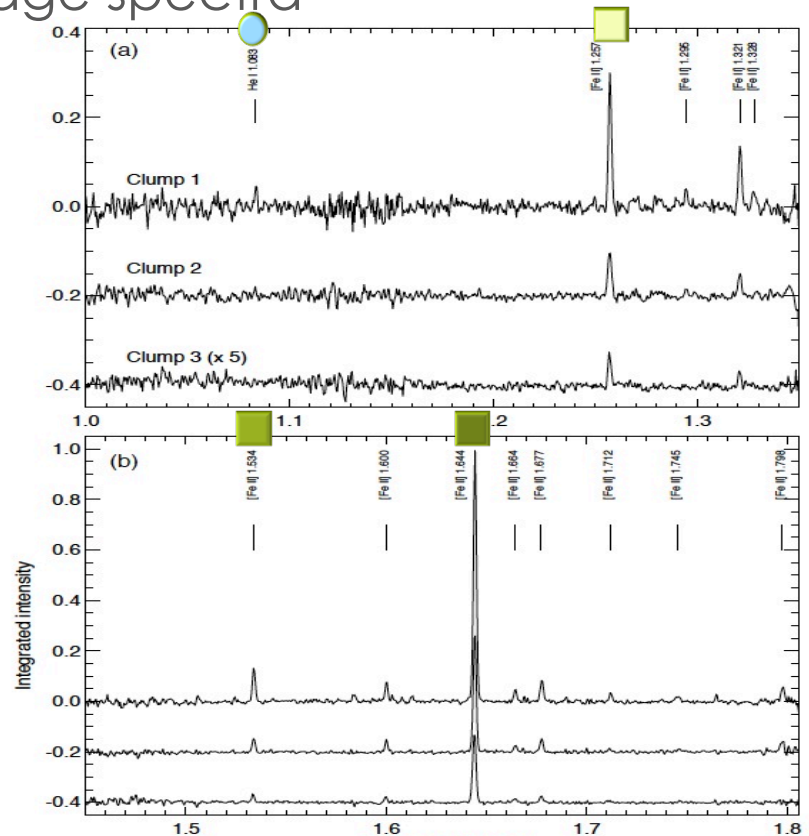
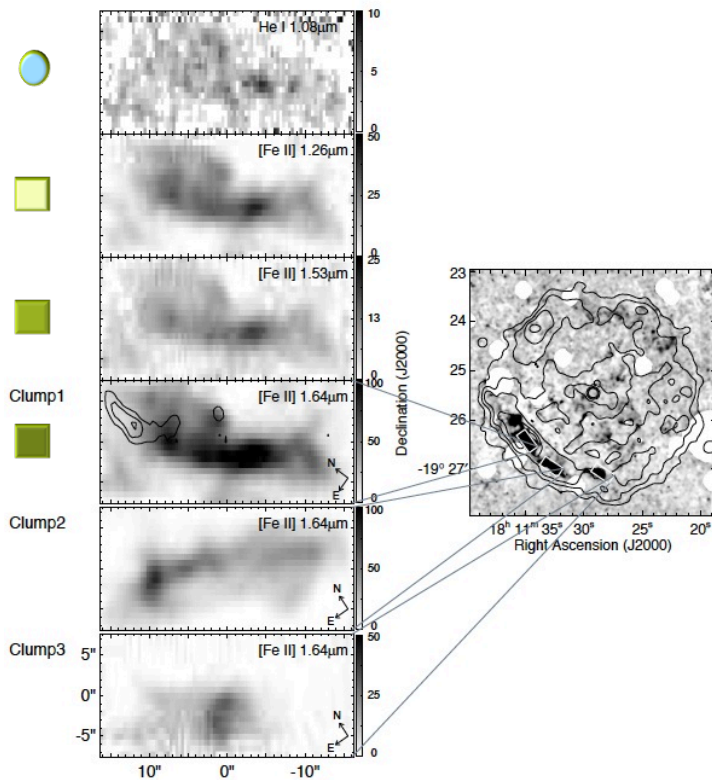
Image construction

- Gaussian fit at each pixel , JH bands



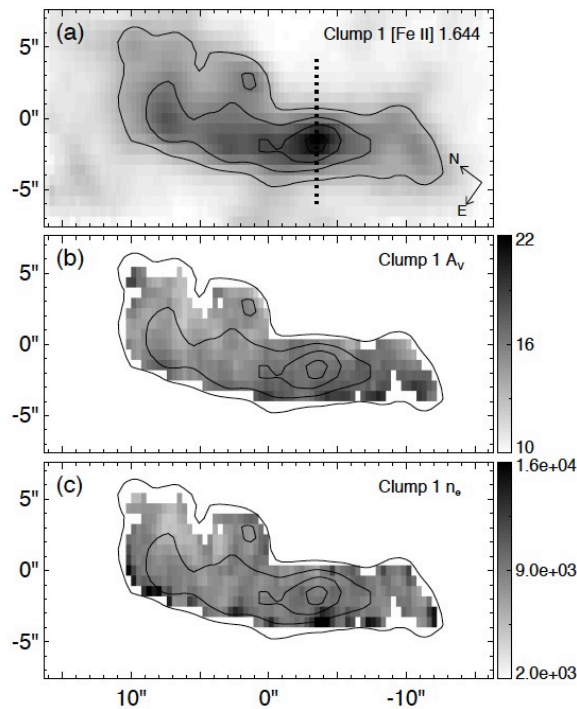
Images & spectra

Line images and average spectra



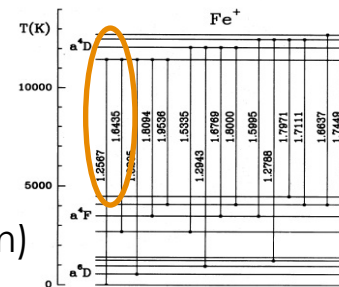
Brightest Clump 1

- Bright enough to provide distributions in several transitions

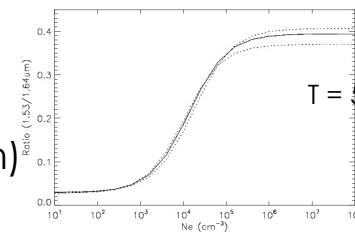


← $I(1.26)/I(1.64\mu\text{m})$

← $I(1.53)/I(1.64\mu\text{m})$



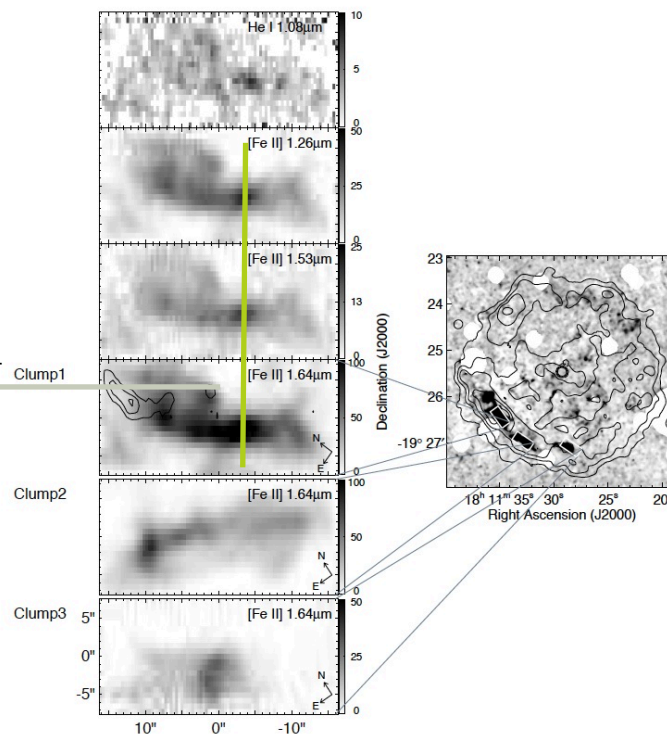
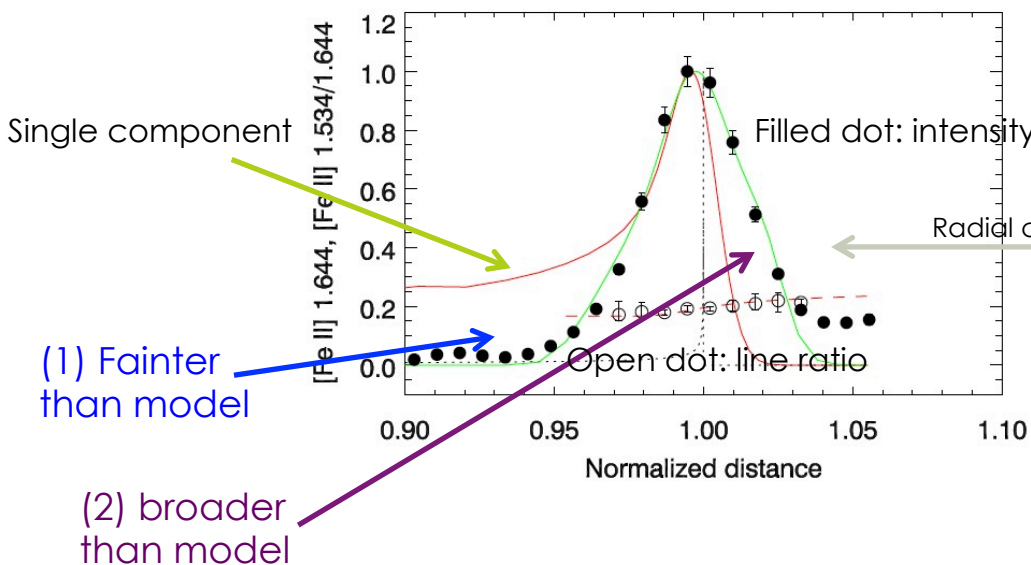
(Transition diagram Oliva et al. 1990)



Radiative shock model for radial profile

Results of shock model

$V_s = 150 \text{ km/s}, n_o = 300 \text{ cm}^{-3}$



Dense pre-supernova CSM medium:
 (1) localized (2) multi-shells

Near-IR IFU line images of G11.2-0.3
 (Lee et al. in preparation)

CSM shell in G11.2-0.3

- Southeastern CSM shell
 - Sum of thin filaments
 - Episodic mass loss from a progenitor star?
- Other SNe/SNRs?
 - There may be similarity/dissimilarity
 - e.g. ring of 1987A

SN 2002hh in NGC6946 (6Mpc)

- Barlow et al. 2005
 - Spitzer
 - Day: 590, 758
 - Gemini North 11.2um (d)
 - 2004 Sep. 26
 - 900 s

STAR	OBSERVATION DATE	IRAC				MIPS, 24.0 μm
		3.6 μm	4.5 μm	5.8 μm	8.0 μm	
1	2004 Jun/Jul	0.72 \pm 0.14	1.22 \pm 0.12	4.28 \pm 0.50	17.0 \pm 1.6	46.5 \pm 5.1
	2004 Nov 25	0.88 \pm 0.17	1.07 \pm 0.12	3.65 \pm 0.35	12.8 \pm 1.3	...
2	2004 Jun 10	119.6 \pm 18.4	68.9 \pm 4.2	54.9 \pm 2.1	31.4 \pm 1.6	...
	2004 Nov 25	115.6 \pm 15.4	58.8 \pm 4.2	53.5 \pm 2.2	30.4 \pm 1.2	...
3	2004 Jun 10	1.12 \pm 0.35	0.54 \pm 0.10	0.71 \pm 0.21	1.23 \pm 0.28	...
	2004 Nov 25	0.78 \pm 0.19	0.62 \pm 0.21	0.58 \pm 0.16	1.78 \pm 0.82	...
4	2004 Jun/Jul	0.64 \pm 0.17	0.57 \pm 0.11	3.52 \pm 0.46	9.3 \pm 1.2	27.7 \pm 4.5
	2004 Nov 25	0.64 \pm 0.24	0.59 \pm 0.13	3.27 \pm 0.36	10.9 \pm 1.1	...
5	2004 Jun 10	2.11 \pm 0.36	8.6 \pm 1.2	...
	2004 Nov 25	...	0.18 \pm 0.09	1.80 \pm 0.32	6.7 \pm 1.1	...

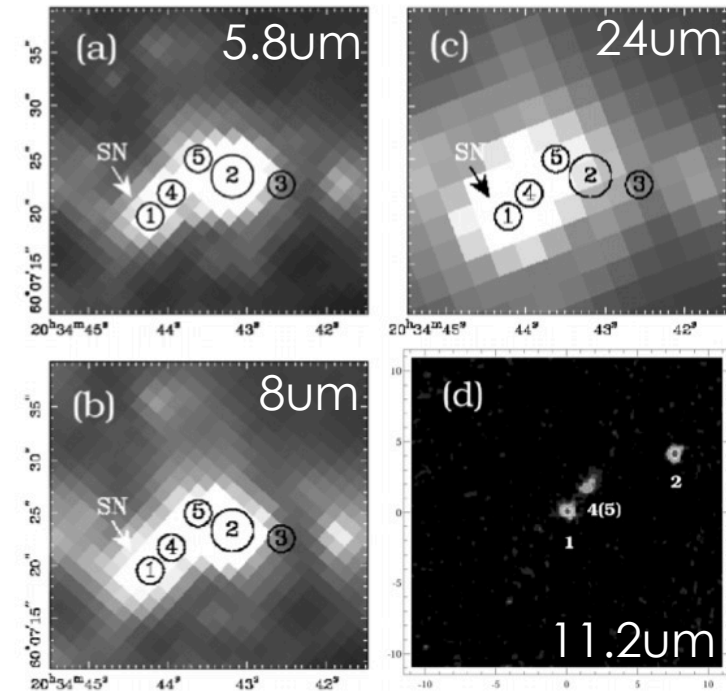
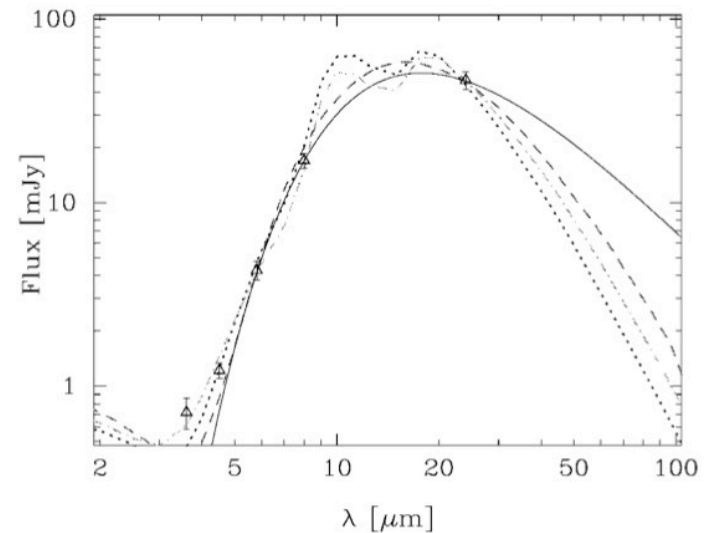


FIG. 1.—(a, b) SINGS IRAC 5.8 and 8.0 μm images of a $30'' \times 29''$ region around SN 2002hh (pixel size = $1''$), obtained on 2004 June 10. (c) SINGS MIPS 24 μm image of the same region (pixel size = $2''$), obtained on 2004 July 9. (d) Gemini North Michelle 11.2 μm image of a $21'' \times 21''$ region centred on SN 2002hh ($0''.099 \text{ pixel}^{-1}$), obtained on 2004 September 26. Offsets in arcseconds from the position of the SN are marked on the axes. A 3 pixel ($0''.3$) FWHM Gaussian filter was applied to the cleaned image. [See the electronic edition of the Journal for a color version of this figure.]

Dust shell or formation?

- Likely dust shell

- $1.6 \times 10^7 L_{\odot}$, 290 K
- $R \sim 10^7$ cm (~ 2 yr)
- $M_d = 0.10-0.15 M_{\odot}$, $M \sim 10 M_{\odot}$



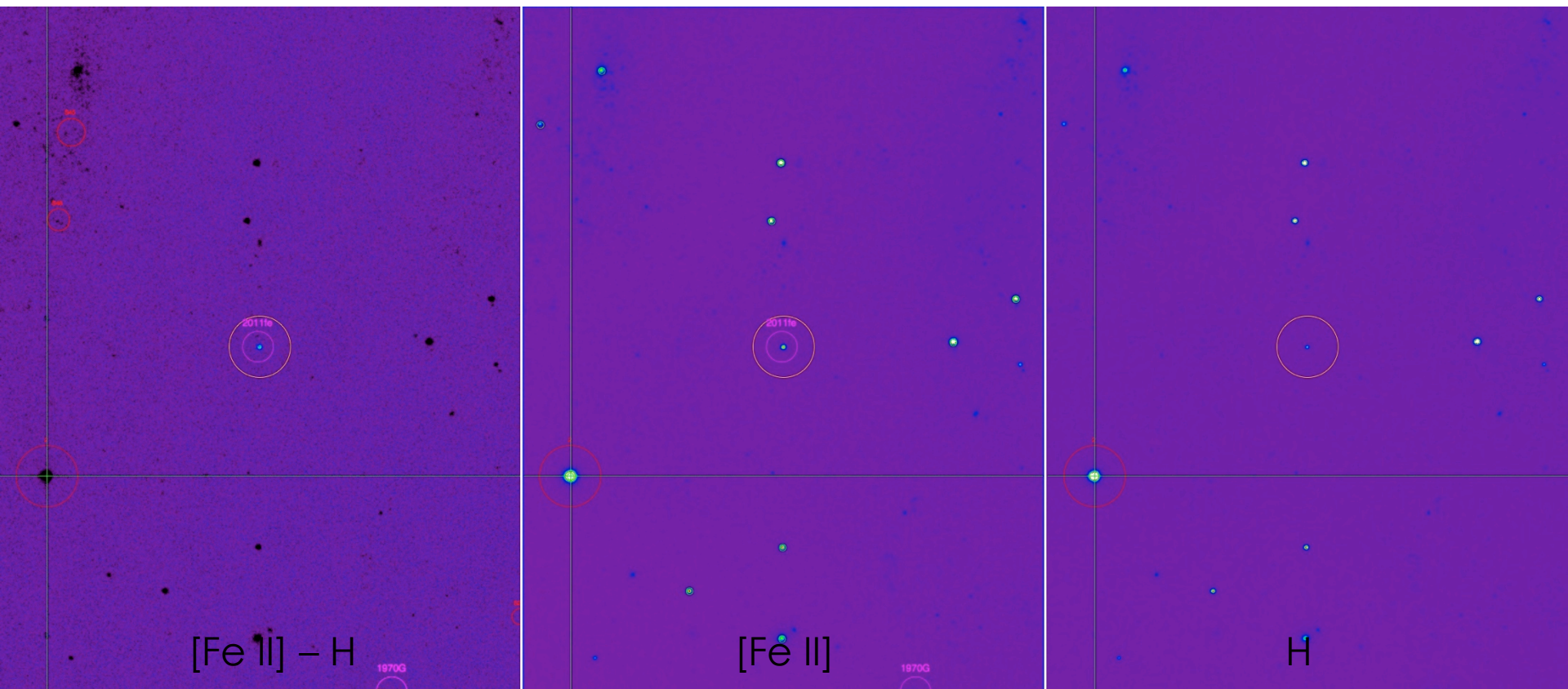
- Unable to completely rule out dust formation in ejecta

Our observations I: H, [Fe II] imaging of SNe in M51 and M101

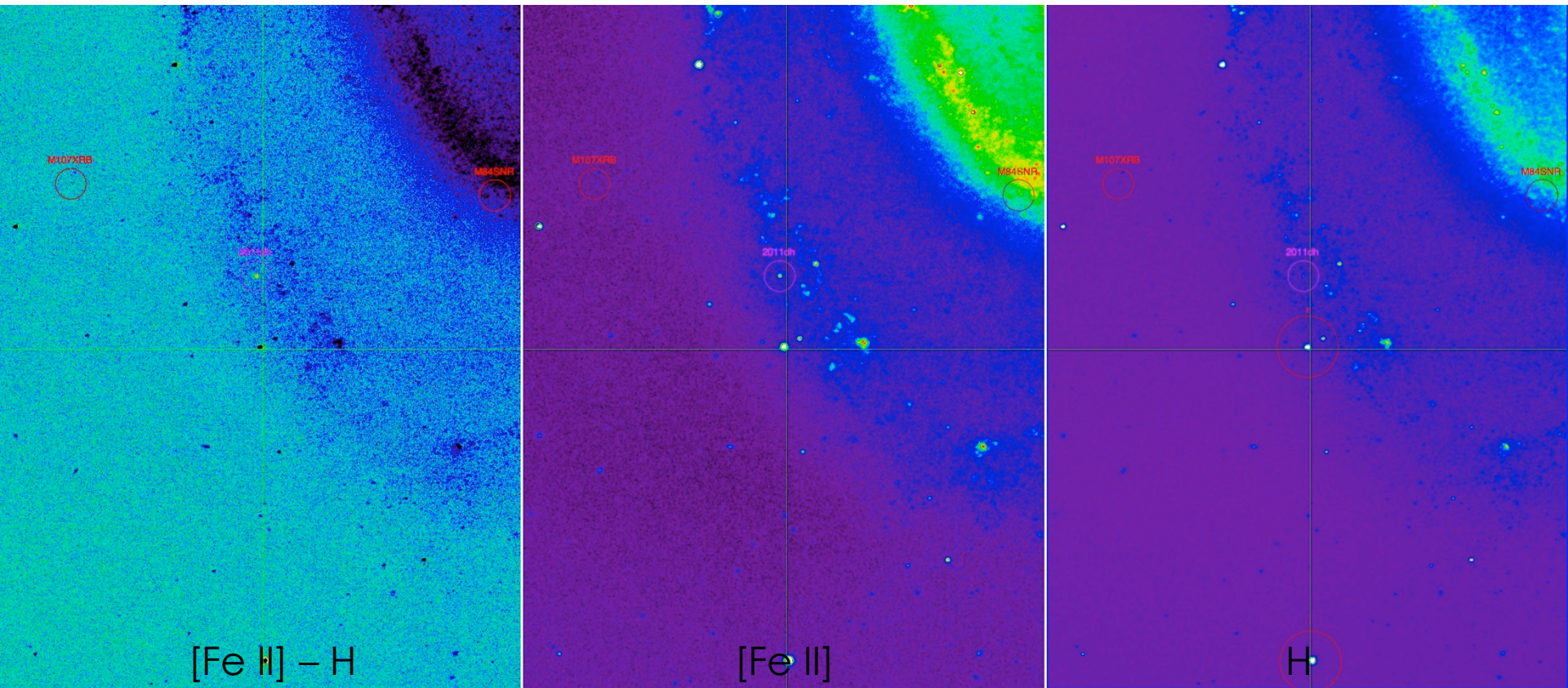
- About 1 year after explosion
 - UKIRT 3.8 m WFCAM
 - Plan: this summer 2013. 6

Host G.	Dist.	SN	Type	Date (Exp.)	Date (Obs.)	[Fe II]	H
M101	6.7 Mpc	2011fe	Ia	Aug. 24	2012.6.24.-7.12	15.5 mag	16.5 mag
M51	8 Mpc	2011dh	IIP	Jun. 01	2012.6.25.-7.8	17.0 mag	18.5 mag

M101 : SN Ia 2011fe



M51 : SN IIP 2011dh



Our observations II: near-IR HK spectroscopy

- HK high-resolution spectroscopy on 2.7m
 - Korean Astronomy & Space Institute (with U. of Texas)
 - Operation: scheduled to start from late 2013
 - Submitted to one of scientific interests

Item		H-band	K-band
Wavelength [μm]		1.65 (1.49 ~ 1.8)	2.16 (1.96~2.46)
Spectral resolution (R)		40,000	40,000
Slit width (@4m telescope)		0.68 arcsec	0.68 arcsec
Beam size		25 mm	25 mm
Main dispersion grating (Immersion Echelle grating)	Glass material	Silicon	Silicon
	Grating angle [deg]	71.56 (R3)	71.56 (R3)
	Line density [l/mm]	36.5	36.5
	Orders (min-max)	98-122	72-92
Cross dispersion grating (VPHG, first order)	Glass material	Corning Fused Silica (HPFS 7980)	Heraeus (Infrasil 301)
	Grating angle [deg]	32.43	32.43
	Line density [l/mm]	650	400
	Order separation [arcsec] (min-max)	11.8 ~ 18.3	12.1 ~ 20.2
Detector	Type	H2RG (2Kx2K)	H2RG (2Kx2K)
	Pixel size [μm]	18	18

SNe bright at the time of detection

1987A		1987	2	24	5	35.4	-69	16			4.5	IAUC	4316	5	35	27.99	-69	16	11.5	IAUC	4327	IIp	1987A	Shelton, Duhalde, Jones
1885A	NGC 224	1885	8	17	0	42.7	41	16 15W	45		5.8											1885A	Hartwig (S And)	
1895B	NGC 5253	1895	7	7	13	39.9	-31	39 16E	23N		8											1895B	Fleming (Z Cen)	
1937C	IC 4182	1937	8	16	13	5.8	37	36 30E	40N		8.4	IAUC	680									1937C	Zwicky	
1972E	NGC 5253	1972	5	6	13	39.9	-31	39 38W	100S		8.5	IAUC	2405						PASP	85, 427	I	1972E	Kowal	
1954A	NGC 4214	1954	4	10	12	15.6	36	20 84E	216S		9.8	IAUC	1453									1954A	Wild	
1993J	NGC 3031	1993	3	28	9	55.4	69	1 45W	160S		10.2	IAUC	5731	9	55	25	69	1	13	IAUC	5731	IIb	1993J	Garcia
1921C	NGC 3184	1921	12	5	10	18.3	41	25 79E	236S		11											1921C	Jones	
2004dj	NGC 2403	2004	7	31	7	37.3	65	36 160E	10N		11.2	IAUC	8377	7	37	17.02	65	35	57.8	IAUC	8377	II-P	2004dj	Itagaki
1961H	NGC 4564	1961	5	2	12	36.4	11	26	0 5N		11.2	IAUC	1759									1961H	Romano	
1980K	NGC 6946	1980	10	28	20	34.9	60	9 280E	166S		11.4	IAUC	3532	20	35	30.07	60	6	23.8	AJ 1	11, 2017	II-L	1980K	Wild
1971I	NGC 5055	1971	5	24	13	15.7	42	1 2W	147S		11.5	IAUC	2330									1971I	Jolly, Clark	
1970G	NGC 5457	1970	7	30	14	3.3	54	21 97W	370S		11.5	IAUC	2269	14	3	0.83	54	14	32.8	AJ 1	11, 2017	II	1970G	Lovas
1960F	NGC 4496	1960	4	17	12	31.7	3	56 38E	24N		11.6	IAUC	1721	12	31	42.05	3	56	47.8	PASP	105, 1250	Ia	1960F	Humason
1962M	NGC 1313	1962	11	26	3	18.2	-66	29	0 150S		11.7											1962M	Sersic	
1920A	NGC 2608	1920	1	1	8	35.2	28	29 19W	5N		11.8											1920A	Wolf	
2013aa	NGC 5643	2013	2	13	14	32.6	-44	13 74W	180S		11.9	CBET	3416	14	32	33.88	-44	13	27.8	CBET	3416	Ia	2013aa	Parker
1968L	NGC 5236	1968	7	17	13	37.1	-29	52 5W		0	11.9	IAUC	2085	13	37	0.51	-29	51	59	AJ 1	11, 2017		1968L	Bennett
1939B	NGC 4621	1939	5	19	12	42	11	39	0 53S		11.9	IAUC	774									1939B	Zwicky	
1939A	NGC 4636	1939	1	17	12	42.9	2	42 26W	20N		11.9	IAUC	737									1939A	Zwicky	
1989Z	NGC 4013	1989	12	30	11	58.6	43	57 10E	4N		12	IAUC	5162									1989Z	Shaw	
1983U	NGC 3227	1983	11	4	10	23.6	19	52 12W		0	12	IAUC	3887	10	23	29.41	19	51	55.7	IAUC	3892	I	1983U	Pronik
1960R	NGC 4382	1960	12	20	12	22.9	18	11 8E	132S		12	IAUC	1750	12	25	24.84	18	9	19.4	PASP	105, 1250	Ia	1960R	Gates, Rosino
1979C	NGC 4321	1979	4	19	12	25.4	15	49 56E	87S		12.1	IAUC	3348	12	22	58.63	15	47	51.7	AJ 1	11, 2017	II-L	1979C	Johnson
1909A	NGC 5457	1909	1	26	14	3.3	54	21 620W	408N		12.1											1909A	Wolf (SS UMa)	
1989M	NGC 4579	1989	6	28	12	37.6	11	49 40W	33N		12.2	IAUC	4802									1989M	Kimeridze	
1961V	NGC 1058	1961	12	5	2	43.4	37	21 76E	17N		12.2	IAUC	1764									1961V	Wild	
1981B	NGC 4536	1981	3	2	12	34.6	2	11 36E	36N		12.3	IAUC	3580									1981B	Tsvetkov	
1956A	NGC 3992	1956	3	8	11	57.6	53	22 67E	9S		12.3											1956A	Gates	
1954B	NGC 5668	1954	4	27	14	33.4	4	27 2W	20S		12.3	IAUC	1449									1954B	Wild	
1919A	NGC 4486	1919	2	24	12	30.8	12	23 15W	100N		12.3											1919A	Balanowsky	
2006ce	NGC 908	2006	5	10	2	22.9	-21	14 136W	28S		12.4	IAUC	8709	2	22	54.63	-21	14	29.4	IAUC	8709	Ia	2006ce	Monard
2003hv	NGC 1201	2003	9	9	3	4.2	-26	5 17E	57S		12.5	IAUC	8197	3	4	9.32	-26	5	7.5	IAUC	8197	Ia	2003hv	LOTOSS
1986G	NGC 5128	1986	5	3	13	25.6	-43	2 120E	60S		12.5	IAUC	4208	13	25	36.51	-43	1	54.2	IAUC	4208	Ia	1986G	Evans
1985L	NGC 5033	1985	6	13	13	13.5	36	36 68W	51N		12.5	IAUC	4077	13	13	21.79	36	36	33	IAUC	4084	II	1985L	Metlova
1983N	NGC 5236	1983	7	3	13	37.1	-29	52 120W	130S		12.5	IAUC	3835	13	36	51.24	-29	54	2.7	AJ 1	11, 2017	Ia	1983N	Evans
1980N	NGC 1316	1980	12	7	3	22.6	-37	14 220E	20S		12.5	IAUC	3548									1980N	Wischnjewsky	
1957B	NGC 4374	1957	4	23	12	25	12	53 8W	47N		12.5	IAUC	1600									1957B	Romano, Gates	
1935C	NGC 1511	1935	8	16	3	59.5	-67	38 55E	8S		12.5	IAUC	4647									1935C	Boyce	
1895A	NGC 4424	1895	3	16	12	27.2	9	25 75E	11S		12.5											1895A	Wolf (VW Vir)	
2008bk	NGC 7793	2008	3	25	23	57.8	-32	33 26E	138N		12.6	CBET	1315	23	57	47.5	-32	33	24	CBET	1315	II	2008bk	Monard
2011ij	NGC 4984	2011	12	9	13	9	-15	31 17E	6S		12.7	CBET	2943	13	8	58.39	-15	31	4.1	CBET	2943	Ia	2011ij	Itagaki
2006mq	ESO 494-G26	2006	10	22	8	6.2	-27	34 17E	124S		12.7	CBET	721	8	6	12.39	-27	33	45.4	IAUC	8771	Ia	2006mq	LOSS
1981D	NGC 1316	1981	3	1	3	22.6	-37	14 20W	100S		12.7	IAUC	3583									1981D	Evans	
2011iv	NGC 1404	2011	12	2	3	38.9	-35	36 7W	8N		12.8	CBET	2940	3	38	51.35	-35	35	32	CBET	2940	Ia	2011iv	Parker
2008ge	NGC 1527	2008	10	8	4	8.4	-47	54 5E	2N		12.8	CBET	1531	4	8	24.68	-47	53	47.4	CBET	1531	Ia	2008ge	Pignata et al. (CHASE)
2005af	NGC 4945	2005	2	8	13	4.7	-49	34 407W	351S		12.8	IAUC	8482	13	4	44.06	-49	33	59.8	IAUC	8482	II	2005af	Jacques, Pimentel
2004et	NGC 6946	2004	9	27	20	35.4	60	7			12.8	IAUC	8413	20	35	25.33	60	7	17.7	IAUC	8413	II	2004et	Moretti
1992A	NGC 1380	1992	1	11	3	36.4	-34	57 3W	62N		12.8	IAUC	5428	3	36	27.43	-34	57	31.5	IAUC	5428	Ia	1992A	Liller, Brown
1985S	MCG -02-07-	1985	9	19	2	27.5	-10	10 10E	10S		12.8	IAUC	5719									1985S	Keel	
1971L	NGC 6384	1971	6	24	17	32.4	7	4 27E	20N		12.8	IAUC	2336									1971L	Logan	
1969L	NGC 1058	1969	12	2	2	43.4	37	21 190E	110S		12.8	IAUC	2194									1969L	Rosino	
1940B	NGC 4725	1940	5	5	12	50.4	25	30 95E	118N		12.8	PASP	52, 206									1940B	Johnson	
1937D	NGC 1003	1937	9	9	2	39.3	40	53 48E	1S		12.8	IAUC	683									1937D	Zwicky	
2007sr	NGC 4038	2007	12	18	12	1.9	-18	58			12.9	CBET	1172	12	1	52.8	-18	58	21.7	CBET	1172	Ia	2007sr	Drake et al.
1978G	IC 5201	1978	11	24	22	21.4	-46	4 96W	42N		12.9	IAUC	3309									1978G	Blades, Griffiths, Ward	
1964E	UGC 6983	1964	3	12	11	59.2	52	42 83W	44S		12.9	IAUC	1858									1964E	Lovas	

Summary

- SNe/SNRs with dense shell
 - May have two interactions
 - Light
 - Shock
- Our study focused on shocked shell
- Interaction by light (light echo) is interesting
 - Ejecta/light echo (second interaction is expected)
 - Characteristic of shell (size, mass, ...)
- Proposal: Monitoring of known SNe