2MASS Near-Infrared Imaging of IC443

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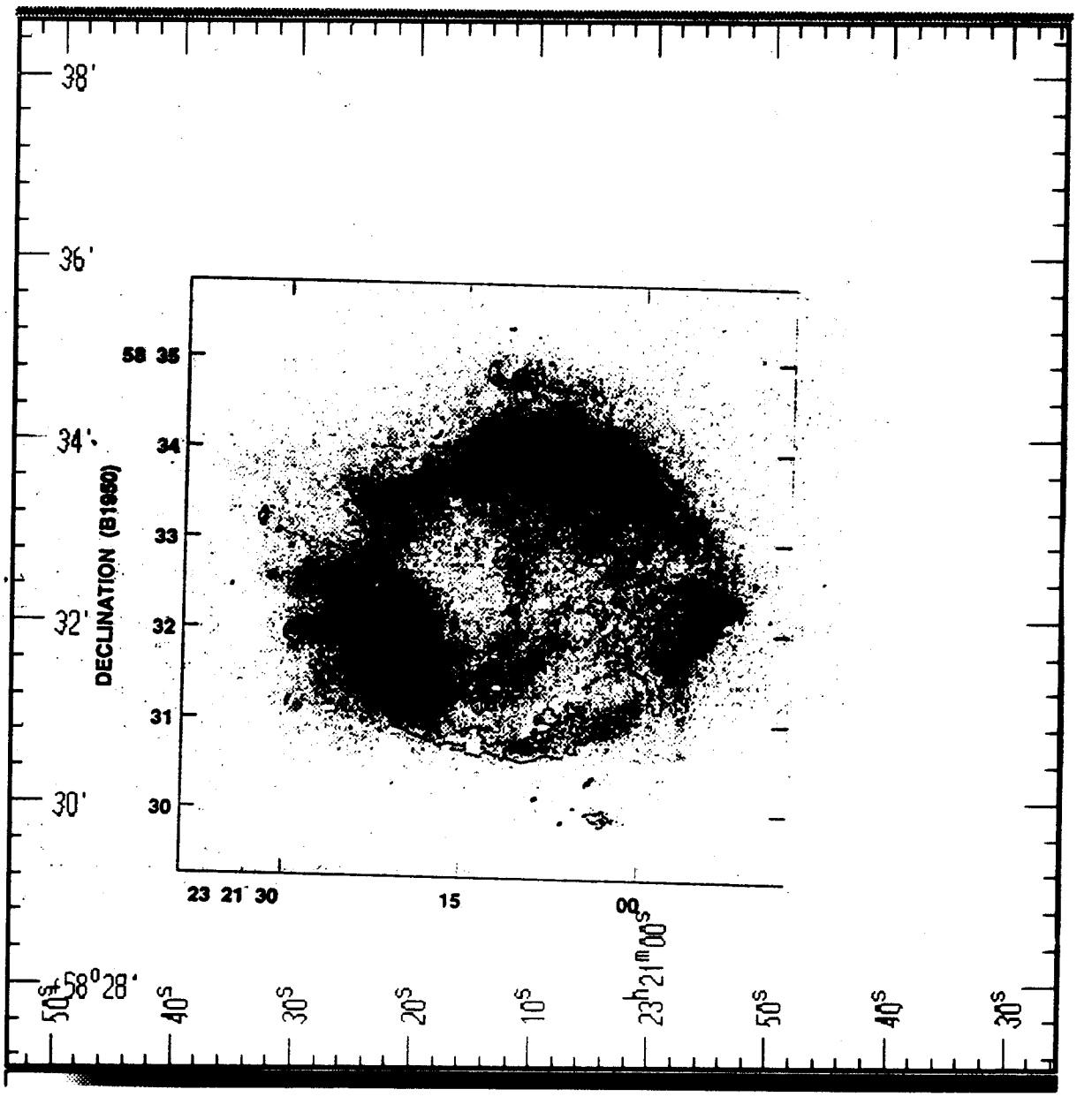
*Introduction : IC 443

1. Radio, optical : shell-like
   ⇒ but amorphouse eastern arm
   & SW filaments
2. X-rays : Peaks appear inside the shell
3. In Gem OB1 association
   nearby HII region (S249)
4. Interaction with <u>Molecular clouds</u>
   a) Shocked <u>molecular Hydrogen</u>
   (Burton et al. 1985. 1988 ; Richter et al. 19
   b) Broad molecular lines ($\Delta v \sim 20$ km/
   c) far-infrared observation
   IRAS

* observation

1) 2MASS J (1.25 μm : 1.13 – 1.37) 1"/pixel
   H (1.65 μm : 1.5 – 1.8)
   K (2.17 μm : 2 – 2.32) 3" resoluti
2) ISO LWS [OI] 63 μm

CAS A


38'
36'
34'
32'
30'
+58°28'
50s
40s
30s
20s
10s
23h21m00s
50s
40s
30s
58 35
34
33
32
31
30
DECLINATION (B1950)
23 21 30
15
00

1576.0 2052.7 3593

* Results

1) Total Images

J : (0.17 ~ 0.87) $\times 10^{-14}$ erg s^{-1} cm^{-2}

H : (0.17 ~ 1.33) $\times 10^{-14}$ erg s^{-1} cm^{-2}

K : (0.22 ~ 3.4) $\times 10^{-14}$ erg s^{-1} cm^{-2}

2) Sinus Ridge (south)

H_2 lines

K : H_2 1-0 S(1) (2.12 μm), H_2 1-0 S(2) (2.03 μm)

H : H_2 1-0 S(7) (1.75 μm)

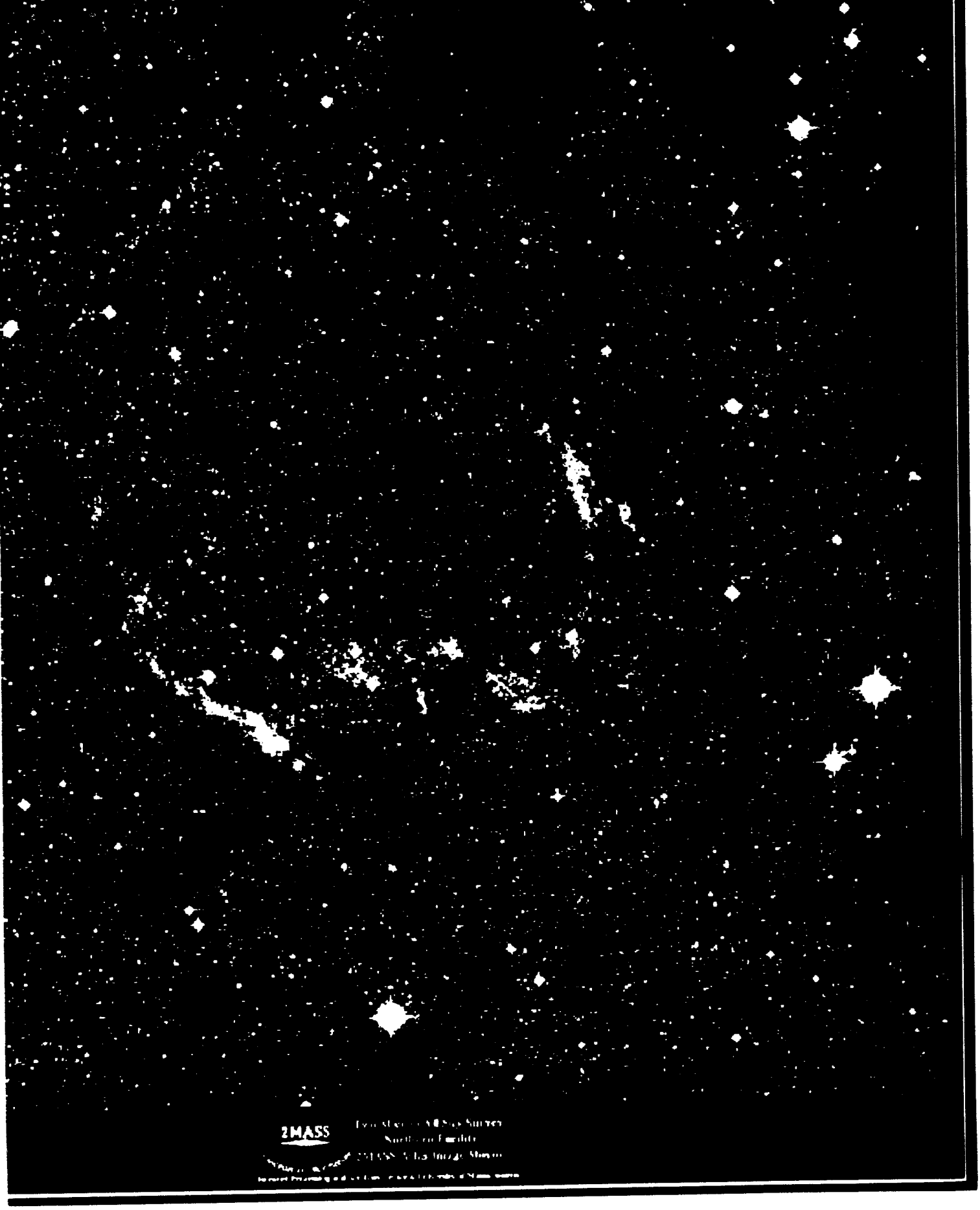
J : H_2 2-0 S(1) (1.16 μm)

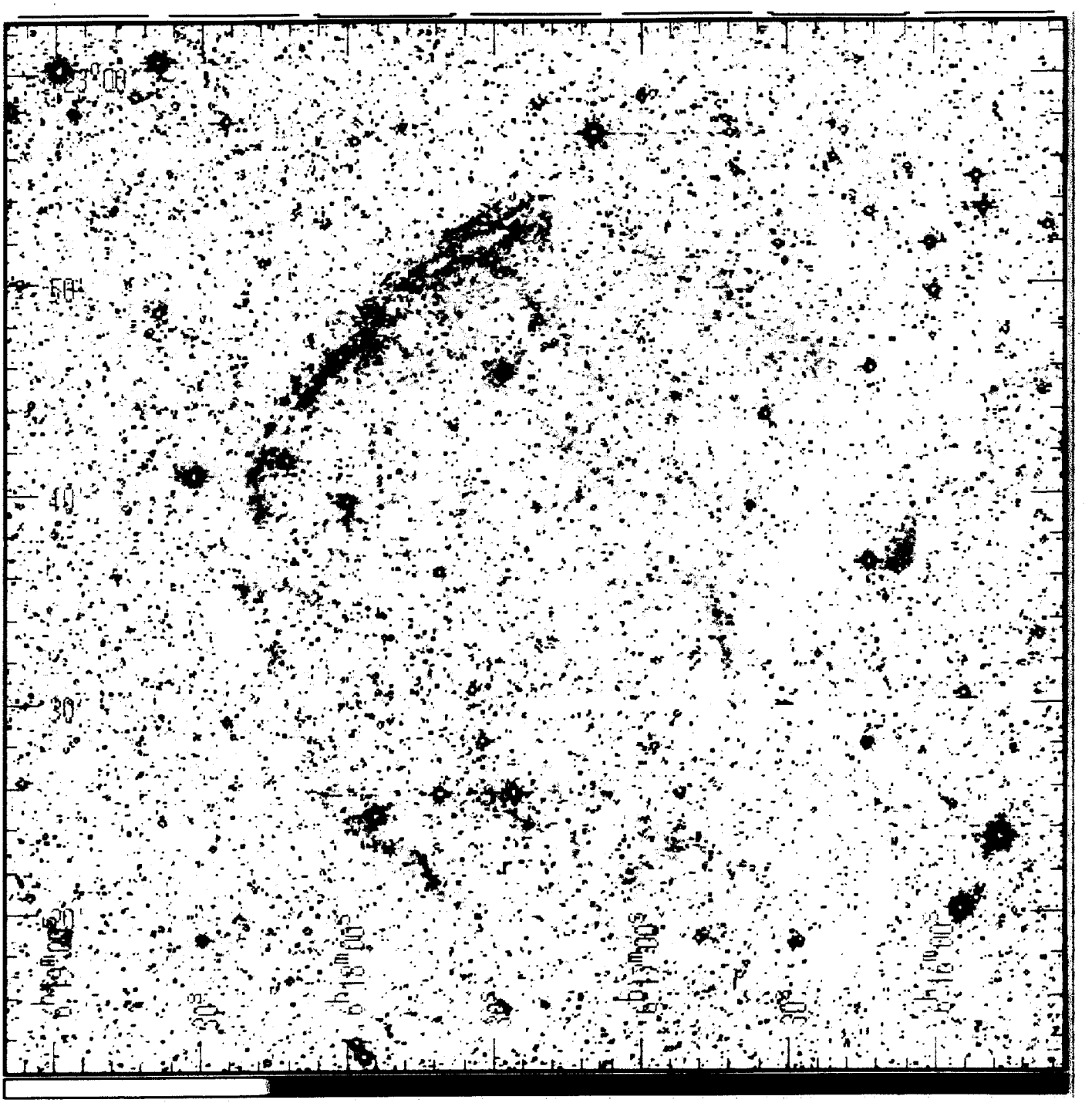
3) Northeastern Rim

J : Pβ

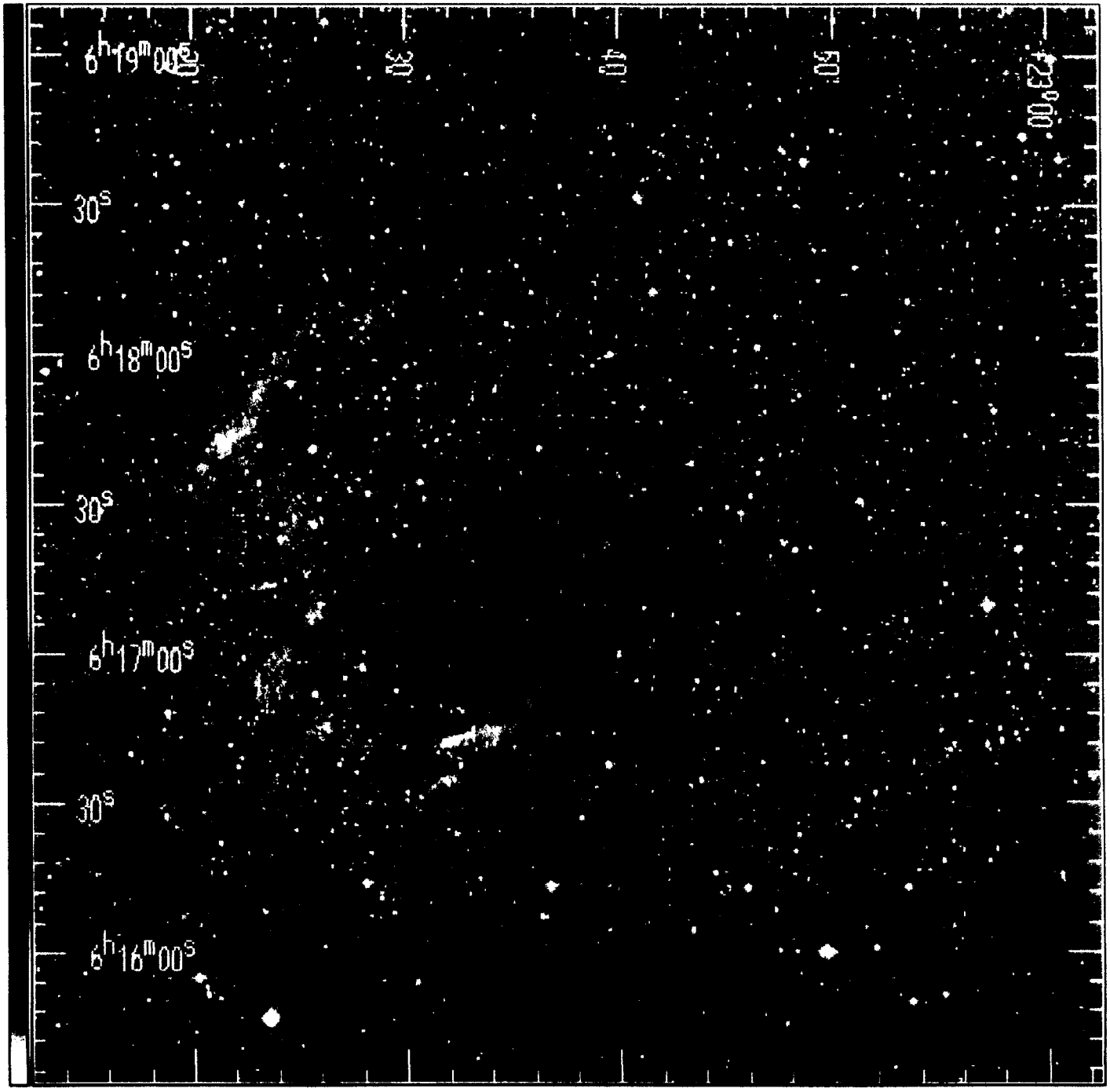
H : [Fe II]

K (North : H_2 (+ Brγ)
  East : H_2


2MASS



J


6h19m00s
30s
6h18m00s
30s
6h17m00s
30s
6h16m00s
20
30
40
50
-23°00'

• N E region

Expected J:H:K Ratio from H recombination lines

		2500K	5000K	10000K	20000K
J band	P beta(1.28mu)	0.21	0.187	0.165	0.146
H band	Br 10(1.74mu)	0.0112	0.0106	0.0092	0.008
K band	Br gamma(2.17mu)	0.0387	0.0332	0.0280	0.0237
	RATIO(J:H:K)	1: 0.05:0.18	1: 0.057:0.18	1:0.056:0.17	1: 0.055:0.1

observed ratio

$J:H:K \simeq 1 : \underbrace{1 : 0.5}_{\text{large errors}}$

(>0.91)

H recombination lines alone cannot explain H band emission

⇒ [Fe II] (1.644μ)

N : $\frac{FeII}{Br\gamma} \simeq 35$ (HII region : $\frac{FeII}{Br\gamma} \sim 0.0$

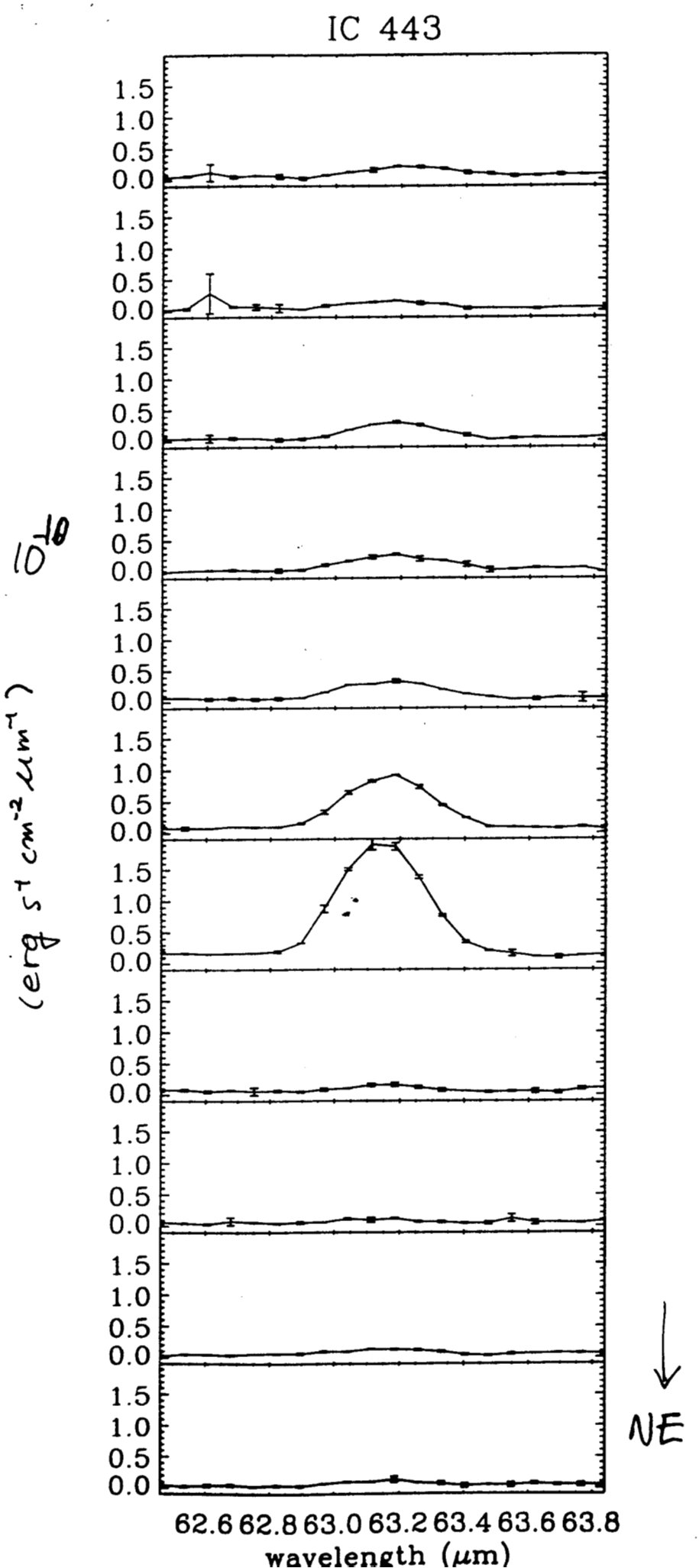
East : $\frac{FeII}{Br\gamma} > 50$ but $\frac{[FeII](1.64\mu)}{H_2 1\text{-}0 S(1)} \sim 5$

$\frac{H\alpha}{P\beta}$ (prediction) $\simeq 17 \sim 30$

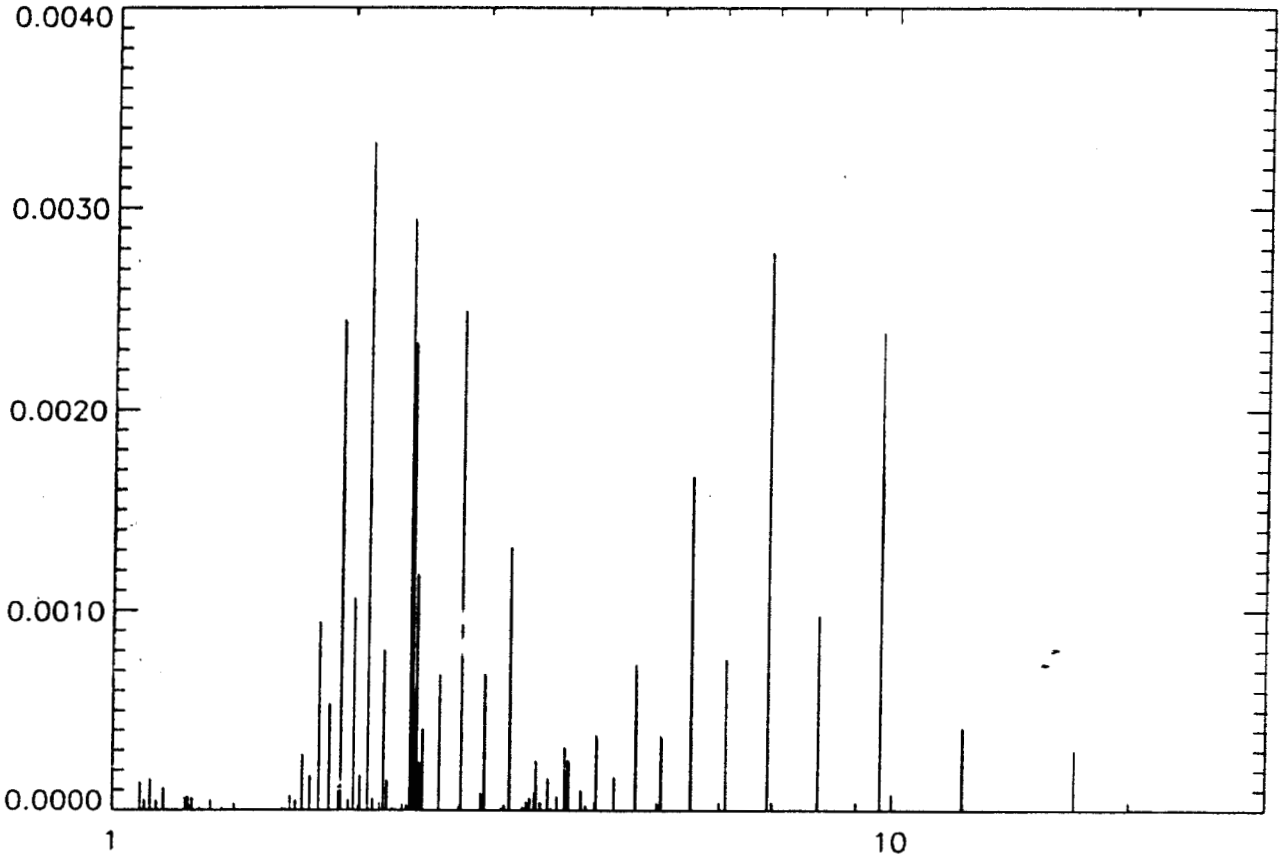
J : Pβ

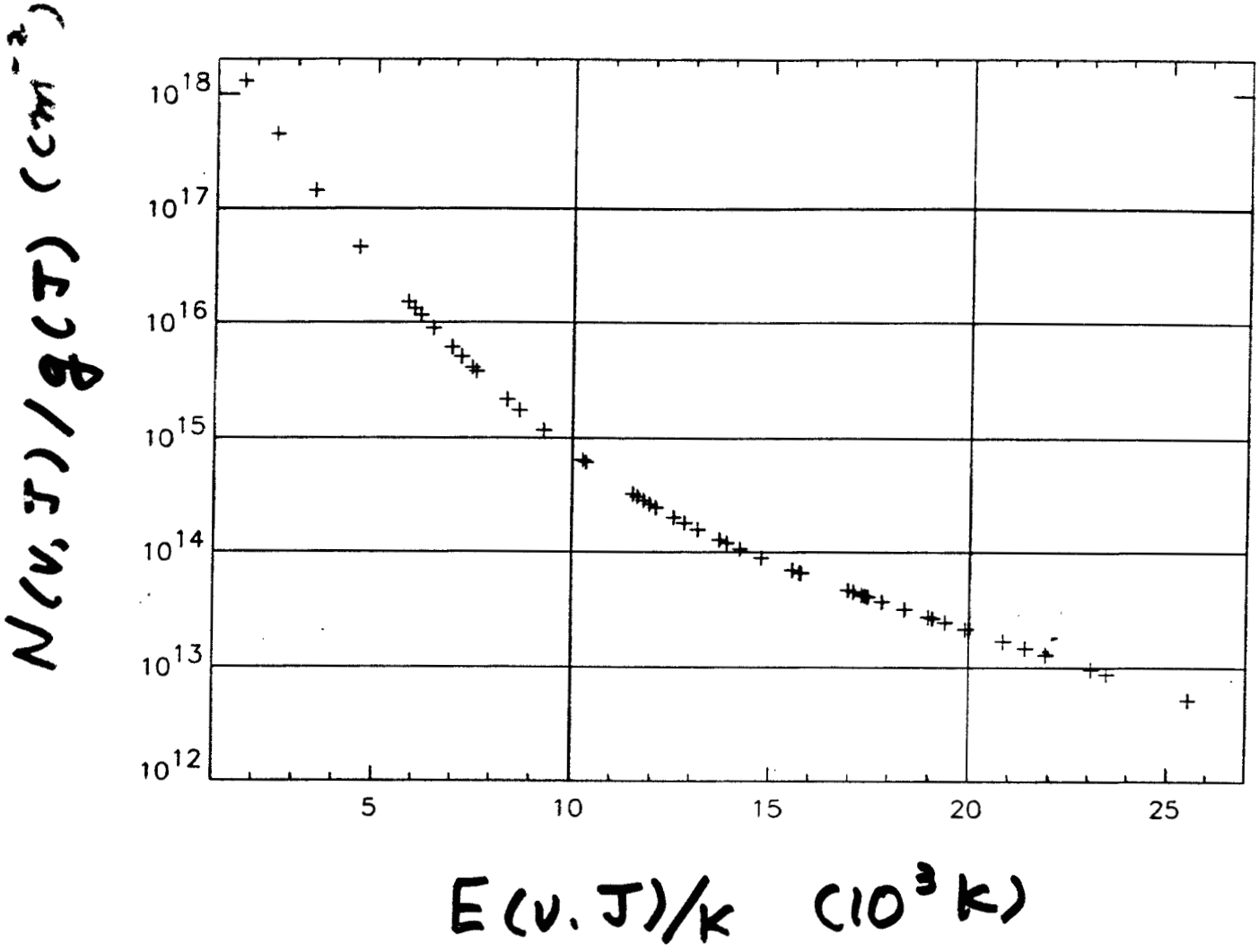
H : [Fe II]

K : H_2


IC 443
1.5
1.0
0.5
0.0
10^{-10}
(erg s^{-1} cm^{-2} μm^{-1})
NE
62.6 62.8 63.0 63.2 63.4 63.6 63.8
wavelength (μm)

H_2 lines



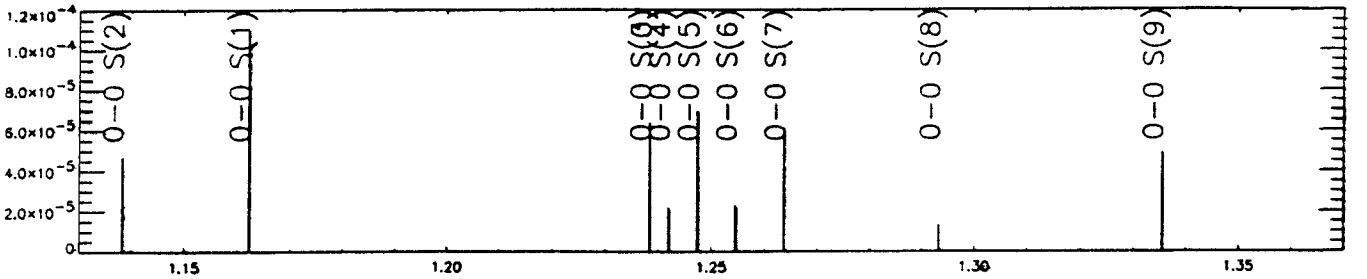


Ref. Cesarsky et al. (1999) ← ISOCAM

Richter et al. 1995

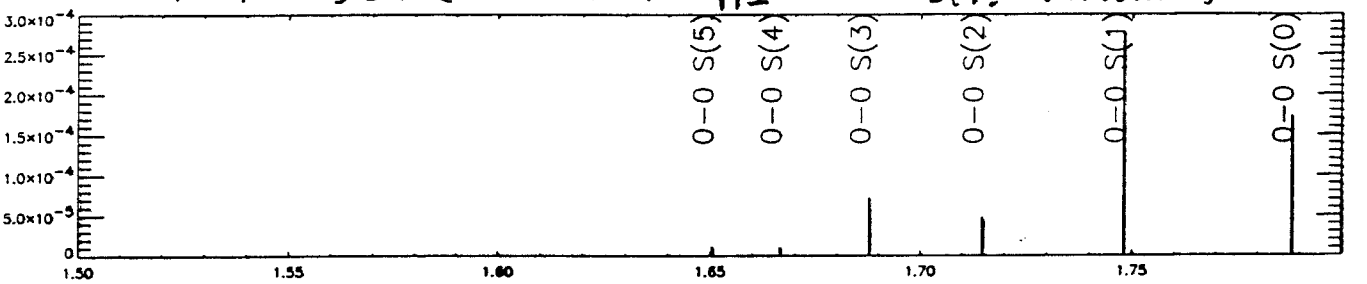
$$I_{ij} = \frac{1}{4\pi} N_i A_{ij} h\nu_{ij} \frac{1}{g(J)}$$

J



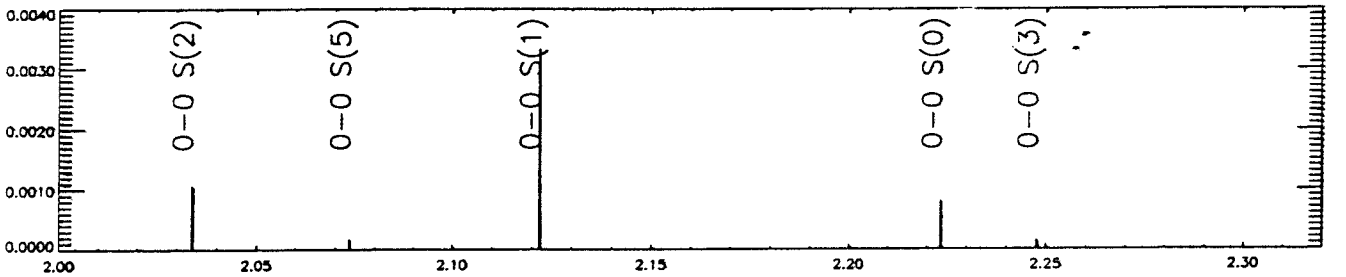
~~H_2 1-0 S(1) (2.12μm)~~, H_2 2-0 S(1) (1.16μm)

H



H_2 1-0 S(7) 1.75μm

K



H_2 1-0 S(1) (2.12μm), H_2 1-0 S(2) (2.03μm)

J : H : K

Temperature		J/K		H/K		K==1	I(K)	I(1-0 S(1))
T=1000K,	J:H:K	0.0116204	:	0.0122660	:	1	0.001073	6.91e-04
T=2000K,	J:H:K	0.14246273	:	0.16675870	:	1	0.034704	1.91e-02
T=3000K,	J:H:K *	0.28146259	:	0.34991497	:	1	0.116537	4.95e-02
T=4000K,	J:H:K	0.37789543	:	0.46029120	:	1	0.214825	7.10e-02

observed J : H : K

0.27 : 0.38 : 1

(0.18–0.38) : (0.23–0.54) : 1

* Using 3T model 657K, 1288K, 2576K

0.08 : 0.1 : 1

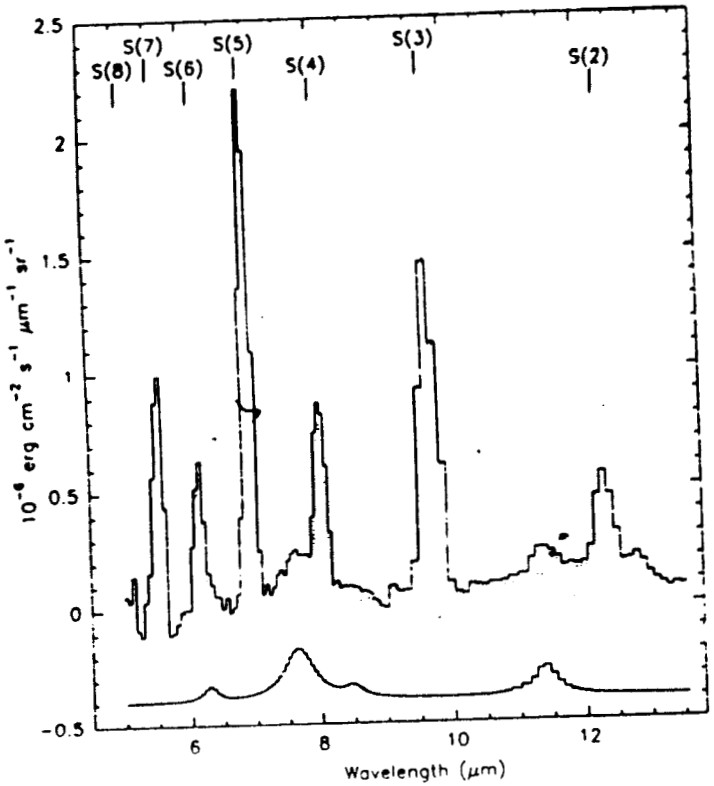
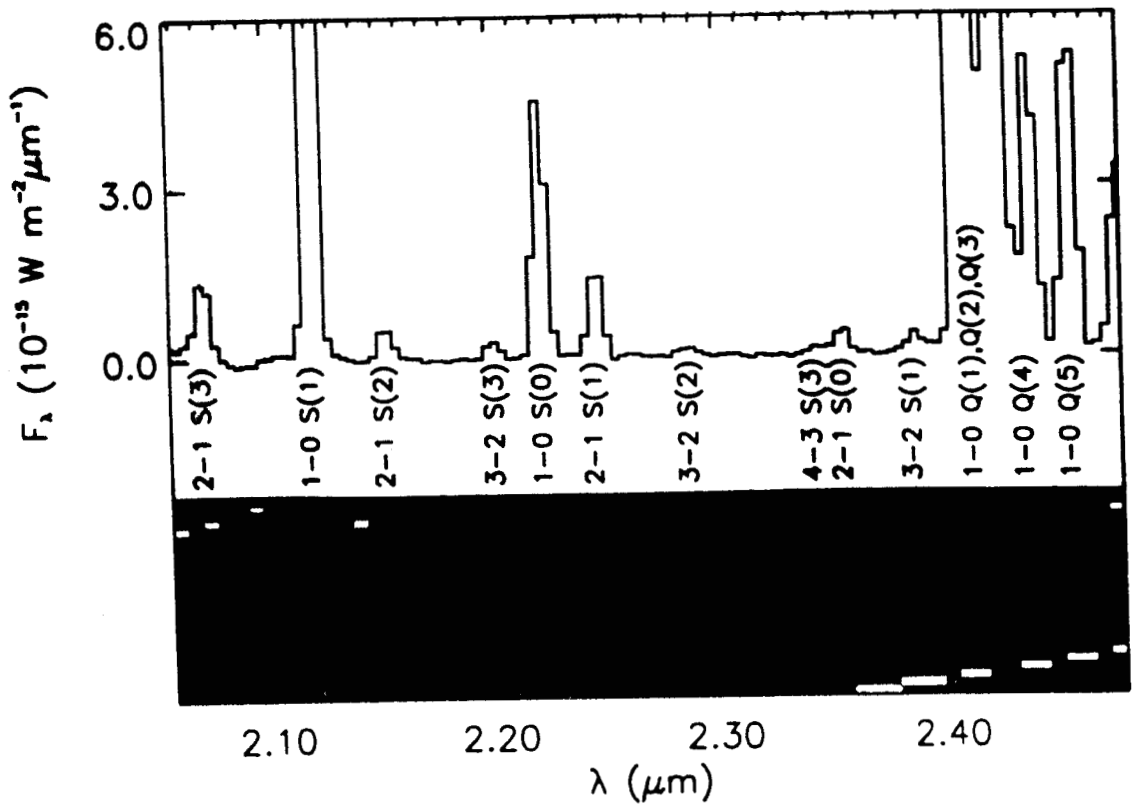


Fig. 2. IC443 mean CVF spectrum before (solid line) and after (dotted line) subtraction of the dust bands spectrum which is shown at the bottom of the figure at true scale but shifted down by $4\,10^{-7}$ erg s^{-1} cm^{-2} μm^{-1} sr^{-1}. The rotational lines of molecular hydrogen are labeled.

Cesarsky et al. 1995
Ic Ion lines



Richter et al. 1995

* Discussion

1) comparison with other images
   - CO map
   - X-rays
   - optical

2) shock diagnostics

NE region

line	λ (μm)	Flux density (10^{-4} erg s^{-1} cm^{-2} sr^{-1})	
[Fe II]	1.644	1.08	
Br γ	2.165	0.03	
[Ne II]	12.8	2.58	
[Ne III]	15.56	1.43	?
[Fe II]	17.93	0.57	
[S III]	18.71	0.57	?
[O IV]	25.88	0.43	?
[Fe II]	25.98	1.14	
[Si II]	34.8	4.45	higher
[O I]	63	4.8	

Highly ionized ions.

Best model $n_0 \sim 10^3$ $v_s \sim 90$ km/s

low density solution ($n = 10$)

cannot explain this infrared line intensity

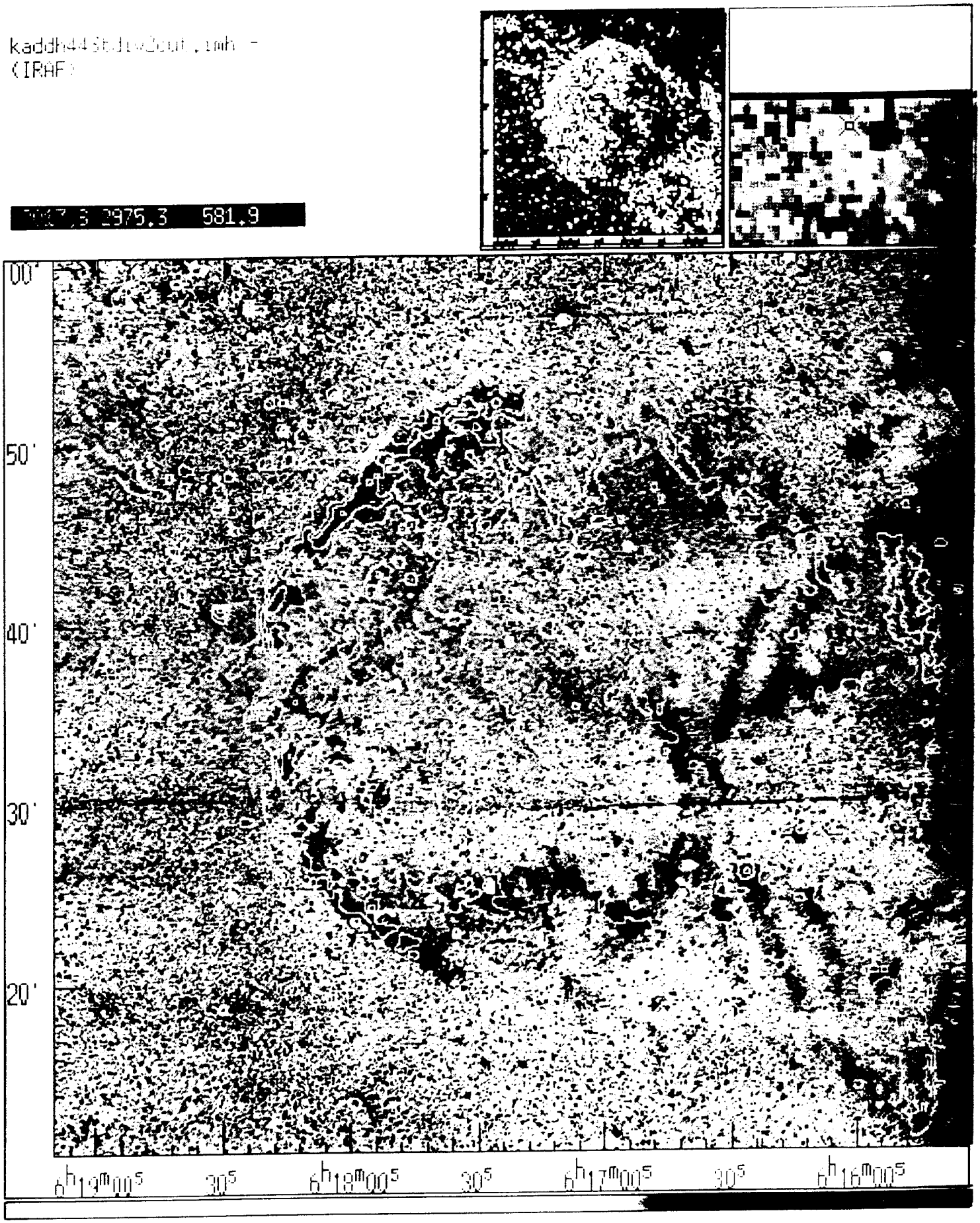
one or two magnitude higher than prediction

3) Comparison between S and NE

	NE	S
	Many Ion lines e.g [FeII]: H band [OI]	H_2 lines for J. H. K No ion lines except [OI]
n_0	$\leq 10^3\ cm^{-3}$	$\sim 10^4\ cm^{-3}$
V_s	$\sim (90\ km\ s^{-1})$	$30 \sim 40\ km/s$
shock	J-shock	C-shock

- dissociative J-shock ?
- NE: low density model ?
  (comparison with Cygnus Loop)

kaddh44[illegible]
(IRAF)



kaddh44[illegible]

SAOimage [illegible] Thu Mar [illegible] 1999

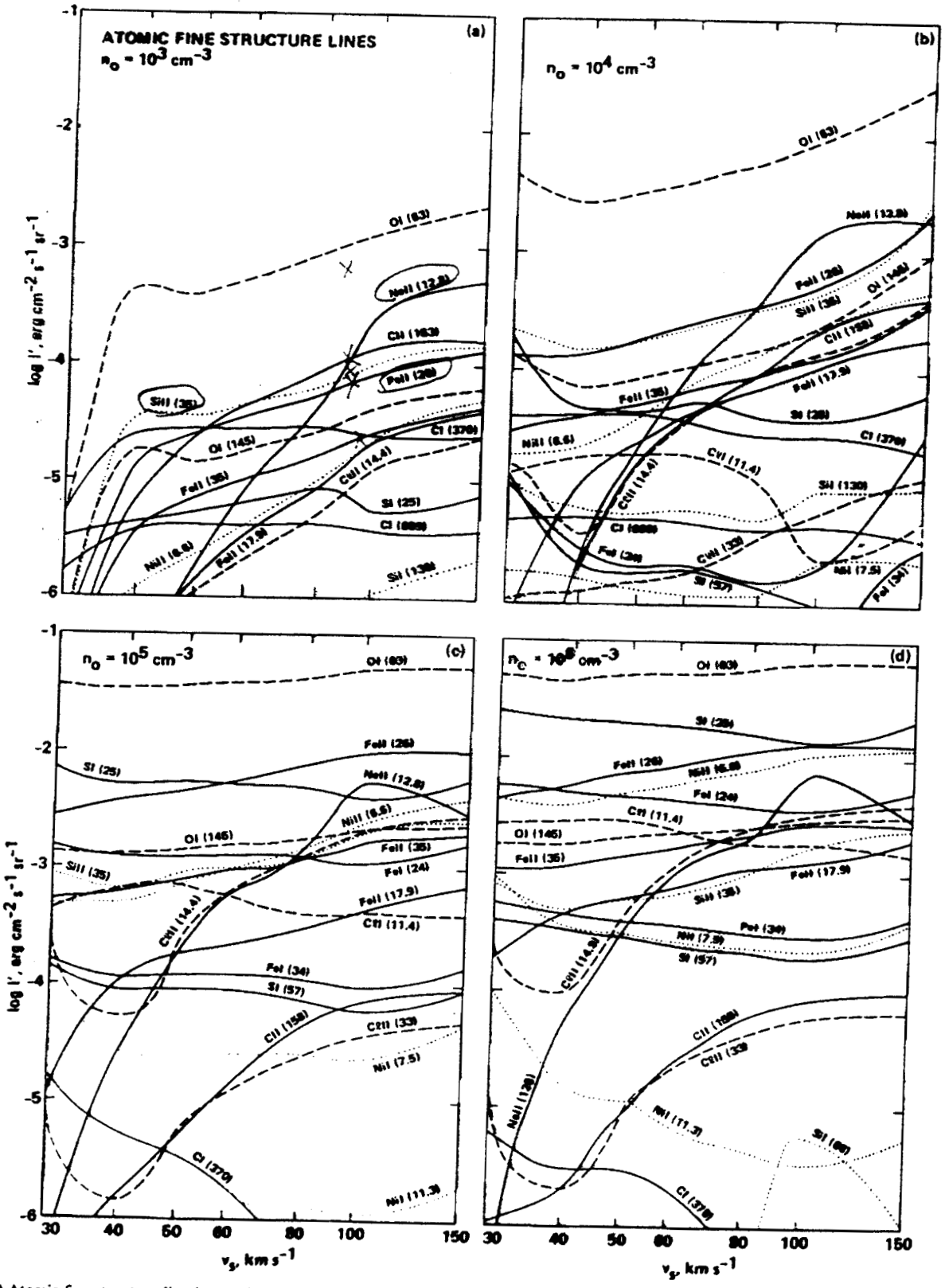


FIG. 7.—(*a–d*) Atomic fine-structure line intensities emergent normal to the shock for n_0 = (*a*) 10^3, (*b*) 10^4, (*c*) 10^5, and (*d*) 10^6 cm^{-3} are plotted as a function of v_s. Solid lines are used for transitions of C, Ne, S, and Fe; dashed lines for transitions of O and Cl; dotted lines for Si and Ni. The intensities for S, Fe, Cl, and Ni are upper limits because of the incomplete chemistry in the code (*see text*).

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