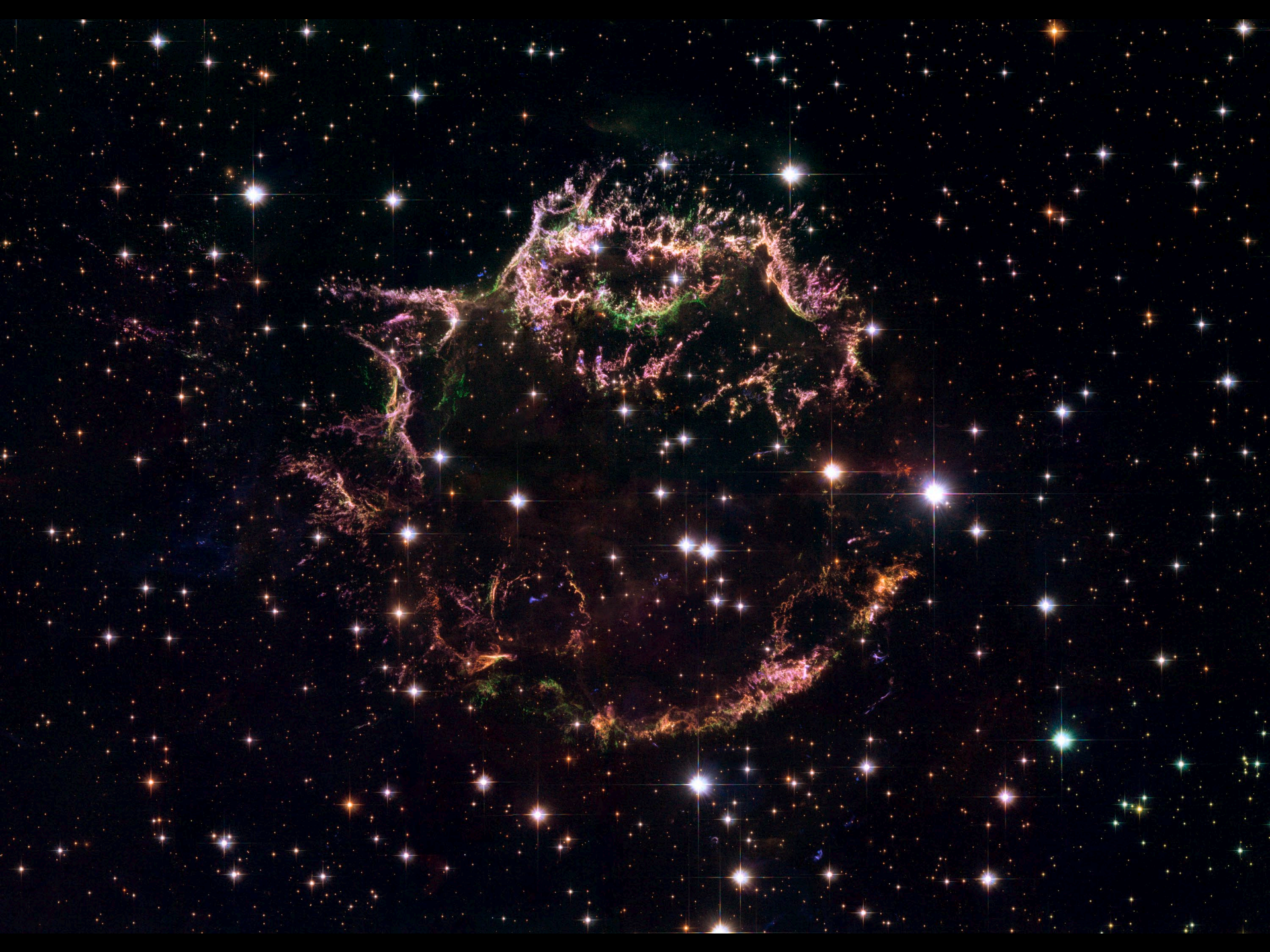
An Optical Study of the Red Supergiant Mass-Loss from the Progenitor of Cassiopeia A

Kathryn E. Weil

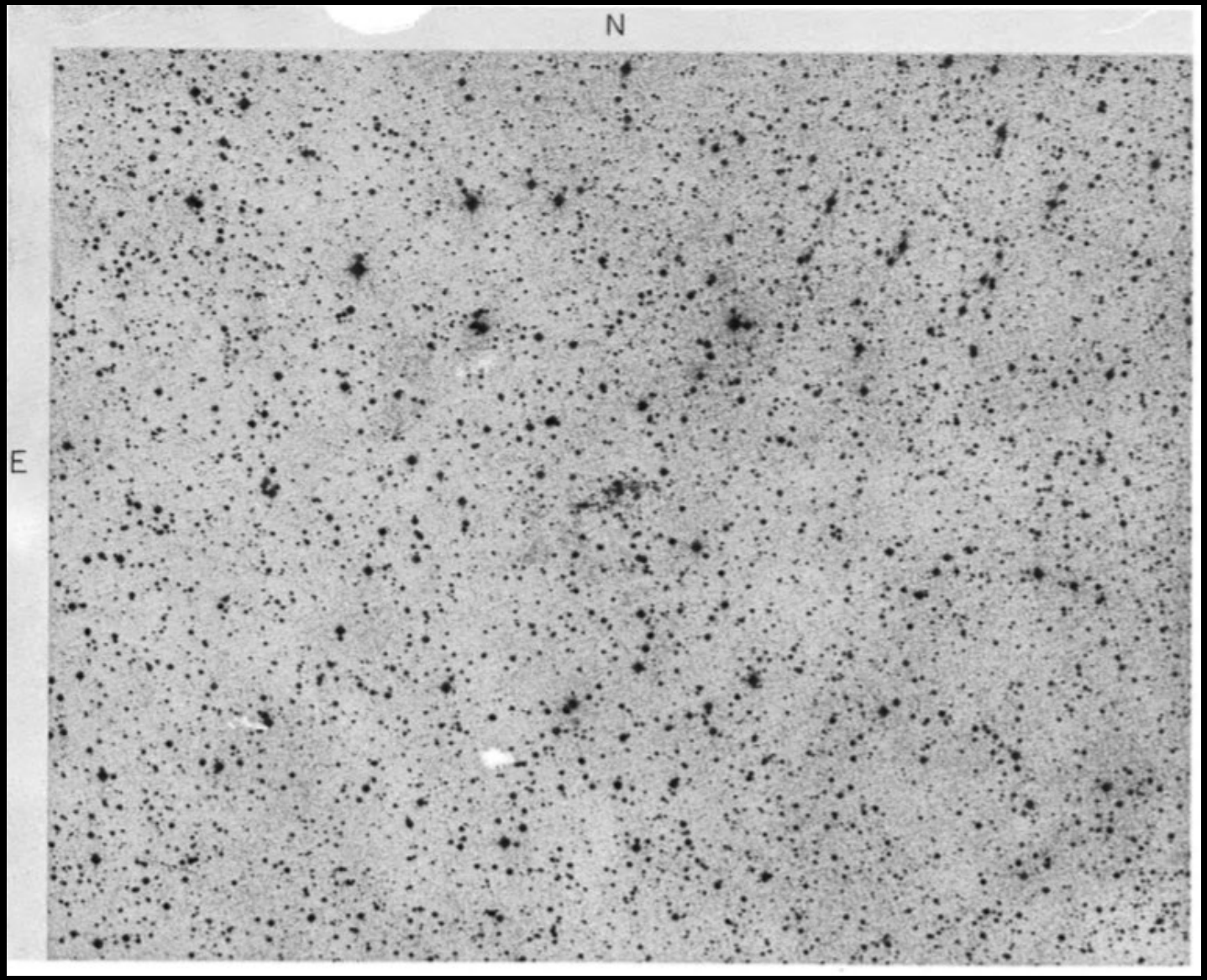
Robert Fesen, Dan Patnaude, John Raymond

DARTMOUTH

Weil+ 2019

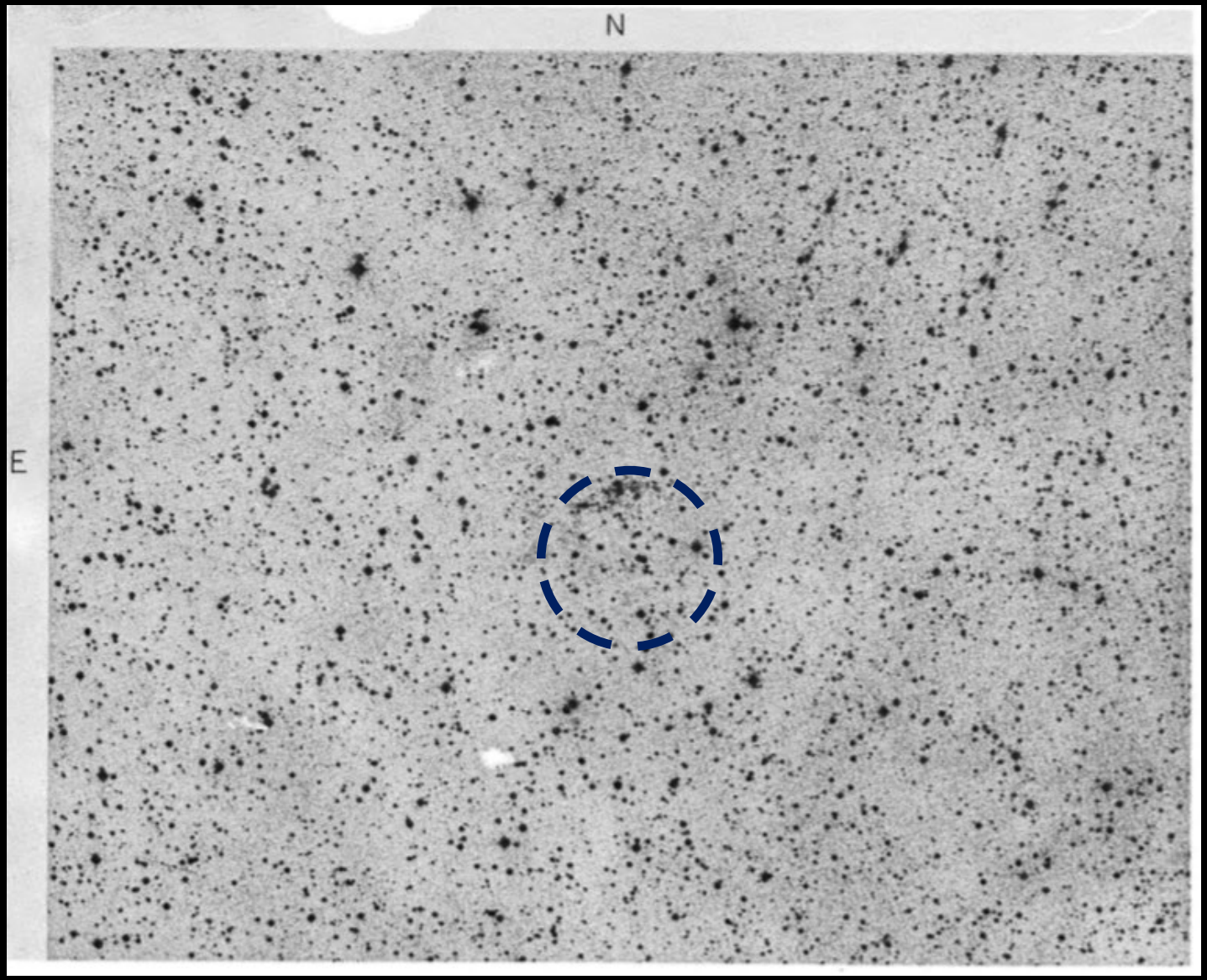


Minkowski's1968 Palomar Schmidt Red Plate



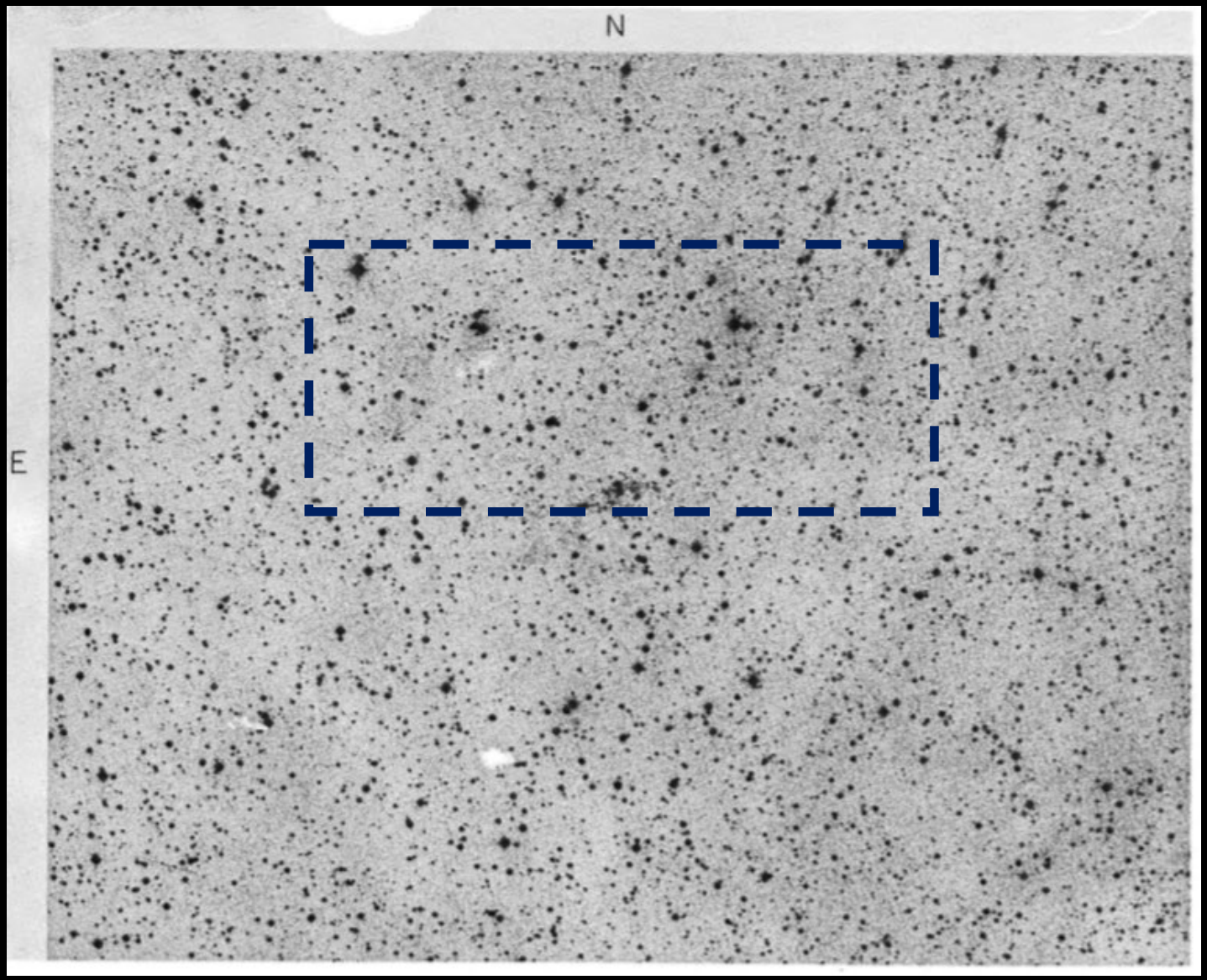
van den Bergh 1971

Minkowski's1968 Palomar Schmidt Red Plate



van den Bergh 1971

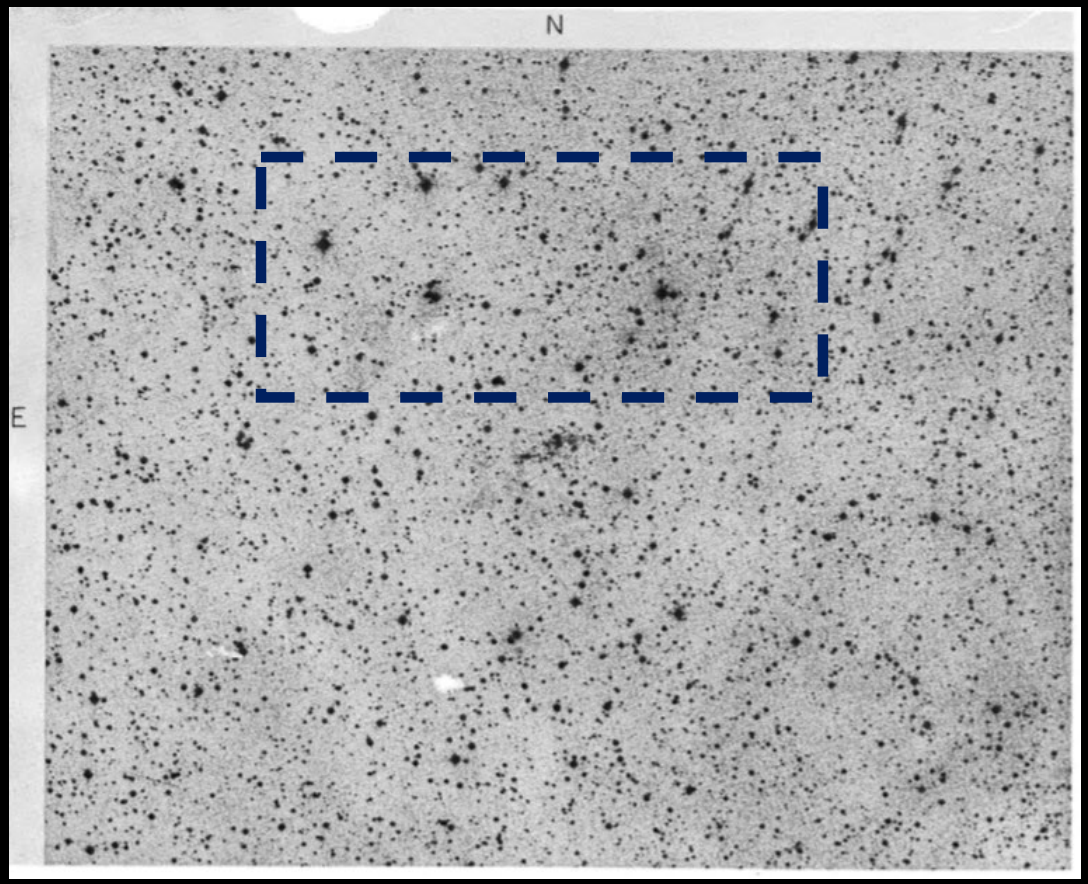
Minkowski's 'H II Region'



van den Bergh 1971

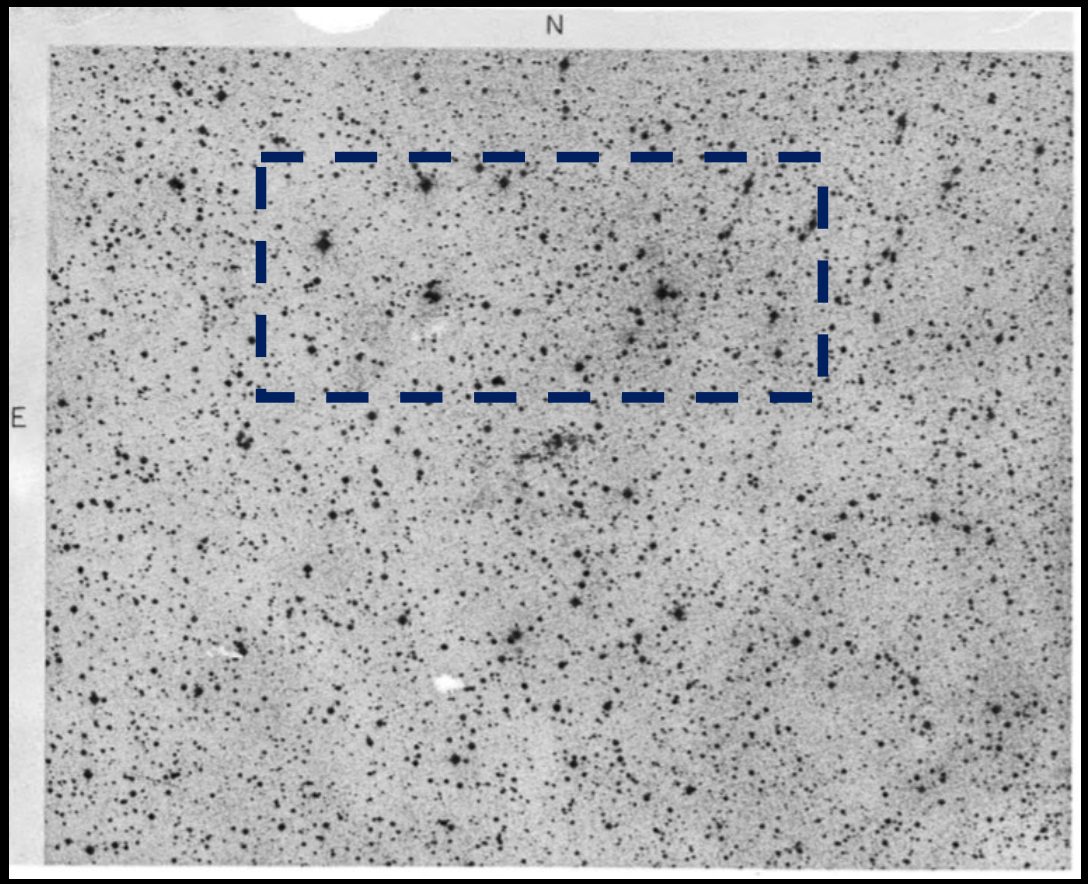
Minkowski's 'H II Region'

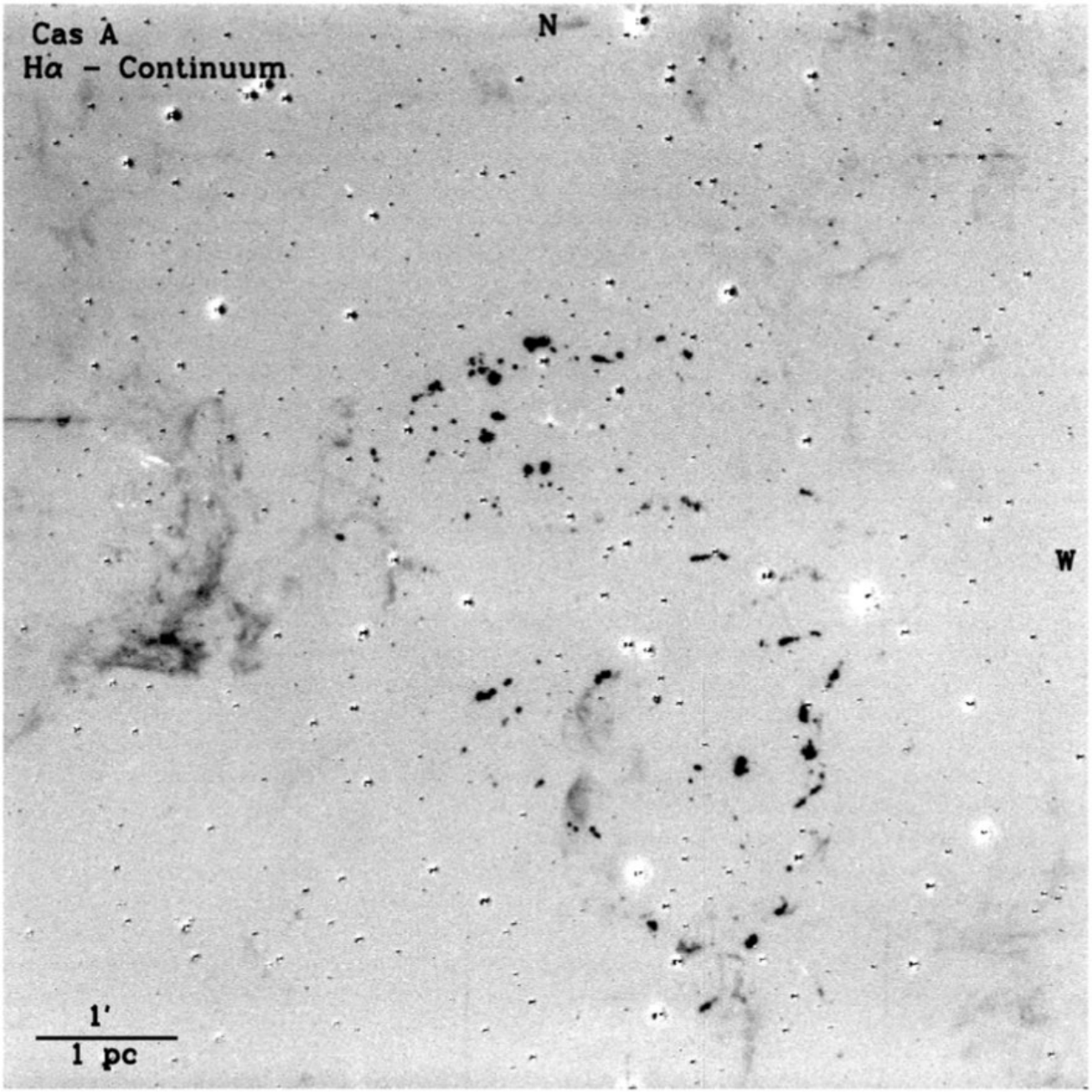
- Lack of OB Stars → Ionized by X-rays during SN outburst (van den Bergh 1971 & Peimbert 1971)



Minkowski's 'H II Region'

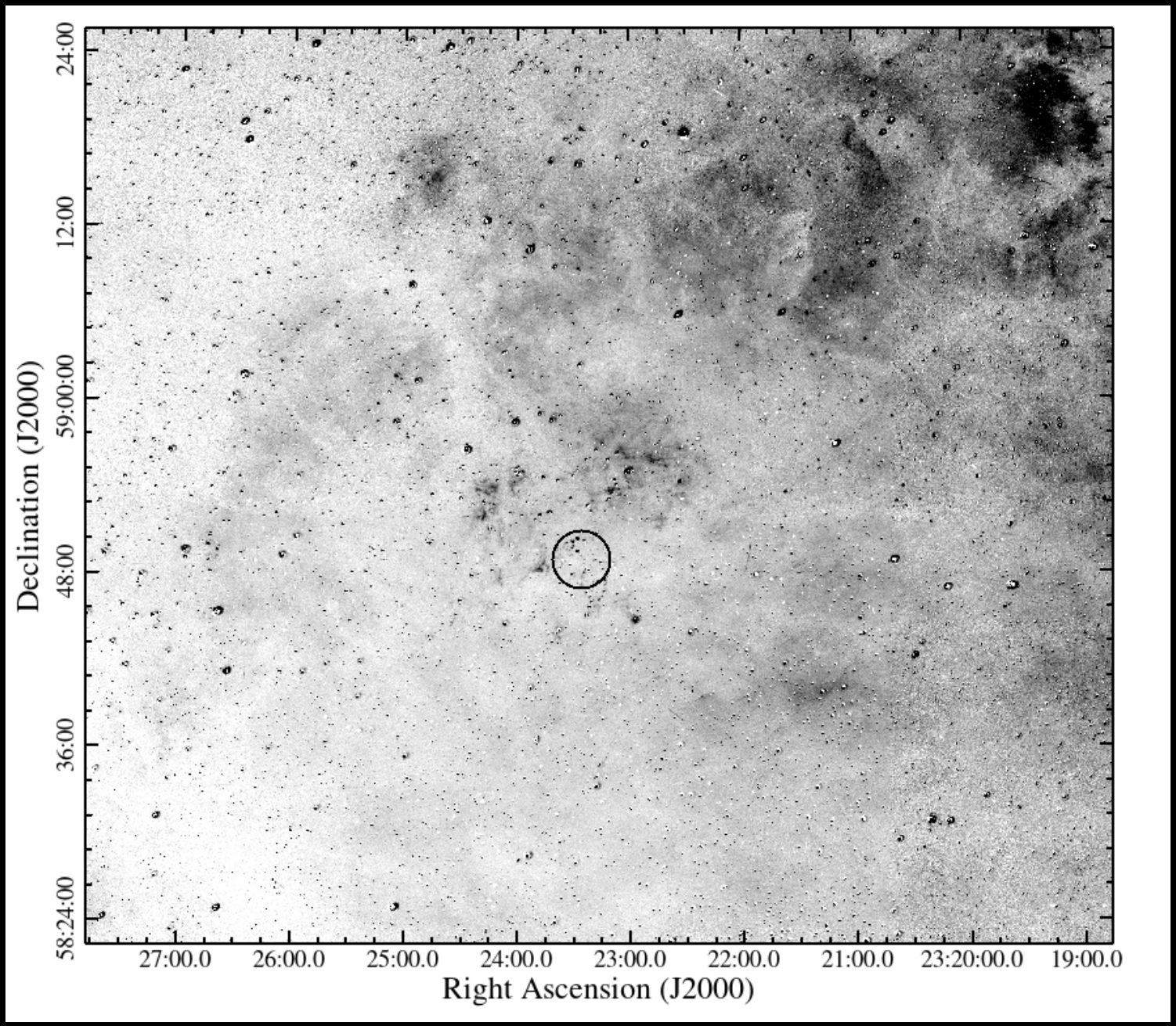
- Lack of OB Stars → Ionized by X-rays during SN outburst (van den Bergh 1971 & Peimbert 1971)
- RSG mass-loss ionized by SN outburst (Chevalier & Kirshner (1978) and Chevalier & Oishi (2003))





- Quasi-Stationary Flocculi (QSFs)
  - Dense CSM
  - $n_e=10^4$-10^5 cm^{-3}
  - Nitrogen Rich
- Eastern Nebulosity
- Faint Northern Emission

Fesen 2001


Declination (J2000)
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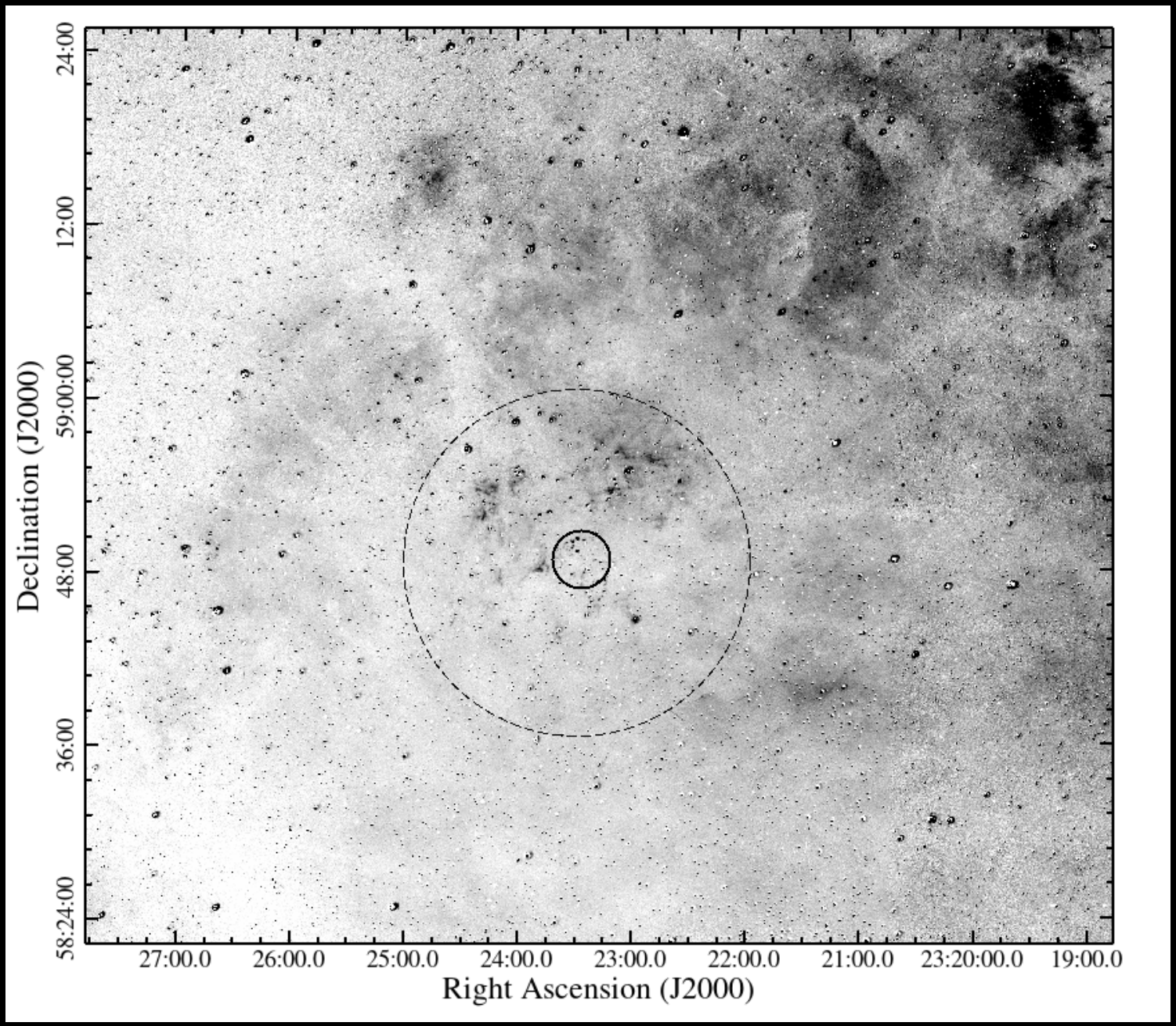
12:00
59:00:00
48:00
36:00
58:24:00
27:00.0
26:00.0
25:00.0
24:00.0
23:00.0
22:00.0
21:00.0
23:20:00.0
19:00.0
Right Ascension (J2000)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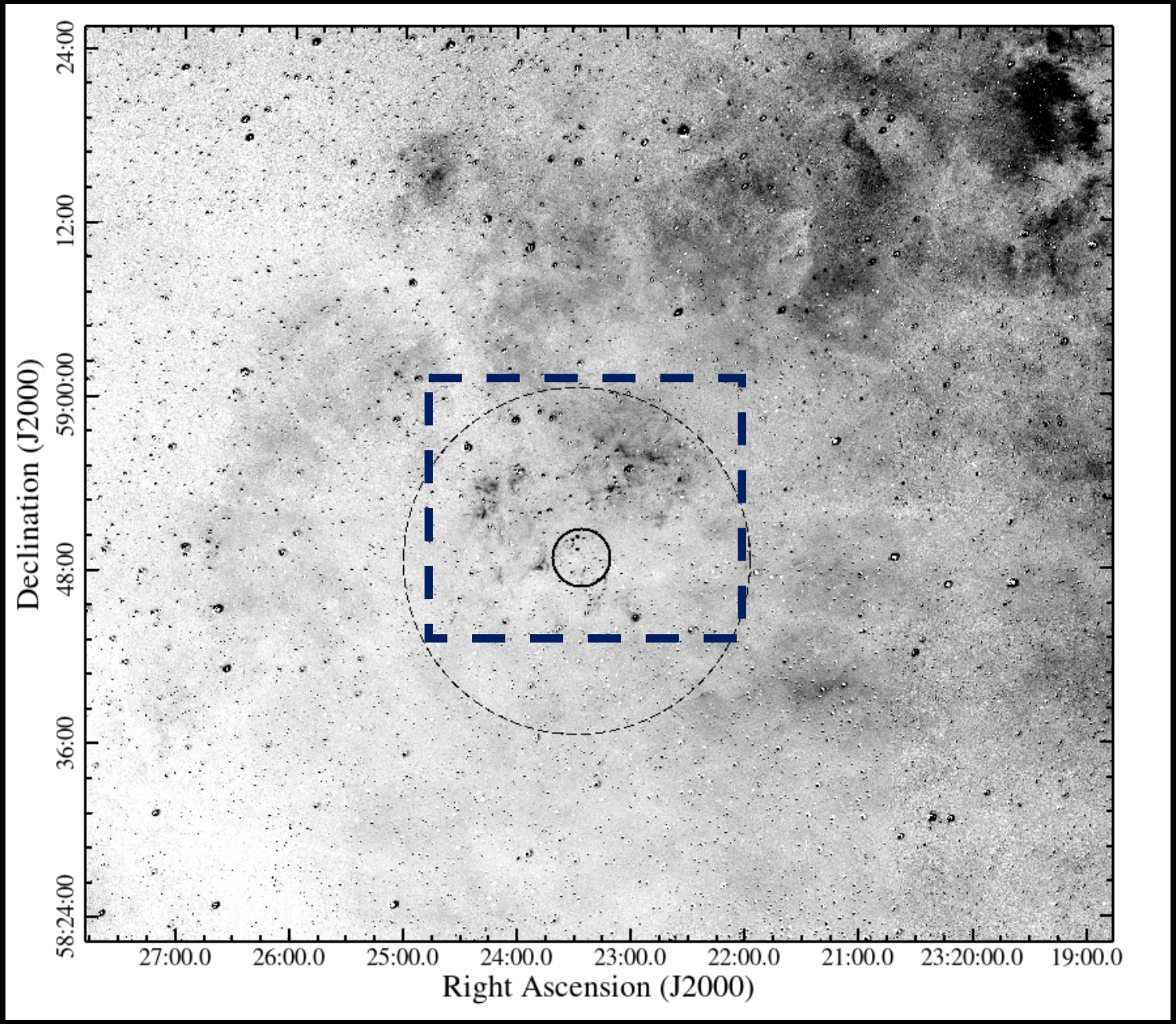
Right Ascension (J2000)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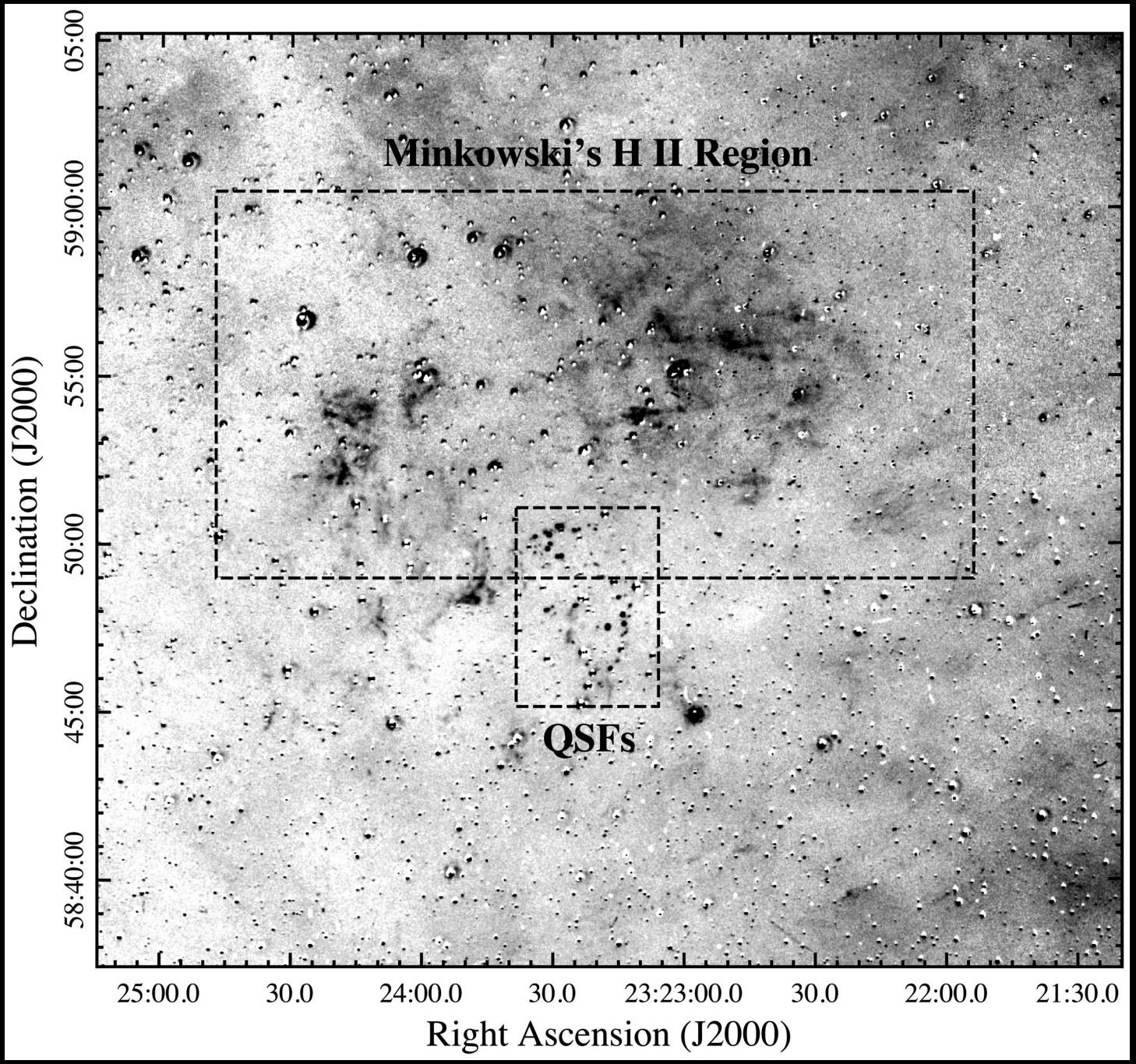
Right Ascension (J2000)


Minkowski's H II Region
QSFs
Declination (J2000)
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59:00:00
55:00
50:00
45:00
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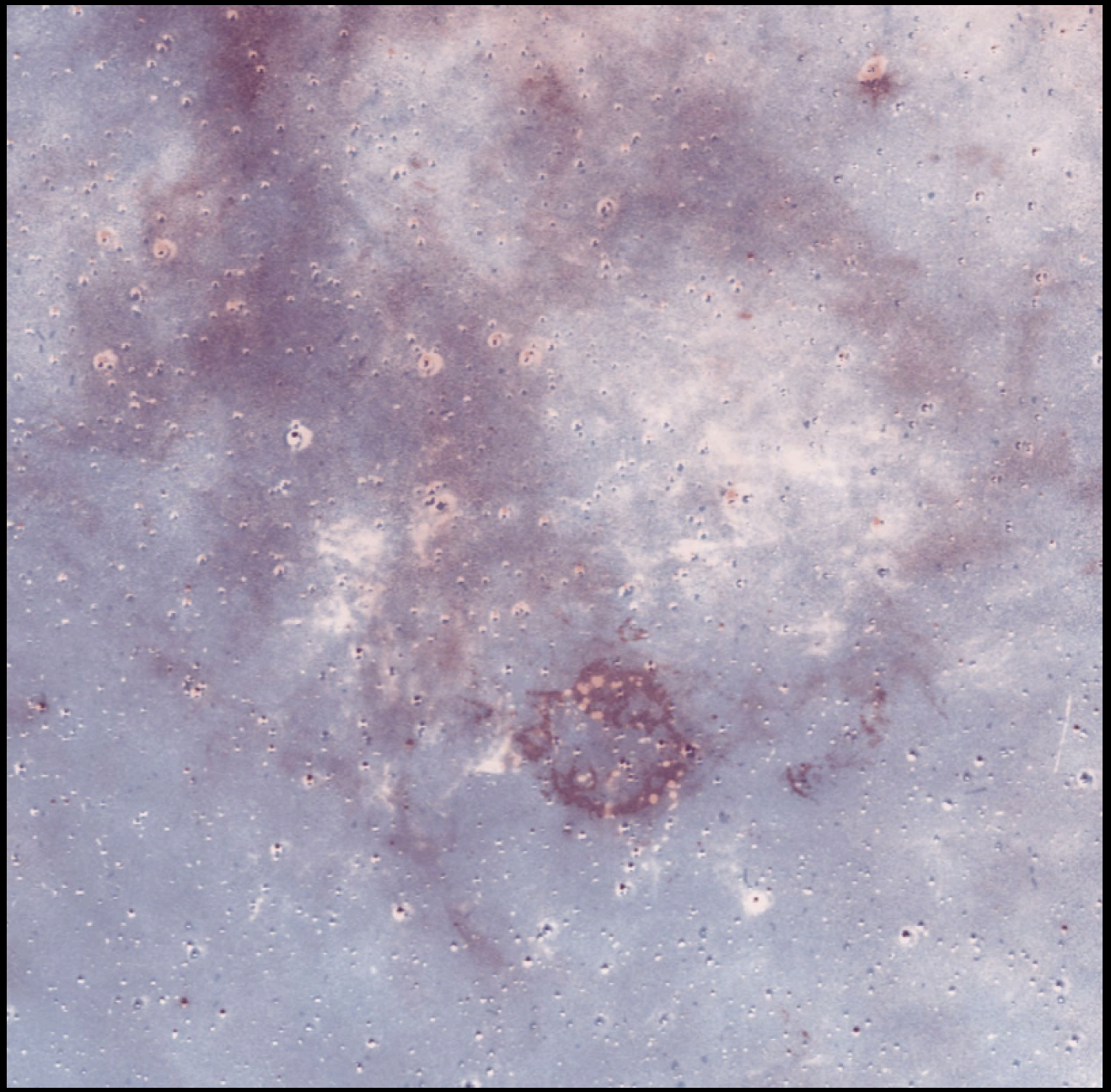
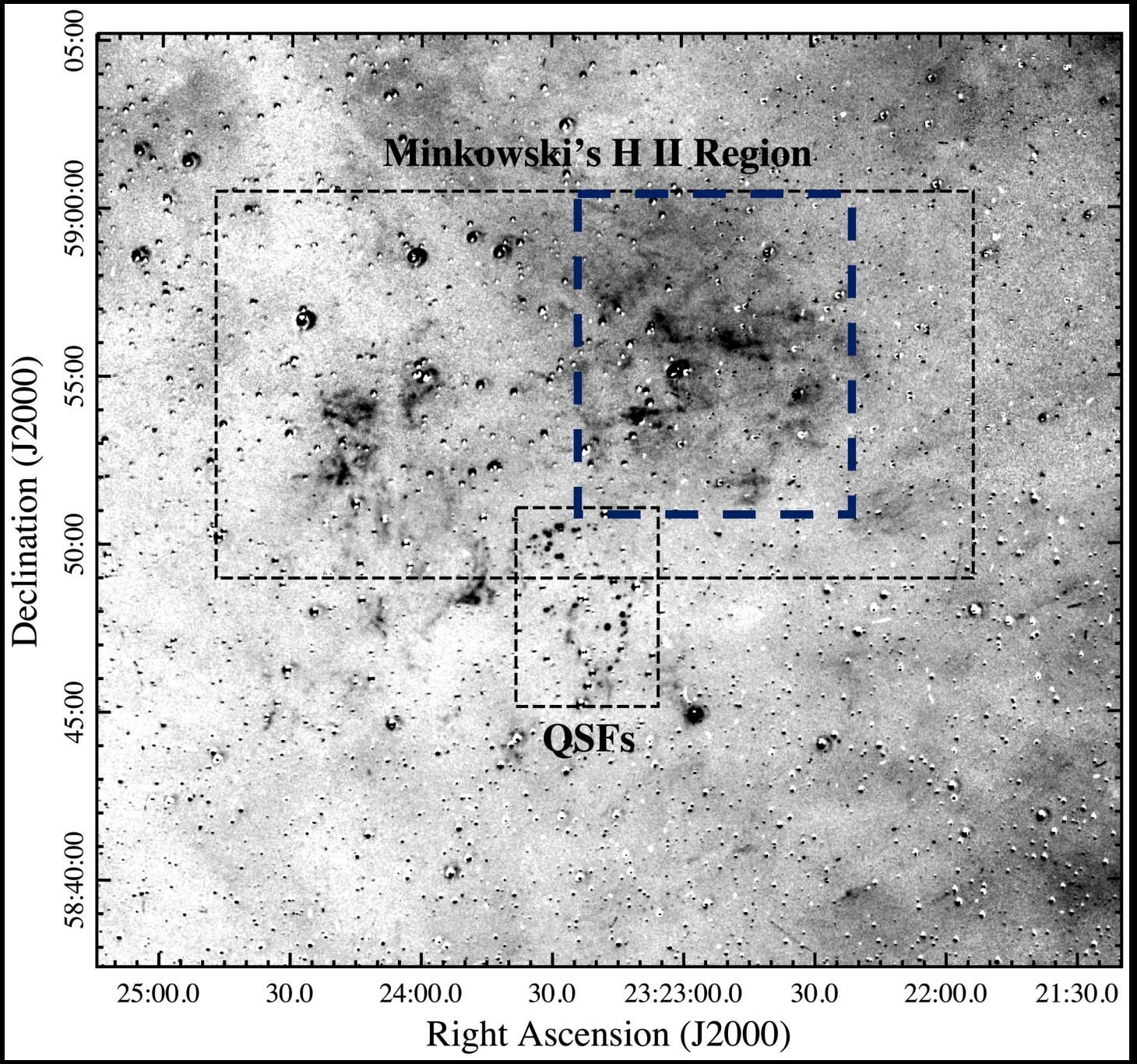
30.0
24:00.0
30.0
23:23:00.0
30.0
22:00.0
21:30.0
Right Ascension (J2000)

White: Hα-Cont.

Red: Spitzer 8μm




Minkowski's H II Region
QSFs
Declination (J2000)
05:00
59:00:00
55:00
50:00
45:00
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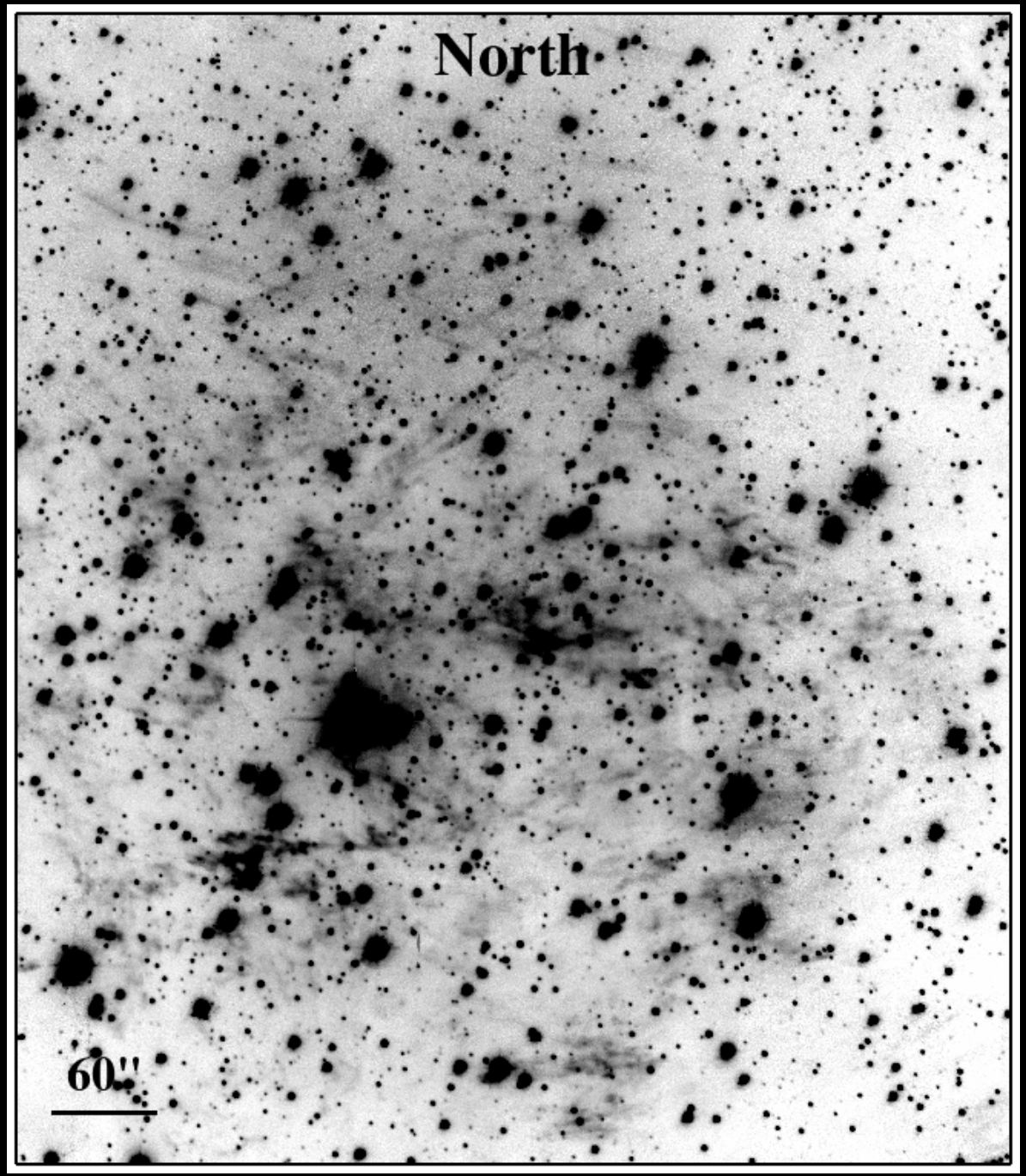
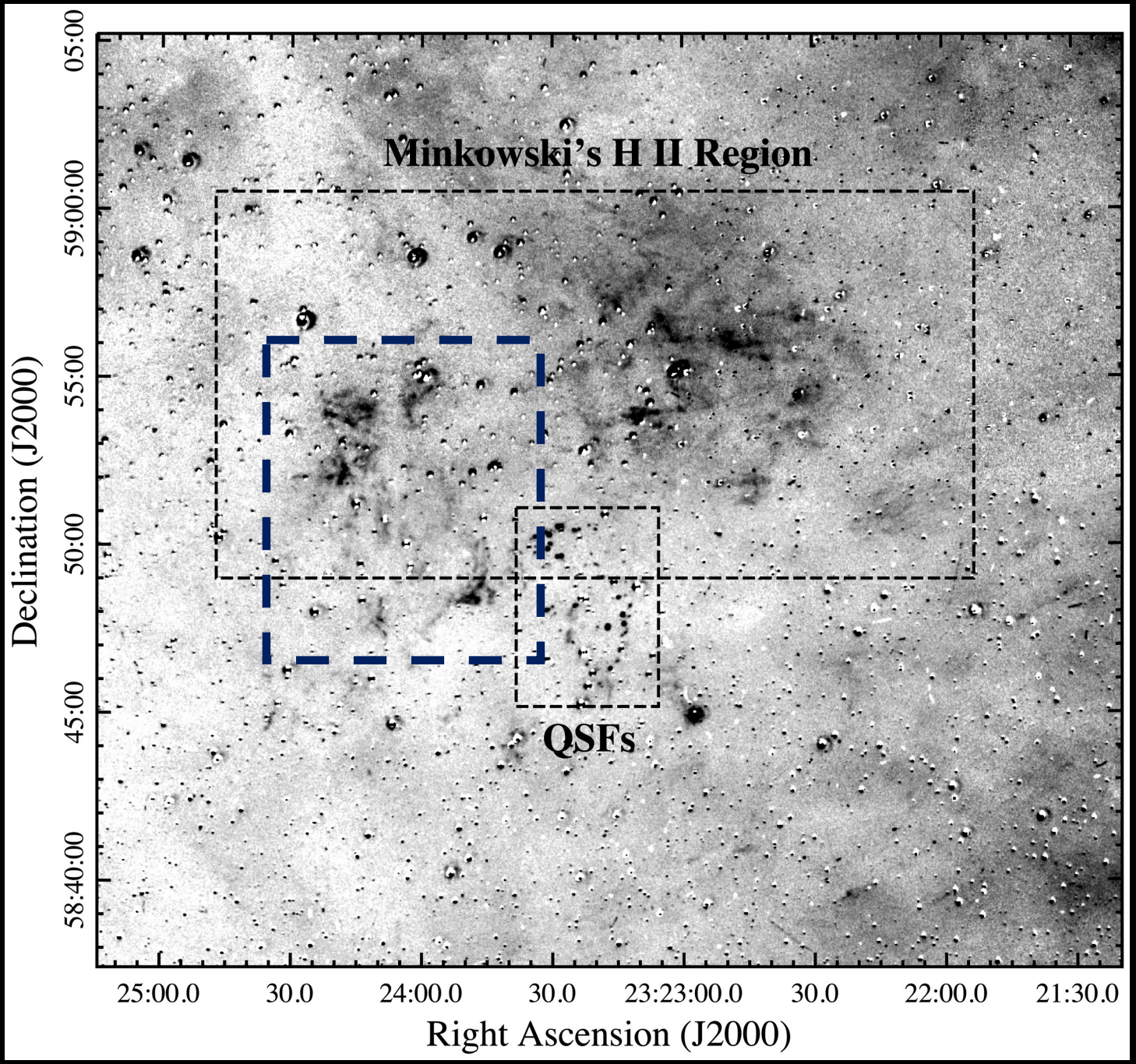
21:30.0
Right Ascension (J2000)


North
60"


Minkowski's H II Region
QSFs
Declination (J2000)
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50:00
45:00
58:40:00
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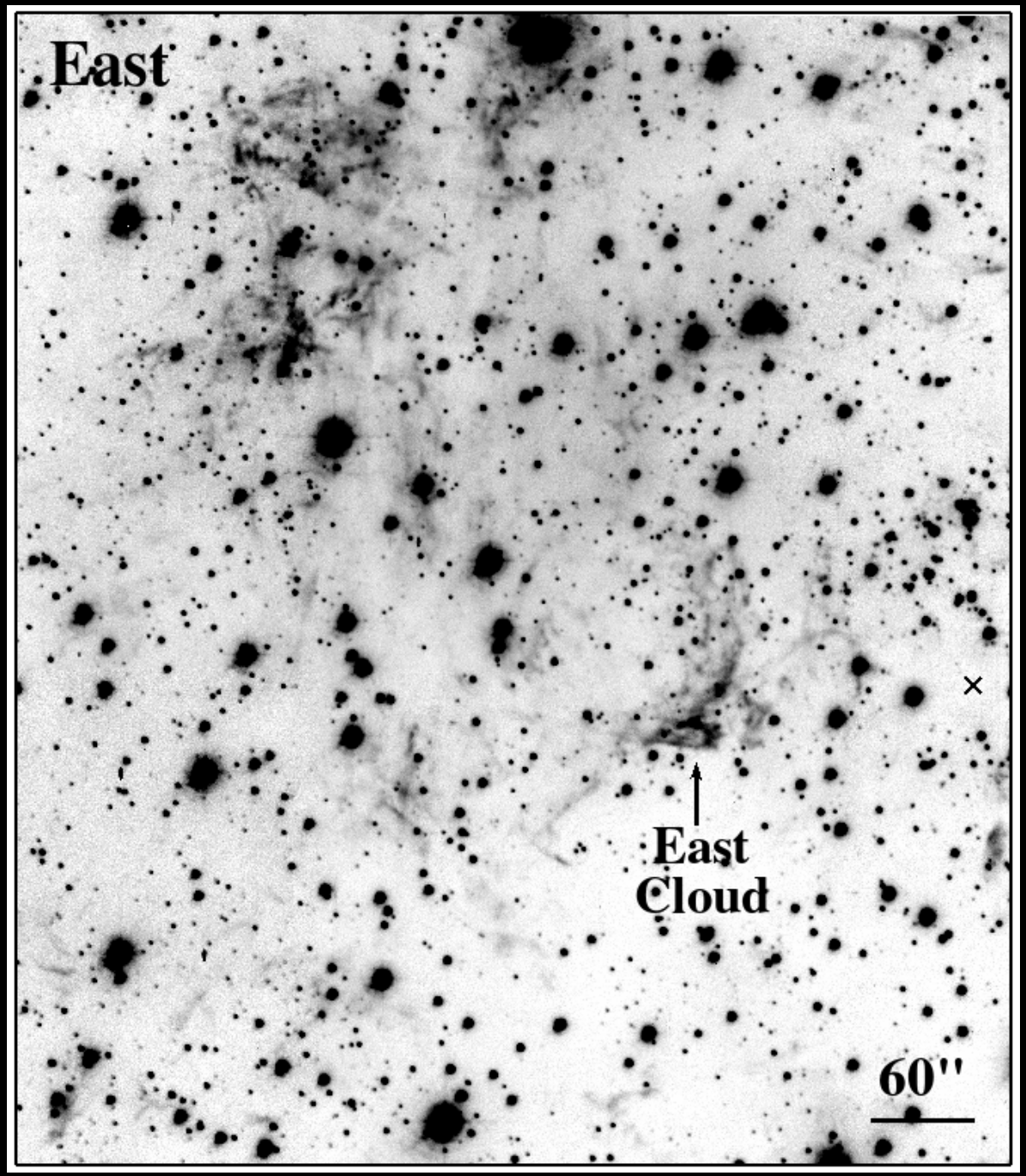
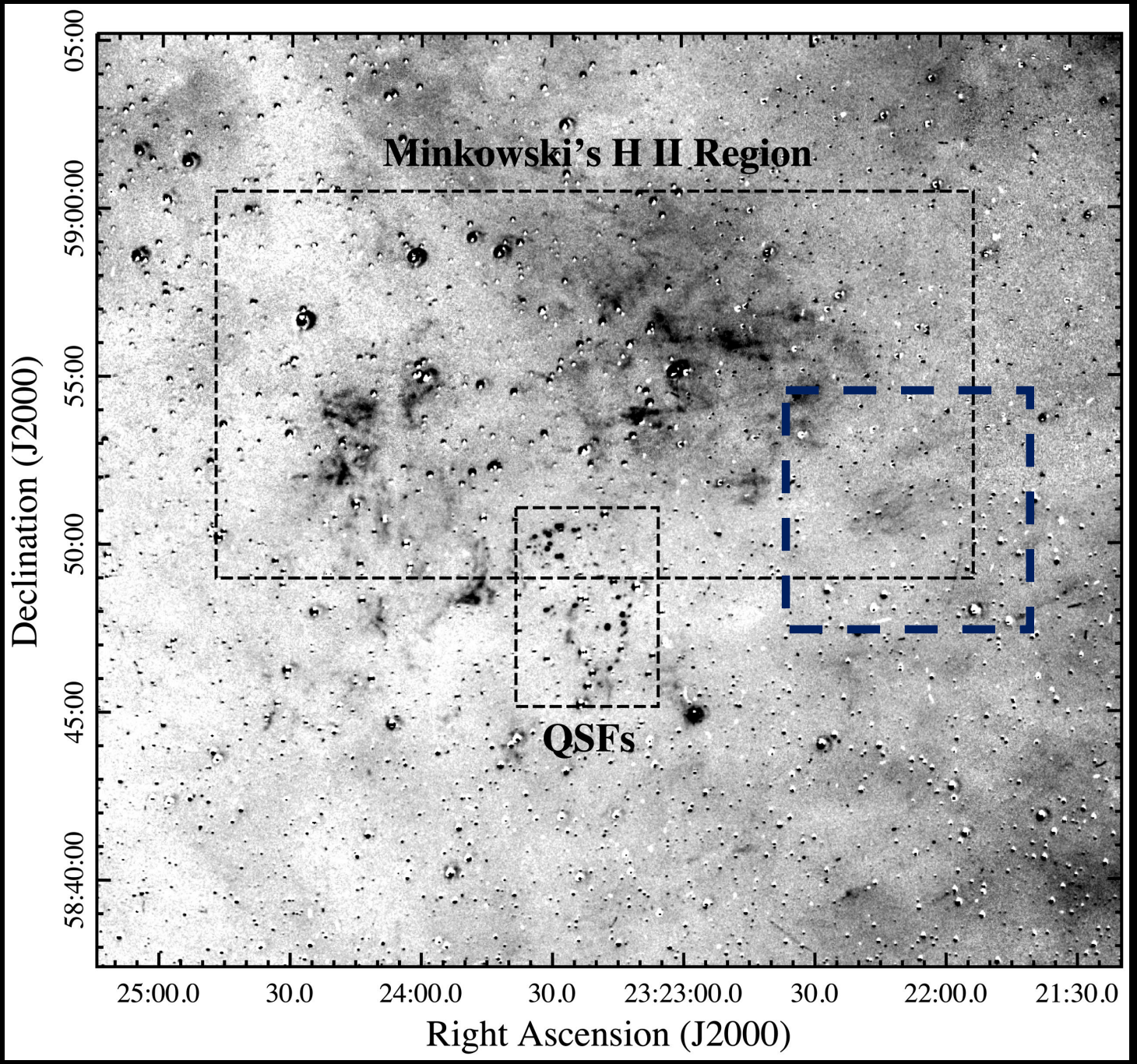
Right Ascension (J2000)


East
East
Cloud
60"


Minkowski's H II Region
QSFs
Declination (J2000)
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50:00
45:00
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25:00.0
30.0
24:00.0
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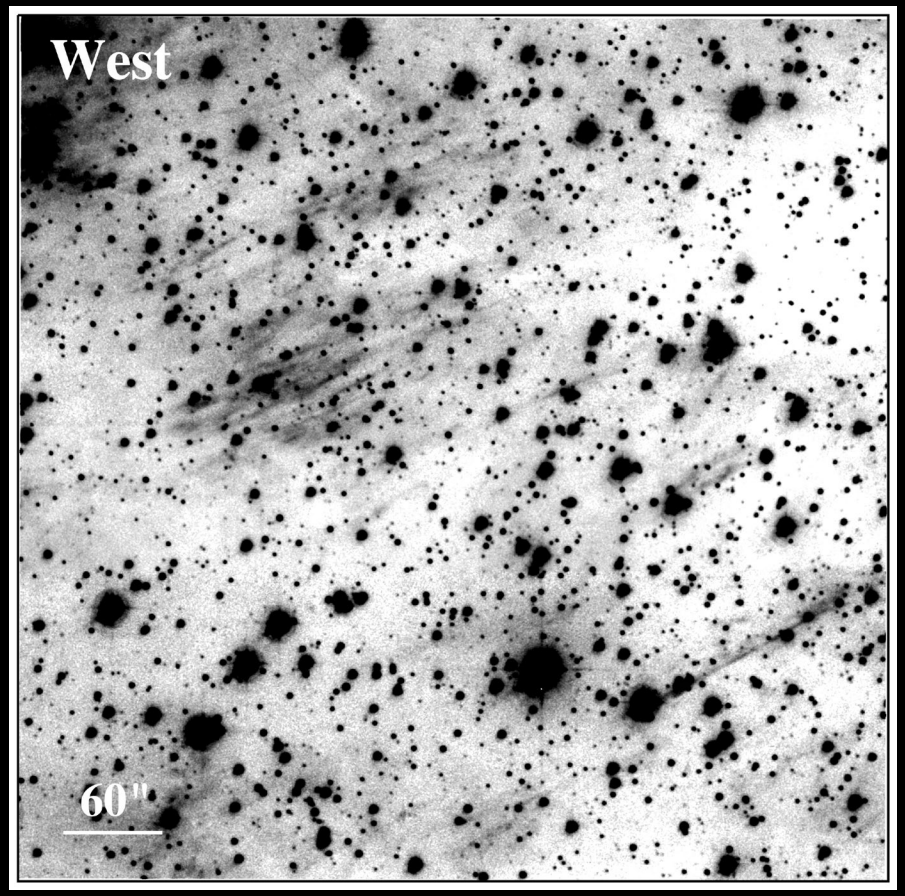
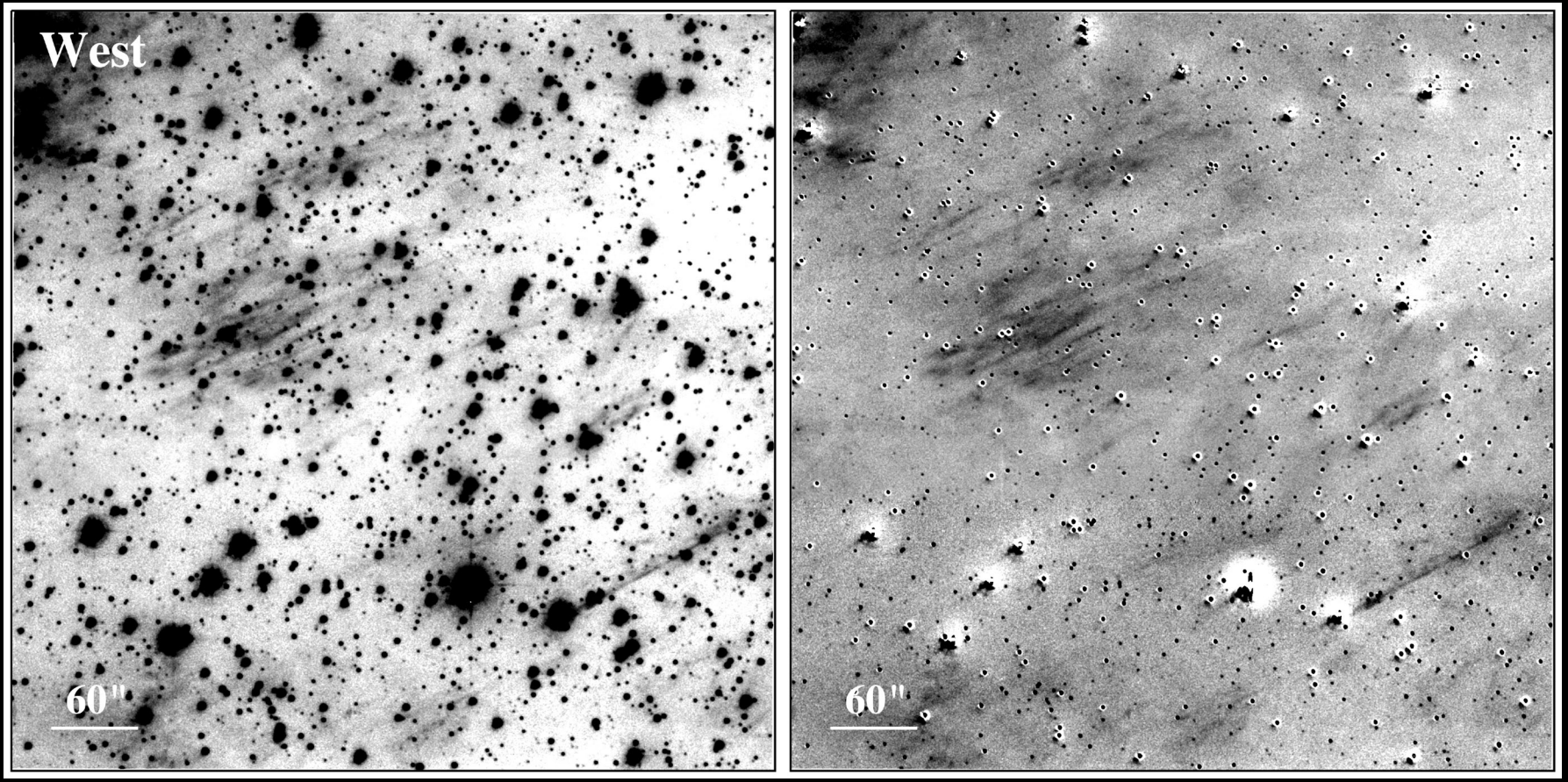
23:23:00.0
30.0
22:00.0
21:30.0
Right Ascension (J2000)

“Streaks”



Hα

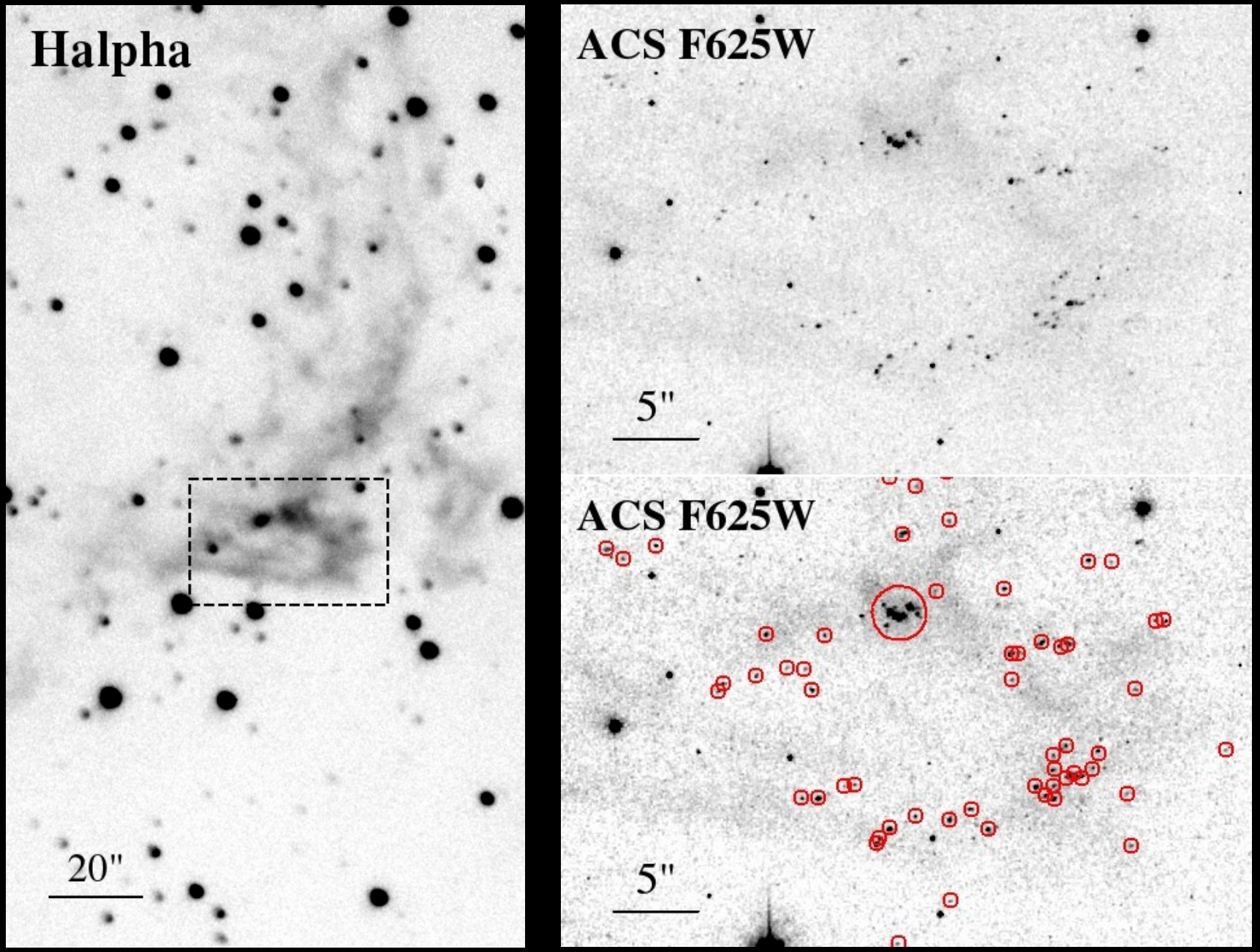
“Streaks”



Hα

Hα-Red Continuum

Are these neighboring nebulosities at Cas A's distance of 3.4 kpc?


Halpha
20"
ACS F625W
5"
ACS F625W
5"

Are these neighboring nebulosities at Cas A's distance of 3.4 kpc?

YES.

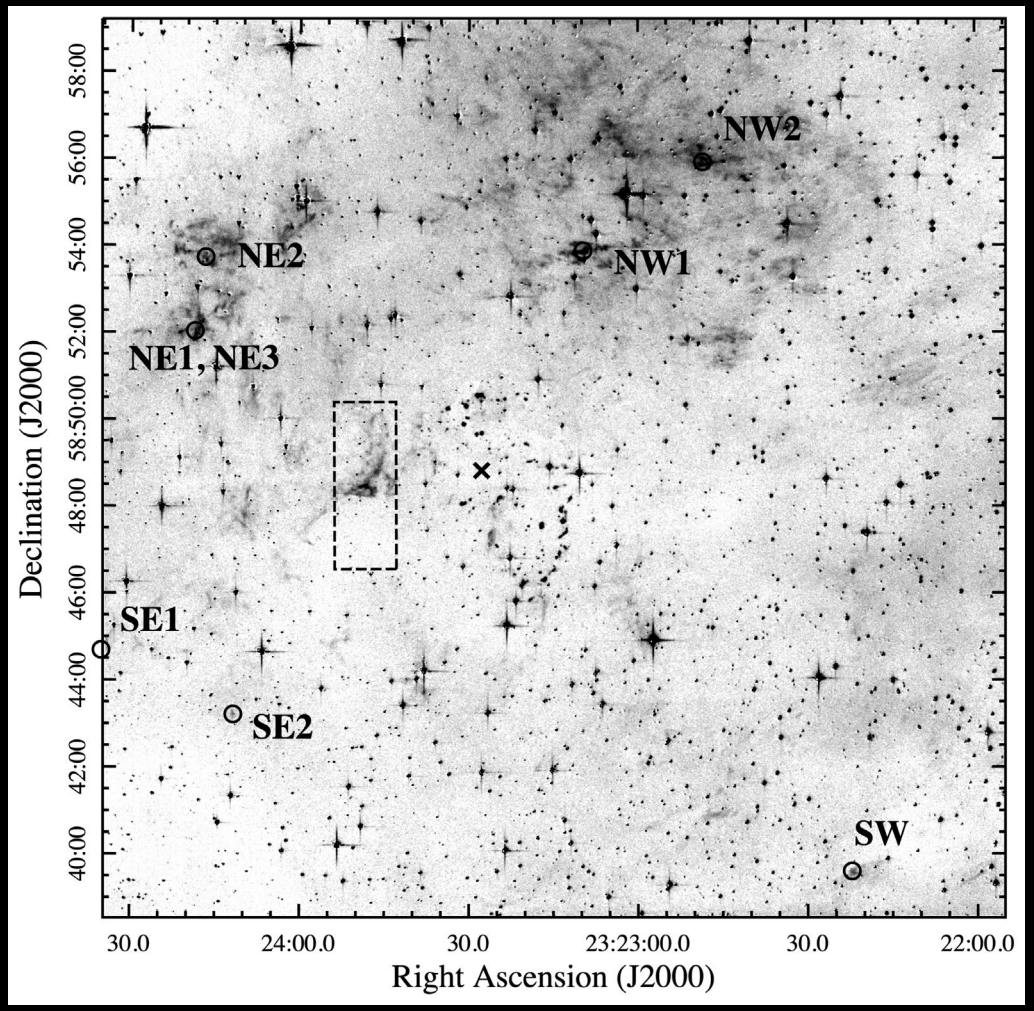
Are these neighboring nebulosities at Cas A's distance of 3.4 kpc?

YES.

The existence of a compact H II region 1 degree NW of Cas A at a distance of 3.3±1.27 kpc supports the notion of accumulation of mass-loss toward the North. (Choi et al 2014)

Why is the supposed RSG mass-loss emission mainly observed North of Cas A?

- We propose that the RSG mass-loss collided with the outskirts of the H II region centered a few degrees to NW.


NW2
NE2
NW1
NE1, NE3
SE1
SE2
SW
Declination (J2000)
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56:00
54:00
52:00
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48:00
46:00
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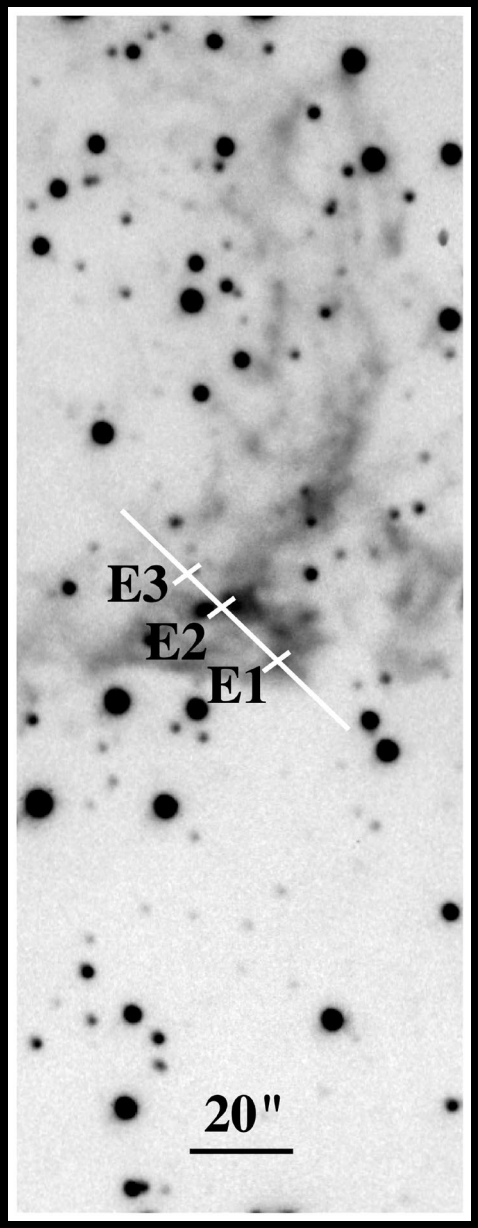
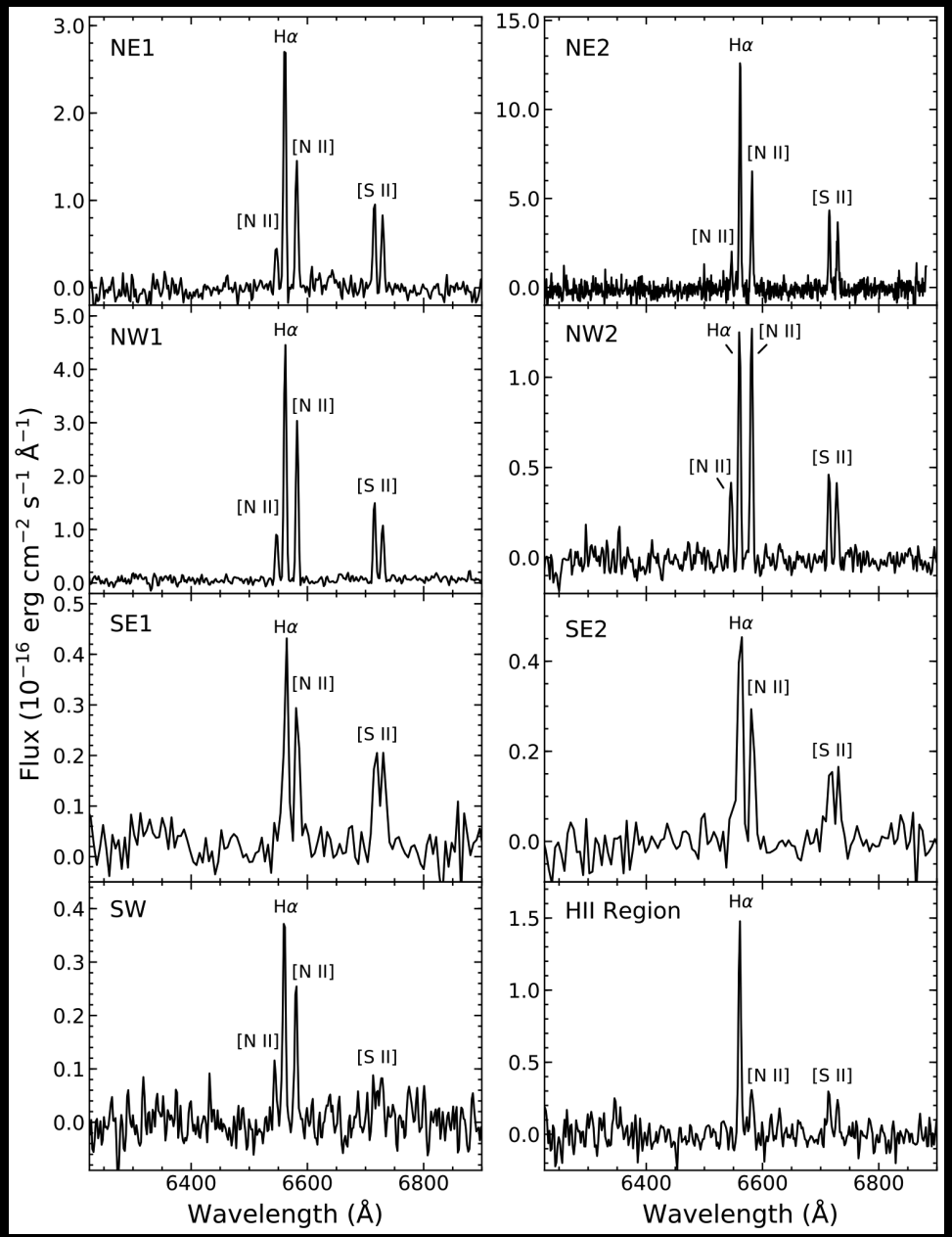
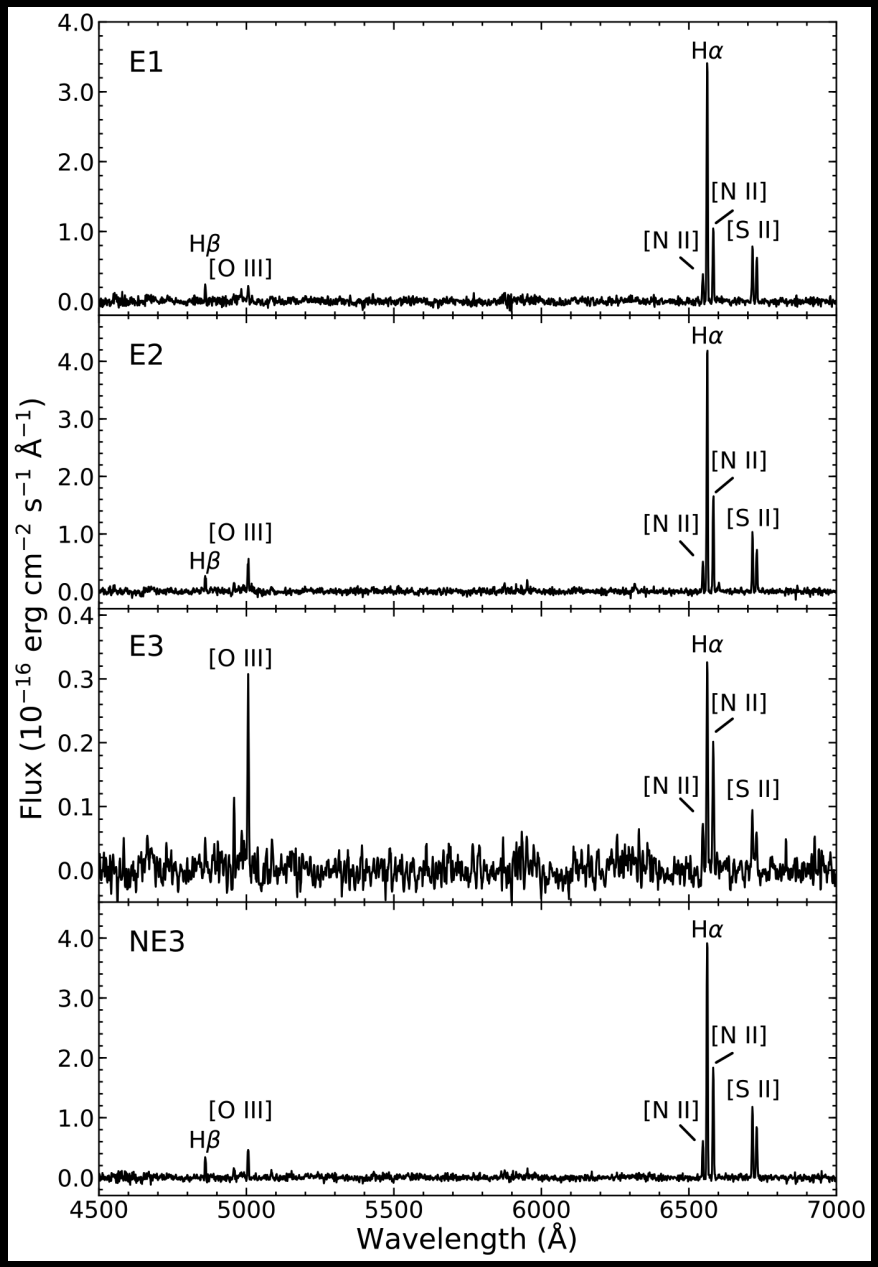
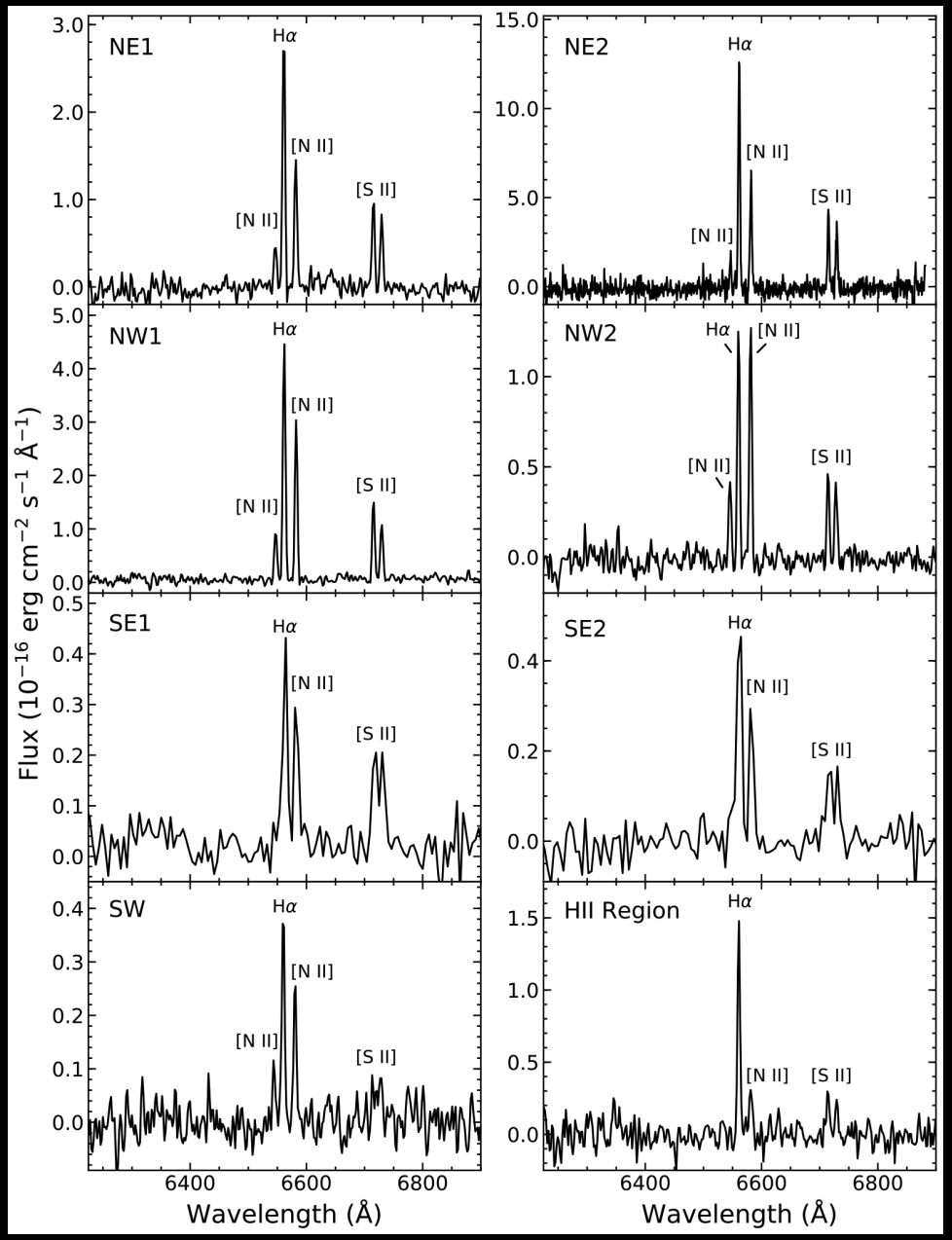
Right Ascension (J2000)


E3
E2
E1
20"


NE1
NE2
NW1
NW2
SE1
SE2
SW
HII Region
Hα
[N II]
[S II]
Flux (10^{-16} erg cm^{-2} s^{-1} Å^{-1})
Wavelength (Å)

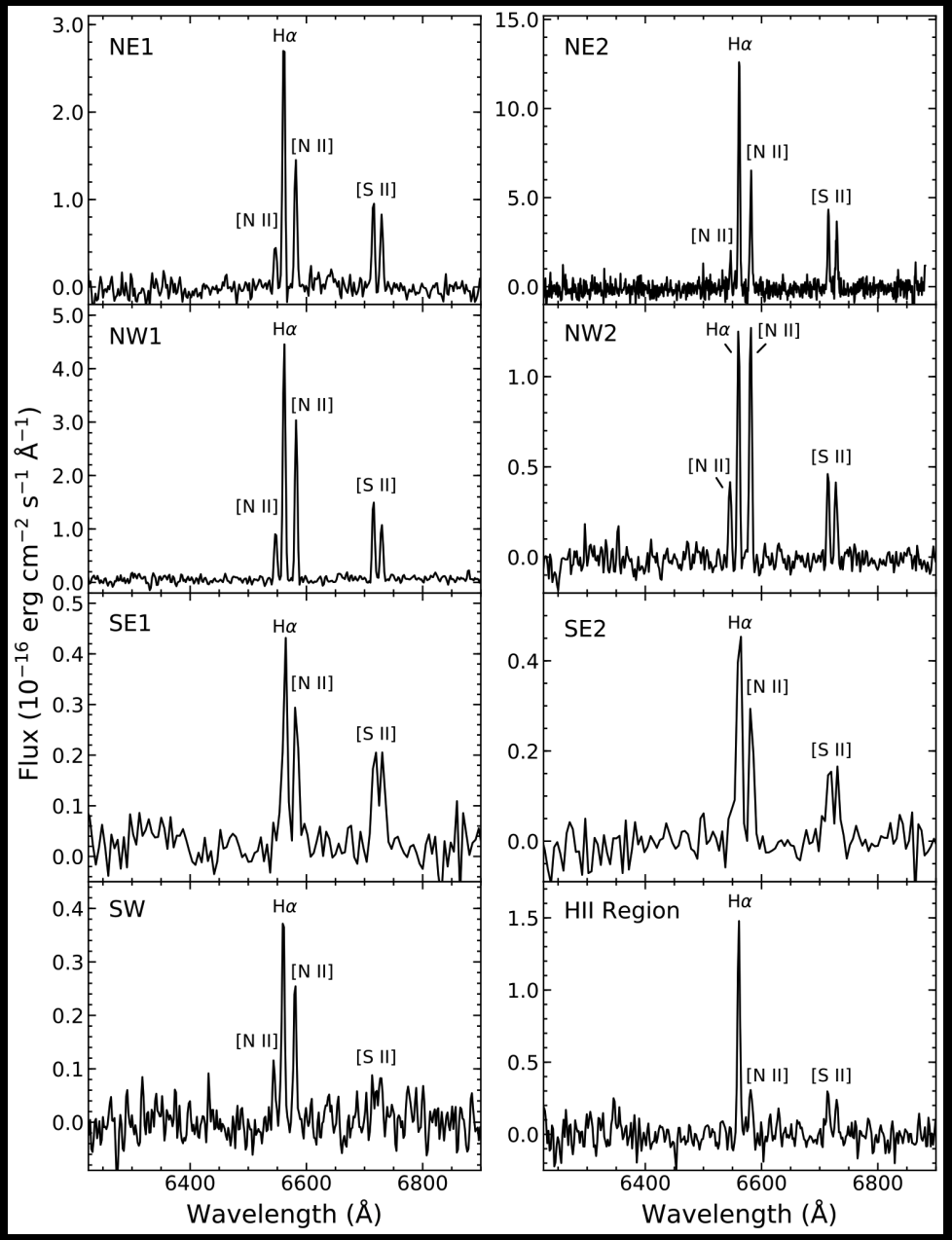

E1
E2
E3
NE3
Hα
Hβ
[O III]
[N II]
[S II]
Flux (10^{-16} erg cm^{-2} s^{-1} Å^{-1})
Wavelength (Å)

- Strong [N II] & [S II]
- [S II]/Hα > 0.4
- No [O I] or [O II]



- Strong [N II] & [S II]
- [S II]/Hα > 0.4
- No [O I] or [O II]

- Emission is from gas cooling and recombining after photoionization from EUV flash during shock breakout.



Take-aways

- We have mapped out the extent of the RSG mass-loss from the Cas A progenitor.
  - The East Cloud lies Cas A's distance due to interactions with the expanding high-velocity ejecta.
  - The asymmetric appearance of the RSG mass-loss can be explained by interactions with the outer edge of the NW H II region.
- RSG mass-loss material was likely ionized by the EUV flash at shock breakout.
- We estimate RSG mass-loss of $\gtrsim 0.5\ M_{sun}$.