Circumstellar Envelope of RS Oph

T. Iijima
Astronomical Observatory of Padova,
Asiago station, Italy

Observations

High dispersion spectra: / = 10000

Reosc echelle spectrograph mounted on the 182 cm telescope of the Mount Ekar Station of the Astronomical Observatory of Padova.

Medium dispersion spectra : / = 1000 with a grating of 600 lines/mm

Boller & Chivens grating spectrograph mounted of the 122 cm telescope of the Asiago Observatory.

Our first high dispersion spectra taken on February 18, 2006: 5.4 days after the explosion.

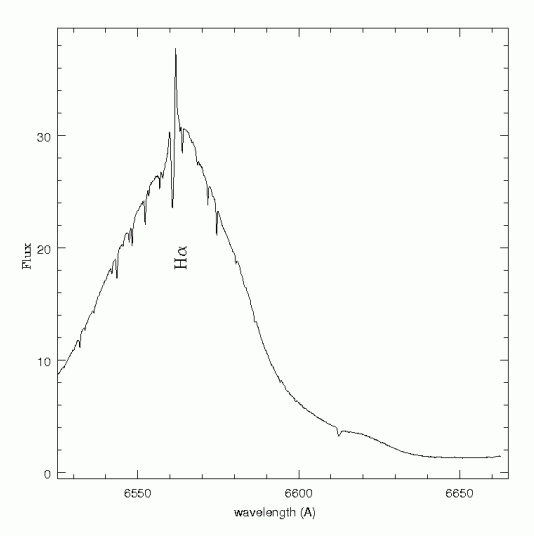

Fig. 1

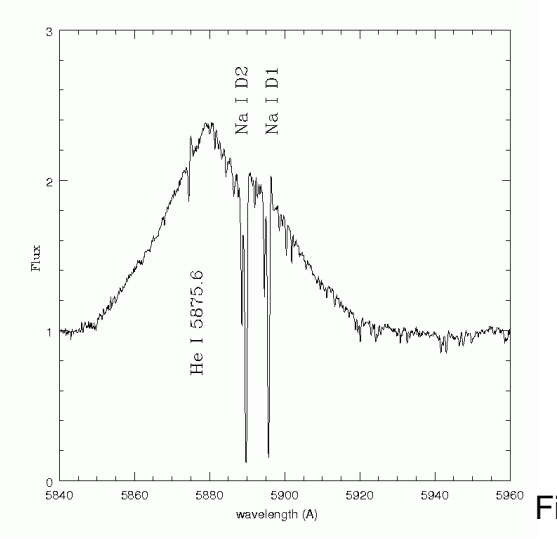

Fig. 2

FWHM ~ 1800 km/s

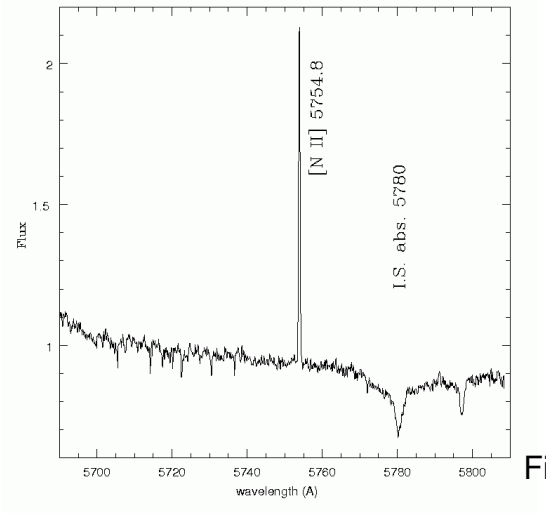

Fig. 3

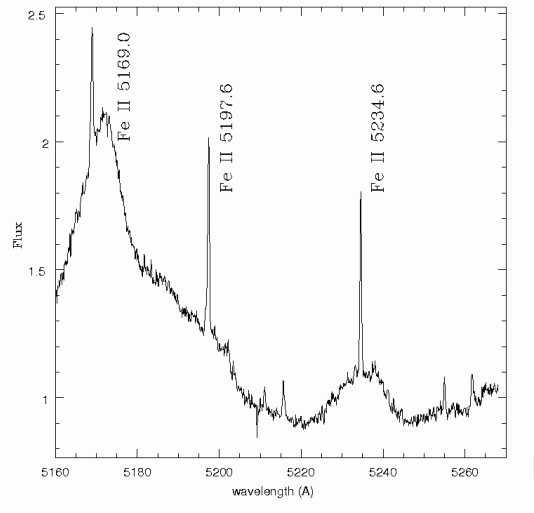

Fig. 4

Interstellar and circumstellar absorption components of Na I D1 and D2 lines.

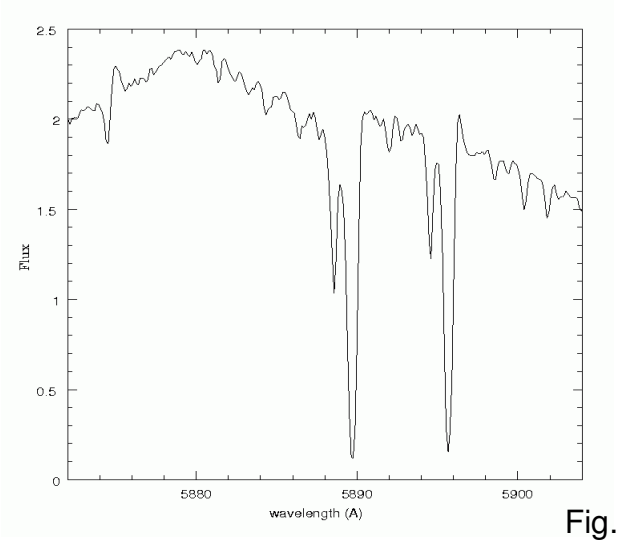

Fig. 5

February 18, 2006

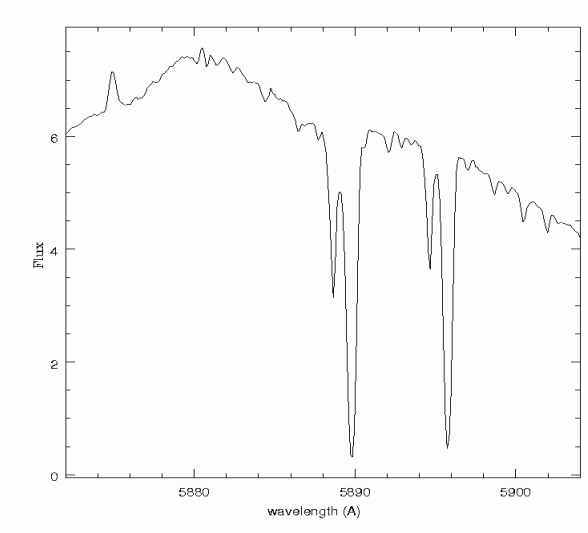

Fig. 6

February 19, 2006

Table 1. Radial velocities and equivalent widths of Na I D1 and D2 lines.

	obs.	V hel (km/s)	V lsr (km/s)	Eq.w. (A)
D2	5888.6	-69.8	-53.8	0.29
D2	5889.7	-10.9	+5.1	0.73
D1	5894.6	-67.8	-51.8	0.16
D1	5895.7	-9.9	+6.2	0.60
	Obs. error	±1	±1	±0.03

Radial velocity of RS Oph is -35.8 ± 1 km/s and the blue shift of the weaker components is 33 km/s.

Column densities of interstellar and circumstaller matter.

Log N(Na) · L = 13.2 cmInterstellar component : ²
Log N(Na) · L = 12.2 cmCircumstellar component : ²
Doublet ratio method (Münch 1968)

Standard abundance of sodium of the interstellar matter is
log N(Na)/N(H) = -8.4 (Cohen 1975)
Log N(H) · L = 21.6 cmInterstellar component : ²
Log N(H) · L = 20.6 cmCircumstellar component : ²

The ratio between the column density and extinction is
N(H) · L / E(B-V) = 6.2 · 10^{21} cm.)Jenkins & Savage 1974(¹ mag ²
E(B-V) = 0.64 : Interstellar component
E(B-V) = 0.06 : Circumstellar component

Total extinction is E(B-V) = 0.71.

Circumstellar envelope and mass loss of the red giant.

High dispersion spectra on February 19, 2006: 6.4 days after the explosion

Intensity ratio of [O III] lines I(5007 + 4959) / I(4363) = 1.7

Ne ~ 10^{8} cm .for Te = 10000 K [3]

dM / dt = 4 r [2] v = 4 r mH Ne v [2]

The radius of the ejecta was r ~ 10^{14} cm : 6.4 days with 2000 km/s.

Ne = 10^{8} cm.and v = 33 km/s [3]

dM / dt ~ 10 [6] Msun year[1]

Dimension of the circumstellar envelope and their evolution.

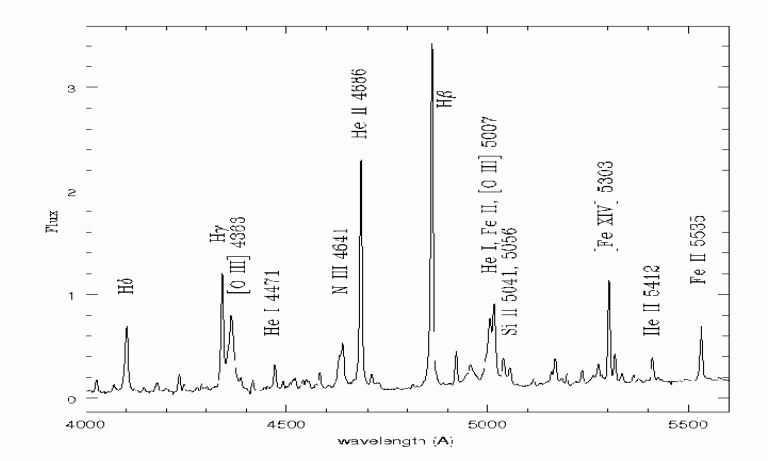

Fig. 7

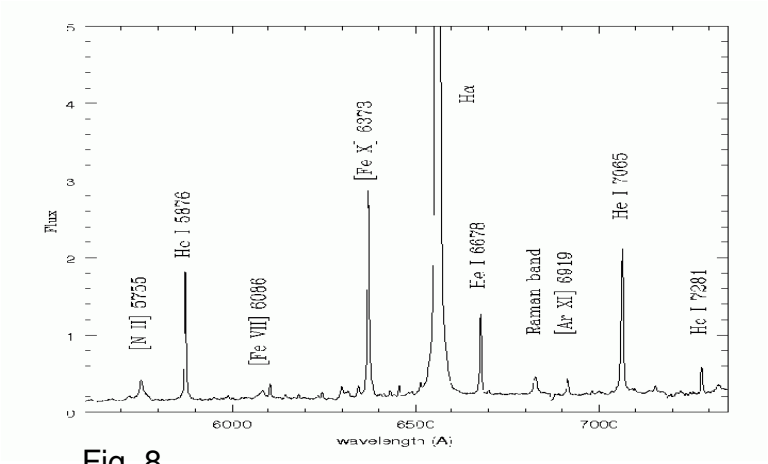

Fig. 8

May 7, 2006: 83.3 days after the explosion

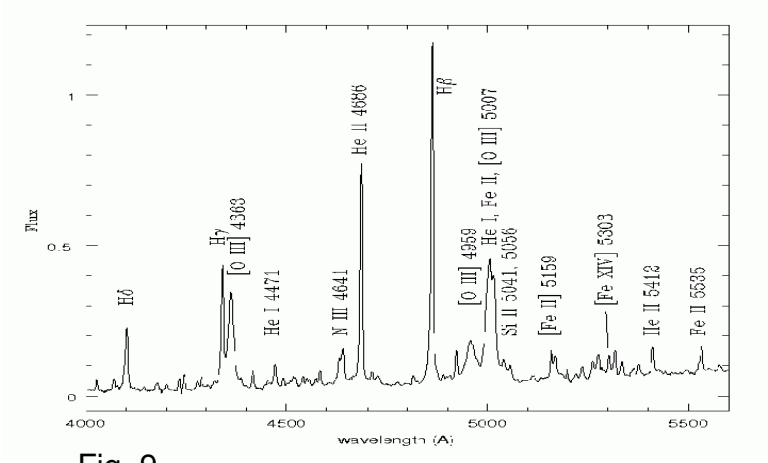

Fig. 9

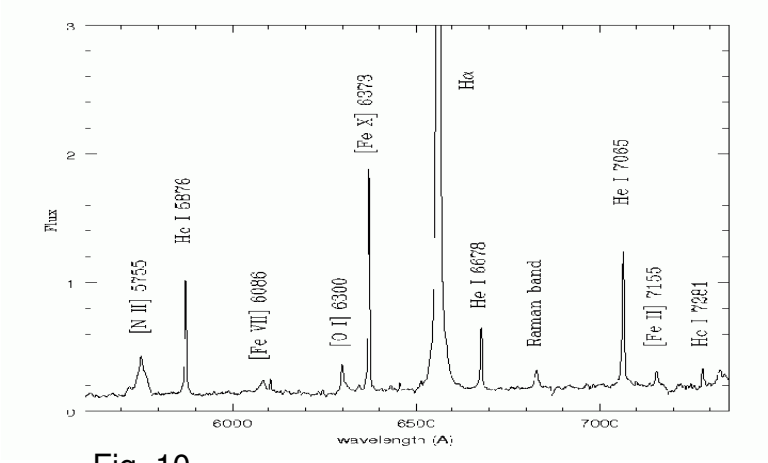

Fig. 10

May 25, 2006: 102.2 days after the explosion

About 100 days after the explosion, the coronal emission lines started fading. The narrow emission component of nebular lines disappeared.

The shock front reached the outer boundary of the circumstellar envelope.

The radius of the ejecta at 100 days after the explosion was $r \sim 10^{15}$ cm.

$r = 2.35 \cdot 10^{10} t^{2/3}$ cm $sec^{-2/3}$, O'Brien et al. (2006)

The time required to travel the stellar wind with the velocity 33 km/s for this distance is about 10 years, which agrees with the interval between the outbursts.

The ejecta sweeps away the circumstellar envelope on every outbursts.

The expanding velocity was 4000 km/s at first and may have become 700 km/s at 100 days after.

The momentum conservation law requires,

$4000 \cdot m_{ej} + 33 \cdot m_{env.} = 700 (m_{ej} + m_{env.})$,

We have $m_{ej} / m_{env.} \sim 0.2$

$m_{env.} \sim 10^{5}$ Msun $m_{ej} \sim 10^{6}$ Msun.

Our results.

Column densities of the interstellar and circumstellar matter.

log N(H) · L = 21.6 cmInterstellar matter : ^{2}

log N(H) · L = 20.6 cmCircumstellar matter : ^{2}

Extinction

E(B – V) = 0.64 : Interstellar matter

E(B – V) = 0.06 : Circumstellar matter

Velocity of the stellar wind and the mass loss rate of the red giant.

v = 33 km/s

dM / dt ~ 10 ^{6} Msun /year

Velocity of the system of RS Oph is -35.8±1 km/s.

Dimension of the circumstellar envelope is ~10^{15} cm.

The envelope is swept away by the ejecta on every outbursts.

m_{ej} / $m_{env.}$ ~ 0.2 $m_{env.}$ ~ 10 ^{5} Msun m_{ej} ~ 10 ^{6} Msun.