FLARE-LIKE EVENTS ON THE T-TAURI STAR RU LUPI*

F.Giovannelli
Istituto di Astrofisica Spaziale, CNR, Frascati, Italy.

D.Castaldo, E.Covino, A.A.Vittone
Osservatorio Astronomico di Capodimonte, Napoli, Italy

C.Rossi
Istituto Astronomico dell'Università La Sapienza, Roma, Italy.

Abstract

A long term multifrequency campaign on the T Tauri star RU Lupi has been carried out in the X-Ray, UV optical and IR spectral regions with ASTRON and IUE satellites and ESO 1.5 m+IDS, 1.4 m CAT, 0.5 m UBVRI and 1 m IR telescopes, respectively.

We present two flare-like events occurred on April 17, 1984 and June 30, 1986. The first one was detected only in the UV, due to lack the of simultaneous observations in other spectral regions. The second one was observed in UV, optical and IR regions showing a maximum roughly in the U band A comparison of the whole energy distribution of this event with that of a quiescent state observed on June 27 shows a flux enhancement of (89 ± 2)%. A detailed analysis of UV continuum and lines, namely N V, C I, C II, C IV, Si II and Si IV, shows that the surfaces fluxes of RU Lupi are always larger than those observed on typical flare stars and on the Sun by a factor of roughly 2 and 3 orders of magnitude, respectively. This fact allows us to conclude that RU Lupi activity cannot be explained even invoking a complete coverage by solar-like plages. On the contrary a patchy distribution of the emitting regions could explain the observed behaviour of this active star.

1. Introduction.

RU Lupi is a late-K type star with extreme T Tauri character exihibiting very strong emission lines of H, Ca II, He I, Fe I, Fe II in the optical range (Gahm et al., 1975).

The Balmer lines show sometimes P Cygni profiles indicating an extended envelope with an expansion velocity of about 100 $Km\ s^{-1}$ and density of about $10^{10}\ cm^{-3}$. Forbidden lines of S II and O I are also present, indicating the existence of an outer extended region having a temperature of 20,000 K and density $10^{6}\ cm^{-3}$. In this region, the outflow velocity is about 10 $Km\ s^{-1}$ (Gahm et al., 1979, Schwartz et al., 1981 and Lago 1982). The detection of nearby H_2Omaser sources, and the existence of the Herbig-Haro object HH 55 at 2' south-west from the star strongly support the stellar wind model. The circumstellar envelope is also detected at near-IR wavelengths (Giovannelli et al., 1986) as clearly shown by the IR two-colour diagrams J-H vs. H-K and H-K vs. K-L (Giovannelli et al., 1987).

* based on observations carried out at VILSPA with IUE satellite and at La Silla with ESO telescopes.

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RU Lupi is also an IRAS source. The measured fluxes show a strong IR excess increasing at longer wavelengths. According to the prescriptions reported in the IRAS Explanatory Supplement (Beichman et al., 1985), the corrected fluxes are 0.86, 4.50, 5.24 Jy at 12.25, 60μ, respectively. The derived colour temperatures from the 12-25 and 25-60 micron bands are 170 ± 20 K and 135 ± 15 K, respectively (Giovannelli et al., 1987). A strong blue and UV excess is another characteristic of this star. From our numerous measurements at ESO telescopes, we found a mean B-V value of about - 0.7 mag. In the IUE band (1200-3200 Å) the total luminosity is $L \sim 0.3\ L_{\odot}$, which implies a hydrogen continuum emission originating in a dense chromosphere (Gahm et al., 1979). On the other hand, X-ray observations of RU Lupi with HEAO-B (0.5-4.5 *KeV*) and with ASTRON (2-6 *KeV*) satellites did not reveal any flux greater than $3 \cdot 10^{-11}\ erg\ s^{-1}\ cm^{-2}$ (Giovannelli et al., 1986), which is too low scaled to the solar values, making clear the differences in the external active layers of the two stars. In this paper we present the analysis of two flare-like events (FLEs) occurred during our long term multifrequency campaign on the T Tauri star RU Lupi.

2. Observations

During two diffrent observing runs on RU Lupi, two FLEs were detected on April 17, 1984 and on June 30, 1986. The closest previous observations were done on April 7, 1984 and on June 27, 1986, respectively.

The UV observations were carried out with IUE satellite from VILSPA station. Fourteen low dispersion spectra both in LW and SW regions were secured from July 1984 to June 1986 the SWP 28551 and SWP 28582 spectra taken on June 27 and 30, 1986 are shown in the paper by Giovannelli et al. (1986).

Thirteen nights of UBVRI and fourteen nights of JHKLM photoelectric photometry observations were obtained from February 1983 to June 1986 at ESO 0.5 m and 1.0 m telescopes respectively. Sixtytwo medium dispersion (60-220 Å mm^{-1}) spectra were secured from April 1984 to June 1986 at ESO 1.5 m + IDS telescope.

Several high dispersion spectra were obtained on March, April and June 1985 with the Coudé Echelle Spectrograph at ESO 1.4 m Coudé Auxiliary Telescope (CAT).

IR low resolution spectrophotometry was carried out from March 1984 to June 1986 at ESO 1 m telescope through three different Circular Variable Filters in the range 1.4 - 5.3 μ.

The total energy distribution of RU Lupi before and during the observed FLEs, is shown in Giovannelli et al. (1988).

3. Results and discussion

We decided to refer each FLE to the corresponding pre-FLE situation, namely April 7, 1984 and June 27, 1986 and we will refer to them as "quiescent levels".

We find a (89 ± 2)% variation of the total observed flux during FLE detected on June 30, 1986 with respect to the corresponding "quiescent level". The same evaluation was not possible for the April 17, 1984 FLE because of the lack of measurements over the whole energy spectral region for "its" quiescence level, but the UV.

The enhancement of the UV continuum flux during the Apr 17, 1984 and June 30, 1986 FLEs were (44 ± 13)% and (224 ± 47)%, respectively.

Fig. 1 shows the surface flux vs. the formation temperature of the observed emission lines of RU Lupi in different epochs and activity levels. As one can see the fluxes in the UV lines, namely: N V (1239 Å), C II (1334, 1335 Å), Si IV (1394, 1403 Å), C IV (1548, 1550 Å), C I (1658 Å), Si II (1817 Å) are larger than the respective quiescent fluxes but are of the same order of magnitude for both FLEs. Furthermore, taking the ratio of the fluxes in the same lines during and before the flare, no significant differences between the two events are present, within the uncertainties of about 20%. This means the two FLEs differ each other essentially for the UV continuum.

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Fig. 2 shows the surface fluxes vs. the formation temperature of the observed emission lines for RU Lupi, for Gl 867A, a tipical flare star, and for the Sun for different activity levels. One notes that the surface fluxes of RU Lupi are always two and three orders of magnitude greater than the fluxes of the flare-star and of the Sun, respectively. This means that even covering the entire stellar surface with solar type activity regions one could not explain the observed line fluxes. In addition, there are observational evidences of the presence of photospheric inhomogeneities (Covino et al., 1988), suggesting that a patchy distribution of very active regions is still more likely.

During the June, 30 FLE the strong enhancement in the UV and optical part of the spectrum has been accompained by an enhancement in the near IR region of about 40%.

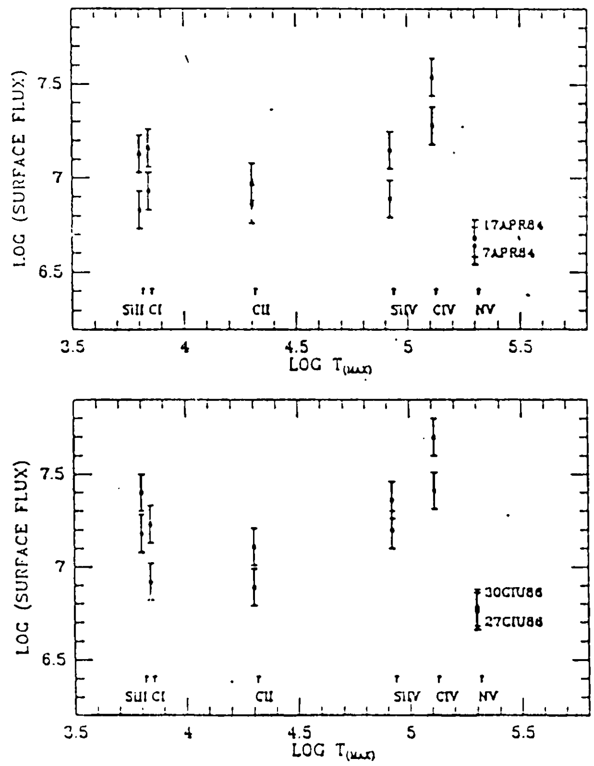

Fig. 1

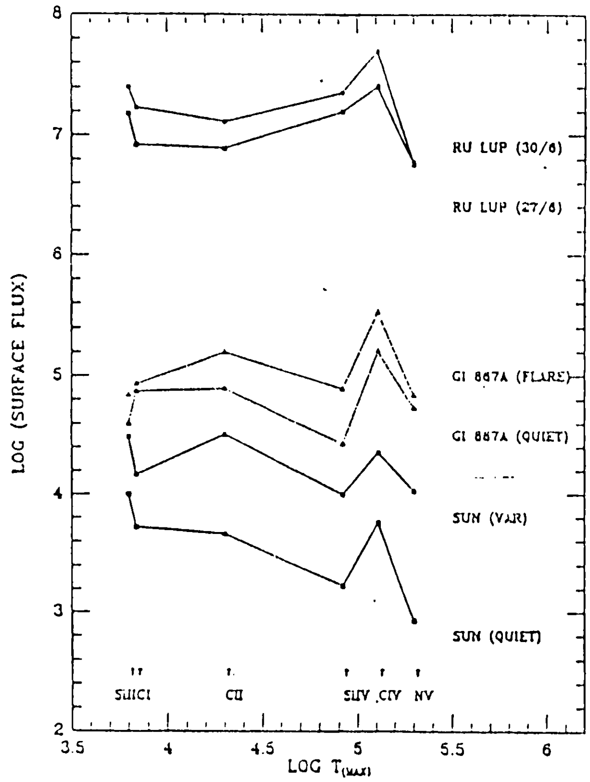

Fig. 2

From a colour indices inspection of June 1986 pre-FLE and FLE, no variations, within the instrumental errors, were detected up to L band. On the contrary, a decrease in the L-M colour-index of about 50% was observed.

4. Conclusions

The two FLEs show very similar characteristics, at least in UV line fluxes, indicating that, likely, FLEs occur in the same region.

The constancy of the near IR colour indices up to L band suggests that no temperature variations of the emitting region occur.

So, to explain the observed IR luminosity enhancement, an expansion of the IR emitting region could be invoked. The decrease of the L-M colour-index could be explained by a circumstellar dust evaporation, as suggested by Bisnovatvi-Kogan and Lamzin model (1977), which triggered our long term multifrequency campaign of observations of RU Lupi (Giovannelli et al. (1984).

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References

Bisnovatyi-Kogan, G.S., Lamzin, S.A.: 1977, *Sov. Astron.*, **21**, 720

Covino, E., Errico, L., Vittone,A.A., Giovannelli,F.: 1988, *Proceeding Convegno Nazionale Frascati, February 17-19, 1988.*

Covino,E., Terranegr*,L., Vittone,A.A.: 1988, *Mem. S.A.It., in press*

Gahm,F.G., Nordh,H.L., Olofsson,S.G.: 1975, *Icarus* , **24**, 372.

Gahm,F.G., Kerstin Fregda, Liseau,R., Dravins,D.: 1979, *Astron.Astrophys. Letters*, **73**, L4.

Giovannelli,F., Bisnovatyi-Kogan,G.S., Golynkaya,I.M., Kurt,V.G., Lamzin,S.A., Mizyakina, T.A., Shafer,E.Yu., Shamolin,V.M., Sheffer,E.K., Smirnoff,A.S., Vittone,A.A.: 1984, *in Fourth European IUE Conference, ESA-SP* **218**, 359.

Giovannelli,F., Vittone,A.A., Rossi,C., Nastari,I., Bisnovatyi-Kogan,G.S., Golynskaya,I.M., Kurt,V.G., Mizyarkina,T.A., Shafer,E.Yu., Shamolin,V.M., Sheffer,E.S., Smirnoff,A.S., Lmzin,S.A., Larionov,M.G., Sidorenko,V.N.: 1986, *in New Insight in Astrophysics, ESA-SP* **263**, 95.

Giovannelli,F., Rossi,C., Errico,L., De Martino,D., Vittone,A.A.: 1987, *Convegno di Astronomia Infrarossa, Vulcano, September 14-18, Mem. S.A.It.*, **58**, 205.

Giovannelli,F., Rossi,C., Covino,E., Errico,L., Vittone,A.A., Bisnovatyi-Kogan,G.S., Kurt,V.G., Sheffer,E.S., Lamzin,S.A.: 1988, *in A Decade of UV Astronomy with IUE, ESA-SP* **281**, vol.2, 101.

Lago,M.T.V.T.: 1982, *Mon. Not. R. astr. Soc.*, **198**, 445.

Schwartz,R.D., Heuermann,R.W.: 1981, *Astron. J.*, **86**, 1526.