arXiv:0708.1216v1 [astro-ph] 9 Aug 2007

GMRT Observations of the 2006 outburst of the Nova RS Ophiuchi: First detection of emission at radio frequencies < 1.4 GHz

N. G. Kantharia

National Centre for Radio Astrophysics, Tata Institute of Fundamental Research, Post Bag 3, Ganeshkhind, Pune 411 007, India

`ngk@ncra.tifr.res.in`

G. C. Anupama, T. P. Prabhu and S. Ramya

Indian Institute of Astrophysics, Koramangala, Bangalore 560 034, India

`gca@iiap.res.in, tpp@iiap.res.in, ramya@iiap.res.in`

M. F. Bode

Astrophysics Research Institute, Liverpool John Moores University, Birkenhead CH41 1LD, UK

`mfb@astro.livjm.ac.uk`

S. P. S. Eyres

Centre for Astrophysics, University of Central Lancashire, Preston PR1 2HE, UK

`spseyres@uclan.ac.uk`

T. J. O'Brien

School of Physics and Astronomy, Jodrell Bank Observatory, University of Manchester, Macclesfield SK 11 9DL, UK

`tob@jb.man.ac.uk`

ABSTRACT

The first low radio frequency (< 1.4 GHz) detection of the outburst of the recurrent nova RS Ophiuchi is presented in this letter. Radio emission was detected at 0.61 GHz on day 20 with a flux density of ~ 48 mJy and at 0.325 GHz on day 38 with a flux density of $\sim$ 44 mJy. This is in contrast with the 1985 outburst when it was not detected at 0.327 GHz even on day 66. The emission at low radio frequencies is clearly non-thermal and is well-explained by a synchrotron spectrum of index $\alpha \sim -0.8$ ($S \propto \nu^{\alpha}$) suffering foreground absorption due to the pre-existing, ionized, warm, clumpy red giant wind. The absence of low frequency radio emission in 1985 and the earlier turn-on of the radio flux in the current outburst are interpreted as being due to higher foreground absorption in 1985 compared to that in 2006, suggesting that the overlying wind densities in 2006 are only $\sim$ 30% of those in 1985.

Subject headings: binaries: close - novae, cataclysmic variables - stars: individual (RS Ophiuchi) - stars: supernovae - stars: radio continuum

1. Introduction

The recurrent nova RS Ophiuchi was discovered to be in outburst on 2006 February 12.83 UT (Narumi et al. 2006), reaching a magnitude of $V = 4.5$. The previous recorded outbursts took place in 1898, 1933, 1958, 1967 and 1985 (Rosino 1987; Rosino & Iijima 1987), with possible outbursts in 1907 (Schaeffer 2004) and 1945 (Oppenheimer & Mattei 1993).

The interacting binary system of RS Oph comprises an M giant and a hot accreting white dwarf with an orbital period of 455.72 ± 0.83 days (Dobrzycka & Kenyon 1994; Anupama & Mikołajewska 1999; Fekel et al. 2000). The nova outbursts are powered by a thermonuclear runaway on the white dwarf surface following accretion of mass from the companion (Starrfield et al. 1985; Kato 1990). There is remarkable similarity between the optical light curves and spectra from different outbursts (e.g. Rosino 1987) . The 1985 outburst of RS Oph was one of the best studied events, with the outburst being recorded from X-rays to radio wavelengths (Bode 1987).

The first detection of the radio emission from RS Oph was made 18 days after the 1985 outburst on January 26, by Padin et al. (1985) who observed a rise in the flux density of the radio source over $\sim$ 20 days and noted that the data indicated high brightness temperatures which suggested a nonthermal origin. Monitoring of the 1985 outburst with the VLA at frequencies of 1.49, 4.85, 4.885, 14.94 and 22.46 GHz (Hjellming et al. 1986) indicated that at least two radio components existed from roughly one to six months; one with a negative spectral index (where $S_{\nu} \propto \nu^{\alpha}$) between 1.4 and 5 GHz; and another with a positive spectral index above 5 GHz. The positive index component completely dominated the decaying spectrum. Taylor et al. (1989) suggested the emission to be thermal at the higher frequencies.

An interesting feature to be noted in the RS Oph radio source is that while it was easily detected at all the higher frequencies (≥ 1.4 GHz) observed, it was not detected at 0.325 GHz (Spoelstra et al. 1987). The emission from the 1985 outburst was also extensively modelled (Bode & Kahn 1985; O' Brien et al. 1992).

The 2006 outburst of RS Oph has been subject to intense monitoring in all wavebands, almost immediately after discovery (O' Brien et al. 2006; Bode et al 2006; Sokoloski et al. 2006; Das et al. 2006). The radio emission was detected, at frequencies ≥ 1.4 GHz as early as 4.7 days from outburst (Eyres et al. 2006). The radio source of RS Oph was resolved on day 13.8 in the VLBI observations (O' Brien et al. 2006). The source, which was found to be an almost complete ring in the initial observations, soon evolved to a complex, multi-component structure consisting of an equatorial ring and polar caps. The early asymmetries in the radio source were explained by O'Brien et al. (2006) as being due to foreground absorption. Based on the observed brightness temperature and the estimate of the density in the shell, O'Brien et al. (2006) concluded that the radio emission is dominated by a non-thermal synchrotron component.

We present in this letter the low frequency radio observations of RS Oph using the Giant Metrewave Radio Telescope (GMRT). We report the detection, for the first time, of RS Oph at frequencies below 1.4 GHz, and interpret the observed light curves.

2. Observations

Continuum observations with the GMRT (Swarup et al. 1991) were first made on 2006 February 24 (day 12.62) at 1.28 GHz. Subsequently, monitoring of the nova was performed at 0.61, 0.325, 0.24, and 0.15 GHz. Since the 0.61 and 0.24 GHz feeds at GMRT are concentric, we observed both the frequency bands simultaneously. The last observation at 0.61 GHz was on 30 Jan 2007, and on 24 Nov 2006 at 0.325 GHz. 3C286 was used as the flux calibrator.

The data obtained in native 'LTA' format were converted to standard FITS format and analysed using standard tasks in NRAO AIPS[1]. Self calibration using wide-field imaging was used to improve the image quality and, on the average, two rounds of phase self calibration were found to give the best images. Radio emission was detected at all the observed radio frequencies, except at 0.15 GHz observed on 2 June 2006 (day 110) to a 3σ limit of 27 mJy. We detected radio emission from the source at 0.325 and 0.61 GHz on all the observed days.

---

[1] AIPS is distributed by NRAO which is a facility of the NSF operated under cooperative agreement by Associated Universities, Inc.

The typical beamsizes at these two frequencies were $\sim 10''$ and $\sim 6''$ respectively and the source was not resolved in our observations. The uncertainty in the flux scale is $\sim 15\%$ and the errors on the flux densities listed in Table 1 reflect this uncertainty.

3. The Radio Light Curves

Fig. 1 shows the flux density evolution of RS Oph at 0.24, 0.325 and 0.61 GHz observed with the GMRT in the period $20-351$ days after the outburst. The first observations at 0.61 GHz, 0.325 GHz and 0.24 GHz were on March 5 (day 20), March 23 (day 38) and March 30 (day 47) respectively. Also plotted in Fig. 1 are the L band observations using GMRT and the 1.49 GHz observations from the 1985 outburst.

The light curves indicate a steep rise in the flux density, followed by a relatively flat maximum and a subsequent decay. While the different frequencies seem to become visible and peak at different epochs with the lower frequencies turning on at later times which is clear from our upper limit at 0.24 GHz around day 25 and subsequent detection around day 45; the post-maximum decay at all the frequencies is fairly similar. The observed spectral index varies from $\alpha \sim -0.1$ around maximum to $\alpha \sim -1.0$ around day 220. These observations clearly show that the radio emission at these frequencies is non-thermal. Although the non-thermal nature of the radio emission was inferred from the brightness temperatures and comparison between radio and X-ray flux (Taylor et al. 1989) for the 1985 outburst, this is the first time that the non-thermal nature of the low frequency radio emission has been clearly demonstrated by the negative spectral index.

4. Discussion

The turn-on delay at longer wavelengths and the power-law decline after maximum with index β and a decreasing spectral index α observed in RS Ophiuchi are very similar to the properties of radio supernovae, and imply the emission to be nonthermal synchrotron. We model the observed light curves adopting the models for radio supernovae (Weiler et al. 1986; Weiler et al. 2002) wherein the relativistic electrons and enhanced magnetic fields necessary for synchrotron emission are generated due to the shock interaction of the nova ejecta with the circumbinary red giant wind material that is ionized and heated by the nova explosion (Chevalier 1982a; Chevalier 1982b). The radio emission rises rapidly as the shock progressively overtakes the wind material, causing a decrease in the line of sight absorption. Evidence for the presence of such an ionised, warm red giant wind is provided by the X-ray (Mason et al. 1987; Bode et al 2006; Sokoloski et al. 2006), radio (O' Brien et al. 2006) and optical (G.C. Anupama et al. 2007, in preparation, Bode et al. 2007) observations.

4.1. Model light curves

The following model, based on Weiler et al. (2002) is adopted.

$$S(\mathrm{mJy}) = K_1 \left(\frac{\nu}{1\mathrm{GHz}}\right)^{\alpha} \left(\frac{t-t_0}{20\mathrm{d}}\right)^{\beta} e^{-\tau^{\mathrm{CSM}}_{\mathrm{homog}}} \left(\frac{1-e^{-\tau^{\mathrm{CSM}}_{\mathrm{clumps}}}}{\tau^{\mathrm{CSM}}_{\mathrm{clumps}}}\right), \tag{1}$$

where

$$\tau^{\mathrm{CSM}}_{\mathrm{homog}} = K_2 \left(\frac{\nu}{1\mathrm{GHz}}\right)^{-2.1} \left(\frac{t-t_0}{20\mathrm{d}}\right)^{\delta} \tag{2}$$

$$\tau^{\mathrm{CSM}}_{\mathrm{clumps}} = K_3 \left(\frac{\nu}{1\mathrm{GHz}}\right)^{-2.1} \left(\frac{t-t_0}{20\mathrm{d}}\right)^{\delta'} . \tag{3}$$

In the above model, t_0 corresponds to 2006 Feb 12.83 and $t - t_0$ is time since the outburst. K_1 represents the flux density, K_2 the attenuation by a homogeneous absorbing medium and K_3 the attenuation by a clumpy/filamentary medium, at a frequency of 1 GHz, 20 days after the nova explosion. The optical depths, $\tau^{\mathrm{CSM}}_{\mathrm{homog}}$ and $\tau^{\mathrm{CSM}}_{\mathrm{clumps}}$ are due to the ionized circumstellar material (CSM) external to the emitting region. α gives the spectral index and β the rate of decline in the optically thin phase. The optical depths in the homogeneous and clumpy/filamentary CSM are described by δ and δ' respectively. A simultaneous, non-linear chi-square fit using the Levenberg-Marquardt algorithm (Press et al. 2002) is made to the data at all the frequencies and the best fit parameters ($\chi_{\mathrm{red}} = 1.5$) are determined as listed in Table 2. The flux density at 1.46 GHz on day 4.7 (2.8 ± 0.2 mJy), reported by Eyres et al. (2006), is also used in the model fit. The resulting model light curves are plotted in Fig. 1. It is clear that the overall evolution of the radio emission at freq $<$ 1.4 GHz is well described by the model. The model predicts the delayed turn-on at different frequencies fairly well (ref. Table 2), implying the turn-on time is determined by the thermal optical depth of the CSM. However it underpredicts the peak fluxes at the 0.325 GHz and 0.24 GHz. Using our model fits and Eqns (11) and (13) of Weiler et al. (2002), we estimate a mass loss rate of $1.6 \times 10^{-7} M_{\odot}$ yr^{-1} for a red giant wind velocity of 20 kms^{-1} (Bode & Kahn 1985).

Excess emission, over the model fit, is observed at 0.61 and 0.325 GHz beyond day ~ 120. No such flux density variation is observed in two other bright sources in the field, implying the enhancement is intrinsic to RS Oph. It is interesting to note that S. P. S. Eyres et al. (2007, in preparation) record a slight enhancement in the flux density at 1.4 and 5 GHz on day 155. The enhancement that we record appears to be different from the short duration ($\lesssim$ 24 hrs) increase in the flux density that was observed at 5 GHz, 41 days after the 1985 outburst and interpreted as being due to increased thermal emission (Spoelstra et al. 1987). To quantify the difference in the observed and modelled light curves, we followed Ryder et al. (2004) and estimated the deviations for all the frequencies. Although the residuals are noisy, excess emission by a factor of 1.8 to 1.4 is observed between days 120 and 200. The deviations in the light curve may be interpreted as being due to modulations in the CSM and the deviations are expected to be pronounced for edge-on viewing of the binary (Ryder 2004). The radio luminosity is related to the change in the CSM density (Chevalier 1982a) and for the RS Oph system (with an inclination of $30° - 40°$; Dobrzycka & Kenyon, 1994), the observed enhancement can be explained if the CSM density is increased by 50% to 25%. It is interesting to note that although it has been proposed that the forward shock may traverse the red giant wind in around 80 days (e.g Bode et al. 2006), VLBI and HST observations (O' Brien et al. 2006; Bode et al 2007) are consistent with enhanced density in the pre-outburst CSM in the plane of the central binary. Shock breakout would therefore be expected to occur much later from material in this plane and thus this could be where the density enhancements inferred from our results reside. Alternately, the flux density enhancement could be related to the presence of a new short lived ($\sim$ 100 days) component in the radio emitting medium. The magnetic field for such a component, estimated assuming equipartition and the break frequency to be 0.325 GHz would be $\sim$ 3.5 G. This is much higher than the equipartition magnetic fields in the remnant which were estimated in the 1985 outburst to be of the order of $0.01 - 0.05$ G (Bode & Kahn 1985; Taylor et al. 1989). Spoelstra et al. (1987) have noted that a uniform magnetic field can be enhanced by a factor of 200 if the cooled remnant material is compressed in volume by a factor of 100 as the nova remnant expands. When the shocked medium becomes well cooled, Rayleigh-Taylor instabilities can cause such clumps to form.

4.2. Comparison with 1985 radio light curves

In Fig. 1, the light curve for 1.49 GHz from the 1985 outburst (Hjellming et al. 1986) is plotted alongwith with the present low frequency light curves. The sharp rise to peak at 0.325 and 0.24 GHz is very similar to the sharp rise to peak observed in 1985. The peak at 0.61 GHz is broader than at other frequencies. Although differences are seen around the maximum phase, it is interesting to note the very similar evolution during both outbursts in the post-maximum phase, particularly after day $\sim$ 60.

We note two major differences in the radio emission during the 1985 and 2006 outburst:

(i) The detection of emission at frequencies < 1.4 GHz. RS Oph was not detected at 0.325 GHz on day 48 down to a 1σ limit of 5 mJy during the 1985 outburst (Spoelstra et al. 1987), while it was detected close to maximum on day 20 at 0.61 GHz and on day 38 at 0.325 GHz during the current outburst.

(ii) The detection of radio emission as early as day 4.7 (Eyres et al. 2006) compared to an implied turn-on at day 14 in 1985 (e.g. Padin et al. 1985).

Both these observations suggest that a steep-spectrum synchrotron source became visible at the lower frequencies during the current outburst due to reduced foreground absorption compared to the 1985 outburst. Using the 3σ limit of 12 mJy on day 56 for the 0.325 GHz emission in 1985 (Spoelstra et al. 1987), the observed value of 57 mJy on day 53 in 2006 and assuming that only foreground uniform absorption is responsible for the difference, we find a relation for the optical depths at 0.325 GHz in the two epochs $\tau(1985) \geq \tau(2006) + 1.6$ from simple radiative transfer arguments. The light curve model indicates that that $\tau(2006) \sim 0.2$ on day 53 which implies $\tau(1985) \sim 1.8$. Since $\tau \propto n_e^2\, L$, this indicates that the electron density of the foreground gas in 2006 is about 30% of that in 1985 for the same linear depth L. Since the two outbursts are otherwise fairly similar (O' Brien et al. 2006), one of the reasons for this difference could be the variation in the clumpiness of the foreground gas. Observations of RS Oph at quiescence do indicate the presence of non-uniform column density in the red giant wind envelope, that is uncorrelated with the binary geometry (Anupama & Mikołajewska 1999). The non-detection at 0.325 GHz of the 1985 outburst had been attributed to absorption by the thermal gas mixed with the synchrotron emitting gas and low frequency cut-off in the electron spectrum (Spoelstra et al. 1987). However both the physical processes appear to be negligible in the 2006 outburst.

5. Summary

GMRT observations of RS Oph during the 2006 outburst have shown early emission at frequencies below 1.4 GHz for the first time. The emission is clearly non-thermal, synchrotron emission and the evolution appears to be similar to that observed for radio supernovae. The light curves at these low frequencies are well explained by decreasing free-free absorption by the foreground CSM of the synchrotron emission from the remnant of the nova outburst. Model light curves with a spectral index of $\alpha = -0.8$, decay power law of index $\beta = -1.2$ and optical depth due to a homogeneous, clumpy absorbing medium well fit the observed light curves. Clumpy medium seems to dominate the absorption at early times. The light curves indicate the appearance of emission components consistent with the VLBA, EVN and MERLIN images (O' Brien et al. 2006) at higher frequencies. Modelling this data with data at higher frequencies will enhance our understanding of this unique recurrent nova system.

The similarity of late time evolution of the nova during the 1985 and 2006 outbursts suggests that the early difference is primarily due to the free-free absorption in the ionized CSM. This makes a case for early multifrequency observations with good temporal sampling during future outbursts.

We thank the anonymous referee for insightful comments on the light curve modelling which have enhanced and improved the results of this paper. We thank Prof. R. Nityananda for providing TOO time on the GMRT during the early stages of the nova outburst and NGK thanks him for discussions. We thank the staff of the GMRT that made these observations possible. GMRT is run by the NCRA, a centre of the TIFR. This research has made use of NASA's Astrophysics Data System.

REFERENCES

Anupama, G. C., & Mikołajewska, J. 1999, A&A, 344, 177

Bode, M. F., & Kahn, F. D. 1985, MNRAS, 217, 205

Bode, M. F., 1987, Proceedings of the meeting on RS Ophiuchi (1985) and the Recurrent Nova Phenomenon, Utrecht: VNU Science Press, (Ed: Bode, M.F)

Bode, M. F., et al. 2006, ApJ, 652, 629

Bode, M. F., Harman, D. J., O'Brien, T. J., Bond, H. E., Starrfield, S., Darnley, M. J., Evans, A., Eyres, S. P. S. 2007, ApJL, 665, L63

Chevalier, R. A., 1982, ApJ, 259, 302

Chevalier, R. A., 1982, ApJL, 259, L85

Das, R., Bannerjee, D. P. K., & Ashok, N. M. 2006, ApJ, 653, L141

Dobrzycka, D., & Kenyon, S. J. 1994, AJ, 108, 2259

Eyres, S. P. S., O'Brien, T. J., Muxlow, T. W. B., Bode, M. F., Evans, A. 2006, IAUC 8678

Fekel F. C., Joyce, R. R., Hinkle, K. H., Skrutskie, M. F. 2000, AJ, 119, 1375

Narumi, H., Hirosawa, K., Kanai, K., Renz, W., Pereira, A., Nakano, S., Nakamura, Y., Pojmanski, G., 2006, IAUC 8671

Hjellming, R. M., van Gorkom, J. H., Seaquist, E. R., Taylor, A. R., Padin, S., & Davis, R. J., et al. 1986, ApJ, 305, L71

Kato, M. 1990, ApJ, 355, 277

Mason, K. O., Cordova, F. A., Bode, M. F., & Barr, P. 1987, in Proceedings of the meeting on RS Ophiuchi (1985) and the Recurrent Nova Phenomenon, Ed: by M.F. Bode. Utrecht: VNU Science Press, p167

O'Brien, T. J., Bode, M. F., & Kahn, F. D., 1992, MNRAS, 255, 683

O'Brien, T. J., et al. 2006, Nature, 442, 279

Padin, S., Davis, R. J., & Bode, M. F. 1985, Nature, 315, 306

Press, W. H., Teukolsky, S. A., Vetterling, W. T., & Flannery, B. P., 2002, The Numerical Recipes, (2ed: Cambridge University Press)

Rosino, L. 1987, in Proceedings of the meeting on RS Ophiuchi (1985) and the Recurrent Nova Phenomenon, Ed: M.F. Bode. Utrecht: VNU Science Press, p1

Rosino, L. & Iijima, T. 1987 in Proceedings of the meeting on RS Ophiuchi (1985) and the Recurrent Nova Phenomenon, Ed: M.F. Bode. Utrecht: VNU Science Press, p27

Ryder, S. D., Sadler, E. M., Subrahmanyan, R., Weiler, K. W., Panagia, N., Stockdale, C. 2004, MNRAS, 349, 1093

Schaeffer, B. 2004, IAUC 8396

Oppenheimer, B. D. & Mattei, J. A. 1993, JAAVSO, 22, 105

Spoelstra, T. A. T., Taylor, A. R., Pooley, G. G., Evans, A., & Albinson, J. S. 1987, MNRAS, 224, 791

Sokoloski, J. L., Luna, G. J. M., Mukai, K., & Kenyon, S. J. 2006, Nature, 442, 276

Starrfield, S., Sparks, W. M., Truran, J. W. 1985, ApJ, 291, 136 Ed: Bode, M. F. & Evans, A., Wiley, Chichester, p39

Swarup, G., et al. 1991, Current Science, 60, 95

Taylor, A. R., Davis, R. J., Porcas, R. W., & Bode, M. F. 1989, MNRAS, 237, 81

Weiler, K. W., Sramek, R. A., Panagia, N., van der Hulst, J. M., & Salvati, M. 1986, ApJ, 301, 790

Weiler, K. W., Panagia, N., Montes, M. J.,& Sramek, R. A. 2002, ARA&A, 40, 387

This preprint was prepared with the AAS LaTeX macros v5.2.

Table 1. Observed flux densities for RS Ophiuchi. The first column indicates the day after the outburst, 2006 Feb 12.83 UT (JD 2453779.33).

Day	ν	S	Phase cal	
	GHz	mJy	Name	S (Jy)
17.19	1.39	56.8 ± 8.5	1743-038	3.5 ± 0.5
11.22	1.28	49.5 ± 7.4	1743-038	2.7 ± 0.4
17.19	1.28	50.0 ± 7.5	1743-038	2.7 ± 0.4
17.19	1.06	55.4 ± 8.3	1743-038	2.3 ± 0.4
20.26	0.61	48.4 ± 7.2	1743-038	1.1 ± 0.2
29.15	0.61	48.9 ± 7.3	1833-210	9.8 ± 1.5
45.07	0.61	47.9 ± 7.2	1822-096	7.7 ± 1.2
92.99	0.61	21.0 ± 3.2	1822-096	8.1 ± 1.2
120.86	0.61	15.3 ± 2.3	1822-096	8.4 ± 1.3
136.92	0.61	15.3 ± 2.3	1822-096	8.5 ± 1.3
147.88	0.61	10.5 ± 1.6	1822-096	8.8 ± 1.3
153.94	0.61	18.2 ± 2.7	1822-096	9.0 ± 1.4
166.77	0.61	10.9 ± 1.6	1822-096	10.0 ± 1.5
192.84	0.61	10.1 ± 1.5	1822-096	9.9 ± 1.5
206.89	0.61	5.5 ± 0.8	1822-096	8.2 ± 1.2
214.66	0.61	5.8 ± 0.9	1822-096	8.3 ± 1.2
221.86	0.61	4.2 ± 2.1	1822-096	9.2 ± 1.4
351.40	0.61	3.9 ± 0.6	1822-096	7.8 ± 1.2
38.15	0.325	43.7 ± 6.6	1822-096	10.4 ± 1.6
53.24	0.325	57.0 ± 8.6	1822-096	11.8 ± 1.8
123.12	0.325	17.2 ± 3.4	1822-096	9.8 ± 1.5
134.07	0.325	18.0 ± 3.6	1822-096	10.7 ± 1.6
169.75	0.325	20.6 ± 5.7	1822-096	10.1 ± 1.5
225.61	0.325	8.1 ± 4.4	1822-096	9.5 ± 1.4
284.43	0.325	6.3 ± 1.8	1822-096	9.7 ± 1.5
29.15	0.24	< 13.0		
45.07	0.24	54.2 ± 8.0	1822-096	14.0 ± 2.1

Table 1—Continued

Day	ν GHz	S mJy	Phase cal Name	 S (Jy)
92.99	0.24	30.5 ± 4.6	1822-096	15.0 ± 2.3
110	0.15	< 9.0		

Table 2. Best fit parameters from least square fits to the low frequency radio emission from RS Ophiuchi

Parameter	Value
K_1	86.4
α	-0.78
β	-1.24
K_2	0.144
δ	-2.29
K_3	0.53
δ'	-3.14
ν (GHz)	Onset (days)
1.28	3
0.61	6
0.325	10
0.24	14

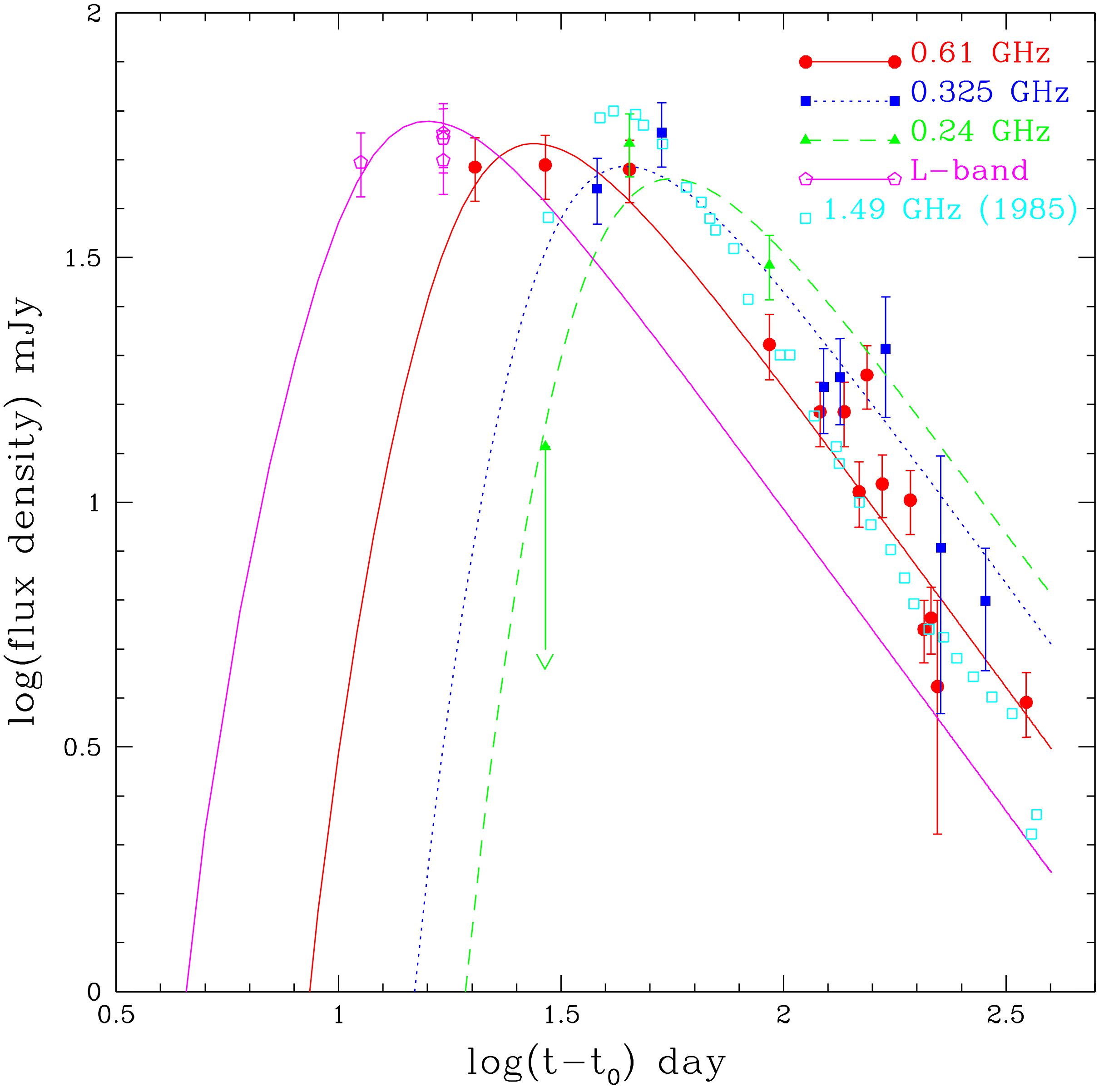

Fig. 1.— Observed light curves of RS Oph (points) at L-band, 0.61 GHz, 0.325 and 0.24 GHz observed in the 2006 outburst. Continuous lines represent the model light curves generated using parameters listed in Table 2. Also plotted is the 1.49 GHz light curve from 1985 outburst (Hjellming et al. 1986).