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Studying galactic novae systems at GMRT frequencies

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Abstract. Galactic novae are binary systems consisting of a white dwarf and a companion star such as a main sequence star or a red giant. As the system evolves, the white dwarf accretes matter from the companion star which leads to a thermonuclear runaway igniting the matter on the white dwarf surface. This causes a sharp rise in the optical brightness of the system by a few to 15 magnitudes compared to quiescence. Several hundred Galactic novae are known and radio emission has been detected from about 33 of these with 9 showing the presence of non-thermal radio emission in their spectra. GMRT is optimal for detecting non-thermal emission from nova systems and has been used to observe about 11 systems to date. Radio continuum emission at frequencies < 1 GHz has been observed from two systems - GK Persei and RS Ophiuchi. We have now started a systematic programme to observe non-thermal radio emission from Galactic Novae called GNovaG which promises to add to the pool of multifrequency data and enhance our understanding of several outstanding questions related to nova progenitors and environment.

1. Introduction

Novae are cataclysmic explosions on the surface of a white dwarf which is a member of a binary system accreting matter from the companion star, generally a main sequence or a red giant star. The explosions brighten the system by several magnitudes in optical and the system radiates γ rays to radio waves. In recent years, the availability of more observing facilities and coordination between telescopes at different wavebands has resulted in the gathering of multifrequency data on these interesting Galactic systems and while this has helped understand these systems; it has also raised

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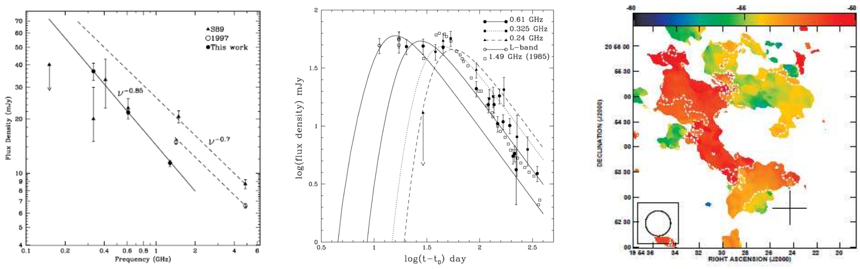

Figure 1. Left: Secular decrease in the flux densities at $\nu > 1$ GHz of the classical nova GK Persei remnant (from Anupama & Kantharia 2005). Middle: The early time radio light curves of the recurrent nova RS Ophiuchi (from Kantharia et al. 2007). The solid lines are the fitted model based on Weiler et al. (2002, ARAA, 40, 387). Right: Expanding HI nebula near V458 Vulpeculae. The colour scale represents velocity in kms^{-1}. (from Roy et al. 2012).

more questions. Fermi LAT detected γ rays from a few systems (e.g. Cheung, T, arXiv:1304.3475v2). This new result has intrigued astronomers especially that such low energy systems can give rise to such energetic radiation. Thus, it is important to monitor such systems at all possible wavebands. Very few nova systems have been observed in low radio frequencies which probe the non-thermal synchrotron emission from such systems. GMRT is an ideal instrument to fill this very important gap in the monitoring observations and requires modest investment of GMRT time.

Novae at GMRT frequencies Unlike the very energetic supernova explosions (SN) and γ ray bursts (GRBs), novae are low energy thermonuclear outbursts on the surface of a white dwarf. Novae might be unimportant in overall galaxy energetics and relativistic particle population but is important in returning metals to the ISM. These are transients in our Galaxy and to get a complete understanding it is important to study phenomena which cover the entire energy spectrum. In the regime of GMRT frequencies, the physics of radio emission is similar to that in the more energetic phenomena, namely non-thermal synchrotron emission. The high expected rate of 30-40 novae per year in our Galaxy can potentially provide a large database to study the following interesting points:

1. Investigate nova system as a possible progenitor of SN Type 1a when the WD mass crosses 1.4 M$\odot$. No prompt radio emission has been detected from a SN Type 1a.
2. Shock physics, particle acceleration, local magnetic field amplification. Non-thermal emission is not detected from many systems – sensitivity or physics?
3. Nova environs - planetary nebulae, nova remnants, interstellar medium.
4. Multifrequency study and modelling can, in principle, allow a physical model for a nova system + its environment and their evolution with successive outbursts.
5. Compare the low energy/high energy synchrotron emitting systems.

2. GMRT study

We have studied 11 novae with GMRT and more observations are planned. Radio continuum emission has been detected from two novae out of these 11. An expanding HI shell around one of the novae has also been detected. GK Persei the long-lived remnant shell has been studied in detail with GMRT (Anupama & Kantharia 2005, A&A, 435,167) and using our data and high frequency archival data from the VLA we have established a secular decrease in the nova shell similar to supernova remnants like Cas A (e.g. Baars et al. 1977 A&A, 61,99). RS Ophiuchi was detected by GMRT (Kantharia et al. 2007, ApJ, 667, L171) soon after outburst in 2006 and the early non-thermal light curve evolution has been studied. The planetary nebulae around two classical nova systems have been studied with GMRT in the 21cm spectral line of HI GK Persei (Anupama & Kantharia 2005) and V458 Vulpeculae (Roy et al, 2012, MNRAS, 427, L55). The details of the novae observed with GMRT and the GMRT observations are given in Tables 1 and 2.

Table 1. Details of the novae observed with GMRT. (Table from Kantharia 2012, BASI,40,311).

No	Nova	Type	Distance[a] kpc	Galactic longitude	Galactic latitude	Height kpc	Outburst
1	GK Persei	classical	0.5	150.9553	−10.1042	0.03	1901
2	RS Ophiuchi[b]	recurrent	1.6	19.7995	10.3721	1.2	11/2/2006
3	V458 Vulpeculae	classical	13	58.6331	−3.6171	0.8	8/8/2007
4	V445 Puppis[b]	classical (He)	8.2	241.1238	−2.1914	0.3	28/11/2000
5	U Scorpii[b]	recurrent	12	357.6686	+21.8686	4.8	28/1/2010
6	T Pyxidis	recurrent	1	257.2072	+09.7067	0.2	14/4/2011
7	V2491 Cygni	classical	10.5	067.2287	+04.3531	0.8	10/4/2008
8	V459 Vulpeculae	classical	4	058.2138	-02.1673	0.2	25/12/2007
9	V2468 Cygni	classical	14	066.8084	+00.2455	0.06	8/3/2008
10	V2467 Cygni	classical	3	080.069	+01.8417	0.09	15/3/2007
11	KT Eridanus	classical	7	207.9863	-32.0202	4.3	25/11/2009

Notes: (a) Distance to the novae are taken from literature.
(b) The mass of the white dwarf is estimated to be close to the Chandresekhar mass limit.

3. Galactic Novae with GMRT (GNovaG) - a regular monitoring programme

We have now started a regular monitoring programme to search for non-thermal emission from Galactic novae, especially recurrent nova systems. This programme which started in 2012 aims at systematically observing Galactic novae at GMRT frequencies. In this programme we are aiming at observing all novae within 8 kpc of luminosity L $\geq 3 \times 10^{12}$ W/Hz at 610 MHz aiming at a 3σ upper limit of about $\sim 350\mu$Jy. For comparision, RS Ophiuchi was fairly lumninous at $5 * L$. This project will be able to examine the presence of non-thermal emission from several Galactic novae for several

Table 2. GMRT observations of novae. Column 4 labeled 'Det?' refers to detection of radio continuum emission from the nova system. Table from Kantharia (2012).

No	Nova	ν MHz	Det?	Dist* kpc	610MHz 3σ mJy	Date of Obs	$L_{610MHz} \times 10^{-12}$ Watts-Hz^{-1}
1	GK Persei	325, 610,1280,HI[a]	Y	0.5	21.8[1]	5/9/2002	0.65
2	RS Ophiuchi	240,325,610	Y	1.6	48.9[2]	13/3/2006	15
3	V458 Vulpeculae	1420, HI[a]	N[b]	13	< 1[3]	11/6/2009	< 20.2
4	V445 Puppis	610,1280	N	8.2	< 0.36[4]	28/10/2009	< 2.89
5	U Scorpii	610,1280	N	12	< 0.3[5]	11/2/2010	< 5.17
6	T Pyxidis	610	N	1	< 0.3[6]	18/3/2012	< 0.036
7	V2491 Cygni	610,240	N	10.5	< 0.5[@,7]	21/6/2009	< 6.59
8	V459 Vulpeculae	610,240	N	4	< 2.0[@,7]	21/6/2009	< 3.83
9	V2468 Cygni	610,240	N	14	< 0.5[@,7]	21/6/2009	< 11.7
10	V2467 Cygni	610,240	N	3	< 1.6[@,7]	21/6/2009	< 1.72
11	KT Eridanus	610	N	7	< 1.0[8]	10/1/2010	< 5.86

Notes: * - Distance estimates obtained from literature. @ - Quick analysis results. (a) This nova was observed in the HI 21cm spectral line. (b) HI was detected near V458 Vulpeculae. 1. Anupama & Kantharia 2005; 2. Kantharia et al. 2007; 3. Roy, et al. 2012 4. unpublished; Ashok, Kantharia, Bannerjee 5. Anupama, et al. 2013,A&A,559,121. 6. Roy et al. 2012 7. unpublished; Eyres et al. 8. O'Brien et al. 2010, ATel 2434

epochs following outburst. The varied behaviour in the non-thermal radio emission displayed by nova systems is not well understood. RS Ophiuchi was detected in non-thermal emission soon after outburst whereas V445 Puppis was detectable $\sim$ 8 years post-outburst and where novae are not detected, lack of well-sampled monitoring data seems like a major issue. In the case of RS Ophiuchi, we could infer a 30% decrease in the densities of the circumbinary material between two consecutive outburts from the evolution of the synchrotron emission thus giving insight into evolution of the densities. GnovaG will follow nova systems at different evolutionary epochs and contribute significantly to obtaining well-sampled monitoring data and model the non-thermal radio evolution of these systems and hence the environment in which the shock propagates. These data will then be very important along with multi-frequency data to compare with the high energy systems and address the scientific issues mentioned earlier.

4. Conclusions

Novae are interesting binary systems which can further our understanding of several outstanding issues such as them being progenitor systems of SN Type 1a, shock acceleration, magnetic field amplification and the evolution of the circumbinary material with subsequent outbursts. 11 novae have been observed with GMRT and radio continuum emission has been detected in two of these. A regular monitoring programme GNovaG is in progress at GMRT for following these interesting and intriguing systems.