Near Infrared Spectroscopy and Photometry of Novae

A THESIS

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MOHANLAL SUKHADIA UNIVERSITY

In the

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by

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Under the Supervision of

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To

my parents and beloved wife

DECLARATION

I, **Mr. Ashish Raj**, S/o Sri Vijay Kumar Srivastava, resident of A-5, PRL residences, Navrangpura, Ahmedabad 380009, hereby declare that the research work incorporated in the present thesis entitled, **"Near Infrared Spectroscopy and Photometry of Novae"** is my own work and is original. This work (in part or in full) has not been submitted to any University for the award of a Degree or a Diploma. I have properly acknowledged the material collected from secondary sources wherever required. I solely own the responsibility for the originality of the entire content.

Date:

Ashish Raj

(Author)

CERTIFICATE

I feel great pleasure in certifying that the research work presenred in the thesis entitled, **"Near Infrared Spectroscopy and Photometry of Novae"** by Mr. Ashish Raj was done under my guidance. He has completed the following requirements as per Ph.D regulations of the University.

(a) Course work as per the university rules.

(b) Residential requirements of the university.

(c) Regularly submitted six monthly progress reports.

(d) Presented his work in the departmental committee.

(e) Published minimum of one research papers in a referred research journal.

I recommend the submission of thesis.

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Abstract

Classical Novae(CNe) outbursts are violent thermonuclear explosions arising on the surface of white dwarfs in close binary systems and are contributors to the chemical evolution of the interstellar medium through the production and ejection of copious amounts of metal rich material. Observations and modeling of CNe eruptions illuminate numerous fundamental processes of astrophysical interest, including non-equilibrium thermonuclear runaway, radiative processes in dynamic nebular environments, binary star interaction, mass loss from red dwarfs, molecule formation, dust condensation and dust growth.

This thesis concentrates on studying the novae near their optical maximum brightness, the temporal evolution of the early decline phase and investigating the physical properties of the underlying binary system. The results that emerged from the extensive studies of three novae, viz., V5579 Sagittarii, V496 Scuti and KT Eridani are presented. Of these three novae, V5579 Sgr and V496 Sct are of Fe II class while the third nova KT Eri is of He/N class. The system parameters like the distance to the nova, absolute magnitude, expansion velocity of the ejecta, mass of the ejecta and gas to dust ratio are calculated.

The nova V5579 Sgr showed pre-maximum rise lasting for about 5 days it was possible to obtain near infrared observations near its optical maximum. The spectra near peak brightness show strong P Cygni signatures. The blackbody fit to the spectral energy distribution of the optical and near infrared data during the fireball phase near optical maximum is consistent with the A - F spectral type pseudo-photosphere usually displayed by novae at outburst. The optical light curve showed a sharp fall about 15 days after the optical maximum indicating the onset of dust formation. The formation of dust in V5579 Sgr is consistent with the presence of emission lines of elements with low ionization potentials like Na and Mg in their early spectra. The early presence of such low ionization potential lines has been suggested as likely indicators of dust formation in the expanding nova ejecta at later times. With $t_2 = 8$ days, V5579 Sgr is one of the few fast Fe II classes of novae that formed dust.

The highlight of our study of V496 Sct is the detection of the rarely observed CO first overtone emission bands of CO. The formation of molecules in nova ejecta is expected to begin before the dust formation epoch. Though the dust formation has been observed in several Fe II class novae the CO detection has been done in very few novae. The CO bands have been modeled, assuming the CO gas to be in thermal equilibrium, to estimate the mass of the CO gas in the ejecta and the temperature of this emitting gas. In addition the $^{12}C/^{13}C$ ratio was estimated and compared with the model predicted values. The subsequent observations have detected the formation of dust in V496 Sct. In addition the evolution of optical spectra has also been studied using the data by Italian group made available as part of the collaborative efforts to study novae.

The He/N class nova KT Eri, which has been proposed as a possible recurrent nova on the basis of its similarity with the observed properties of RS Oph, was observed during the first 100 days following its discovery and evidence for high velocity bi-polar flow is presented. With its location at galactic latitude of -32 deg, KT Eri is one of the very few novae discovered at such high galactic latitudes. The nature of progenitor of KT Eri has been studied using the pre-discovery optical and near-infrared photometric data. The spectral energy distribution shows a power law dependence with a spectral index of 1/3 suggesting an accretion disk as the source of this continuum radiation. The evolution of post-outburst continuum radiation over an extended infrared spectral range using the WISE data was done and it shows a departure from the expected free-free phase following its fast decline.

The research work presented in this thesis is based on the photometric and spectroscopic observations of selected novae discovered during the period 2008 to 2010. The near-infrared observations were obtained from the 1.2m telescope at Mt. Abu Infrared Observatory of Physical Research Laboratory, Ahmedabad using the near-infrared camera/spectrograph (PRLNIC). The optical photometric data from the archives of American Association of Variable Star Observers (AAVSO) were used to generate the light curves of the novae.

LIST OF PUBLICATIONS

A. Publications related to the thesis work

1. **"Nova V5579 Sgr 2008: near-infrared studies during maximum and the early decline phase"**
   Ashish Raj, N. M. Ashok, D. P. K. Banerjee
   2011, Mon. Not. R. Astron. Soc., **415**, 3455

2. **"V496 Scuti: an Fe II nova with dust shell accompanied by CO emission"**
   Ashish Raj, N. M. Ashok, D. P. K. Banerjee, U. Munari, P. Valisa and S. Dallaporta
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B. Conference Proceedings

1. **"Near-infrared study of fast nova KT Eridani"**
   Ashish Raj, N. M. Ashok, D. P. K. Banerjee
   2011, BASI, 3, 113

C. CBETs and ATels

1. **Ashish Raj**, N. M. Ashok, D. P. K. Banerjee, 2009, CBET, 2002

2. **Ashish Raj**, N. M. Ashok, D. P. K. Banerjee, 2009, CBET, 2069

3. **Ashish Raj**, N. M. Ashok, D. P. K. Banerjee and V. Venkata Raman, 2012, ATel, 4027

4. **Ashish Raj**, N. M. Ashok, D. P. K. Banerjee and V. Venkata Raman, 2012, ATel, 4093

5. **Ashish Raj**, V. Venkata Raman, N. M. Ashok and D. P. K. Banerjee, 2012, ATel, 4107

6. **Ashish Raj**, N. M. Ashok, D. P. K. Banerjee, 2012, ATel, 4169

7. **Ashish Raj**, N. M. Ashok, D. P. K. Banerjee, 2012, ATel, 4211

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