Extragalactic Classical Nova Surveys

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Abstract. We are currently involved in a multifaceted campaign to study extragalactic classical novae in the Local Group and beyond. Here we report on-going results from the exploitation of the POINT-AGAPE M31 dataset; initial results from our Local Group imaging, and spectroscopic CNe follow-up campaign and introduce the Liverpool Extragalactic Nova Survey.

1. Introduction

Although much has been learnt from the study of Galactic classical novae (CNe), it is clear that Galactic data are not ideal for establishing the population characteristics of novae because these data are often heavily biased by selection effects. To-date no RNe have been identified outside the Milky Way and its companions, but CNe have been studied in about a dozen galaxies. To gain further insight into the population of novae, and specifically to explore further the question of whether there exist two distinct nova populations (see e.g. della Valle et al. 1992), we are involved in a number of campaigns to study a large sample of novae in the Local Group and beyond. The following sections briefly describe the current status of the three parts of our extragalactic CN work: the POINT-AGAPE survey; our Local Group CN follow-up project, and the Liverpool Extragalactic Nova Survey.

2. The POINT-AGAPE Survey

The Pixel-lensing Observations with the Isaac Newton Telescope – Andromeda Galaxy Amplified Pixels Experiment (POINT-AGAPE) survey (Calchi Novati et al. 2003) was an optical search for gravitational microlensing events towards the Andromeda Galaxy (M31). As well as microlensing, the survey was sensitive to many different classes of variable stars and other transients, including Classical Novae (Darnley et al. 2002).

Previous work with the POINT-AGAPE dataset included the development of an automated CN detection pipeline, which led to the discovery of 20 CNe (Darnley et al. 2004). Using the results from the catalogue, a global CN rate for M31 of $65^{+16}_{-15}$ yr\textsuperscript{-1} was derived (Darnley et al. 2006). Separate M31 bulge
and disk rates of $38^{+15}_{-12}$ yr$^{-1}$ and $27^{+19}_{-15}$ yr$^{-1}$ respectively were also determined. The derived global rate is a factor of around two higher than the most robust previous result of $37^{+12}_{-8}$ (Shafter & Irby 2001) and strong evidence in favour of two separate CN populations was provided: one associated with the M31 bulge, the other with the disk.

Darnley et al. (2006) were able to use the M31 dataset and various assumptions about the Milky Way (see Shafter 2002) to deduce a Galactic bulge nova rate of $14^{+6}_{-5}$ yr$^{-1}$, a disk rate of $20^{+14}_{-11}$ yr$^{-1}$ and a global Galactic rate of $35^{+15}_{-12}$ yr$^{-1}$. This rate is remarkably similar to independent estimates computed from direct observations of the Milky Way’s CN population (Shafter 1997).

Recently, an additional fourth season of POINT-AGAPE legacy data has been obtained. These data are being analysed with the expectation of additional CNe detections and hence further refining the M31 bulge and disk rates, and strengthening the evidence in favour of two distinct M31 CN populations.

3. The Local Group

As part of ongoing work observing Local Group CNe, programmes with guaranteed observing time are in place on a number of telescopes to follow-up novae discovered in the Andromeda Galaxy, its companion (M32) and the Triangulum Galaxy (M33). To provide optical follow-up observations the 1m telescope at the Mount Laguna Observatory (MLO), the Steward 2.3m and the LT are employed. Time has also been granted on the Hobby-Eberly Telescope (HET) to obtain low-resolution optical spectra and Spitzer Space Telescope time to perform IR photometry and spectroscopy.

Systematic studies of M31 (and the Local Group) have become feasible for the first time in recent years due in part to the advent of robotic telescopes, such as the Liverpool Telescope (LT, Steele et al. 2004) and Faulkes Telescopes. However a large number of novae are discovered in M31 each year by amateurs and professionals alike. Over the past two years, a total of 31 CNe have been discovered during the ∼8 month M31 observing season. This number neglects any contribution from routine optical imaging of M31 with the LT (undertaken by the Angstrom project, (see Kerins et al. 2006, and Figure[1]), MLO and Steward, amongst others. The Local Group nova sample is also being supplemented by CN alerts from the Angstrom M31 bulge micro-lensing survey (Darnley et al. 2007a; Darnley et al. 2007b) and serendipitous nova discoveries made by the Lick Observatory Supernova Search (LOSS) and the ROTSE IIIb programme.

During the last M31/M33 observing season (August 2006 – February 2007) six novae in M31 and one in each of M32 and M33 have been followed-up with all three optical telescopes and low-resolution spectroscopy has been performed with the HET (Shafter et al. 2006a). Figure[2] shows HET spectra of three Local Group novae. Infrared photometry and spectroscopy for four CNe in M31 has recently been obtained from Spitzer; these data are still being analysed.
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Figure 1. Angstrom DIA light-curve of Classical Nova 2006 #8 (Darnley et al. 2007a), first announced by Burwitz et al. (2006). This nova has a $t_2 \leq 10$ days and is classed as a “very fast” nova. This light curve provides the best sampled light-curve of an extragalactic CN to-date.

Figure 2. HET spectra of three of our target Local Group novae, one from each of M31, M32 and M33 (Shafter et al. 2006b). These spectra show strong Hydrogen emission lines as well as prominent Fe II emission lines with characteristic P Cygni profiles (Williams 1992). All three are classic examples of Fe II CNe.
4. Liverpool Extragalactic Nova Survey

The Liverpool Extragalactic Nova Survey (LENS) is a high cadence extragalactic CN monitoring survey. Conceived to expand upon the results of the POINT-AGAPE CN survey, LENS studies three more distant galaxies, covering a range of Hubble types; namely, M81, NGC 2403 and M64. This survey operates primarily on the robotic 2m LT and also utilises some RoboNet-1.0 time on the Faulkes Telescope North (FTN, Burgdorf et al. 2007). A primary objective is to determine how the nova rate varies with Hubble type.

LENS has to-date taken three seasons of data (including an initial pilot season during the commissioning of the LT) for each galaxy, with guaranteed time on the LT to conduct a fourth observing season. These data are reduced using a fully automated difference-image-analysis (DIA) pipeline (Darnley et al. 2008), with nova detection via the POINT-AGAPE algorithm (Darnley et al. 2004). Variable object detection and classification is currently being performed on the LENS dataset, and a number of CN candidates have already been identified.

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References

Burgdorf, M. J., Bramich, D. M., Dominik, M., Bode, M. F., Horne, K. D., Steele I. A., Rattenbury, N., Tsapras Y. 2007, P&SS, 55, 582
Burwitz, V., Pietsch, W., Stefanescu, A., Schrey, F., Hatzidimitriou, D., Reig, P., Papamastorakis, G. 2006, ATel, 884, 1
Calchi Novati, S., Jetzer, P., Scarpetta, G., Giraud-Héraud, Y., Kaplan, J., Paulin-Henriksson, S., Gould, A. 2003, A&A, 405, 851
Darnley, M. J., Bode, M. F., Kerins, E. J., O’Brien, T. J. 2002, AIPC, 637, 481
Darnley, M. J. et al., 2004, MNRAS, 353, 571
Darnley, M. J. et al., 2006, MNRAS, 369, 257
Darnley, M. J. et al., 2007a, ApJ, 661, L45
Darnley, M. J., et al. 2007b, ATel, 1192
Darnley, M. J., et al. 2008, in preparation
della Valle, M., Bianchini, A., Livio, M., Orio, M. 1992, A&A, 266, 232
Kerins, E., Darnley, M. J., Duke, J. P., Gould, A., Han, C., Jeon, Y.-B., Newsam, A., Park, B.-G. 2006, MNRAS, 365, 1099
Shafter, A. W. 1997, ApJ, 487, 226
Shafter, A. W., Irby, B. K. 2001, ApJ, 563, 749
Shafter, A. W. 2002, AIPC, 637, 462
Shafter, A. W., Coelho, E. A., Misselt, K. A., Bode, M. F., Darnley, M. J., Quimby, R. 2006a, ATel, 923, 1
Shafter, A. W., Coelho, E. A., Misselt, K. A., Bode, M. F., Darnley, M. J. 2006b, AAS, 209, #09.20
Starrfield, S., Truran, J. W., Sparks, W. M., Kutner G. S. 1972, ApJ, 176, 169
Steele, L. A., et al. 2004, SPIE, 5489, 679
Warner, B. 1995, Cataclysmic Variable Stars, Cambridge University Press
Williams, R. E. 1992, AJ, 104, 725