PROCEEDINGS OF SCIENCE

CV Research in a Golden Age

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In these concluding remarks, I highlight results that give a flavor of the state of cataclysmic variable (CV) binary star research. It is certainly a Golden-Age for CV research as observations are being made an exponentially increasing way and even more importantly technical innovation has led to both the full exploitation of classical techniques, like stellar parallax, as well as the opening of the new frontiers of multi-messenger astrophysics. The effects of this Golden Age in CV research are bound to continue.

The Golden Age of Cataclysmic Variables and Related Objects V (GOLDEN2019)
2-7 September 2019
Palermo, Italy

[*]Speaker.
[†]This work supported by PRO-ARC

PoS(GOLDEN2019)060

1. Introduction

The work presented at this workshop clearly demonstrates that we are indeed in a golden age for cataclysmic variables (CVs). Multi-wavelength studies will be augmented by multi-messenger analyses in the coming decades. It is difficult to imagine the rewards to our field from the combined datasets provided by Gaia (1 Gaia Collaboration 2018), large-scale spectroscopic surveys like SDSS/APOGEE, and LAMOST, as well as transit surveys, e.g. ZTF (2 Szkody et al. 2020). Of course, new X-ray observatories will leverage outburst information from survey data and study newly discovered sources. But it is the so-called Multi-messenger Era that currently supplies considerable excitement. Ultimately bringing gravitational waves, cosmic-rays, and neutrino observations to the study of individual sources will result in the transformation of many if not most fields in astrophysics. For example, much of what is known about the formation and chemical evolution of the Galaxy is already being transformed. The study of gravitational waves and their multi-wavelength electromagnetic emission from binary black holes, neutron stars, and white dwarfs of all types and in all combinations will occupy a significant number of investigators in the not-so-distant future.

The implications for this in terms of CV theory are quite significant. Simple models and paradigms will necessarily have to be improved or discarded in the wake of an unprecedented data stream. Machine learning will play an ever-increasing role in the analysis of survey data promised in the 2020s and beyond. In these brief remarks, I comment on examples of how CV modeling now must confront big-data.

2. White Dwarf Masses and their Mergers

One example challenge relates to the mass distribution of white dwarfs in CVs as compared to isolated white dwarfs and in particular on how those distributions are related. Something that was not discussed here is the formation of the very high magnetic field isolated white dwarfs by the merger of lower field white dwarfs in binaries (3 Tout et al. 2012). Efforts to reconcile these distributions will continue to be focused on the loss of angular momentum leading to merger, i.e. the accretion of the entire red-dwarf companion. Improving data on a vast number of white dwarfs, in and out of binaries, will place needed constraints on CV evolution models. Population modeling constrained by high quality data will also address key questions on both single-degenerate and double-degenerate pathways to Type Ia SNe.

3. Gravitational Radiation from Binaries

There could be a lot said about the impact of gravitational wave astronomy, however I will just note that there is a difference between the opening of this new window to astronomy and others in the past. Instruments for gravitational wave astronomy, e.g. the Laser Interferometer Gravitational-Wave Observatory (LIGO) were built to test a weak but well understood prediction. Radio and Gamma-ray astronomy were both founded on the detection of completely unforeseen sources. X-ray astronomy originating from rockets (e.g. 4 Giacconi et al. 1962) expected to find something in the X-ray sky, but they really did not know what. Gamma-ray astronomy famously originated in an attempt to monitor cold-war nuclear testing activities. High energy gamma-ray emission (bursts) from the accreting black hole binary Cygnus X-1 was also unexpected (5 Mason et al. 1997).

As such, Gravitational Radiation (GR) studies of binaries are easily within the foreseeable future. Ultimately, GR-noise from too numerous local binaries will be a problem as sensitivity improves. I mention this because long-term electromagnetic period studies of the closer very short period binaries will not only benefit the study of those individual systems, but it will also be essential in knocking down GR-noise caused by binaries at various frequencies. One persons rubbish is another's treasure. These binaries will be important sources and will need to be adequately characterized. Knowing the phase and orbital period of predictable, yet gravitationally unresolved, binaries will aid in the interpretation of weak gravitational wave signals and will be lots of work for binary observers.

4. Accurate CV Distances and Radio Studies

Having well established distances to magnetic CVs, provided by Gaia parallaxes, is an important step in establishing absolute energy production from stellar components as well as the accretion processes at work. In terms of emission from magnetic CVs with detected radio emission, recent improvements in sensitivity of the Jansky Very Large Array have established magnetic CVs as a real class of radio sources (6,7 Barrett et al 2017, 2020), rather than just a few detections from nearby sources; see e.g. 8 Chanmugam et al. (1976), 9 Beasley et al.(1994), and 10 Mason et al. (1996). The latter two consisted of non-detections. The radio study of CVs is a field that has long awaited sources, both non-magnetic (11 Coppejans et al. 2015) and magnetic (12 Mason and Gray 2007). The detailed radio study of these new sources promises progress in differentiating between potential radio emission mechanisms.

5. Acknowledgments

I thank Franco Giovannelli for his kind invitation to present these remarks. Picture Rocks Observatory and Astrobiology Research Center (PRO-ARC) provided for funding for this research.

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