Progress Report for TG-AST120060 "Magnetic Towers and Binary-Formed Disks"

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1 Summary of Scientific Discoveries

Our allocations of TG-AST120060 was 1.1 million SUs on Kraken and 1.3 millions SUs on TACC's Ranger. Part of SUs on ranger was transfered to Stampede (41600 SUs) in February 2013. The allocations ended on September 30, 2013. As of September 30, 2013, we used 100% of our allocation on Kraken and 99% of our allocation on Ranger/Stampede to do high resolution simulations on disks and 2.5-D jets. In summary, our principle scientific discoveries are as follows

- We have completed an initial study of wind capture disks providing initial limits as to disk formation, mass accretion rates and disk structure.
- We have complete a study of magnetized jets in 2.5-D (axisymmetry) at extremely high resolution. Our simulations capture the dynamics of both the global magnetic field structure in the jet as well as the emission patterns in the cooling zone behind internal working surfaces. The simulations are the first to resolve and predict predict both H_α as well as [SII] emission patterns.
- We have completed an initial study of disks formed from the disruption of a binary companion during common envelope evolution. Our simulations have presented a high resolution view of instabilities occurring at the disk/envelope interface which lead to mixing and disk dispersal.

2 Accomplishments of Computational Plan

The goals of our study have been to the articulate the evolution of evolved binary stars and the outflows they generate. Highly collimated outflows in the form of planetary nebulae (PNe) and proto-planetary nebulae (pPNe) represent the observational signatures of what are believed to be winds driven by magnetic processes from a central engine that dominated by the interaction of an AGB star with a companion. Using the Adaptive Mesh Refinement (AMR) Multi-physics code AstroBEAR (developed by our group Cunningham et al 2009, Carroll et al 2012, Frank et al 2014) we have carried out high resolution simulations that shed light on a number of aspects of the jet and binary interaction problem.

Our studies (Huarte-Espinosa et al 2012, 2012b, 2013) of binary stars interactions focused initially on the evolution of disks around the secondary via AGB wind capture (Bondi-Hoyle or BH flows). While previous works found significant enhancements over theoretical BH accretion rates onto the secondary, the resolutions were insufficient to fully model the disk. Our studies provided a better account of the accretion rates as well as resolving the critical disk impact parameter which controls disk formation. Newer work focuses on exploring a broader range of orbital parameter for the binaries. In particular we have pushed to find the upper limits on orbital radii at which a disk will still form via the BH process. (Frank et al 2014).

We have also used our allocation to begin exploring binary interactions and disk formation where the binary separation is much smaller. Our eventual goal is to model Common Envelope evolution where the secondary is engulfed by the expansion of the AGB star and then plunges inward to the core (via dynamical friction with AGB envelope material). Such simulations hold many computational challenges and as a step forward we modeled disks which can form around the primary core due to the disruption of the secondary (Nordhaus et al 2014). These models of allowed us to gain an initial understanding of the stability properties and longevity of disks embedded within an extended stellar envelope.

We have also carried out simulations of both magnetized jets and (episodic ejections) "bullets" relevant to pPNe and PN. Detailed high resolution simulations of MHD jets with a full compliment of microphysics allowed us to resolve the "cooling regions" behind internal shocks in the jet beam. These studies which will be useful for both PN studies and jets from young stars have, for the first time, resolved the MHD regions where observed emission lines (Hα and [SII]) form allowing for direct contact with Hubble Space Telescope Images (Hansen et al 2014).

3 Publications and Reports that Result from XSEDE support

Publications related to this projects are Refs.(Huarte-Espinosa et al 2012, 2012b, 2013).Three more papers related to this project are currently in preparation (Frank et al, 2014, Hansen et al, 2014 and Nordhaus et al 2014).

References

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[5] Huarte-Espinosa, M., Frank, A., Blackman, E. G., Carroll-Nellenback, J. J. & Nordhaus, J. 2012, American Astronomical Society Meeting 219, 404.06

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