# PHYS6500 Literature Review Plan

Discs in Binary Star Systems and Around Extrasolar Planets
Ryan White, with supervisor Dr Benjamin Pope

## 1 Introduction

Discs are commonly seen in star systems throughout all stages of stellar evolution. At the moment of birth, stars are enshrouded in a protostellar disc that fuels their growth, often transitioning to a protoplanetary disc where planet formation occurs. As stars within binary systems evolve, they can enter a stage of mass transfer between the primary and secondary stellar components which produces an accretion disc. Accretion discs are also seen around stellar remnants such as black holes, neutron stars, and white dwarfs and are some of the brightest transient phenomena. Dusty debris discs are also seen around young planet forming stars, and similarly dusty ring systems have been seen around exoplanets giving indications of so called 'exomoons'. One of our best tools to study these discs and rings are through the observed dips in the stellar light curves as these discs transit the face of the star. In particular, these discs reveal themselves through especially broad transit profiles, often lasting several weeks or more and featuring multiple flux minima [Hoard et al., 2010, Mamajek et al., 2012, Bernhard and Lloyd, 2024].

The physical parameters of these systems can be inferred from the observed transit profile, especially when combined with spectra. Many of the discovered disc-eclipsing systems to date are composed of at least one evolved star [Torres and Sakano, 2022] including the prototype disc-eclipser $\varepsilon$ Aurigae [Hoard et al., 2010], whose Roche-lobe overflow likely powers the secondary's disc. As a result, this system and others like it offer a unique view into the evolutionary history of supernovae (both core collapse and Type Ia) and gravitational wave (GW) progenitors and are invaluable to population synthesis models through our developing understanding of binary mass transfer. Eclipsing discs have also been observed in hierarchical multiple systems [Kenworthy et al., 2022], cementing them as a key observational probe into the dynamics and behaviour of hierarchical GW progenitors as a path to intermediate mass black holes such as GW190521.

Ring eclipsing systems are emerging as powerful laboratories in the study of exomoon formation and stability around gas giant planets. The most researched ring eclipsing system so far, V1400 Centauri, hints at a highly complex and extended ring structure [Mamajek et al., 2012] that is entirely unlike those in our solar system gas giants. By studying this and similar systems, we can better understand in which environments ring systems form and compare these to our own solar system, including the population and properties of moons embedded in the ring system [Kenworthy and Mamajek, 2015].

## 2 Review Plan

To date, there does not appear to be a published literature review on either eclipsing disc binaries or eclipsing planetary ring systems. Their related observational clues in an extended transit profile makes for a good case of a combined review, despite their unrelated physical processes.

We have already compiled a substantial body of literature on eclipsing disc and ring systems, learning where the field is and what open questions there are. So far, we believe more work needs to be done particularly on

- understanding the stellar evolution history (both past and future) of the disc-eclipsing systems,
- inferring the geometry of the transiting disc and why the discs are apparently long lived which often cannot be reproduced in simulations [e.g. Zhou et al., 2018], and
- understanding the origins, population and composition of exoplanet rings,

and the literature on these topics will be discussed with mention of areas of further study.

This review topic is important in the context of my thesis topic as eclipsing astrophysical discs are a key observational probe into binary stellar evolution. Binary mass transfer is one of the main scenarios in which Wolf-Rayet stars are understood to be produced, and so understanding the physics behind mass transfer through accretion/dust discs is essential. Eclipsing ring systems and debris discs are of interest in the same review due to their extremely similar transit profiles, and so it is important to list the ways in which discs and rings differ physically and observationally.

## References

K. Bernhard and C. Lloyd. ZTF J185259.31+124955.2: A new evolved disc-eclipsing binary system. *arXiv e-prints*, art. arXiv:2405.15555, May 2024. doi: 10.48550/arXiv.2405.15555.

D. W. Hoard, S. B. Howell, and R. E. Stencel. Taming the Invisible Monster: System Parameter Constraints for epsilon Aurigae from the Far-ultraviolet to the Mid-infrared. ApJ, 714(1):549–560, May 2010. doi: 10.1088/0004-637X/714/1/549.

M. A. Kenworthy and E. E. Mamajek. Modeling Giant Extrasolar Ring Systems in Eclipse and the Case of J1407b: Sculpting by Exomoons? ApJ, 800(2):126, Feb. 2015. doi: 10.1088/0004-637X/800/2/126.

M. A. Kenworthy, D. González Picos, E. Elizondo, R. G. Martin, D. M. van Dam, J. E. Rodriguez, G. M. Kennedy, C. Ginski, M. Mugrauer, N. Vogt, C. Adam, and R. J. Oelkers. Eclipse of the V773 Tau B circumbinary disc. A&A, 666: A61, Oct. 2022. doi: 10.1051/0004-6361/202243441.

E. E. Mamajek, A. C. Quillen, M. J. Pecaut, F. Moolekamp, E. L. Scott, M. A. Kenworthy, A. Collier Cameron, and N. R. Parley. Planetary Construction Zones in Occultation: Discovery of an Extrasolar Ring System Transiting a Young Sun-like Star and Future Prospects for Detecting Eclipses by Circumsecondary and Circumplanetary Disks. AJ, 143(3): 72, Mar. 2012. doi: 10.1088/0004-6256/143/3/72.

G. Torres and K. Sakano. $\eta$ Geminorum: an eclipsing semiregular variable star orbited by a companion surrounded by an extended disc. MNRAS, 516(2):2514–2521, Oct. 2022. doi: 10.1093/mnras/stac2322.

G. Zhou, S. Rappaport, L. Nelson, C. X. Huang, A. Senhadji, J. E. Rodriguez, A. Vanderburg, S. Quinn, C. I. Johnson, D. W. Latham, G. Torres, B. L. Gary, T. G. Tan, M. C. Johnson, J. Burt, M. H. Kristiansen, T. L. Jacobs, D. LaCourse, H. M. Schwengeler, I. Terentev, A. Bieryla, G. A. Esquerdo, P. Berlind, M. L. Calkins, J. Bento, W. D. Cochran, M. Karjalainen, A. P. Hatzes, R. Karjalainen, B. Holden, and R. P. Butler. Occultations from an Active Accretion Disk in a 72-day Detached Post-Algol System Detected by K2. ApJ, 854(2):109, Feb. 2018. doi: 10.3847/1538-4357/aaa9b9.