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Linear Polarization and the Dynamics of Circumstellar Disks of Classical Be Stars

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Abstract. The intrinsic linearly polarized light arising from electron scattering of stellar radiation in a non-spherically symmetric distribution of gas is a characterizing feature of classical Be stars. The distinct polarimetric signature provides a mean for directly probing the physical and geometric properties of the gaseous material enveloping these rapidly-rotating massive stars. Using a Monte Carlo radiative transfer computation and a self-consistent radiative equilibrium solution for the circumstellar gas, we explore the role of this observable signature in investigating the dynamical nature of classical Be star disks. In particular, we focus on the potential for using linearly polarized light to develop diagnostics of mass-loss events and to trace the evolution of the gas in a circumstellar disk. An informed context for interpreting the observed linear polarization signature can play an important role in identifying the physical process(es) which govern the formation and dissipation of the gaseous disks surrounding classical Be stars.

Keywords. polarization, circumstellar matter, stars: emission-line, Be

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1. Introduction

The non-LTE radiative transfer code BEDISK (Sigut & Jones 2007) computes a self-consistent temperature structure for the circumstellar gas by solving the coupled problems of statistical and radiative equilibrium. BEDISK employs escape probability calculations for an axisymmetric disk of gas with specifiable chemical composition and density parameterized by a base number and a radial power-law. The Monte Carlo code MCTRACE (Halonen & Jones 2013a) procedure adopts the BEDISK-computed atomic level populations and gas temperatures as the underlying model of a three-dimensional circumstellar envelope and simulates the propagation of photons originating in the radiation field of a star described by a model atmosphere. Combining the thermal solution from the BEDISK code with the Monte Carlo simulation MCTRACE provides an effective computational procedure for producing models of circumstellar environments, such as the disks of classical Be stars.

2. Classical Be Stars

Classical Be stars are rapidly rotating B-type stars surrounded by thin, equatorial, decretion disks of gas. The interaction between the radiation emitted by these hot massive stars with the gaseous circumstellar material that envelops them produces detectable observational properties: a prominent emission line spectrum, an excess in the infrared and radio continuums, and a partial polarization of radiated light. Due mainly to the continually evolving physical state of the disk, fuelled by yet unidentified equatorial mass-loss mechanisms, the observational properties typically vary on timescales of days to decades.

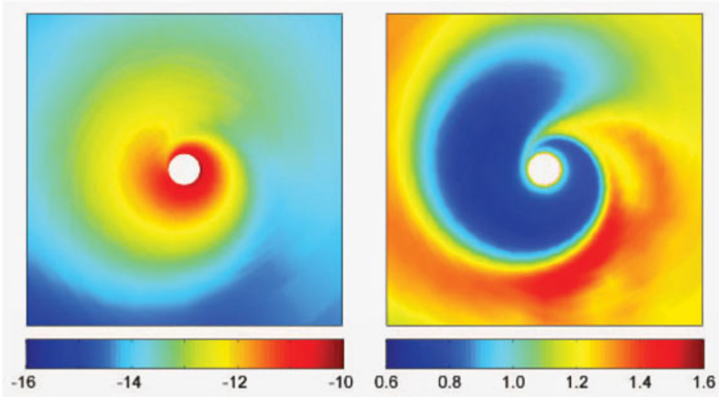

Figure 1. Properties of a modelled one-armed oscillation in the circumstellar disk surrounding a B2V star. The disk density distribution is parametrized by $n = 3.5$ and $\rho_0 = 5.0 \cdot 10^{-11}$ g cm^{-3}. The squares are 20 by 20 stellar radii. The frame on the left shows the equatorial logarithmic density distribution in the disk (g cm^{-3}) while the frame on the right shows the density-weighted gas temperature (10^4 K).

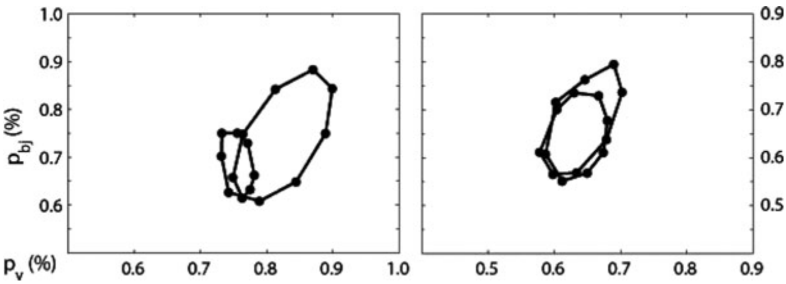

Figure 2. Balmer Jump vs. V-band polarization (BJV) diagrams for a spiral oscillation model produced by MCTRACE. The frame on the left shows a system viewed at inclination 75° while the system in the frame on the right is viewed at inclination 60°. The loops trace out line-of-sight absorptive and scattering opacities in the disk based on the geometry of the structure as seen by the observer. See Halonen & Jones (2013b) for further details of these results.

3. Linear Polarization

The light from classical Be stars is partially polarized due to electron scattering in the disk. The polarized light provides us with a direct probe of the gaseous circumstellar environment in which the scattering occurs. For non-uniform disks, the polarization signature can provide crucial information for tracing the gas in the disk. Figure 1 shows the density and density-weighted gas temperature arising from a global one-armed oscillation in the disk. Polarimetric features originating in different formation regions show phase differences leading to particular behaviour in polarization-color diagrams, such as the Balmer Jump vs. V-band polarization plot illustrated in Fig. 2. Thus, polarimetry represents an important diagnostic of the dynamical nature of the circumstellar gas.

References

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