Unambiguous Black Hole Mass from Polarimetry and Application to Hot Jupiters

Dissertation by

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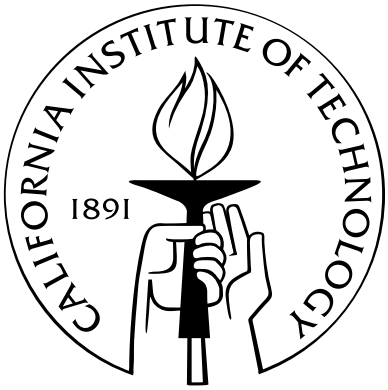
In Partial Fulfillment of the Requirements

for the Degree of

Doctor of Philosophy



California Institute of Technology

Pasadena, California

2009

(Defended July 28, 2008)

This dissertation is dedicated to my wife Sharon, who has stood by my side and supported me while writing. I also dedicate this work to my family, who have encouraged me to pursue my love of the stars and whose advice and support through the years have been essential.

Acknowledgements

Many thanks go to Keith Matthews, whose help and advice have been essential in construction of my instrument. I would like to thank Michael Ireland and Ian McEwan for valuable discussions on instrumentation, polarimetry, and signal processing. I appreciate the help of the Palomar Observatory staff, especially Bruce Baker, Karl Dunscombe, John Henning, Greg van Idsinga, and Steve Kunsman. Without their help, this instrument would literally not have gotten off the ground. I thank Shri Kulkarni, who inspired me to pursue instrumentation. I acknowledge David Stevenson for a valuable debate regarding condensation in a water-hydrogen mixture and Conner Wiktorowicz for his help in determining uncertainty along the photospheric adiabat. I would like to acknowledge funding from the Moore Foundation. This research has made use of the SIMBAD database, operated at CDS, Strasbourg, France.

Abstract

A novel technique for detecting light scattered by extrasolar planets is presented that has the potential to constrain orbital inclination and planet mass. To develop this technique, I have commissioned a high precision polarimeter on the Hale 5-m telescope at Palomar Observatory. The high mass X-ray binary Cygnus X-1 has been observed, which is a proxy for extrasolar planet studies. The single scattering model of Brown et al. (1978), widely used in the literature, predicts an orbital inclination for Cygnus X-1 that is inconsistent with the lack of observed X-ray eclipses to $4\sigma - 5\sigma$. Previous studies have hinted at this discrepancy, but data quality was such that the confidence in such a discrepancy was not statistically significant. My observations represent the highest precision study of this object, and they illustrate the overwhelming complexity of the supergiant/black hole system. They also call into question the validity of the Brown et al. (1978) formalism, widely used by the community, for inclination estimation in binary systems.

Extrasolar planet host stars have also been observed, and precision of order one part per million has been achieved on bright targets. Precision attained on fainter host stars is of order one part in 10^5. While scattered light from extrasolar planets has not been conclusively detected, a planetary transit in the HD 189733 system may have been observed in polarized light. Such an event is observed to be 1,000 times weaker in polarized light than in photometry, and it indicates a planetary transit of the Southern Hemisphere of the host star. Such geometric information is difficult to determine by other methods.

The integrated polarization of the debris disk surrounding γ Ophiuchi has been observed to high precision, and the position angle of net polarization is aligned with the disk major axis as seen by the Spitzer Space Telescope. This indicates the disk is primarily composed of forward scattering dust grains larger than the wavelengths of visible light.

Finally, Neptune-mass extrasolar planets orbiting close to their host stars have been modeled to be far too warm for liquid water oceans to exist in their upper atmospheres.

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