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SUSI's Potential for Cepheid Studies

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Abstract. The Sydney University Stellar Interferometer (SUSI) is the first instrument with sufficient resolving power to measure the angular sizes of a large number of stars over the full range of spectral classes. It can also resolve the orbits of spectroscopic binaries, allowing masses and distances to be determined directly. One of the major programs envisaged for the instrument is a study of pulsating stars, in particular Cepheids.

1. Introduction

SUSI is a very long baseline optical amplitude interferometer with a north-south baseline array of eleven 14cm apertures, which can be combined in pairs to give baselines between 5m and 640m. The longest baseline results in a limiting resolution of ~50 micro arc sec at λ=442nm. Currently, baselines up to 160m are equipped, giving a resolution of 300 micro arc sec. 14cm apertures sample single r_0 (Fried, 1965) sections of wavefront, which are actively corrected for tip-tilt error and optical path length variations. Aperture size and the tip-tilt servo place an ultimate limit of B~8 on the system. At present, observations are limited to very bright stars by the path length tracking servo, but a new detector should allow observations to V~4, with further improvements later. Currently, spectral bandwidths of a few nanometers in the range $\lambda\lambda$400–500 are used. For a full description of the instrument see Davis et al. 1995.

2. Distance determinations for Cepheids using SUSI

SUSI will measure the angular size change of Cepheids due to their radial pulsation. Combining this with a linear size change obtained by integrating the velocity curve will yield a distance to the star, which is purely geometric and independent of other calibrators. This impacts on the zero point of the period luminosity relation, as other methods are all indirect or model dependent.

It may also be possible to improve the *accuracy* of the zero point of the period luminosity relation. Accuracies < 2% can be achieved in angular size measurements, giving a typical accuracy for the change in angular size of a Cepheid of ~10%. If this is the dominant uncertainty then the distance can be obtained to the same accuracy (distance modulus $\simeq \pm$0.2mag). Some 20 southern Cepheids of V $\leq$ 6.5 will be accessible to SUSI, thus a statistical improvement in accuracy to ~3% ($\pm$0.07mag) should be possible.

In practice, several factors can bias the result of the distance determination. The p-factors to convert the observed Doppler shifts into pulsation velocities must be carefully computed. For this level of accuracy it appears necessary to do fully dynamical calculations for the pulsating atmosphere (Sasselov & Karovska, 1994). A further complication is line asymmetries. It is well known that Cepheid metal lines display moderate asymmetry that changes through the pulsation cycle (Butler, 1993), and this must reflect velocity changes with atmospheric depth (Albrow & Cottrell, 1995). Thus, not only is it difficult to integrate the velocity curve unambiguously, but there will be some uncertainty in relating the velocity at the depth of line formation to that at the depth of continuum formation, which is essentially what is measured by SUSI. Such uncertainties amount to velocities of order $1\,\mathrm{km\,s^{-1}}$, which corresponds to a distance error of about 10%. In the most extreme cases line splitting can occur (Sasselov & Lester, 1990), making velocity assignment very difficult.

Limb darkening affects both the p-factors (Sasselov & Karovska, 1994) and angular diameters. SUSI observations yield a diameter of an equivalent uniform disc, not a true stellar diameter. Fortunately the resulting uncertainties are small; in any case, SUSI observations can probe limb darkening by measurement of angular size at different continuum wavelengths.

3. Other fundamental data obtainable from SUSI observations

In addition to distances, SUSI can be used to accurately determine other fundamental properties that will enhance our understanding of these stars. Angular diameters combined with total fluxes give effective temperatures (accurate to a few percent), and temperature changes during the cycle. From distances and angular sizes come linear sizes with similar accuracies. In addition to limb darkening investigations, observations inside broad metal and hydrogen lines can be combined with continuum observations to probe atmospheric structure and refine models. SUSI can also be used to determine masses and distances of stars in spectroscopic binaries (including some Cepheids) by resolving the orbit and thereby determining its angular size and inclination.

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