

A Polarimetry Module for the Fan Mountain Near Infrared Camera

AAS SMALL RESEARCH GRANT PROPOSAL

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PURPOSE

I propose to implement a simple, cost-effective instrumental design for precision stellar polarimetry in the near infrared by adding readily available components to a state-of-the-art camera now under development at the University of Virginia Fan Mountain Observatory. An immediate application leading to advancements in the understanding of Be stars is given as an example of the ways in which it will significantly expand both the research capabilities of the camera and the learning opportunities of the students who will be using it.

SUMMARY

Astronomical cameras are most commonly adapted for imaging polarimetry by inserting a beamsplitting polarization analyzer such as a Wollaston prism in the optical train to separate the incoming light into orthogonally polarized components (Hough et al. 1991). To determine both normalized Stokes parameters of the linear polarization with such a device requires two differential measurements with the polarization axis rotated by 45° . This is done using a rotatable halfwave retarder placed in front of the analyzer to rotate the plane of polarization of the incident beam without changing the direction of the offset between the two split component images (Serkowski 1974; Tinbergen 1996). It is possible to manufacture a halfwave plate which is effective over the full range of near infrared wavelengths from 1 to $2.5\ \mu\text{m}$, including the standard *JHK* passbands. Unfortunately the cost amounts to tens of thousands of dollars, the optical element is very fragile, and it is a source of thermal noise because it must be mounted outside the cryogenically cooled section of the instrument to avoid mechanical difficulties. An additional instrumental complication in imaging polarimetry of extended sources is the necessity of a focal plane mask to prevent overlapping of the double images produced by the analyzer.

Stellar polarimetry with an imaging camera can be done, however, with a much simpler system at no loss in precision, including entire star fields or open clusters as well as individual stars. Two individual Wollastons oriented differently by 45° , fixed in available positions in one of the filter wheels in the cold collimated beam near the re-imaged pupil, will suffice to give independent differential measurements of both linear Stokes parameters, without the expense and complication of a rotating retarder and focal plane mask.

For near infrared *JHK* wavelengths, Wollaston prisms made of MgF_2 are in good supply at reasonable prices. It is not a strongly birefringent material, but the typical beam separation of about 0.5° yields a perfectly acceptable image separation on the order of $30''$ for our camera focal length, and a clear aperture of 18 mm will accommodate the pupil diameter to cover the full $8' \times 8'$ field of view. Given the known range of variation of the refractive indices of MgF_2 over the *K* band (Oliva et al. 1997), blurring of the star images by about $0.6''$ is to be expected, but that is not enough to degrade the aperture photometry method of data reduction. The calculated image distortion at *J* and *H* is smaller by a factor of about 2.

JUSTIFICATION

With the purchase of two inexpensive optical components and with no added design constraints, the research and teaching program of the new Fan Mountain near infrared camera can be extended to include precision stellar polarimetry.

IMPORTANCE AND RELEVANCE TO ASTRONOMY

Linear polarization of astronomical sources often reveals the operation of physical processes that go undetected by other means, and such processes can be extremely important for the understanding of unexplained phenomena. Polarization due to electron scattering in a circumstellar disk is one of the most distinctive characteristics of Be stars, providing diagnostics of the disk structure necessary to understand the instability leading to its formation. This is one of the most venerable mysteries in stellar astrophysics, involving stellar rotation, stellar magnetism, extended stellar atmospheres and stellar winds, the evolution of massive stars, and binary evolution (Porter & Rivinius 2003).

The advantages of studying the polarization of Be stars in the near infrared have been largely neglected, even though they were pointed out quite clearly by Jones (1979). First, the observed polarization of Be stars in the 2.2 μm *K* passband is a direct indicator of the intrinsic position angle, since the strength of any interstellar component drops rapidly longward of 1 μm . Second, the *JHK* wavelength dependence of the polarization is a valuable constraint on the density and temperature distribution in circumstellar disk models (Millar et al. 2000, McDavid 2001) since it is dominated by the diluting effect of the strong free-free disk emission which also produces the characteristic infrared excess of Be stars.

STATEMENT OF ACCOUNTABILITY

Funds will be used for the requested purpose, and an accounting will be furnished to the AAS within eight months after receipt of the grant.

OTHER SOURCES OF FUNDING

This proposal is the third attempt to obtain funding for the project through the AAS Small Research Grant program. No local funds are available, and there is no direct connection with any NASA mission.

ITEMIZED BUDGET

One Pair MgF₂ Wollaston Prism Polarizers, 18 mm clear aperture, 0.5° beam divergence at 2.2 μm
Price: \$5200 (B. Halle Optical Workshop, Berlin)

TOTAL AMOUNT REQUESTED: \$5200

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