Prospects for Mid-infrared Imaging and Polarimetry with Denver’s TNTCAM2

Robert E. Stencel
The Observatories, University of Denver, Denver CO 80208 USA
rstencel@du.edu

Abstract. Structural detail of asymmetric planetary nebulae is conditioned by the mass loss history of central stars (and their planets?). Much of this outlying structure can be mapped with thermal infrared imaging and polarimetry – both of which are capabilities designed into our second generation, NSF-sponsored Ten and Twenty micron CAMera, featuring collaborative access to the community of interested researchers. The University of Denver is now completing construction of a mid-infrared imaging polarimeter dubbed TNTCAM Mark II. The instrument will be the only one of its kind capable of attaining polarimetric accuracy of 0.2 % across the 5 - 25 micron spectral interval. This sensitivity is only attainable by cooling the transmissive polarizing optics to liquid helium (LHe) temperatures.

A major technical challenge in the design of this instrument has been finding a way to modulate the polarization signature of the incoming beam at a rate sufficient to combat the degrading effects of the atmosphere. Our group has chosen to quickly rotate a half-waveplate situated on the cold (i.e. 4 degrees Kelvin) work-surface. The waveplate is rotated between two fixed positions separated by 45 degrees at a rate of 1 Hz to obtain one of the two Stoke’s parameters required to measure linear polarization. The waveplate is then offset by 22.5 degrees and then rotated again at 1 Hz between two positions separated by 45 degrees to obtain the other Stoke’s parameter. In addition to rotating the waveplate, the waveplate itself must be moved out of the beam during normal imaging applications. This instrument is being developed under NSF grant AST-9724506 to the University of Denver and is slated for community access after January 2000.

1. Introduction

Mid-IR imaging is a valuable tool in probing dusty environments near young stellar objects (YSO), evolved stars undergoing mass loss and warm molecular cloud cores. Mid-IR polarimetry measurements can allow astronomers to determine whether dust grains around both evolved and young stars are aligned, and if so will give us insight into the role stellar and circumstellar magnetic fields play in the structure of mass loss events and morphological evolution of circumstellar matter.
Mid-infrared imaging effectively probes the parts of universe dominated by the thermal emission from solid phase warm dust at temperatures of a few hundred K that may be optically thick at shorter wavelengths. Dust emits preferentially at wavelengths comparable to or less than their physical size. Few grains are large enough to emit efficiently at far-IR and longer wavelengths, and only very hot grains (a few 1000 K) emit most of their radiation in the near-IR. Very few processes can raise grains to these temperatures without destroying them, so the mid-IR is where dust is the brightest in many parts of the universe. At mid-IR wavelengths extinction is very small, so virtually all the detected signal arises from grain emission and not scattered light (the latter is selectively polarized depending on the angle of the scatter and the grain orientation so such measurements are difficult to interpret). Polarization measurements in the mid-IR directly sample the alignment of semi-conducting grains as they emit radiation like small linear antennae. This makes imaging polarimetry a very effective tool in studying grain alignment.

Qualitatively, grain alignment occurs due to interaction between the ambient B-field and the field induced in a spinning grain. When the induced field lags behind the B-field because the internal field can not move completely freely relative to the grain, torques are induced on the particle that damp the angular momentum components normal to the direction of the magnetic field. This makes grain alignment one of very few means of characterizing weak interstellar magnetic fields. For these reasons, our group at the University of Denver is now completing construction of a mid-infrared imaging polarimeter dubbed TNTCAM Mark 2 (cf. Klebe et al. 1995; Theil et al. 1999). TNTCAM2 saw first light in imaging modes at IRTF during May 1999, and we hope to test polarimetry modes at WIRO in the near future.

2. Young Stars

Magnetic fields play an integral role in our current picture of the star formation process. They are implicated in molecular cloud fragmentation models and in slowing the collapse of low to medium mass stars during formation. There is evidence of substantial amounts of dust entrained in the molecular outflows of YSOs. Polarimetric observations of these short lived objects (dynamical ages on the order of $10^4$ yr) can test collimation theories involving elaborate magnetic fields. Dusty disks have been resolved around many nearby YSOs in Orion and the IR excesses of most more distant young stars indicate the have dusty disks. Magnetic fields are invoked in viscosity assisted accretion theory onto YSOs yet extinction is too high in most of these disks to make useful polarimetry measurements at near-IR wavelengths. Polarimetry of dense dusty disks around very young stars such as those found in Orion by can measure magnetic fields associated with them and put further constraints on both stellar accretion and planetary formation models. Thinner disks around somewhat older stars (such as Vega) that have recently entered the main sequence are notoriously difficult to study due to scattered light from the star, which is not an issue at longer wavelengths.
3. Evolved Stars

Polarimetry can be extremely helpful in examining evolutionary characteristics of dying red giant and supergiant stars. These stars shed huge amounts of gas during their death throes which then cools at high density near the stars forming dust. Optical and near infrared (near-IR, 1-4μm) polarimetry, is already a well established observational technique for these objects. At these wavelengths, most authors interpret the polarization of stars with circumstellar dust shells as resulting from scattering of stellar light in an aspherical distribution of dust around the star. Some observations suggest that this interpretation may be too simplistic. The dust in circumstellar shells may be aligned by the ambient magnetic field in the shell. Our whole picture of aspherical mass loss (equatorial disks, polar winds and clumps) from late type stars is based extensively on polarimetry results. If polarization in red giants is due to transmission through aligned grains, our understanding of these phenomena is called into question. The presence of aligned grains would also firmly establish the presence of significant magnetic fields in red giant winds. Such magnetic fields may be the underlying cause of the aspherical morphology seen in subsequent phases of evolution of red giant stars (see my paper about polar breakouts elsewhere in these proceedings).

4. Interstellar Medium

The stellar ejection of mass at the ends of stars' lifetimes, particularly in energetic supernova explosions, can have a considerable impact on the interstellar medium and the galactic magnetic field. The inflation of large bubbles of hot gas displaces both gas and the B-field and can create a dusty shell around the bubble periphery. While these shells are young the dust can be as warm as 100K lending themselves to mid-IR study. Their large spatial scales make these objects ideal for extragalactic studies using the small arrays that are sensitive in the mid-IR. Mid-IR observations enable the study of large scale field orientations in external galaxies. Due to high extinction, the nuclei of nearby starburst galaxies also lend themselves to mid-IR work.

References

III. Shaping the AGB Wind: Binarity, Pre-planetary Nebulae, Etc.