NEW OBSERVATIONS OF THE KINEMATICS OF THE ZODIACAL DUST CLOUD. G. J. Madsen[1], R. J. Reynolds[2], S.I. Ipatov[3], A. S. Kutyrev[4], J.C. Mather[4], and S.H. Moseley[4], [1]Anglo-Australian Observatory, P.O. Box 296, Epping, NSW 1710, Australia, *madsen@aao.gov.au,* [2]Univ. of Wisconsin – Madison, Madison, WI, 53711, [3]Univ. of Maryland, College Park, MD 20740, [4]NASA/GSFC, Greenbelt, MD, 20771.

Introduction: The motion of interplanetary dust particles contains important information about the origin, distribution, and evolution of the cloud in which they move. At optical wavelengths, dust with radii ~10-100μm that lie within ~3 AU of the Sun scatters the incident solar radiation to produce zodiacal light, and the relative motion of the dust modifies the location and shape of solar spectral lines [1-2]. The fraction of zodiacal dust with cometary or asteroidal origin is not well constrained at present [3], and the kinematics of these two components may shift the velocity and widths of the spectral features in unique ways.

However, the low surface brightness of zodiacal light has, until recently, limited the observability of this effect, requiring a combination of high sensitivity and high spectral resolution. Here, we report on new measurements of scattered solar Mg I λ5184 absorption line in zodiacal light with the Wisconsin H-Alpha Mapper (WHAM), and compare the observations with predictions from dynamical models of the zodiacal dust cloud.

Observations: WHAM consists of a 15cm, dual-etalon Fabry-Perot spectrograph coupled to a 0.6m siderostat, and produces an average spectrum over a 1^{o} circular field of view with a 12 km/s resolution within a 200 km/s spectral window. It is specifically designed to detect faint, diffuse optical light [4]. We have recorded spectra centered on the Mg I line at

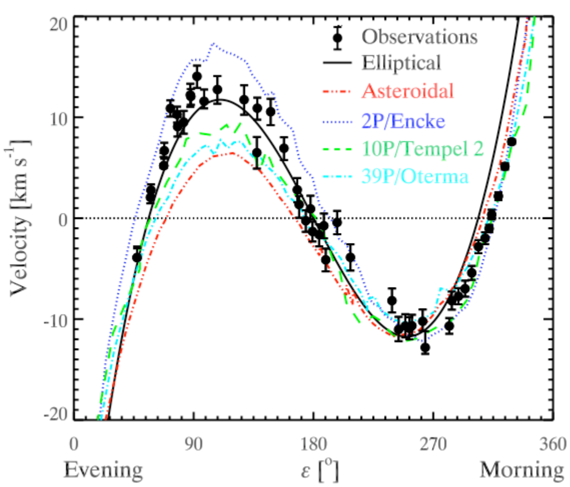

Figure 1: Velocity centroid of the scattered solar Mg I line as a function of solar elongation, with several models overlaid.

5183.6Å toward 49 directions along the ecliptic equator, with two directions at high ecliptic latitude [5]. We identified and removed several weak atmospheric emission lines that probably affected the results of previous investigations [6-7]. The line centroid, width, and area were measured for each spectrum. Figure 1 shows the change in velocity centroid with solar elongation for directions along the ecliptic equator. Figure 2 compares an average of several spectra taken toward the north ecliptic pole with an unperturbed twilight spectrum, demonstrating the high resolution and sensitivity of the observations. We see that the width of the line near the pole is broadened by 15-20 km/s relative to the solar line, suggesting that a significant number of particles follow orbits with inclinations up to 40^{o} [5]. Somewhat less, but still significant, broadening is also observed along the ecliptic equator, including the antisolar direction. This implies particles with non-circular orbits [5].

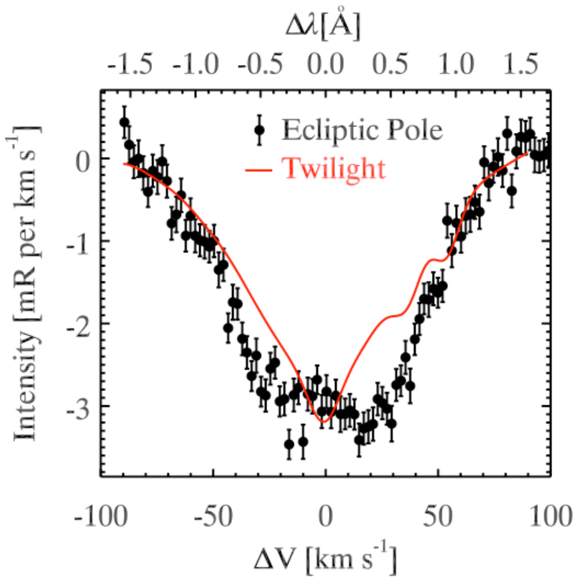

Figure 2: Spectrum of the twilight sky (red) and the zodiacal light toward the north ecliptic pole (circles), centered near the Mg I λ5184 line. The abscissa is in mill-Rayleighs per km/s.

Comparison to Models: The shape of the observed line profiles is determined by the population of dust particles of varying size, radial distance, scattering function, and relative motion along the line of sight. We compare our observations with dynamical models of the zodiacal dust cloud in order to constrain the orbital properties of the particles which comprise the cloud. We consider a number of published models that make specific observable predictions, particularly for the change in velocity centroid with elongation angle.

Some of the models that compare favorably to the data are shown in Figure 1. The solid black line is a fit to a model from Hirschi & Beard [8]. This model describes particles on prograde, elliptical orbits with eccentricities uniformly distributed between 0 and 1, with randomly distributed perihelions. Their model did not include the influence of radiation pressure, and the particles were confined to the ecliptic plane. The model fits the centroid data well, but strongly overestimates the width of the lines. The inclusion of radiation pressure and/or inclined orbits could provide a better match to the observations [5,9].

The colored lines in Figure 1 are models from Ipatov et al. [10-11], which trace the motion of different populations of dust particles subject to gravity, radiation pressure, and drag forces. The individual lines represent particles with asteroidal and various cometary trajectories, with a ratio of radiation pressure to gravitational force of 0.002. We find that a better match is provided by the cometary particles on inclined, eccentric orbits compared to the asteroidal particles. We note that none of the models with trans-Neptunian particles match the data and are omitted for clarity.

Summary and Future Work: Observations of scattered solar absorption lines in the zodiacal light are a powerful technique for exploring the kinematics of the zodiacal dust cloud. Our data are fit well by models that contain particles on elliptical orbits that are inclined to the ecliptic plane. This suggests that most of the dust in the zodiacal cloud has a cometary origin [3].

Higher signal-to-noise observations covering a larger fraction of the ecliptic sky, that include other, more intrinsically narrow, absorption lines will provide a more complete picture of the kinematics of the zodiacal dust cloud. New dynamical models that explore a wider range of dust parameters can provide strong, quantifiable constraints on the nature of the zodiacal dust cloud when compared to the observations.

References:

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