Determining the Sources of the Zodiacal Cloud Using Relative Velocities of Dust Particles From High-Resolution Spectroscopy

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Abstract

The zodiacal cloud is the Solar System debris disk in which the Earth's orbit is located. The dust that comprises the cloud comes from cometary, asteroidal, interstellar, and other source populations, but the relative ratios have proven hard to determine. However, asteroidal and cometary particles typically have different types of orbits, with asteroidal particles having more circular and lower inclination orbits than cometary particles. Accordingly, the relative velocities of these groups of particles with respect to Earth are also different, and measurements of these relative velocities can help distinguish between the sources. The spectrum of the zodiacal light contains solar absorption lines that are Doppler-shifted by moving dust particles. It is possible to determine dust particle velocities by observing the Doppler-shifted zodiacal light using the Wisconsin H-alpha Mapper (WHAM) — a specialized Fabry-Perot spectrometer. Focusing on a pair of scattered solar Mg I Fraunhofer lines, we have recently begun a three-year observing campaign with WHAM. In order to interpret these observations, we need to produce synthetic observations of how different orbital distributions of dust particles would shift and modify the observed spectral lines. Comparing these synthetic spectra to the actual observations will allow us to constrain the sources of the dust composing the zodiacal cloud. Here I present an overview of this new project and my work in analyzing the Ipatov et al (2008) code that will be altered to generate the synthetic spectra.

Motivation

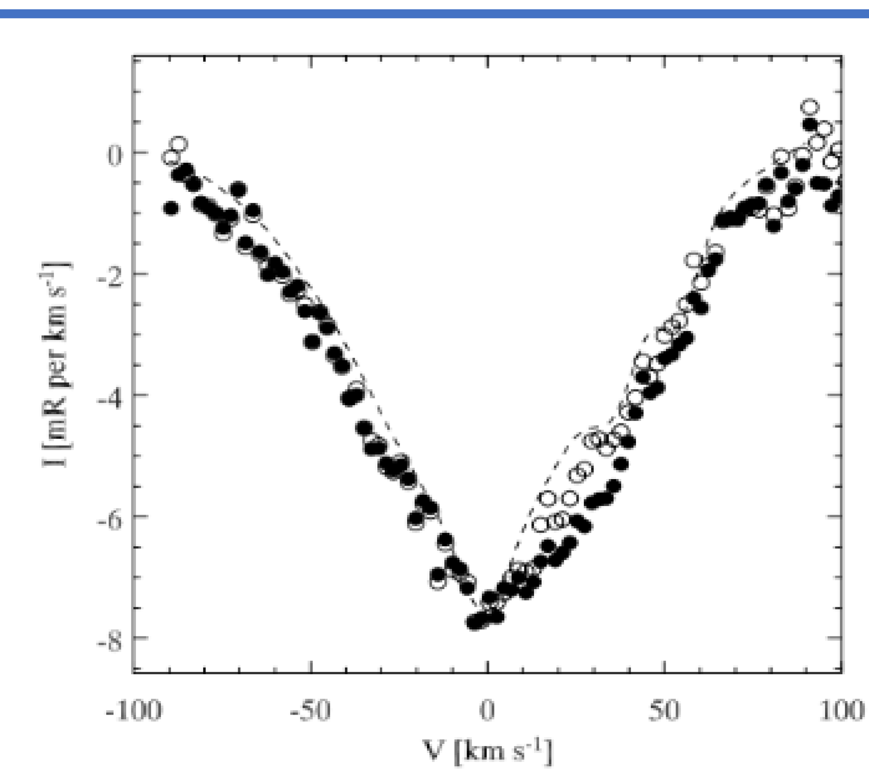
Zodiacal Cloud:

- Debris Disk in Inner Solar System
- Unknown Relative Contributions of Sources
  - Asteroidal
  - Cometary
  - Interstellar
- Each source has different orbital parameters
- These particles will have different relative velocities
- Spectral lines will be Doppler shifted
  - Can provide information about origins of dust particles
- Will use Wisconsin H-alpha Mapper (WHAM)
- Focus on a pair of scattered magnesium I Fraunhofer lines
  - Previous attempts and proofs of concept only used one
- Observations will last 3 years

Model

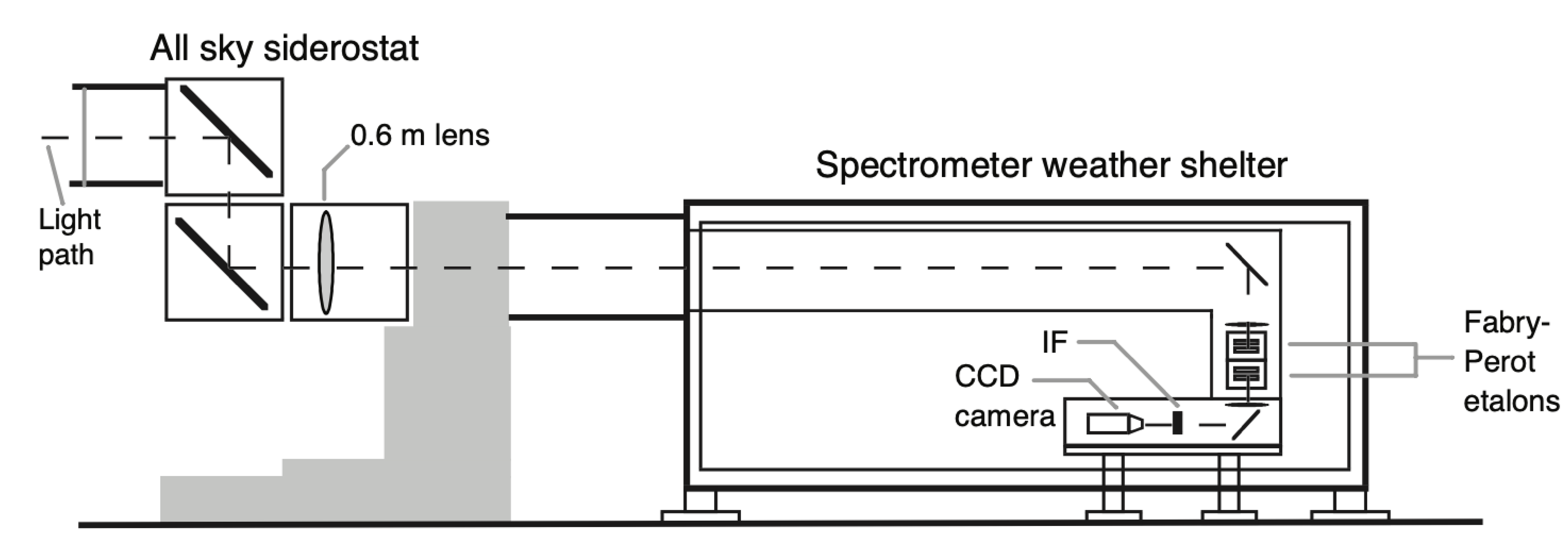
- Code written by Ipatov et al. (2008)
- Made use of Swift subroutine package
  - Written by Hal Levison and Martin Duncan in the 90's
- Calculates intensity and velocity shift of Doppler shifted solar absorption lines
- Takes into account:
  - Particle Radial and azimuthal velocity
  - Earth's azimuthal velocity
  - Angles between Sun, Earth, and particle
  - Solar elongation angle
  - Gravitational effects from other planets

The zodiacal light is sunlight reflected off the dust particles in the zodiacal cloud and is best seen close to sunrise or sunset. The image shown here is taken at ESO's La Silla Observatory in Chile, westward just after sunset. Credit: ESO/Y. Beletsky.



The spectrum of the zodiacal light from WHAM centered on a Mg I line (dots) in the anti-solar direction is broadened as compared with an unperturbed twilight spectrum (line), (Reynolds et al., 2004).

The WHAM facility at Cerro Tololo, Chile



A schematic of the WHAM instrument. The dashed line denotes the path of an on-axis ray through the system. As shown in the diagram, both flat mirrors in the siderostat rotate independently, allowing all-sky pointing and tracking.

WHAM

- Specialized Fabry-Perot spectrometer
- Operated by University of Wisconsin-Madison
- Currently located at the Cerro Tololo Inter-American Observatory in Chile

Methods

Analysis of Code:

- Learned Fortran
- Went through code, line by line
- Created variable dictionary, making note of:
  - Type
  - Array/Matrix
  - Character
  - If it was defined in code
- Downloaded Swift package

Discussion

Revisions to code needed:

- Since code only accounts for one Mg I line, need to copy every manipulation for the second Mg I line
- May need to take into account radiation affects
  - PR drag
  - Radiation pressure
- May need to do away with Swift subroutines and replace with new inputs
  - Those inputs originating from a separate dynamical evolution code written by Dr. Kehoe

References

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Levison H., and Duncan M. (1993) SWIFT A solar system integration software package https://www.boulder.swri.edu/~hal/swift.html