

Precision Radial Velocity Program Reveals Evidence for Low Mass Companions

Six years of observations with the coude spectrograph and hydrogen fluoride cell have paid off in providing tentative evidence for substellar companions to solar-type stars. Bruce Campbell (U. Victoria), Gordon Walker (U.B.C.), and Stephen Yang (U.B.C.) announced at the joint Canadian Astronomical Society—American Astronomical Society meeting in Vancouver last June the finding of long-term, low-level velocity variations consistent with objects in the 1-10 Jupiter mass range.

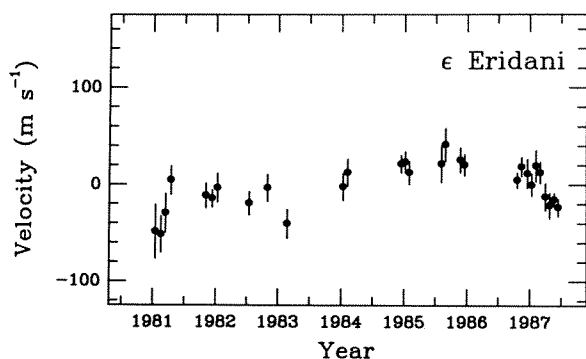


Figure 14: Precision radial velocities for the K2 dwarf ϵ Eridani. Error bars are 1σ .

The precision radial velocity program began in late 1980, soon after the coude spectrograph was commissioned. Campbell had built a hydrogen fluoride absorption cell, the key element in this precision technique, while a Resident Astronomer at CFHT. Continuing observations have produced about four spectra per year for each of 16 stars. Spectral analysis yields radial velocities with average external errors of 13 m/sec!

Such high precision is realized because the starlight passes through the hydrogen fluoride cell before it enters the coude spectrograph. (The cell is placed in the slit room between M7 and the image slicer). A band of HF lines is thus superimposed on the stellar spectrum, and these lines cannot be displaced relative to the stellar absorption lines by any of the optical or mechanical effects that lead to systematic errors in conventional velocity measurements. As well, spectra are obtained with the 1872 Reticon system, which permits very high signal-to-noise ratios, typically 1000:1. In such high quality spectra the relative positions of absorption lines can be determined to about 0.01 pixels, which translates to very high velocity precision in the absence of systematic errors.

The surprising result from the analysis of 16 stars is that none shows any short-term radial velocity variation. The generally constant velocities imply that there is no unanticipated source of error affecting the results; the HF technique seems to work as well as originally hoped. The lack of rapid variations also means the stars are well behaved—they do not show signs of velocity variations due to oscillations, starspots, or some other effect not related to center-of-mass motion.

Seven of the stars show long-term trends in the data, with total variations in the range 25-65 m s⁻¹. (An example, ϵ Eridani,

is shown in Figure 14.) These trends generally imply periods of more than 10 years, but they cannot be due to brown dwarf companions of 10-80 Jupiter masses in long-period orbits, since these would have been previously detected by conventional astrometry. Applying constraints from the observed velocities and archival astrometry yields companion masses in the range 1-10 Jupiter masses. Since "massive" brown dwarfs (10-80 Jupiter masses) have not been found, despite numerous intensive searches, these very low mass companions could represent the tip of the planetary mass spectrum.

Only one of the 7 candidate stars shows a periodic velocity variation; clearly it is desirable to follow the others for several more years to determine periods, and to confirm the velocity variations so far detected. So beware, coude observers, you may be seeing the hydrogen fluoride equipment in the neighborhood of the coude spectrograph for some time to come!

Stars in M31 Globular Clusters

Globular clusters are key objects related to a number of astrophysical problems including stellar evolution, stellar dynamics, galactic cosmo-chemistry and cosmology. A handful of such objects have been studied in the Magellanic Clouds, but such work has not been accomplished in other Local Group Galaxies. The motivation for resolving globulars in external galaxies into individual stars is to intercompare the stellar populations, metallicities, and ages of such objects. The highest resolution is required, and typically this type of work has been reserved for space instrumentation. Nevertheless it is worthwhile to attempt the program in an effort to study at least the outer parts of the clusters in nearby galaxies.

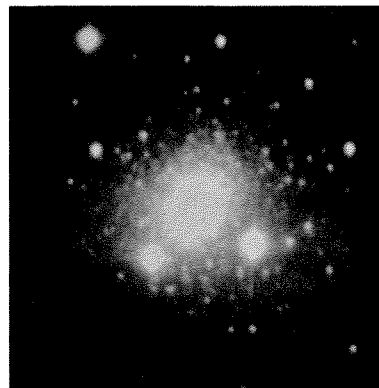


Figure 15.

The program being conducted by J. Heasley, E. Friel and C. Christian is designed to study a few of the brightest M31 clusters. Images of one cluster were obtained at F/8 with RCA2. Multiple images of the cluster in two colors were obtained. A sample image in the I band pass is shown (Figure 15) where the brightest stars have $I \approx 19.8$ mag. The outer parts of the cluster are clearly resolved with seeing ≈ 0.7 arcsec in a 900 second exposure. The data is being processed with iterative PSF fitting routines to 'peel off' the stars from the cluster, calculating the photometry for each object. The color-magnitude diagram of this and other clusters are being intercompared.

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