Conference "The Milky Way halo - Stars and Gas", AIfA Bonn, May 2007, Poster #n/a

The Bulge Radial Velocity Assay (BRAVA): Techniques and Results

Christian D. Howard, David B. Reitzel, R. Michael Rich and Andreas Koch
Department of Physics and Astronomy, UCLA, Los Angeles, CA 90095-1547
HongSheng Zhao *SUPA, School of Physics and Astronomy, University of St. Andrews, KY16 9SS, UK*

Summary

We present initial results of a large scale radial velocity survey of the Galactic bulge, using M giant stars selected from the *2MASS* catalogue as targets for the CTIO 4m Hydra multi-object spectrograph. The purpose of this survey is to test dynamical models of the bulge and to detect the presence, if any, of cold stellar streams in the bulge and its vicinity. We report on two years of observations of approximately 2900 stars which allow us to sample the kinematics of 2 strips of fields at -10°<*l*<+10° and *b*=-4° (bulge major axis), and -6°<*b*<6° and -0.4°<*l*<0.0° (bulge minor axis). The high precision of our radial velocity measurements (~5km/s) yields interesting results. Comparing the data to current models shows disagreement with either predicted rotation, predicted velocity dispersion, or both, and we see hints of cold kinematic features in a number of the line of sight velocity distributions.

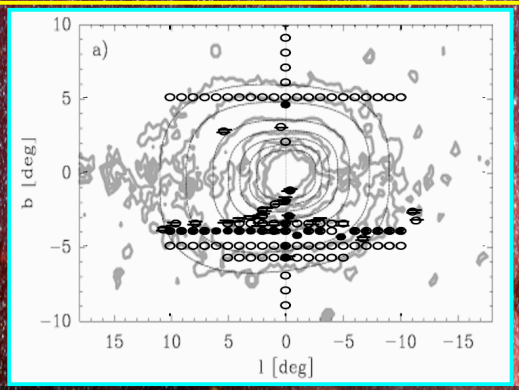

Figure 1: Galactic bulge fields overplotted on the COBE 2 um image (Dwek et al 1995). Filled ovals represent target fields in 2005 and 2006, open circles represent proposed future observations, and dashed circles represent fields for which there are proper motion studies. 1° corresponds to 140 pc for a distance of 8 kpc; the -4° strip lies roughly 550 pc south of the Galactic center. Results form this survey are also given in Rich et al. 2006.

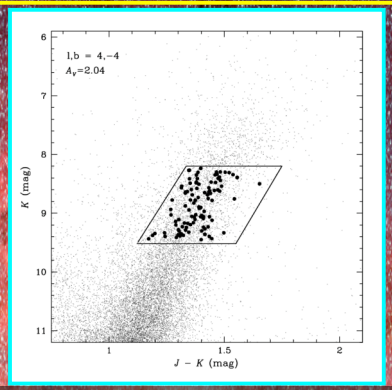

Figure 2: Color-Magnitude Diagram of 2MASS targets in the field at (*l*,*b*)=(4°,-4°). Filled circles indicate stars for which we have spectra. The parallelogram indicates our selection region; the blue cutoff rejects many objects that are closer than the bulge, which have lower reddening and are brighter than the red giant branch.

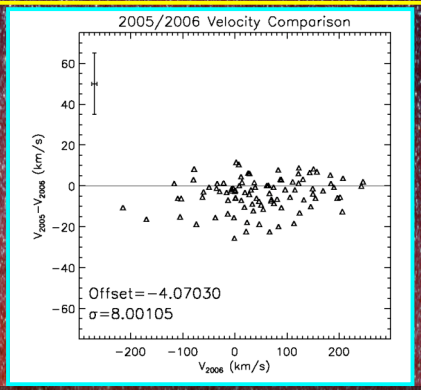

Figure 3: Velocity offset between 2005 and 2006 observations for field (*l*,*b*)=(-1°,-4°) in Baade's Window, observed by Sharples, Cropper, and Walker (1990). Our 2005/2006 individual stellar velocities show agreement that is consistent with the error of the 2005 stellar velocities. The increased error of the 2005 values is due to the lower resolution and different wavelength coverage of the 2005 data. Typical error bar located in top left of graph.

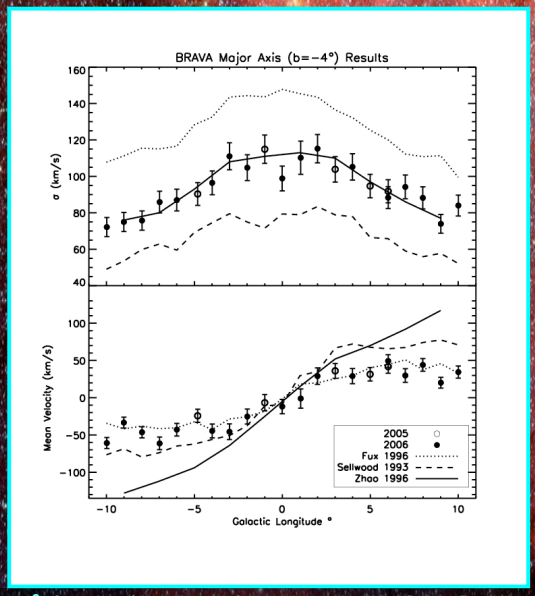

Figure3: Comparison of data with models for the major axis (*b*=-4°) "strip". *Upper Panel* - Velocity dispersion with the predictions of Zhao (1996), Sellwood (1993, and Fux (1996). *Lower Panel* - Rotation curve with predicted values of rotation. Zhao's model fits the dispersion profile but not the rotation, whereas Fux's model fits the rotation but the dispersion is too high. Our data is at odds with the widely held view that the bulge has solid body rotation, as the velocity profile flattens at large *l*, reaching a maximum amplitude of ~45 km/s.

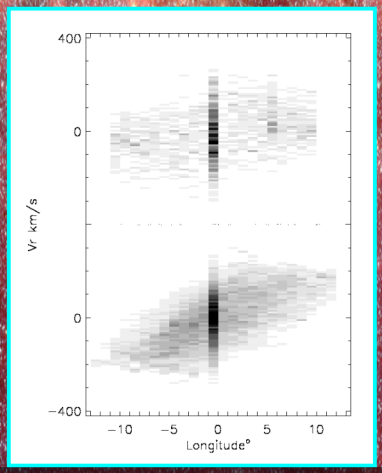

Figure 5: *Upper Panel*- longitude-velocity plot for the data along *b*= -4° and the minor axis, smoothed to 0.5° bins and by 8 km/s. *Lower Panel*- The same regions extracted from the Zhao (1996) model. By construction, the model has no retrograde orbits, the inclusion of which may help bring the model into agreement with the data. The dark stripe at *l*=0 corresponds to the greater number of stars observed on the minor axis.

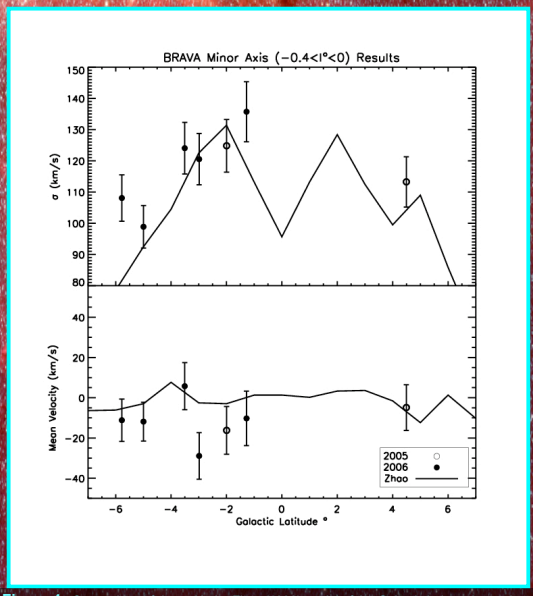

Figure 4: Comparison of data with the Zhao (1996) model of the Galactic bulge minor axis (*b*=0, -0.4°<*l*<0°). *Upper Panel*- The velocity dispersion is consistent with the trend of the model at negative latitudes, although more data is needed at positive latitudes. *Lower Panel*- The mean velocity is consistent with the model in that it shows no appreciable minor axis rotation.

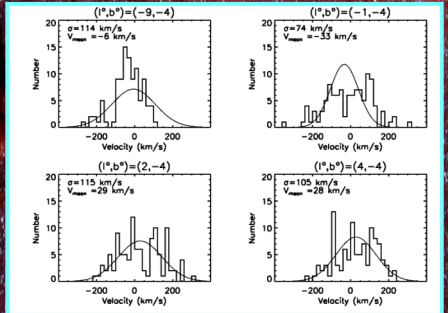

Figure6: Samples of interesting velocity dispersion profiles (bin size= 20 km/s) from our data set, with superposed best fit gaussians. The "clumpiness" of the velocities is intriguing, and the significance of the "spikes" seen in the lower left and lower right panels, and the possible detection of cold stellar streams, is examined by Reitzel et al. (this session, poster 172.17). The fields shown in the upper panels are not well represented by the gaussian fits, and hint at a bi-modal distribution.

Conclusions

We present the first large scale radial velocity survey of the Galactic bulge, using nearly 3000 *2MASS* selected M giants as kinematic probes of the central parts of our galaxy. Our measured major axis bulge rotation and velocity dispersion are in disagreement with current models and we find no indication of minor axis rotation, although more data is needed at positive latitudes to constrain our limits. We see hints of cold kinematic structure in several of the velocity fields.

Acknowledgements

RMR, DBR, and CDH acknowledge support from grant GO-10868 from the Space Telescope Science Institute. We are grateful to the CTIO staff and to Robert de Propris for advice.

References

Beaulieu, S., Freeman, K.C., Kalnajs, A., Saha, P., & Zhao, H. 2000, MNRAS, 368, 1309
Dwek, E. et al. 1995 ApJ, 445, 716
Rich, R.M., Reitzel, D.B., Howard, C. D., and Zhao, H. astro-ph/0611403; ApJ Submitted
Sellwood, J. A., 1993, AIP Conf. Proc. 278, Back to the Galaxy, ed. S. S. Holt & F. Verter (New York AIP), 133
Sharples, R., Walker, A. & Cropper, M., 1990, MNRAS, 246, 54
Zhao, H.S. 1996, MNRAS, 283, 149
Background image: Center of the Milky Way Galaxy, courtesy NASA, JPL-CalTech, S. Stolovy (SSC/CalTech)