The Origins Billion Star Survey

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Abstract

We describe a concept for an all-sky, astrometric, photometric, and spectroscopic survey to $m_V = 20$. The survey would utilize a spaceborne three aperture, three mirror anastigmat telescope orbiting at L2. The spin axis would precess so as to yield 70% sky coverage every 20 days, and ~ 6600 observations per star over a five year mission length. For a V = 14 star, OBSS would yield a mission astrometric accuracy of 10 microarcseconds, and a mission radial velocity accuracy of 40 km/s.

The Origins Billion Star Survey (OBSS) is a unique astrometric and astrophysical space-based survey mission which would measure a billion stellar positions, parallaxes (distances), proper motions, luminosities, binarity determinations, photometry, spectroscopy, and photometric variability. OBSS would provide

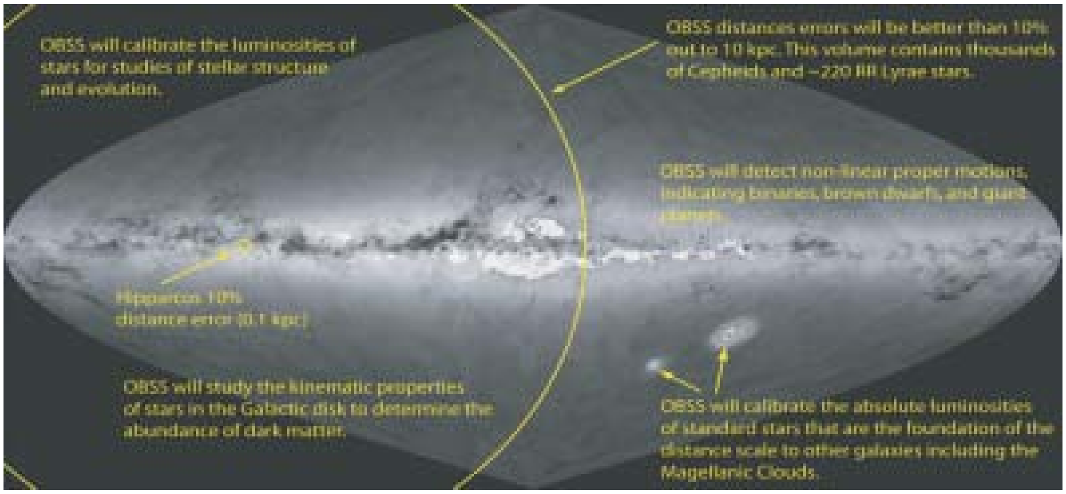

Fig. 1. OBSS coverage in a Galactic context.

observations of stars 7th to 20th visual magnitude with an astrometric precision of 10 microarcseconds at 14th magnitude. An optimized scanning law would enable the determination of temporal variations in each observable. While an accurate measurement of any one of these observables would be useful, the synergy of these measurements would enable a revolutionary increase in astrophysical knowledge.

The OBSS satellite would be positioned at L2, spinning once every hour about an axis which itself would precess about the Sun-spacecraft line with a period of 20 days. The resultant scanning law yields 70% sky coverage every 20 days. A mission length of five years would yield an average of 127 measurement epochs for each star. The scanning law has excellent temporal coverage with:

- 3 apertures imaged simultaneously on a $1^\circ \times 1^\circ$ focal plane
- 3 focal plane transits per 60 min spin period
- 3 detections per focal plane transit
- an average of 6600 observations per star on average over the 5 years mission.

The OBSS instrument is a three-aperture, three mirror anastigmat telescope with a focal length of 45 meters, a field of view of $1^\circ \times 1^\circ$, and a focal plane consisting of 290, 4096×670 CCD arrays. Key components of the instrument include:

- a 1.5×1.5 meter square off-axis primary,
- 10-15 optical surfaces, for an optical throughput of 40-60% over a 300-1000nm bandpass,
- a reflection grating with resolution R = 3000, and a 15nm range centered on MgB at 510nm,
- 8 photometric filters,
- 174 astrometry CCDs, 58 photometry CCDs, and 58 spectroscopy CCDs,

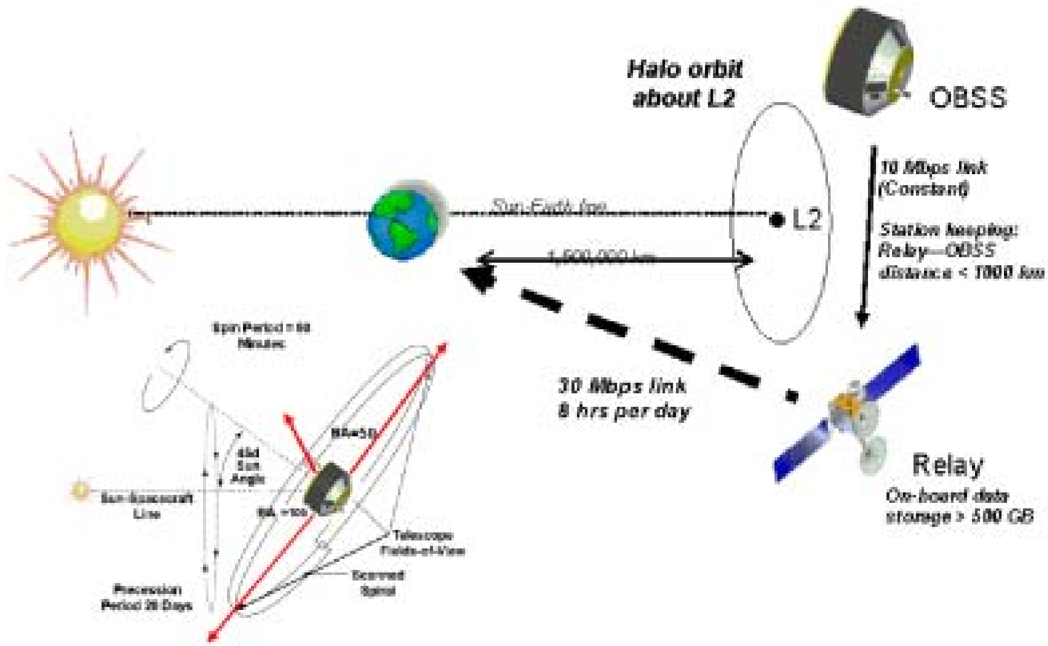

Fig. 2. OBSS and relay mission concept. Scanning geometry is shown at lower left.

- net data generation rate $\approx$ 10 Mbps continuous, requiring the use of a nearby relay satellite.

OBSS would have a profound impact on several areas of active research, including:

- Galactic Structure and Dynamics:
  · measuring positions, distances, and velocities of stars in known tidal streams (eg. Sagittarius dwarf, Palomar 5) would enable measurement of the Galactic potential to an accuracy $\sim 1\%$.
  · phase space discovery of new tidal streams, remnants, and substructure,
  · accurate measurement of the distance to the Galactic center,
  · measurement of the Galactic rotation curve,
  · proper motions (orbits) of M31, the Magellanic Clouds, and several other Local Group galaxies,
  · internal kinematics in the Magellanic Clouds and other Local Group galaxies, and
  · kinematics and ages of young stars in star formation regions.

- Stellar Luminosities and Ages:
  · calibration of stellar atmospheric and interior models over the whole range of spectral types using $\sim 30,000$ detached eclipsing binaries for which we can measure all important physical parameters and hence their ages,

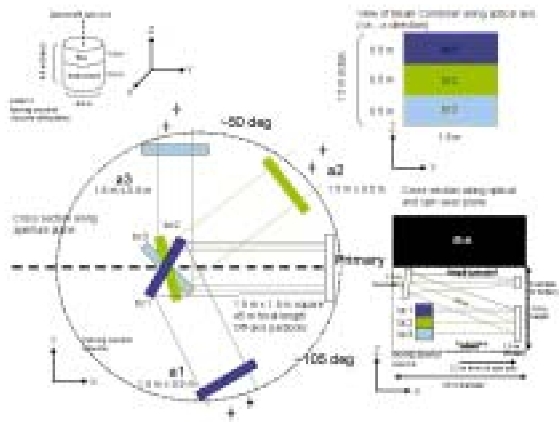

Fig. 3. OBSS-A Optics Concept. Shown are: (upper left) spacecraft volume assuming Atlas-V 5m short fairing; (lower left) Cross section of the aperture plane. Light entering an aperture (a1,a2,a3) hits a "beam combiner" mirror (bc1,bc2,bc3) and is directed along the optical axis to the primary. (Lower right) The off-axis primary directs the combined light to a secondary above bc1, which directs the beam to a tertiary and a series of fold flats. The final fold flat directs the beam onto the focal plane, which lies below the aperture plane. (Upper right) View of the beam combiner mirrors.

- binning stars and averaging to resolve different age groups in the disk to 8 Myr, and in the halo to 20 Myr,
- measuring accurate distances for individual stars in star formation regions (Taurus-Auriga, Orion) too faint to be observed by Hipparcos.
- calibrating the absolute luminosities of "standard candles" such as Cepheids and RR Lyrae stars.

- Giant Planets and Brown Dwarfs
  - Conservative detection thresholds predict $\sim 9,500$ extrasolar giant planets in the OBSS catalog detected through astrometric wobbles out to ~ 190 pc, of which 7,500 would yield orbit solutions.
  - Excellent temporal coverage would enable detection of ~ 2000 giant planets through transit photometry.

- Solar System Studies
  - OBSS would detect $> 80\%$ of near Earth asteroids with $r > 140$ meters,
  - would provide a warning efficiency of $> 90\%$ for hazardous objects,
  - would detect hundreds of new Kuiper Belt and trans-Neptunian objects.