Abstract

This thesis presents the hardware development and flight performance of two balloon-borne astrophysical experiments. The Spider experiment is a millimetre-wavelength polarimeter designed to measure a $B$-mode pattern of polarization in the Cosmic Microwave Background at degree angular scales. This pattern, if present, would be the imprint of primordial gravitational waves, which are predicted to have been produced during an inflationary epoch in the early universe. The BLASTPol experiment is a submillimetre-wavelength polarimeter designed to measure the linearly-polarized emission from aligned dust grains in Galactic molecular clouds, thereby inferring the projected directions of the magnetic fields there. One goal of this measurement is to understand more about the role of magnetic fields in the earliest stages of star formation.

Spider has had a successful Long Duration Balloon flight around Antarctica, in January 2015. BLASTPol has had two such flights, in December 2010 and December 2012. The analysis of Spider data is underway. Results of the analysis of data from BLASTPol 2012 are presented herein.

The design and performance of a power system for these experiments is presented, including electronics allowing power switching and current sensing in flight. In the Spider flight, the power system has been found to produce a peak input power of 1100 W for each of the two solar arrays, comparable to the input on the ground at lower irradiance but also lower solar cell temperature.

The design and performance of the pointing control system for Spider is presented in detail. A new control mode for the pivot azimuth motor has been developed, in which the servo drive controls motor velocity rather than current. This mode has been tested in flight, and allows for sinusoidal azimuth scans at a peak speed of nearly 5 deg/s, with a peak angular acceleration of 0.5 deg·s$^{-2}$. The system has been demonstrated in flight to produce pointing stability of 1 to 2 arcseconds RMS. An entirely new elevation drive system has been designed and built for Spider, and flown.

The observing strategy developed for Spider is presented. This strategy has enabled observation of a 10% patch of sky, avoiding the sun and Galactic plane, with uniform coverage in declination, and good cross-linking over the coverage area.

The BLASTPol 2012 point spread function has been characterized. A beam model has been developed that allows centroiding, flat-fielding, and map deconvolution, which is attempted in Fourier space and using the Lucy–Richardson method.

A net linear polarization of the dust submillimetre emission in the Carina Nebula has been measured by BLASTPol. This fractional polarization $p$ is at mean levels of 6.75% ± 0.015%, 6.84% ± 0.016% and 7.06% ± 0.019%, at 250 µm, 350 µm, and 500 µm respectively. A falling polarization spectrum (decreasing fractional polarization with increasing wavelength) has been found, in contrast with the V-shaped spectrum measured in other molecular clouds. The median ratios of the fractional polarization between bands have been measured to be 1.0155 ± 0.00035 between 250 µm and 350 µm, and 0.9376 ± 0.00056 between 500 µm and 350 µm. The uncertainties indicated above are estimates of the standard errors of the mean polarization levels and of the median polarization ratios.