Radio Imaging of the Gravity Probe B Guide Star IM Pegasi

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Abstract

We present very-long-baseline inter-ferometry (VLBI) images of the radio star, IM Pegasi, which is used as the guide star for the NASA/Stanford rela-tivity mission Gravity Probe B (GP-B). We present a selection of the images obtained from our 35 sets of 8.4 GHz VLBI observations between 1997 and 2005, and discuss the origin of the star's radio emission.

Introduction to IM Pegasi

IM Pegasi (HR 8703, HD 216489, FK5 3829) is a Canum Vanaticorum spectroscopic binary star, which was chosen as the guide star for GP-B. Its distance is ~100 pc. The binary period is ~25 days. The primary is a K2 III star, with a mass of ~1.8 solar masses and an effective surface temperature of ~4800 K. The secondary is somewhat hotter and has a mass of ~1 solar mass. The orbit is circular and is inclined to the plane of the sky by ~72°. The rotation of the primary is synchronous with the orbit (see e.g., Marsden et al. 2005, ApJL, 634, L173). An illustration of the system is shown in Figure 1.

Observations

Between 1997 and 2007, we had 35 sessions of VLBI observations at 8.4 GHz (λ=3.6 cm), each using 12 to 16 telescopes of world-wide network which included the 10 dishes of the Very Long Baseline Array (VLBA), the Very Large Array (VLA), of the National Radio Astronomy Observatory (NRAO), the Effelsberg telescope in Germany, and the three 70-m dishes of the NASA Deep Space Network in the USA, Spain, and Australia. The data were correlated using NRAO's VLBA processor in Socorro, New Mexico. During most of our sessions, the variation of the total flux density was monitored at the VLA.

Our observations of IM Pegasi were all phase-referenced to two or three nearby quasars, which assures both accurate astrometry necessary for Gravity Probe B, and unbiased images of the radio emission of the star. The reference sources are described in the poster by N. Bartel et al.

Results and Discussion

Our observations of IM Peg represent the most extensive set of VLBI observations of any radio star. We show a represen-tative selection of our 35 VLBI images in Figure 2, which illus-trates the variation in radio morphology. IM Peg ranges from a single, marginally resolved component, to a core-halo mor-phology, to a clear double and in one case (2003 Dec. 5) possible triple structure. The radio emission is presumably related to magnetic structures above the surface of the star as illustrated in Figure 1.

The primary is known to be variable both in radio and optical. The radio emission is highly variable on hour time scales, ranging from below 1 mJy up to ~100 mJy, (see Figure 3). Optical Doppler imaging and photometry has shown that variable dark spots cover a significant fraction of the star's surface (e.g., Berdyugina et al. 2000, A&Ap, 360, 272).

We observed no correlation between the flux density and orbital phase, as can be seen in the left panel of Figure 3. The right panel of Fig. 3 shows the flux density as a function of Julian date, showing a general decline in the average flux density over our 8+ years of observations.

Our precision astrometry is consistent with the radio emission being on average centered on the primary, but not on the secondary or at the center of mass: the orbital motion can be seen in the radio data, and the projected length of the semi-major axis of the radio emission is consistent with that of the primary, rather than that of the secondary (talk by I. Shapiro).

The image data and the total flux density observations show that IM Peg is rapidly variable, with timescales much shorter than the orbital (or rotational) period, and with no apparent correlation between the radio emission and the orbital phase.

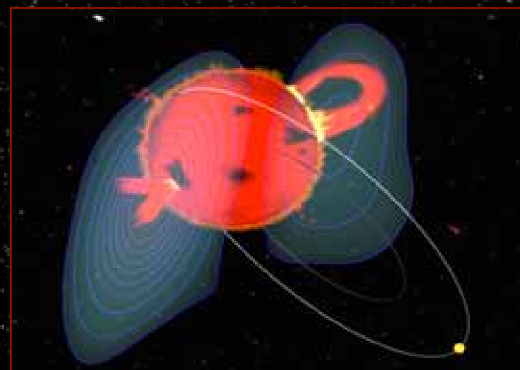

Fig. 1: An artist's impression of IM Peg., showing both the K2 primary (red) and the secon-dary (yellow) stars and their orbits. The radio emission likely originates from the vi-cinity of the K2 primary. Two prominent flares, as may be responsible for the radio emis-sion, are illustrated. Super-posed are contours (blue) showing the radio emission as seen on 1999 Sep 18.

Image by Ryan Ransom.

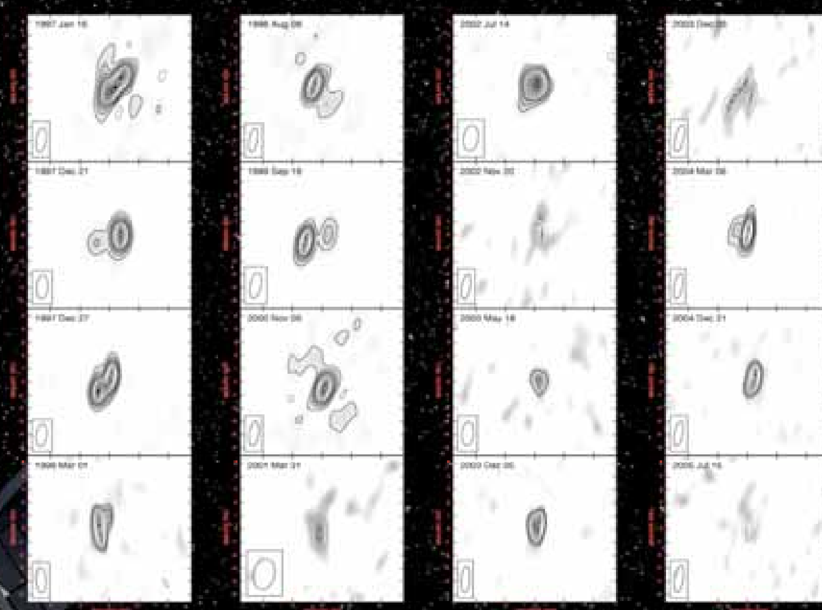

Fig. 2: VLBI Images of IM Peg, at 8.4 GHz on the dates indicated. In each panel, the contours are drawn at 10, 20, 30, ... 90, 98% of the peak brightness, starting at the first contour above 3 times the image rms, with the contours from 50% upwards being white, and negative contours being dashed. The ellipse at lower left indicates the FWHM resolution. North is up and east is to the left.

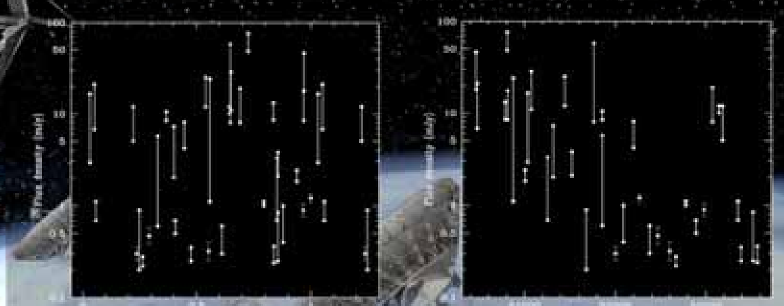

Fig. 3: The radio flux density at 8.4 GHz, from our VLA observations, as a function of orbital phase (left), and of Modified Julian date (right). Each vertical bar indicates the range of flux density during a single observing run. The orbital phase is defined using the ephemeris of Marsden et al. 2005, ApJL, 634, L173.

The poster background is an image of the Gravity Probe B satellite in orbit, with several VLBA radio dishes, rendered by A. Jeziak