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## Some recent results from the CHARA Array

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**Abstract.** The CHARA Array is a six 1-m telescope optical and near infrared interferometer located at the Mount Wilson Observatory in southern California and operated by the Center for High Angular Resolution Astronomy of Georgia State University. The CHARA Array has been in regular scientific operation since 2005 and now has over 55 publications in the refereed literature, including two in *Science* and one in *Nature*. The Array now supports seven beam combiners ranging from 0.5 microns up to 2.3 microns and combing from 2 to 4 beams at a time. An upgrade to a full 6 beam combiner is now underway and fringes with all six telescopes were achieved soon after the meeting. We present some of the more recent results from the CHARA-Array.

## 1. Introduction

The CHARA Array (ten Brummelaar et al. 2005) has been in regular scientific operation since 2005. Many recently published results are to be found elsewhere in these proceedings (Aufdenberg 2011; Baron 2011; Boyajian et al. 2011; Kloppenborg 2011; Monnier et al. 2011; Parks et al. 2011; Rajagopal et al. 2011; Schaefer et al. 2011; Simon et al. 2011; Stencel et al. 2011; Touhami et al. 2011; White et al. 2011; Zhao et al. 2011), and so in this paper we will focus on work in progress that had not been published at the time of this meeting.

## 2. NOAO Time

Applications for observing time in 2010 and 2011 were solicited and processed by the 2010A and 2011A NOAO proposal cycles. During 2010, 7.4 nights were reserved and 13 proposals requesting 17.1 nights were received for an over-subscription rate of 2.31. The 2011A cycle saw 20 CHARA proposals submitted requesting 24.5 nights, which compared with the 5.0 nights set aside yields an over-subscription rate of 4.90. The growth rate of proposals exceeded 50% from the first to the second year. We regard this experience as providing solid evidence of strong community interest in, as well as for the broad applicability of interferometry.

## 3. Work in Progress

Here we describe four projects that were underway at the time of this meeting. Since that time, two of them have been published (Derekas et al. 2011; von Braun et al. 2011).

### 3.1. Combining Kepler Photometry with CHARA Interferometry

The high-precision photometry of the Kepler space telescope is currently delivering ground-breaking discoveries in many fields of stellar physics. Interferometric follow-up, however, is limited by the small sizes of the stars and requires the long-baselines and high sensitivity in the visible only available at CHARA. See Figure 1.

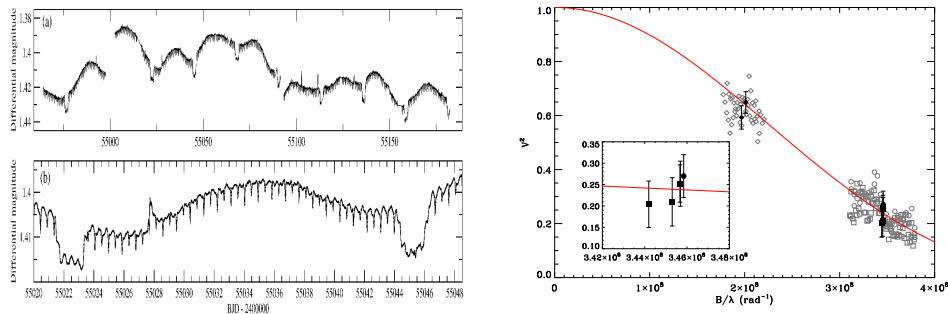


Figure 1. Left: The Kepler discovery of the hierarchical triple system with triple eclipses HD 181068. As confirmed by supplementary radial-velocity data, the primary component is eclipsed with an orbital period of 45.5 days by a pair of faint companions which themselves eclipse each other with an orbital period of 0.9 days. Right: Using the PAVO beam combiner we have measured the angular diameter of the primary to be  $0.461 \pm 0.011$  mas, which combined with the parallax yields  $12.4 \pm 1.3$  R<sub>sun</sub>. This confirmed that the primary is a  $\approx 3$  M<sub>sun</sub> red giant orbited by pair of red dwarfs. All three stars have very similar surface temperatures of  $\approx 5100$ K, explaining the disappearance of the 0.9 d eclipses when the short-period binary is in front of the red giant (see lower left figure). Further studies of this system are expected to yield important constraints on the dynamical evolution of multiple systems.

### 3.2. The Luminous Blue Variable P Cygni

P Cygni is a bright ( $V=4.8$  mag) luminous blue variable whose well-studied wind serves as the prototype for objects of its type. Simultaneous attainment of high spatial and spectral resolutions are enabling significant progress on constraining wind geometry and pinpointing the origin of the emission line flux. Full two-dimensional imaging is also being pursued. See Figure 2.

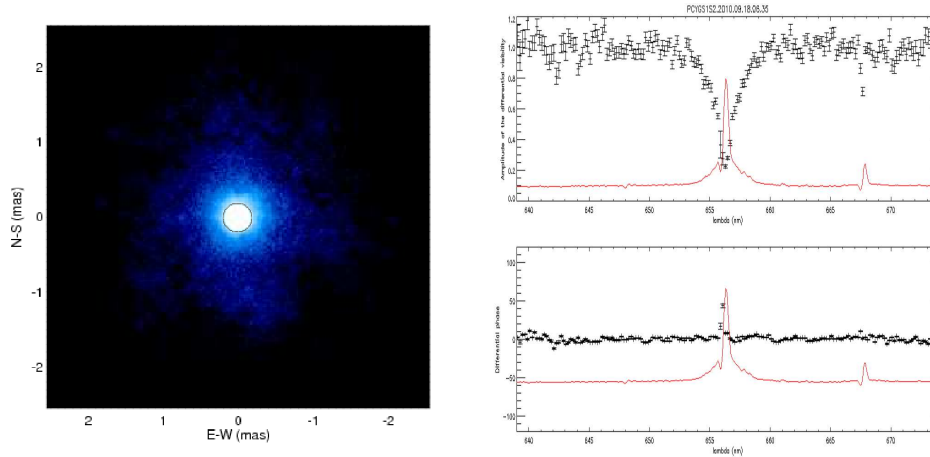


Figure 2. Left: A very preliminary image of P Cygni in the H band made using the MIRC beam combiner. The slight asymmetry is extremely similar to the asymmetries observed in the large scale (arc-second and arc-minute scale) ejecta surrounding the star. Right: The visibility (top) and differential phase measurements (bottom) for the smallest 30m baseline near the  $H\alpha$  line using the VEGA beam combiner. The second smaller line shown is He I line. The  $H\beta$  line was also monitored in a separate spectral channel of the spectrograph and is not shown here. The visibility is lower inside the lines, indicating that we are resolving the emission line region. There is also a clear differential phase signal in the line indicating strong asymmetries in the ejecta.

### 3.3. The Habitable Zone of the Exoplanet System GJ 581

The nearby, low-mass star GJ 581 is reported to have either four or six planets in two rivaling scenarios in the literature. Here we directly measure GJ 581's surface temperature and stellar diameter, which is about three times the diameter of Jupiter. A direct consequence identifying the location and extent of GJ 581's Habitable Zone (HZ). Figure 3 shows the location of GJ 581's HZ (gray shaded region) and its planets in the two literature scenarios.

### 3.4. Are you Sirius? In and Out of the $H\alpha$ Absorption Line

Limb darkening in absorption lines is expected to be less than it would be in the continuum because the line is formed all the way out to the stellar surface. More recent modeling shows that limb darkening changes between the line wings and center also. See Figure 4.

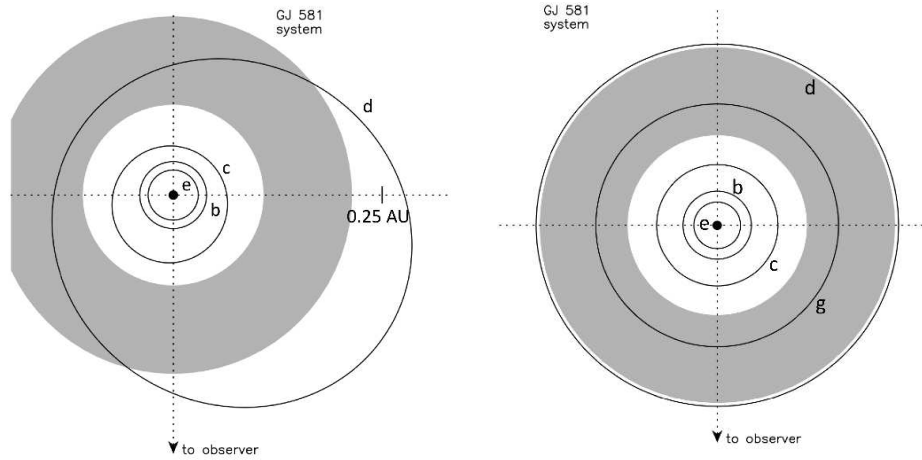


Figure 3. The HZ and planetary orbits of the GJ 581 system. Left: Four planet scenario (Mayor et al. 2010). Planet d spends most of its 67-day orbit in the HZ, thereby changing its equilibrium temperature by more than 80K. Right: Six planets scenario (Vogt et al. 2011). Planet g's 36-day circular orbit is inside the HZ, while planet d's 67-day orbit puts it right at the HZ's outer edge. Any planet in the system's HZ with a moderately dense atmosphere could harbor liquid water

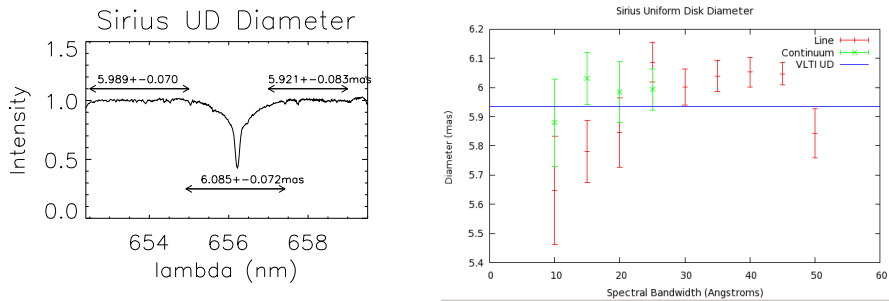


Figure 4. Left: Data taken by the VEGA beam combiner shows the uniform disk size inside the  $H\alpha$  is indeed larger than on either side of the absorption line. Right: The same data analyzed with band-passes centered on the line and with a range of bandwidths. Here the uniform disk size seems to be smaller in the line center, while being larger once the line wings are included.

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