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The MASCARA and bRing photometric monitoring networks

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Abstract

MASCARA is a network of observatories aimed at finding Hot Jupiters around bright stars using photometry. MASCARA has two stations, one in the northern hemisphere at La Palma, the Canary Islands, and one in the southern hemisphere at La Silla, Chile. Each station is equipped with five interline CCD cameras, and observes down to an airmass of around 2. These stations have been combined with bRing, two observatories in Siding Springs, Australia, and Sutherland, South Africa, which are designed similar to MASCARA to originally observe the Beta Pictoris Hill sphere transit. The combination of three stations in the southern hemisphere gives near-continuous photometric observations from a declination range between -30 to -90 degrees. With five minute exposures, this offers a set of observations for tens of thousands of stars over years with an unprecedented window function for a ground based network of telescopes. This allows for a detailed search for Hot Jupiters, as well as for variable stars. The exoplanets found using this network are excellent candidates for further atmosphere characterization studies, due to their brightness, size, and periods. MASCARA can also be used in conjunction with TESS on candidates where only a single transit has been observed, which constrains the depth, transit midpoint, and period for a search within the MASCARA database.

1. The MASCARA/bRing network

The primary science objective of the Multi-Site All-Sky CAmeRA (MASCARA), is to find transiting planetary systems around bright ($4 < m_v < 8$) stars[1]. MASCARA started in 2015 with the northern Observatorio del Roque de los Muchachos, La Palma, Canary Islands in Spain, and was upgraded with a southern station in mid-2017 at La Silla in Chile. Each of the five cameras per station are fixed on-sky, meaning the observed stars move along the same track along the CCD each night. Each image is taken with an exposure time of 6.4 seconds so that stars travel less than one pixel between exposures, with photometry from every fifty images binned together after reduction[2]. With interline CCDs, no observation time is lost between exposures.

The β Pictoris-b ring (bRing) instruments are originally designed as “mini-MASCARAs", with two cameras fixed to observe a declination range of -30 to -90 degrees down to an airmass of 10[3]. The primary goal of bRing was to photometrically observe β Pictoris during the Hill-sphere transit of β Pictoris-b. Two instruments were commissioned, one in Siding Springs, Australia, and one in Sutherland, South Africa.

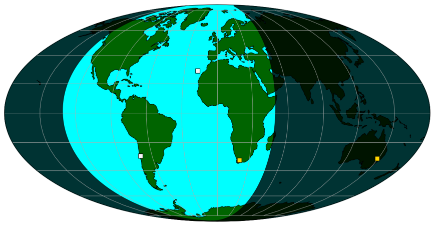

Figure 1: Global view of the MASCARA/bRing network. The two MASCARA instruments (red squares) are located in La Silla, Chile, and La Palma, the Canary Islands, Spain. The two bRing instruments (yellow squares) are located in Sutherland, South Africa, and Coonabarabran, Australia[4].

The locations of the three southern observatories (MASCARA-S, bRing-SA, and bRing-AU) is ideal for a large-field, photometric exoplanet search. As shown in Fig. 1, the southern observatories are strategically located in such a way to maximize the observation hours per day. At worst, there is a gap of thirty to sixty minutes from when one station closes after observations until the next station opens. If weather permits, throughout the majority of the year at least one station is observing at any given time.

2. Photometric capabilities

Each MASCARA and bRing network can achieve a photometric precision of $\sim 1\%$ over five minutes of observations. This means we are most sensitive to Jupiter-sized objects. In signal recovery tests, we show that with a single station we are most sensitive to shorter periods (< 5 days, with lower probabilities of finding signals with periods close to integer multiples of one day[5]). When combining the three southern stations, we become much more sensitive toward one day and multiple day periods. An example photometric light curve obtained via the three southern stations is shown in Fig. 2

3. MASCARA and bRing in the era of TESS

The MASCARA/bRing network is useful to the TESS mission. Though TESS has a much larger photometric precision compared to the MASCARA/bRing networks, TESS observes most of the sky for only thirty days, whereas the MASCARA/bRing network

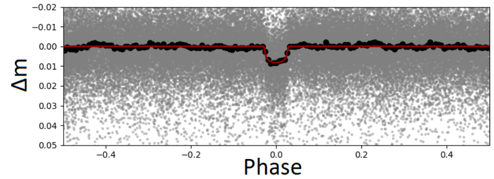

Figure 2: An example light curve from MASCARA-4 b. The grey dots are the five minute binned photometric data, and the black dots are these data binned such that there are nine data points within the transit event. The red line denotes the Mandel Algol model used to fit this data.

has multiple years of data. TESS is great at finding short period planets, but it is expected that there will be many interesting transit events where only a single transit is seen. MASCARA and bRing can use these single transit events to refine our search, fixing the depth and transit midpoints, and constraining the periods.

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