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New or Increased Cometary Activity in (2060) 95P/Chiron

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ABSTRACT

Asteroid Terrestrial-impact Last Alert System (ATLAS) observations of Centaur (2060) 95P/Chiron show a brightening in the apparent magnitude not due rotational light curves or phase effects. This onset or enhancement of cometary activity started after 2021 February 8 UT and continued in later observations from 2021 June 18 UT onward. Recent ATLAS observations and deeper follow-up imaging obtained using the Las Cumbres Observatory (LCO) 1.0-m robotic telescope network find no confirmed signature of coma or tail-like features.

INTRODUCTION

(2060) 95P/Chiron is a Centaur residing in the middle Solar System on a giant planet crossing orbit. Past observations of this planetesimal have identified periods of cometary-like outbursts and activity (e.g. Bus et al. 1988; Luu & Jewitt 1990; Dahlgren et al. 1991; Marcialis & Buratti 1993; Elliot et al. 1995; Lazzaro et al. 1997; Silva & Cellone 2001; Duffard et al. 2002). In Astronomer’s Telegram Dobson et al. (2021), we report an initial brightening indicative of new or increasing activity. In this Research Note, we present the two filter ATLAS phase curves (distance corrected brightness versus the angle between the Sun, the Centaur, and the observer), the follow-up imaging, and further interpretation of our results.

ATLAS DETECTION OF CHIRON BRIGHTENING

The Asteroid Terrestrial-impact Last Alert System (ATLAS) wide-field survey (Tonry et al. 2018a) uses two 0.5-m Schmidt telescopes located in Hawai’i to search for near-Earth asteroids down to a limiting magnitude of ~19.7 in two wide-band filters - cyan (‘c’, of wavelength range 420-650 nm) and orange (‘o’, of wavelength range 560-820 nm). Fields are observed at a 2 night cadence, with four 30-second exposures taken per frame of observation over a 1 hour interval. (Tonry et al. 2018a,b). Throughout its search to detect near-Earth asteroids, ATLAS has serendipitously observed Chiron for 6 years.

Phase Curve Analysis

Archival photometry of Chiron was obtained using the ATLAS Forced Photometry Server1, performing measurements at Chiron’s predicted position from JPL Horizons2 on static-sky subtracted images. Outlying datapoints were rejected by the following criteria: data with the largest 15 percent of error bars were removed, and the remaining data sigma-clipped to 3σ. The photometry ranges in time from 2015 August 12 to 2021 August 15 UT (c-filter) and 2015 November 4 to 2021 August 30 UT (o-filter), with 257 and 903 measurements in the c and o filters respectively.

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1 https://fallingstar-data.com/forcedphot/
2 https://ssd.jpl.nasa.gov/horizons.cgi
Apparent magnitude values were then corrected for geocentric and heliocentric distances at each observation time to derive distance-invariant reduced magnitude values. Chiron’s phase curve is shown in Figure 1 (reduced magnitude vs. phase angle).

A measurement of the Chiron’s linear phase coefficient, $\beta$ (the slope of the phase curve), was made using all data from epochs prior to 30 March 2021 (MJD = 59303), with its value in each ATLAS filter found to be $\beta_c = 0.089 \pm 0.006$ mag/° and $\beta_o = 0.098 \pm 0.003$ mag/°. Both phase coefficient values are the median of $10^5$ synthetic values generated per filter dataset by varying each phase curve datapoint by a random fraction of its error and then performing a weighted linear fit to each synthetic curve. The associated uncertainties of the derived values are the 95th percentile limits of the distribution of $10^5$ synthetic phase coefficient values. These result in absolute magnitude values in each filter of $H_c = 5.69 \pm 0.01$ mag and $H_o = 5.430 \pm 0.007$ mag. However, all photometry since 2021 March 30 are brighter than the previous ATLAS measurements at the same phase angles (see Figure 1), with median brightening values of 0.426 mag and 0.403 mag in the c and o filter respectively. The brightness differences are approximately half that of the brightening observed by Bus et al. (1988) between 1986 and 1988. This increase is in excess of Chiron’s light curve amplitude of 0.09 mag (Bus et al. 1988; Luu & Jewitt 1990), and so cannot be attributed to rotational variation. A recent onset of or increase in cometary activity would result in both the observed increase in brightness and the offset of new epoch data from the general phase curve trend.

**Figure 1.** Lower and Upper Left: (2060) Chiron’s ATLAS Phase curves. Black lines indicate each filter’s best fit linear phase curve. Upper right: Co-added ATLAS Chiron image. Red arrow denotes the anti-heliocentric velocity direction. Lower right: Average combined stack from the LOOK w-band observations of Chiron taken on 2021 September 06 UTC. Background banding is an instrumental effect not corrected for in LOOK’s quick look data reduction pipeline.
Point-Spread-Function (PSF) Analysis

Twenty ATLAS images of Chiron, taken from 2021 August 08 to 2021 August 29 (all 30-second exposure) were co-added, and the point-spread-function (PSF) of Chiron in the resulting image found its profile to be consistent with those of background stars. The stacked image (shown in Figure 1) features a possible marginal extension to Chiron’s PSF, located at position angle 250 degrees, approximately 9 arcsec from the center of Chiron’s signal.

LOOK FOLLOW-UP

Additional imaging was obtained as part of the Las Cumbres Observatory (LCO) Outbursting Objects Key (LOOK) Project in order to search for possible coma or tail-like features. The LOOK Project is a three year large observing program studying dynamically new comets and characterizing outbursts in small Solar System bodies, using the LCO 1.0-m network (Brown et al. 2013). Four 245 s exposure w-band (equivalent bandpass to $g'+r'+i'$) images were taken of Chiron on 2021 September 06 UTC using one of the LCO 1-m telescopes at Cerro Tololo Interamerican Observatory (CTIO). All images tracked Chiron’s position non-sidereally at its rate of apparent motion. Chiron’s PSF in each image is consistent with background field stars; FWHM match to \( \leq 0.2 \) pixels (or within 1 to 2\( \sigma \)) in each of the four epochs and showed no evidence for PSF extension or outgassing features (see Figure 1). Therefore, the marginal extension reported in ATLAS images cannot be confirmed.

CONCLUSIONS

Ortiz et al. (2015) report a stellar PSF in Chiron imagery from 2013. On 2021 February 8 and January 2 UT, ATLAS measured reduced magnitudes of 5.9 \( \pm \) 0.1 mag and 5.63 \( \pm \) 0.09 mag in the c and o filter respectively. These measurements are the last data points consistent with the 6 year ATLAS phase curve measured in Figure 1. The onset of this increased activity occurred between 2021 February 8 UT and 2021 June 18 UT, before Chiron passed through aphelion (18.87 au) in late August. Although no coma or tail has yet been detected, Chiron’s brightening is consistent with the past sporadic episodes of enhanced dust production/activity at large heliocentric distances (e.g Tholen et al. 1988; Marcialis & Buratti 1993; Bus et al. 2001). Further community follow-up of Chiron is warranted, in particular deep imaging and continued monitoring.

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