

CALL FOR OBSERVATIONS OF THE ACTIVE CENTAUR 29P/SCHWASSMANN-WACHMANN

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29P/Schwassmann-Wachmann is the most famous resident of the Centaur-JFC (Jupiter Family Comet) “gateway” region just beyond Jupiter. It may eventually become the brightest JFC in human history (Sarid et al., 2019). Its nucleus has exhibited a dust coma for more than 90 years, and it undergoes explosive outbursts several times a year. It is a strong candidate for a future space mission, and long-term dedicated and coordinated surveys from amateur and professional astronomers are needed to characterize the near-nucleus region and monitor material produced during outbursting events and quiescent outgassing activity. Through long-term monitoring we also seek to constrain the nucleus’ rotation period and spin pole orientation. We request multi-wavelength, multi-modality observations, including visible lightcurves, photometry, broadband filter imaging, astrometry, spectroscopy, interferometry and occultations. This article provides suggested observing dates, guidance about useful observations, predictions for a minimum visual magnitude, and a link to an observing campaign planning website. Interested observers are also welcome to contact the first author.

Key observations of Centaurs (objects orbiting primarily between Jupiter and Neptune) will allow us to better understand ongoing evolutionary processes in relatively pristine icy bodies. These objects transition from cryogenic storage in the Kuiper Belt region to active lifetimes as Jupiter-Family comets (JFCs). Approximately 10% of known Centaurs show episodic periods of cometary-like activity (Jewitt, 2009) and 29P/Schwassmann-Wachmann (hereafter 29P/SW1) is the most famous for exhibiting continuous activity that is likely related to its current orbit in the Gateway region (Sarid et al., 2019). Due to its importance to understanding icy planetesimals and solar system formation and evolution, 29P/SW1 was recently the target for two proposed NASA Discovery missions (Harris et al., 2019; Singer et al., 2019), and it is likely to be a candidate in future proposals.

Comet 29P/SW1 was the first small body discovered to have an orbit entirely beyond Jupiter. For many decades it has been the most distant object to show comet activity. Later discoveries of the population of objects in the giant planet and trans-Neptunian regions have shown it to be a Centaur. It is the most active icy body in the solar system and regularly exhibits a coma with

apparent magnitudes of $m_v \sim 16$ -17, superimposed with major outbursts of 1 - 4 magnitudes several times a year, and nearly continuous smaller outbursts of 0.5 - 1.0 magnitudes (Miles et al., 2016; Trigo-Rodríguez et al., 2010; Wierzechos and Womack, 2020). During Fall 2020, 29P/SW1 emerges from solar conjunction and will be observable from many ground-based observatories. Here we briefly describe some of the observations that will help constrain nucleus and activity models and prepare for an orbital or flyby mission.

Historical tracking with lightcurves shows that large outbursts appear preferentially on the outbound leg, moving away from perihelion (Krisandova and Svoren, 2014). 29P/SW1’s last perihelion was in 2019 March, and thus, if its behavior repeats, then we expect that the number of major outbursts to increase over the next 10 years.

Some analysis of the major outbursts using lightcurves has proposed a very long (>50 days) rotational period for 29P/SW1; however, the link between rotation and outburst is still controversial (Trigo-Rodríguez et al., 2010). Continuous and high precision lightcurves, accompanied by simultaneous broadband optical or infrared imaging (cf. Schambeau, 2018) are needed to test models of the nucleus spin period and pole orientation, as well as dust coma properties. Observers reporting visual magnitudes are strongly encouraged to also record the photometric aperture and filters used so that the data can be used for later calculations of A/p values for the dust coma (Womack et al., 2020).

29P/SW1’s coma has a semi-persistent jet-like feature, which is evident in dust, and possibly CO gas, emission at a 20 - 30 arcsec offset from the nucleus (Whipple, 1980; Gunnarsson et al., 2008; Stansberry et al., 2004; Miles et al., 2016; Womack et al., 2017; Schambeau, 2018). High angular resolution images and interferometry, especially during perigee (see Table I), would be especially useful to examine the recurrence and extent of this feature.

Infrared and mm-/submm wavelength molecular spectroscopy, including CO, the dominant outgassing volatile (Senay and Jewitt, 1994), and interferometry is also needed to characterize the nucleus’ composition and test outgassing models. Continuous long-term (>80 days) monitoring of the CO production rate, preferably with high spectral resolution ($<0.1 \text{ km s}^{-1}$), is needed to document any increases in gas production that lead to dust outbursts. Recent observations show that there is not always a strong correlation with dust and CO gas outbursts (Wierzechos and Womack, 2020), and more observations will improve statistics for further analysis of these important events. Such a long-term CO survey should be accompanied by simultaneous documentation of the dust coma. Time-series monitoring of other molecular species, including CN, N₂⁺, and CO⁺, will also be useful to constrain models of gas coma and solar wind interaction (Ivanova et al., 2019).

Although somewhat observable at other times, the Centaur is especially well-situated in the sky for observing from many ground-based observatories at optical, infrared and mm/submm-wavelengths during the date ranges listed in Table I.

Rings and shrouds of debris seen at the Centaurs Chariklo and Chiron raise the possibility that there may be stable structures in the inner coma of the much more active 29P/SW1. Ground-based stellar occultations at optical and infrared wavelengths are an excellent method to measure the diameter of 29P/SW1 and characterize any surrounding debris (e.g., Sickafoose et al., 2020),

and are also strongly encouraged. **29P/SW1 crosses the Milky Way plane (with Galactic latitude $|b| < 20$ degrees) during 2021-2023, and again during 2029-2031.** The high stellar density in this region provides increased opportunities for occultation events.

Continued astrometric observations are also requested because the coma obscures the nucleus, which makes it difficult to accurately determine its position (Miles and Kretlow, 2018).

Even if 29P/SW1 dims significantly, lightcurve photometry, imaging, and spectroscopy measurements obtained during times of very low or no activity will be invaluable to constraining models of the nucleus' size, albedo, shape, and rotational state. We use equations provided by the Asteroid Size Estimator (https://cneos.jpl.nasa.gov/tools/ast_size_est.html), and assume $R_{\text{nuc}} = 32$ km for radius (Schambeau, 2018), an albedo of $p_V = 0.04$, and a spherical shape to predict the nucleus' absolute magnitude to be approximately $H = 10$. We then convert this to an apparent visual magnitude, m_v , using $m_v = H + 5 \log D + 5 \log R$ and assume that the geocentric distance ranges from $D = 5.0 - 7.1$ au, and that the heliocentric distance is $R = 6$ au. We estimate that **29P/SW1's bare nucleus will be as faint as $m_v < 17.4$ to 18.1 magnitudes**, depending on how close it is to perigee. It could be another ~ 0.5 magnitude fainter if the nucleus is aspherical, has an albedo lower than 0.04, or experiences significant phase scattering.

An international observing campaign for 29P/SW1 was initiated in 2018 (http://wirtanen.astro.umd.edu/29P/29P_obs.shtml) by M. Womack and G. Sarid. Participation is strongly encouraged since it may help different teams coordinate observing runs, increase the chances of obtaining simultaneous measurements, thus maximizing scientific return. Additional information about the observations requested may be found on the web site. Interested observers should enter information about planned (or recent past) observations at the link. Signing up does not commit anyone to sharing their data, but we hope this will be a gathering place for researchers to see who is at the telescope and when, and perhaps lead to new collaborations. Useful repositories for data, depending on format and data type, may include this bulletin, the Minor Planet Center, International Comet Quarterly, the NASA Planetary Data System Small Bodies Node, or another resource agreed upon by the collaborators.

Solar elongation > 85 degrees (yyyy mm)	Perigee and Date (au) (yyyy mm)
2020 08 - 2021 02	4.859 in 2020 11
2021 09 - 2022 03	4.962 in 2021 12
2022 09 - 2023 03	5.078 in 2022 12
2023 10 - 2024 04	5.189 in 2024 01
2024 11 - 2025 05	5.275 in 2025 02
2025 12 - 2026 06	5.324 in 2026 03
2027 01 - 2027 07	5.324 in 2027 04
2028 01 - 2028 08	5.273 in 2028 05
2029 02 - 2029 08	5.176 in 2029 05
2030 03 - 2030 09	5.048 in 2030 06
2031 04 - 2031 10	4.915 in 2031 07

Table I. Optimal observing dates, including perigee, for the Centaur 29P/Schwassmann-Wachmann. Stellar occultations are the most favorable during 2021 – 2023 and 2029 – 2031.

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ROTATIONAL PERIODS OF THREE MAIN-BELT ASTEROIDS

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Here are reported the result of photometric work on three asteroids: 3222 Liller, $P = 12.576 \pm 0.001$ h, $A = 0.31$ mag; (8278) 1991 JJ, $P = 75.028 \pm 0.007$ h, $A = 1.50$ mag; and 10111 Fresnel, $P = 7.421 \pm 0.001$ h, $A = 0.20$ mag;

From 2020 April through June, Bigmuskie Observatory observed three main-belt asteroids to determinate their rotational periods. All three were reported on the CALL website (http://www.minorplanet.info/PHP/call_OppLCDBQuery.php), with no previous observations.

The setup at the Bigmuskie Observatory includes a Marcon 0.30-m $f/8$ Ritchey-Chretien telescope coupled with a Moravian G3 01000 equipped with a KAF-1001E CCD with a pixel array of $1024 \times 1024 \times 24$ microns. This gives a pixel scale of 2 arcsec/pix and a field of view of 36×36 arcmin. Images were unguided and taken through a Topotec R filter. Camera and telescope control were with *Maxim DL* (<http://diffractionlimited.com/product/maxim-dl/>) and *The Sky 6 Pro* (<http://www.bisque.com>). These were controlled by *Voyager* (<http://software.starkeeper.it>) to automate the entire observatory. All photometric reductions were done with *MPO Canopus* v10.7.12.9 (<http://bdwpublishing.com>), which permits obtaining fast results and precise night-to-night zero-point calibration using the Comparison Star Selector utility.

3222 Liller. Due to its period being very close to an Earth day, it took many sessions to reach the final result, which was found thanks to sessions 1217 and 1219 that aligned together into the deepest minimum of the curve. This provided a sort of “stationary landmark” and helped to find the right lightcurve. The period is $P = 12.576 \pm 0.001$ h with an amplitude of $A = 0.31$ mag.

(8278) 1991 JJ. This target showed a very large amplitude which helped to remove any uncertainty due to some low-quality sessions. The final period is $P = 75.028 \pm 0.007$ h, $A = 1.5$ mag.

10111 Fresnel. This was the most difficult target due to the low amplitude and its faint magnitude. Many periods appeared as more sessions were added, but in the end, after some shifting of zero points, the result seems to be reliable. The period is $P = 7.421 \pm 0.001$ h and $A = 0.20$ mag.

Number	Name	yyyy mm/dd	Phase	L _{PAB}	B _{PAB}	Period(h)	P.E.	Amp	A.E.	Grp
3222	Liller	2020 04/03-06/23	8.5, 18.8	208	17	12.576	0.001	0.31	0.05	MB
8278	1991 JJ	2020 04/15-06/06	10.1, 24.5	194	11	75.028	0.007	1.50	0.05	MB
10111	Fresnel	2020 04/23-06/29	16.6, 14.9	248	18	7.421	0.001	0.20	0.05	MB

Table I. Observing circumstances and results. The phase angle is given for the first and last date. If preceded by an asterisk, the phase angle reached an extrema during the period. L_{PAB} and B_{PAB} are the approximate phase angle bisector longitude/latitude at mid-date range (see Harris et al., 1984). Grp is the asteroid family/group (Warner et al., 2009).