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Predicting outbursts of comet 29P/Schwassmann-Wachmann

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Abstract

Comet 29P/Schwassmann-Wachmann is located in a near-circular orbit some 6 au distant from the Sun. The nucleus is very large being ~50 km in size, and since its discovery in 1927 it has continued to exhibit sudden outbursts, brightening by typically 2-4 magnitudes several times each year. Nine reports in the literature of its rotation rate have failed to identify a definitive rotation period. Values reported range between 8.5 h and 67 d. An analysis reported here of the MPC observation archive starting in 2002 has identified 52 outbursts, the times of which have been determined with a mean accuracy of ±0.6 d. These data together with observations using the 2.0-m Faulkes Telescopes have shown that the outbursts originate from at least four discrete, long-lived sources and that the fundamental period underlying the outbursts equals 28.86±0.02 d (interpreted as the length of the mean solar day of the nucleus). These characteristics represent a new form of cometary cryovolcanism triggered by solar heating in a very slow rotator at large heliocentric distance. Following each outburst, the source responsible typically requires 2-8 rotations of the nucleus before another eruption is possible from the same site, with 2 rotations being the most likely number to trigger a further outburst. The characteristics of individual sources have evolved since 2002 and currently Source B is most active, the ephemeris for which has enabled all three of 29P’s recent outbursts to be successfully forecast with a mean accuracy of 2.8 d.

1. Outburst characteristics

Outbursts of comet 29P develop within an hour or so and are characterised by dust-rich outflows moving away from the nucleus at speeds of up to 100-150 m s^{-1} indicative of events of an explosive nature. In spite of many attempts to determine the rotational state of the nucleus, it is not known how many active sites are present, or, if such sites do exist, whether they persist over time. Period analysis can readily identify a single long-lived source such as an enduring jet but where several variable sources contribute, an iterative method can be usefully employed. That is provided outbursts arise from only a few physically well-separated sources, each outburst from which is triggered within a relatively narrow local time window, for instance when the solar heating rate is close to maximum. This paper outlines the results of such an analysis carried out in 2014.

2. A new form of cryovolcanism

Faulkes Telescope images show discrete patterns within the expanding inner coma, which are often then followed ~60 days later by repeat outbursts having similar patterns to the earlier ones, indicative of enduring active sites [1]. From these observations, it is concluded here that the nucleus of 29P exhibits a mean solar day approximately (57.2/n) days in length (±8%) where 'n' equals 1, 2 or 3. Analysis of the outburst time data gleaned from more than 16300 photometric measurements in the MPC observation archive (made largely by amateur astronomers) has been carried out in two stages to minimise the chances of randomly arriving at an apparent correlation. Initially, 37 outburst times of the most energetic outbursts since 2002 were analysed and a period of 57.74 days was tentatively identified, but later it was found that the fundamental period was half this value at 28.86±0.02 d and that outbursts occurred in 4 groupings well separated in rotational phase space. A further inspection of the MPC archive yielded an additional 15 outbursts, mainly of lower amplitude, and when these were added to the original dataset, the gaps between the groupings remained essentially uncontaminated: the probability this arose by chance was calculated to equal 0.0003 showing that the groupings in the data are real.

The analysis showed that outbursts typically require 2-8 rotations of the nucleus before the next eruption occurs, which is triggered within a brief local solar time interval spanning some 2-4 hours local time. This behaviour represents a new form of cometary cryovolcanism in which individual sources outburst intermittently in an explosive fashion over many years, with each outburst triggered close to the time of maximal solar heating.

3. Outburst predictions

The four outburst sources identified, named A, B, C and D, appear to be distributed in longitude as follows: 358 ± 14°, 187 ± 24°, 82 ± 15°, and 292 ± 13° respectively (1σ spread quoted for each source). Source A has been responsible for at least 14 outbursts including two very energetic ones, the last in 2010 Feb 02 being the brightest of the past 12 years and after which time Source A has remained subdued, outbursting less frequently and with much less vigour. In contrast, Source B has grown in activity such that in recent years it has become the most active, and tending to outburst every second rotation of the nucleus.

The present analysis also shows that the fundamental ~29-day period has remained essentially constant (to within ±0.03 %) over more than a decade permitting an ephemeris to be devised for each source, which in the case of Source B is currently:

$$\text{Julian Date, } T_B\ (\pm 3.9\text{ d, } 2\sigma) = 2456718 + 28.86 * n$$

where n is an integer. The last three outbursts have been predicted in advance assuming that Source B is responsible in all cases, as summarised in Table 1. The first prediction in 2013 was the topic of a private communication whereas the last two were made via the **comets-ml** webgroup (messages #23289 and #23393) in 2014.

Table 1: Comet 29P outburst predictions

Date prediction made	Outburst date (predicted)	Outburst date (actual)	O – C d
20130419	20130614	20130612.9	-1.5
20140227	20140227.6	20140302.9	+3.3
20140327	20140428.0	20140501.6	+3.6

4. Summary

It has been possible to accurately forecast the last three outbursts of comet 29P based on a rotational model of the nucleus derived from inner coma studies and an analysis of 52 outburst times since 2002. This analysis has revealed a fundamental periodicity of 28.86±0.02 d, indicative of at least four active sites distributed in longitude around the nucleus. Each site has been responsible for many explosive outbursts and each has undergone an evolution over time. A detailed paper on the nature of, and possible mechanism driving outbursts of 29P's nucleus was submitted to *Monthly Notices of the Royal Astronomical Society* in early April this year [2].

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References

[1] Miles, R.: Microporosity, the wetted layer and the role of CO and CO_2 driving the activity of comets 29P/Schwassmann-Wachmann and 17P/Holmes, European Planetary Science Congress, 8-13 September 2013, Abstract EPSC2013-7, 2013.

[2] Miles, R., Faillace, G.A., Watkins, A., Roche, P., Roberts, S., Tripp, A., Mottola, S., Raab, H., and Vitagliano, A.: Discrete sources of cryovolcanism on the nucleus of comet 29P/Schwassmann-Wachmann, submitted to MNRAS, 2014.