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Outbursts of Comet 67P/Churyumov-Gerasimenko

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Abstract

We monitored the comet 67P/Churyumov-Gerasimenko close to its perihelion in November 2021 with the GROWTH-India Telescope. We observed two outbursts of this comet on 2021 October 29.940 and November 17.864 UTC, −3.12 days and +15.81 days respectively from the perihelion date. The brightening in the first outburst appears as a compact source, with a radial extent up to 8$''\!.$5. The comet brightened by 0.26 ± 0.03 mag in the outburst, with a 27% increase in the effective geometric cross-section and total outburst dust mass of ~5.3×10^5 kg. The second outburst caused a brightening of 0.49 ± 0.08 mag with effective geometric cross-section and total outburst dust mass 2.5 times larger than the first event. These outbursts are up to an order of magnitude larger than the strongest outburst event observed in situ by the Rosetta spacecraft in 2015.

Previous article in issue

Next article in issue

1. Introduction

Comet 67P/Churyumov-Gerasimenko (67P hereafter) is a Jupiter-family comet with an orbital period of ~6.4 yr. The comet recently moved past its perihelion on 2021 November 02.057 UTC (UTC Julian date, $T_p = 2459520.557$). Observations of the comet by the European Space Agency's Rosetta mission during the comet's last perihelion passage revealed numerous mini-outbursts with ejected dust masses of ~10^4–10^5 kg (Tubiana et al. 2015; Vincent et al. 2016). Near perihelion, there was approximately one outburst every 2.4 rotations of the nucleus (~29 hr).

However, few outbursts were seen in ground-based observations of the comet during the same apparition (Boehnhardt et al. 2016; Knight et al. 2017; Snodgrass et al. 2017). We have been monitoring this comet in ground-based data close to its 2021 perihelion, to look for additional evidence of its potential outbursts. We report the detection of two mini-outbursts of this comet on 2021 October 29 and November 17.

2. Observations and Lightcurve

We monitored comet 67P with the GROWTH-India Telescope (GIT). GIT is a 70 cm telescope located at the Indian Astronomical Observatory. Equipped with an Andor iKon-XL 230 4k back-illuminated CCD, the primary camera of GIT has a $0\overset{\circ}{.}7$ field of view with $0\overset{''}{.}67$ resolution. GIT was set up as part of the Global Relay of Observatories Watching Transients Happen (Kasliwal et al. 2019).

Nightly averaged photometry was computed within $8\overset{''}{.}5$ radius apertures and calibrated against the PanSTARRS–1 photometric catalog (Chambers et al. 2016). The colors of the comet are $g - r = 0.617 \pm 0.003$ mag and $r - i = 0.236 \pm 0.004$ mag, as measured outside of the outbursts. The lightcurve, spanning observations from 2021 September 15.901 UTC ($T - T_p = -47.16$ days) to 2021 November 19.935 UTC ($T - T_p = 17.88$ days), is plotted in Figure 1. On 2021 October 22.904 UTC ($T - T_p = -10.15$ days), the comet had an apparent magnitude of $r = 11.88 \pm 0.02$ mag, and a rate of change of magnitude $dm_r/dt = -0.019$ mag day^{-1}, averaged from $T - T_p =$ -19.15 to 3.87 days, excluding the first outburst. The expected magnitude of the comet on 2021 October 29.940 UTC ($T - T_p = -3.12$ days) was $r = 11.71 \pm 0.02$ mag. Instead, the comet had brightened to $r = 11.45 \pm 0.02$ mag, suggesting a brightening of 0.26 ± 0.03 mag.

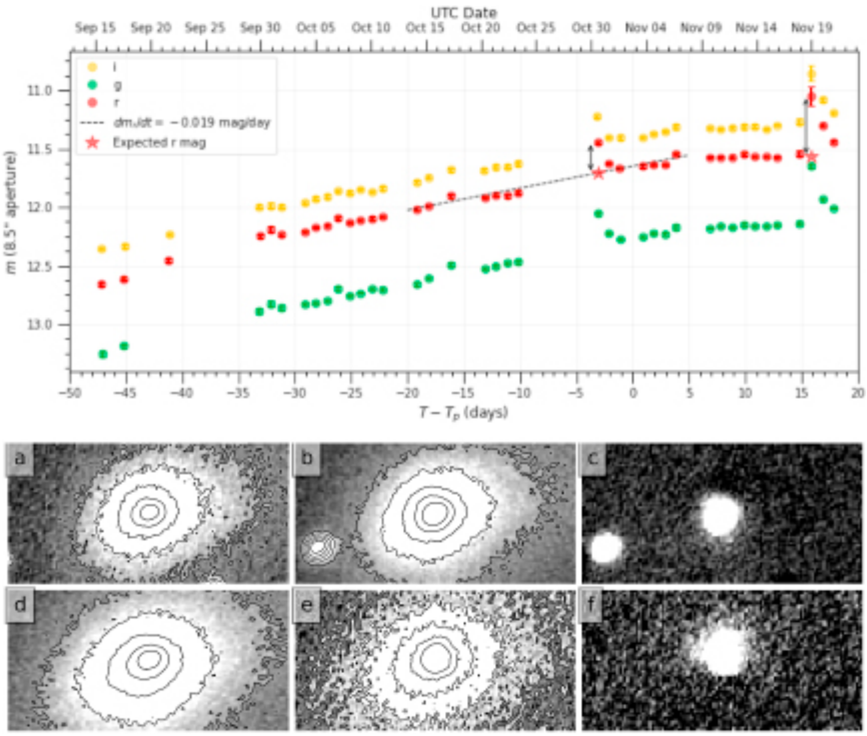

Figure 1. Top: Lightcurve of comet 67P measured within 8″.5 radius apertures. The data used to create this lightcurve are available as a machine-readable table. The typical photometric error is <0.03 mag. Middle: r-band images showing changes in the comet in the first outburst. Image (a) shows the morphology on 2021 October 22.847 UTC, scaled to the expected brightness at the epoch of the outburst using our local best-fit photometric trend. Panel (b) shows the outburst discovery image on 2021 October 29.918 UTC, while (c) shows the difference of (b) and (a) isolating the first outburst. Images are 80" × 40", and contours are shown starting at 16.8 mag arcsec^{-2} with a spacing of 0.75 mag arcsec^{-2}. Bottom: similar sequence of images for the second outburst: (d) was acquired on 2021 November 16.850 UTC; (e) on 2021 November 17.865 UTC; and (f) is the difference of (e) and (d) isolating the second outburst.(The data used to create this figure are available.)

A second outburst was observed on November 17, previously identified by Kelley et al. (2021). In our data, the comet had an apparent magnitude of $r = 11.54 \pm 0.02$ mag on 2021 November 16.849 UTC ($T - T_p = 14.79$ days), which brightened to $r = 11.05 \pm 0.08$ mag on 2021 November 17.864 UTC ($T - T_p = 15.81$ days), suggesting an outburst of 0.49 ± 0.08 mag, approximately twice that of the first outburst.

The colors of the comet during these events were $g - r = 0.608 \pm 0.020$, $r - i = 0.223 \pm 0.021$ and

$g-r = 0.598 \pm 0.080$, $r-i = 0.195 \pm 0.104$ respectively. These measurements are consistent with our mean quiescent coma colors. During the two outbursts, the comet was at a heliocentric distance $r_h = 1.211$ au and $r_h = 1.227$ au respectively, with corresponding observer-comet distances $\Delta = 0.424$ au and $\Delta = 0.419$ au. The physical variation of the $8\overset{\prime\prime}{.}5$ radius aperture is ~3600 to ~2500 km.

3. Morphology Analysis

We confirmed the outbursts by inspecting the comet morphology. All images were scaled to a common zero-point, followed by sky background removal and astrometric alignment on the comet position. To study the first outburst, we subtracted the quiescent coma from the initial outburst image using the October 22 r-band image as a reference. For the second event, an image from November 16 was used as a coma reference. In each case, the reference image was scaled to match the expected flux of the comet before subtraction.

We see a clear detection of an additional compact component in both candidate outburst images (Figure 1). There is a slight over-subtraction of the tail on October 29, perhaps due to the changing 3D geometrical circumstances over the 9 day period. The outburst materials are nearly symmetric, with radial extents out to $8\overset{\prime\prime}{.}5$. We additionally inspected the images from October 30 and 31, where we observed the quiescent coma. This is consistent with the near-complete return to the quiescent coma lightcurve on October 30. Similar rapid evolution was also observed in the second outburst, where the comet evolved from $r = 11.05 \pm 0.08$ mag on 2021 November 17.864 UTC ($T - T_p = 15.81$ days) to $r = 11.44 \pm 0.02$ mag on 2021 November 19.935 UTC ($T - T_p = 17.88$ days), thus nearly returning to the quiescent coma lightcurve.

4. Outburst Mass and Conclusions

We computed the effective geometric cross-section (G) from the observational data, assuming a dust r-band geometric albedo of 6%, similar to the comet's nucleus (Sierks et al. 2015). The geometric cross-section between $T - T_p = -20$ and -10 days was increasing at a rate of $dG/dt = +4.5$ km^2 day^{-1}, with an expected $G = 319 \pm 6$ km^2 on $T - T_p = -3.12$ days. However, we observed $G = 406 \pm 6$ km^2, which results in an effective outburst cross-section of 87 ± 8 km^2. Similar calculations for the second outburst reveal an effective outburst cross-section of 214 ± 8 km^2. In order to convert effective geometric cross-section to dust mass, we assumed a grain density of 1000 kg m^{-3}, differential grain-size distribution with a power law index of $k = -2.6$, and the dust grain size range of 1–10 μm, as described in Vincent et al. (2016). The converted outburst dust masses for the two events are ~5.3×10^5 and ~1.3×10^6 kg respectively.

The events described above are one to two orders of magnitude larger than the mini-outbursts observed by the Rosetta spacecraft. For the "typical" outburst on 2015 July 29.559 UTC, Vincent et al. (2016) estimated a total ejecta mass of 2.0×10^4 kg. The strongest event characterized by Vincent et al. (2016) was ~6.3 times more massive, i.e., 1.3×10^5 kg. Given that the GIT–observed outbursts presented a small change in brightness of the coma (0.3–0.5 mag), the more frequent smaller events should be challenging to identify in typical ground-based photometry. This is consistent with the lack of smaller outbursts in the remainder of our lightcurve.

GIT is a 70 cm telescope with a $0\overset{\circ}{.}7$ field of view, set up by the Indian Institute of Astrophysics (IIA) and the Indian Institute of Technology Bombay (IITB) with funding from DST-SERB and IUSSTF. It is located at the Indian Astronomical Observatory, operated by IIA. We acknowledge funding by the IITB alumni batch of 1994, which partially supports operations of the telescope. Telescope technical details are available at https://sites.google.com/view/growthindia/.

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