Studying the Color, Brightness, and Outbursts of Comet 12P/Pons-Brooks

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Abstract

Comets are large objects primarily made up of dust and gas that orbit around the Sun. I studied **Comet 12P/Pons-Brooks.** This comet is known for having **massive outbursts**, which is when a comet becomes drastically brighter. The outbursts can be **unpredictable in cause and duration.** There are many theories as to why these outbursts happen, but we don't always know the causes. Through this semester, we studied the **mass of the outbursts** and the **light curve of this comet** to learn information about the outbursts.

Introduction

Comet's Tail:

- During their path around the Sun, at the point closest to the Sun, **comets emit a tail** that consists of the same dust and gas that the comet is composed of.
- The **heat** from the Sun **vaporizes** some of the comet's materials, and some of the ice from the comet **sublimates**. Dust particles that were previously trapped in the ice are **released and emit a tail** (Temming, 2014).

Comet 12P:

- It has a **period of roughly 71.3 years** and was last closest to the Sun on April 21st, 2024. Its nucleus is a maximum of 17 ± 6 km in radius (Ye, 2020).

Throughout the semester, we **calculated the mass of the outburst** of this comet on July 21st, 2023, and October 5th, 2023.

Data

- Zwicky Transient Facility or **ZTF** is an Image Database that uses an extremely wide field of view camera to capture **images of the northern night sky** (Bellm, 2022).
- ZTF also contains data on various objects like Comet 12P which was used to create a **lightcurve** that helped us study the Comet.
- The images taken were opened in **DS9**, and **aperture photometry** was completed to find the brightness.
- This brightness data was used to **calculate the mass of the outbursts** on the two nights.

Finding the Color of Comet 12P

Plotting the data:

- We graphed the **magnitude versus heliocentric distance** in three filters. **zg: green, zr: red, zi: infrared** which did not line up as seen in Figure 1.

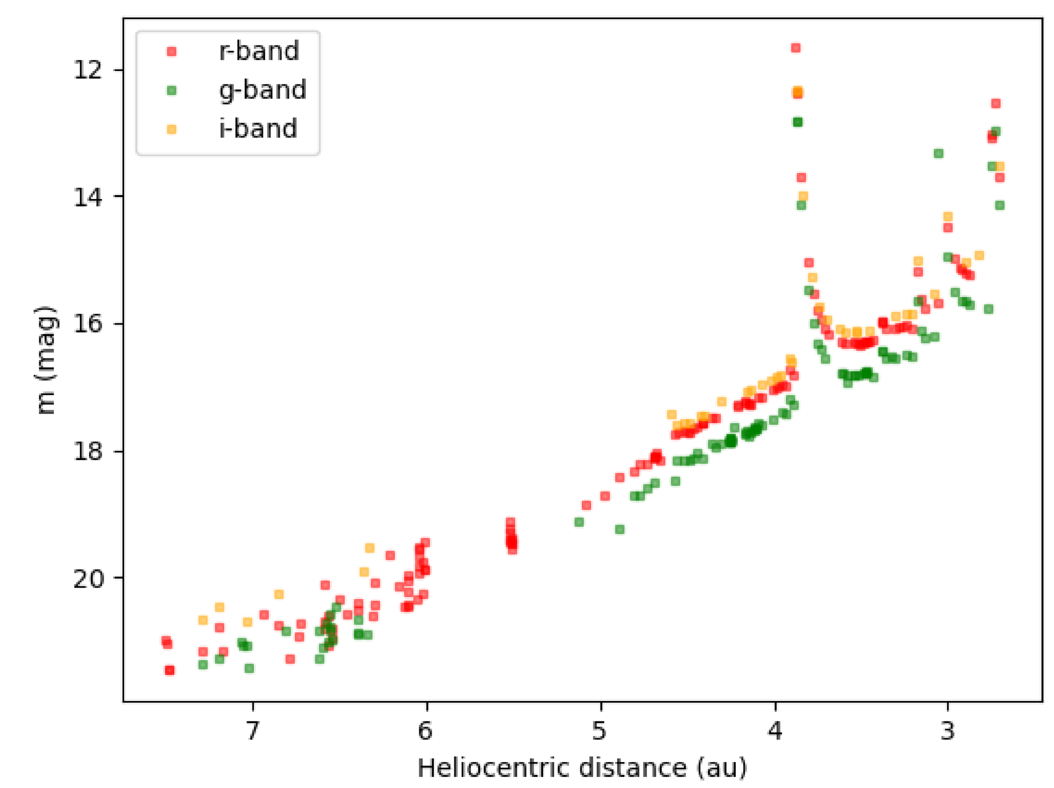

Fig. 1 Graph of magnitude versus Heliocentric distance where filtercode zr is red squares, zg is green squares, and zi is orange squares.

Correct the **offset zg and zr values**:

- We created a **loop that went through every data point.** If the points were within twelve hours of each other, we **averaged them to get an average zg, zr, and zi magnitude for each night.**
- We subtracted these values from the initial magnitudes gets us **corrected value for each night in the r and g filters.** G minus r offset: 0.39 mag. R minus I offset: 0.12 mag.
- We the replotted the original points with the **corrected magnitude values** as seen in Figure 2.

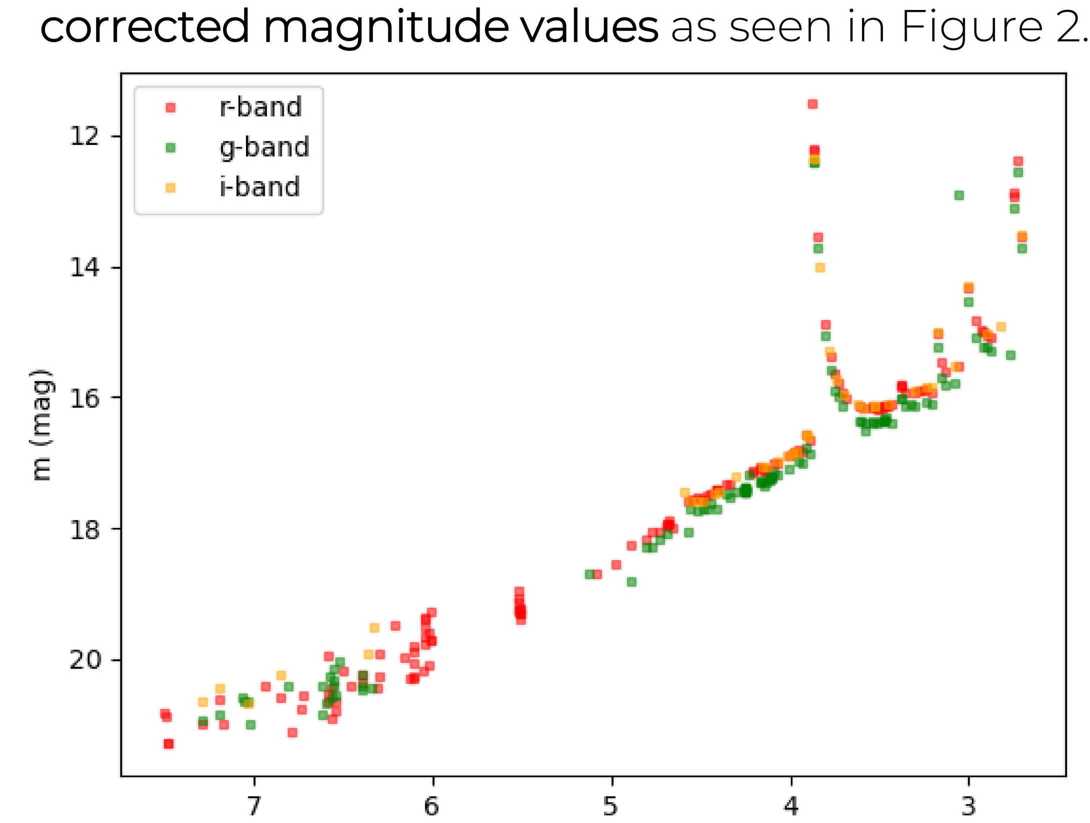

Fig. 2 Graph of corrected magnitude versus Heliocentric distance where filtercode zr is red squares, zg is green squares, and zi is orange squares.

Measuring the Brightness of the Comet

Calculating the mass of an outburst:

- We opened the October 5th, 2023, image in the g filter and **created an aperture around the comet** and a **secondary aperture of the background**, seen in Figure 3.
- We then used Equation 1 to **find the apparent magnitude** of the comet in that image.

$$m = -2.5\log_{10}(sum - background) + magzp$$

Eq. 1. Where m is the apparent magnitude, sum is the total pixel count in the comet aperture, background is the average background value per pixel, and magzp is the photometric zero-point extracted from DS9 (Masci, 2024).

- We found the magnitude on October 5th, 2023 using an image in the **green filter: 13.158 mag.** We can use this to find the **mass of the outburst.**

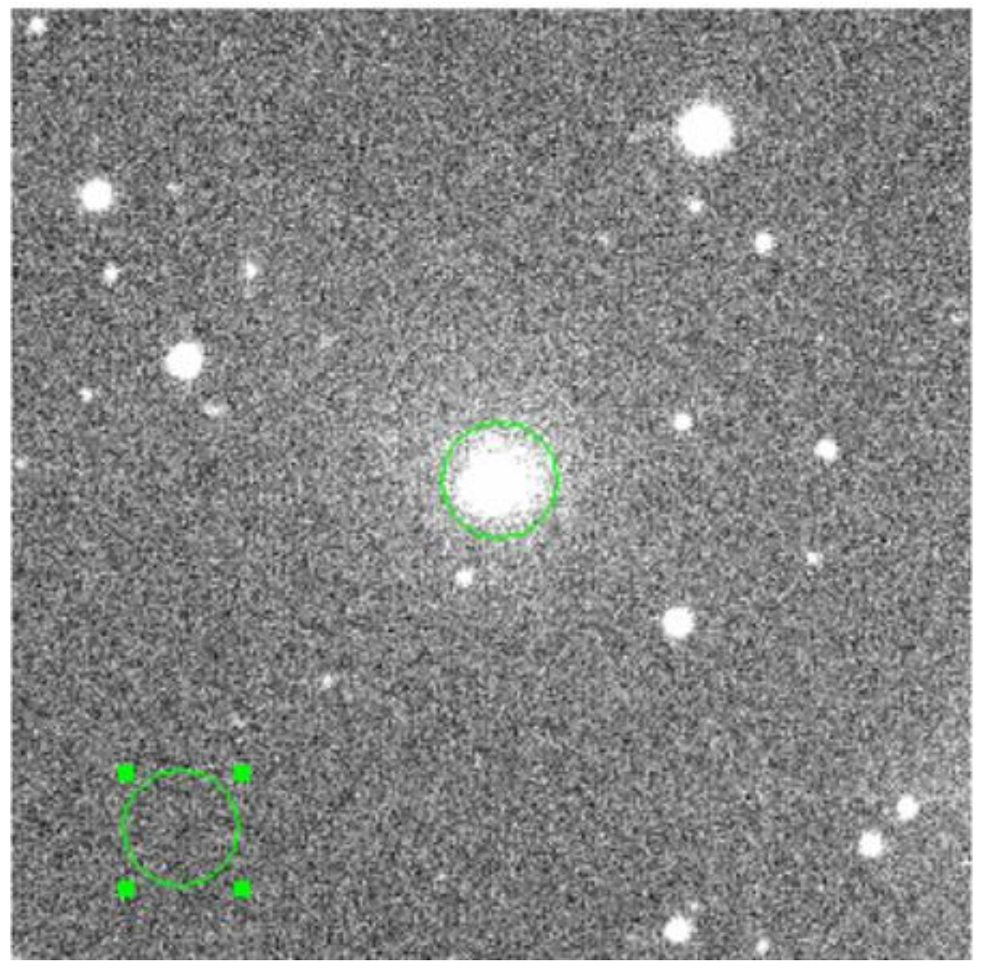

Fig. 3 The comet aperture and background aperture used on the October 5th, 2023 image in the green (g) filter.

Total Mass of the Comet's Outburst

	July 21st	October 5th	
C value	8.88×10^6	1.17×10^6	Eq. 2, 3
Number of Dust Grains	1.41×10^{14}	Not Calculated	Eq. 4
Cross-Sectional Area	1.85×10^9 m^2	Not Calculated	Eq. 5
Mass of the Outburst	$5.18 \times 10^9 kg$	$9.75 \times 10^8 kg$	Eq. 6

Equations

$$F_\nu = \int_{a_0}^{a_1} \frac{A_p \varphi(\theta)\sigma}{\pi\Delta^2} S_\nu \frac{dn}{da} da$$

Equation 2: Where F_ν is the spectral irradiance of the comet, A_p is the albedo of a dust grain, $\varphi(\theta)$ is the phase angle, σ is the cross-sectional area, Δ is the observer-comet distance, S_ν is the solar spectral irradiance at the dust grain, a_1 is the size of the largest dust grain (1 cm), a_0 is the size of the smallest dust grain (0.1 μm), and $\frac{dn}{da}$ is the differential size distribution of the comet given by Eq. 3.

$$\frac{dn}{da} = Ca^{-3.5}$$

Equation 3: Where $\frac{dn}{da}$ is the differential size distribution of the comet, C is a constant calculated on each date, and a is the size of a dust grain.

$$N = \int_{a_0}^{a_1} \frac{dn}{da} da$$

Equation 4: Where N is the number of dust grains in the comet's outburst, $\frac{dn}{da}$ is the differential size distribution of the comet given by Eq. 3, a_1 is the size of the largest dust grain (1 cm), and a_0 is the size of the smallest dust grain (0.1 μm).

$$A = \int_{a_0}^{a_1} \sigma(a) \frac{dn}{da} da$$

Equation 5: Where A is the cross-sectional area of the comet, σ is the cross-sectional area of each grain, $\frac{dn}{da}$ is the differential size distribution of the comet given by Eq. 3, a_1 is the size of the largest dust grain (1 cm), and a_0 is the size of the smallest dust grain (0.1 μm).

$$M = \int_{a_0}^{a_1} DV(a) \frac{dn}{da} da$$

Equation 6: Where M is the mass of the comet's outburst, D is the density of the dust grains, V is the volume of the dust grains, $\frac{dn}{da}$ is the differential size distribution of the comet given by Eq. 3, a_1 is the size of the largest dust grain (1 cm), and a_0 is the size of the smallest dust grain (0.1 μm).

Conclusion

- This information can be used to understand **the scale of these outbursts.**
- Based on the mass, we can **create theories for why outbursts happen** and compare the **mass to predictions** from **different models.**

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References