Pre-Disintegration study of comet C/2021 A1 (Leonard)

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Introduction

Comet C/2021 A1 (Leonard) was discovered on January 2021 with a magnitude of V~19 at a heliocentric distance r_H=5 au [1]. Leonard is an hyperbolic comet (long-period comet before its income in the planetary region), with perihelion distance q=0.61 au, eccentricity e=1.0001 and inclination i=132.6°, reaching perihelion in January 2022. The comet achieved visibility with the naked eye in late 2021 and then showed spectacular gas and dust tails. However, Leonard became photometrically unstable in December 2021 and January 2022 [2]. The morphology has also changed, becoming diffuse and the tail becoming more relevant on January 22, 2022 at r_H~0.74 au. Jewitt [3] presented images of the Leonard disruption, considering that the complete disintegration of the nucleus was near mid-December, 2021.

Methods and Results

Images of comet Leonard on the broadband B, V, and R filters were taken with the 0.6 m HSH telescope in CASLEO, Argentina on December 21 and 23, 2021. Our goal is to study the comet dust behavior in the previous moments of the disintegration event.

To characterize the activity and the evolution of the dust environment of the nucleus we used digital filters (after the basic reduction) to enhance the contrast in the cometary images. That permitted us to determine the presence of subtle morphological details in the objects that cannot be detected in the unprocessed images. The use of digital filters also allowed us to reach a better understanding of the level of activity ([4],[5]) and estimate the position of active zones.

We also obtained magnitudes and measured the A(0°)fρ parameter of the comet (Table 1). Those values are used as a proxy for the dust production [6].

Finally, in order to better understand the dust environment of the Leonard's nucleus, we tried to fit the observations to a new and improved theoretical model developed for the study of dust comas. Since the motion of cometary dust is affected mainly by gravity and radiation pressure, we can use our numerical model to solve the dust particles movement equation when they left the nucleus's surface and to estimate their brightness contribution [7], [8] (Fig. 1a).

It was possible to characterize the cumulative function of comet sizes to know a little more about the dust that composes it (Fig 1b). Further analysis can be done by plotting the weight of each particle's contribution to brightness to the final modeled image (Fig. 1c).

The model also allows the calculation of the lost-mass rate of the comet. Following the approach of Moreno [8]:

$$\frac{dM}{dt} = \frac{3C_{pr}Q_{pr}}{2\,A_p(\alpha)}\int_{\beta_i}^{\beta_f}\frac{F(\beta)}{\beta}d\beta\,,$$

which give an average dust emission rate of 943.296 kgs^{-1} and 34.775 kgs^{-1} in each observing night, respectively.

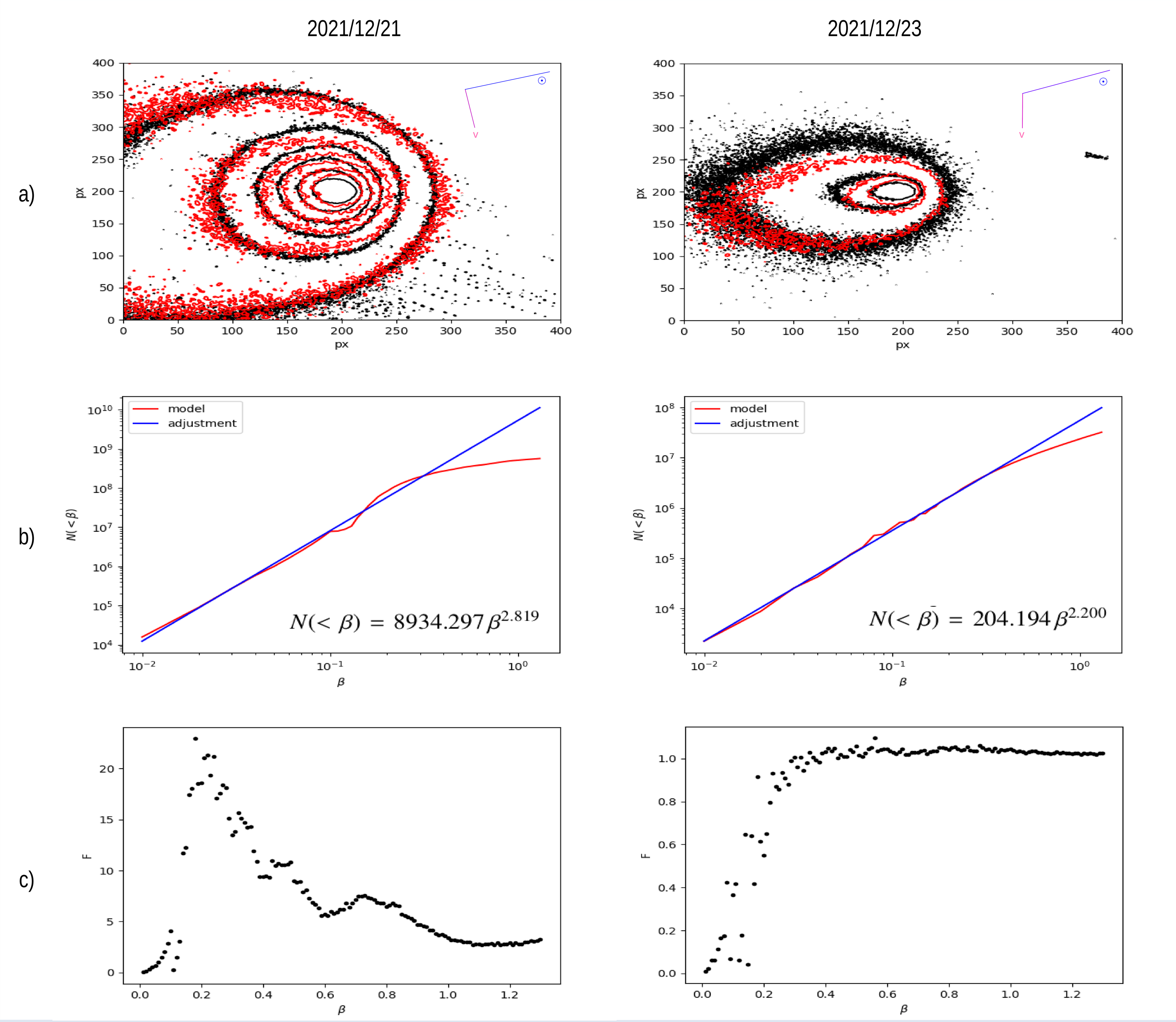

Figure 1: (a) Leonard's dust coma model (red) contrasted with the real image (black), (b) particle distribution and (c) weight of each β value for particles in the final model solution.

Conclusions

- The application of enhancement techniques shows that there are two active regions in opposite directions.
- Leonard's activity can be modulated by an isotropic emission plus two active areas, located at cometocentric coordinates of (180°, 80°) and (0°, −10°), considering a rotation period of ∼ 15 hours and a spin axe at the heliocentric coordinates (250°, 10°).
- Considering the calculated magnitudes and dust production rates the object would seem to be more active in December 21 than December 23, in agreement with the dust-mass lose calculated and the model fitted, emitting 3000 particles in each integration step against 1300, in each corresponding night.
- The first night model is dominated by the comet's isotropic emission while the second night model is modulated by a lower isotropic emission but accompanied by a very intense jet with a wide ejection cone angle.
- Dust grains of bigger size dominates the dust coma model on the 21/12 image, while the general trend of two days later shows that the weight of the dust grains to that solution is equitable for 0.3 ≤ β ≤ 1.3.

	m_B	m_V	m_R	A(0°)ρ_B (cm)	A(0°)ρ_V (cm)	A(0°)ρ_R (cm)
21/12/2021	6.394±0.075	5.266±0.087	5.145±0.041	2293.216±152.811	3582.047±275.831	2890.491±107.106
23/12/2021	-----	7.407±0.079	7.587±0.031	-----	1080.498±75.827	660.730±18.599

Table 1: Leonard's magnitudes and dust production rates at zero degree phase angle for the B, V and R filters used during the observations.

Bibliography

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