# Morphological Consistency Between the Cassandra Leak and Post-Perihelion Jet Images of 3I/ATLAS

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**Abstract**

We compare a pair of leaked images of the interstellar object 3I/ATLAS (the "Cassandra" images) with a set of independent post-perihelion images of the same object, published later by professional and advanced amateur observers and compiled by Loeb in two Medium essays. The Cassandra images predate those public releases but exhibit a distinctive bundle of morphological features: a bright central condensation, a strong anti-tail, a narrower main tail, and a set of secondary jets that form a characteristic "V" pattern in the upper-right quadrant of the frame. When the later images are rotated and scaled so that this V-shaped jet pattern is used as a registration marker, the large-scale jet morphology of all data sets becomes strikingly similar. Although morphology alone cannot conclusively prove authenticity, the detailed agreement between independently obtained images and the Cassandra leak strongly disfavors the hypothesis that the leak is an arbitrary forgery. Instead, it suggests that the Cassandra images are likely to depict the real object and therefore provide an additional qualitative anomaly to be considered alongside the quantitative probability analysis carried out in Spinelli (2025).

**Plain-language summary (for non-specialists)**

This paper looks at a simple but important question: do a pair of leaked pictures of the object 3I/ATLAS really show the same thing as later, independent telescope images? 3I/ATLAS is an interstellar visitor that passed through the Solar System in 2025 and showed unusually complex jets of gas and dust. Months after the encounter, two images known as the "Cassandra leak" appeared online, claiming to show the object near perihelion.

We compare those leaked images with several later pictures collected by professional and advanced amateur astronomers and presented by Avi Loeb in two public articles. After rotating and scaling the images so that the bright core and main jets line up, we find that the leaked pictures and the later images share the same overall pattern: a bright central region, a strong sunward "anti-tail," a long tail in the opposite direction, and a pair of jets forming a clear "V" shape in the upper-right part of the image. This level of agreement would be very hard to get by accident if the leaked images were invented without access to the later data.

The comparison does not prove beyond doubt that the Cassandra images are authentic, but it makes that explanation much more plausible than a random forgery. If the Cassandra images are real, they add one more unusual feature to an already long list of odd properties for 3I/ATLAS. Together with earlier work on the statistics of these anomalies, this raises a deeper question: what kind of natural or artificial process could produce this whole bundle of features so easily?

# 1 Introduction

The interstellar object 3I/ATLAS (C/2025 N1) has been argued to display an unusual cluster of anomalies across its orbital, photometric, morphological, chemical, polarimetric and dynamical properties (Spinelli, 2025). A recent Bayesian analysis based on the twelve "Loeb anomalies" shows that, under reasonable priors, the joint probability of all reported features arising in a natural cometary object is exceedingly small (Spinelli, 2025).

In parallel with these developments, a pair of images—the "Cassandra leak"—has circulated online, purporting to show 3I/ATLAS near perihelion or shortly thereafter. These images appeared before the publication of a series of high-quality post-perihelion jet images compiled and discussed by Loeb (2025c,a). Independently, a number of astrophotographers contributed deep stacks showing a complex network of jets, including a prominent anti-tail, a narrower main tail and multiple jets pointing in different directions (Thaluang, 2025; Murata, 2025).

The goal of this short paper is not to re-evaluate all the anomalies of 3I/ATLAS, but rather to examine whether the Cassandra images are morphologically consistent with the later, independently obtained images, and what this implies for their authenticity. This provides an additional qualitative anomaly that complements, but does not replace, the quantitative probabilistic analysis.

# 2 Data Set

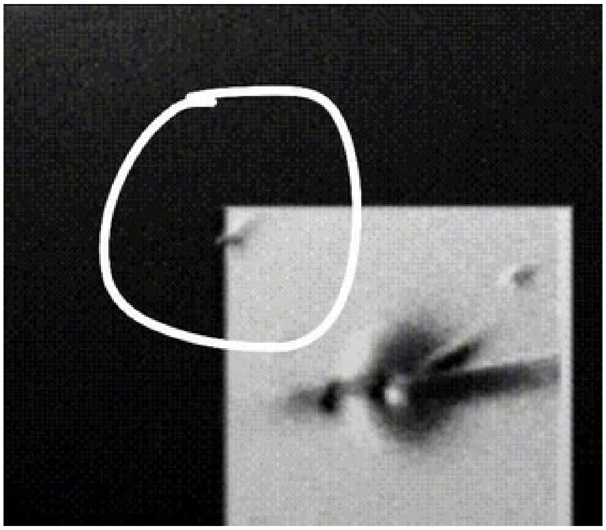
## 2.1 The Cassandra Leak

Figure 1 shows the two Cassandra images as provided: a negative version and a positive/contrast-enhanced version. No detailed observing metadata (telescope, exposure time, filter) are available for these images beyond the claim that they were obtained by an advanced amateur observer and leaked without authorization (Cassandra, 2025). Nevertheless, several robust morphological features are apparent:

- A bright central condensation.
- A broad, high-surface-brightness feature extending roughly in one direction (candidate anti-tail).
- A narrower, more diffuse tail extending in the opposite direction.
- A bundle of secondary jets, including a pair of bright jets forming a "V" in the upper-right quadrant of the frame.

## 2.2 Post-perihelion Images from Loeb's Compilation

Avi Loeb has published several Medium essays collecting independent images of 3I/ATLAS obtained after perihelion by professional and advanced amateur astronomers (Loeb, 2025c,a). In this work we use the subset of images reproduced in Figures 2 and 3, namely:



(a) Cassandra image in negative representation.

(b) Cassandra image with positive stretch.

Figure 1: The two versions of the Cassandra leak used in this analysis. Both views show a bright core, a strong anti-tail, a narrower main tail, and multiple secondary jets, including a distinctive V-shaped jet pattern in the upper-right quadrant.

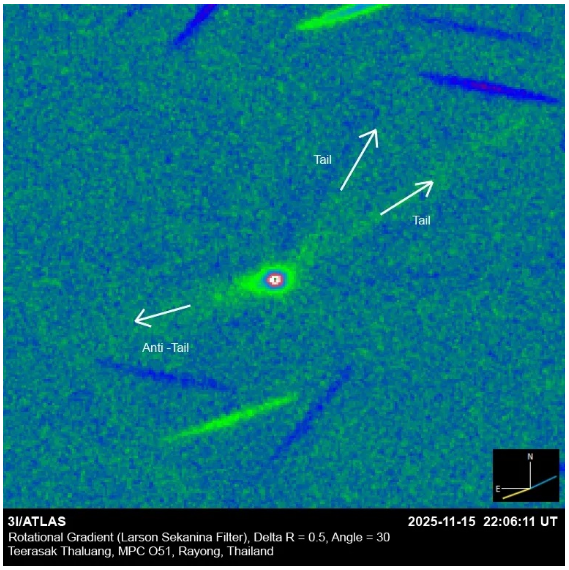
- A green-color image of 3I/ATLAS showing multiple jets on both sunward and anti-sunward sides (credited to astrophotographic contributors in Loeb 2025c).
- A Larson–Sekanina rotational-gradient image taken on 2025-11-15 at 22:06 UT from Rayong, Thailand, showing a prominent anti-tail plus two tails, with the sunward direction toward the lower-left corner (Thaluang, 2025).
- Deep stacked grayscale images showing a complex jet structure extending in multiple directions, discussed in Loeb (2025a).
- A wide-field color image by Satoru Murata, shown both as a raw frame and on a coordinate grid with identified objects such as the galaxy NGC 4691 in the upper left (Murata, 2025; Loeb, 2025c).

# 3 Alignment and Morphological Comparison

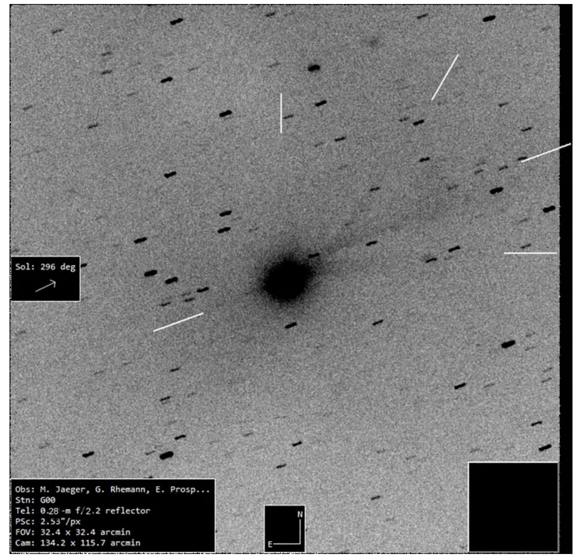
## 3.1 Registration by the V-shaped Jet Pattern

To compare the Cassandra images with the later data, we treat all frames purely as intensity maps and ignore color information. Each image is rotated and rescaled so that:

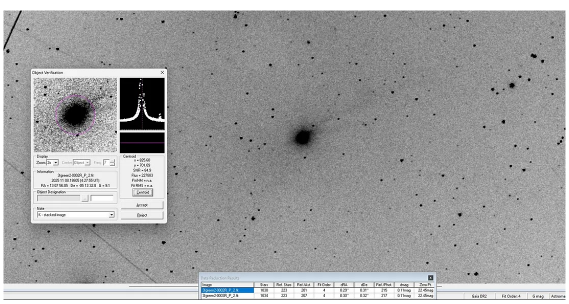
1. The bright central condensation is placed at the origin.
2. The broad anti-tail is aligned approximately along the horizontal axis.



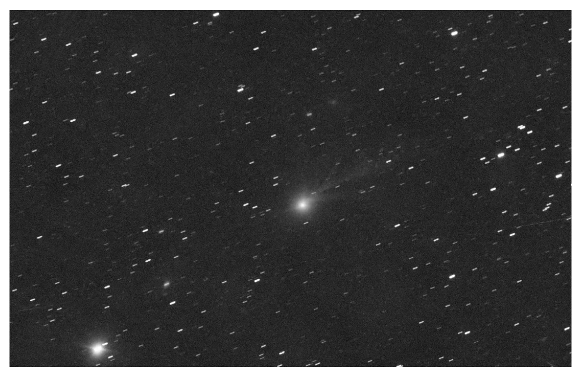

(a) Color image with multiple jets and bright core.




(b) Rayong rotational-gradient image with labeled anti-tail and tails.

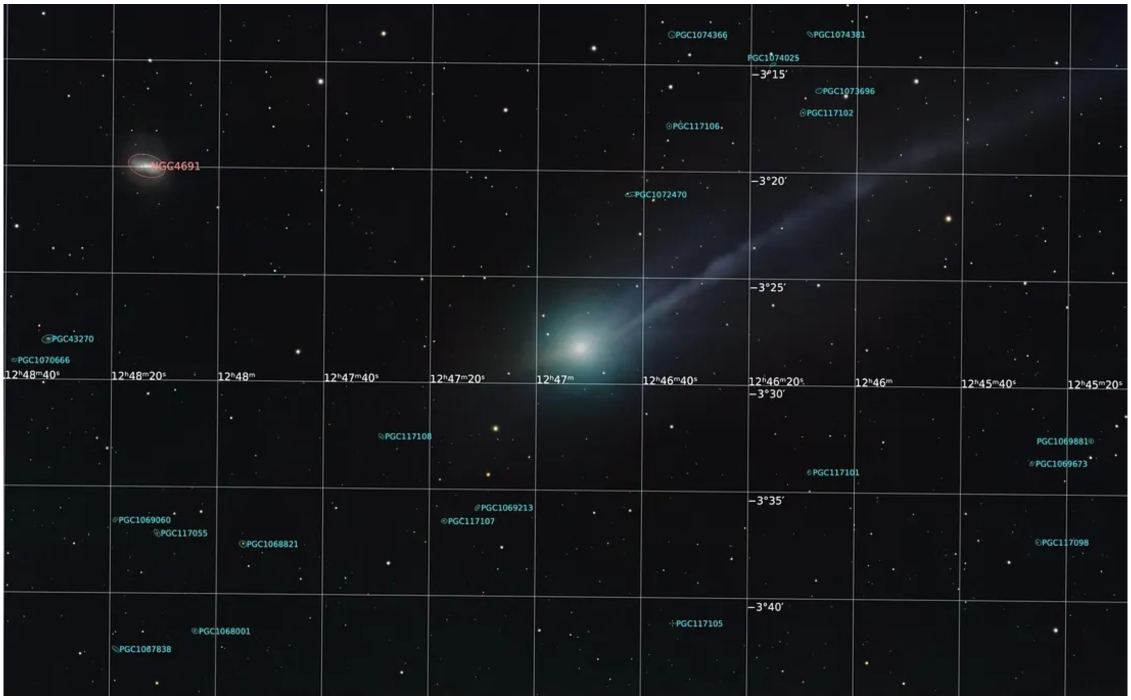


(c) Stacked grayscale image with extended jet.

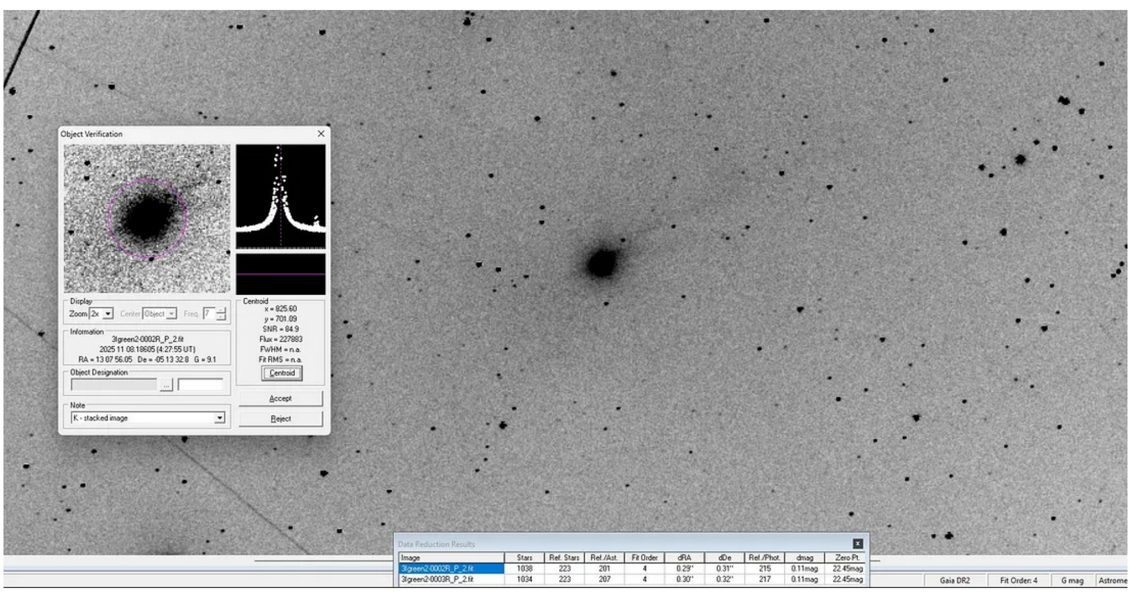


(d) Deep stacked image with multiple jets.

Figure 2: Selection of post-perihelion images of 3I/ATLAS compiled by Loeb (2025c,a). These frames consistently show a bright central condensation, a strong anti-tail, a narrower main tail, and multiple secondary jets in different directions, including a V-shaped pattern similar to that seen in the Cassandra leak.




(a) Wide-field grayscale view of extended jets.




(b) Same region on a coordinate grid with labeled galaxies, including NGC 4691.

Figure 3: Wide-field imagery of 3I/ATLAS and its environment, including the coordinate-grid version with identified background objects (Murata, 2025; Loeb, 2025c). The long, tightly collimated jet and the anti-tail structure are clearly visible and provide additional constraints on the global jet geometry.

3. The bright pair of jets that form a V shape in the upper-right quadrant of the Cassandra images is used as a fiducial feature.

After this registration, the V-shaped structure in the Cassandra images coincides closely with the corresponding jets in the Rayong rotational-gradient image and in the deep stacked grayscale images shown in Figures 2 and 3. The angles between the anti-tail, the main tail, and the V-shaped jets agree to within a few degrees, and the relative brightness ranking (brightest anti-tail, fainter main tail, still fainter secondary jets) is the same.

## 3.2 Qualitative Consistency

Several qualitative points follow from this registration:

- The number and approximate orientation of major jets in the Cassandra images are consistent with those seen in the later, independently obtained images, including the distinctive V-shaped pair.
- The presence of a strong sunward anti-tail and a much longer, tightly collimated jet in the opposite direction is common to all data sets.
- The fine structure of the jets, including small kinks and brightness variations, shows similar patterns when the images are aligned, despite being taken with different instruments, filters and exposure times.

While it is always possible that a forger could have anticipated such a configuration, any hypothetical forgery would have had to reproduce not only the gross morphology (anti-tail plus tail) but also the specific arrangement of secondary jets that only became widely known after the images compiled by Loeb (2025c,a) were released.

# 4 Implications for Authenticity and Anomaly Counting

## 4.1 Posterior Plausibility of the Cassandra Images

The morphological concordance described above increases the posterior probability that the Cassandra images are genuine, in the Bayesian sense. A random or purely invented image of a comet-like object would have to land, by chance, in a very narrow region of parameter space that reproduces all of the following simultaneously:

- A sunward anti-tail and anti-solar tail with the correct relative position angle.
- A V-shaped pair of jets in the same quadrant and with similar opening angle.
- Additional jet features and brightness structure consistent with independent observations taken with different instruments.

This multi-dimensional coincidence is difficult to obtain accidentally. Although we do not attempt to quantify this with a full probabilistic model for jet morphology, it can reasonably be treated as an additional qualitative anomaly feeding into the broader question addressed in Spinelli (2025): *What realistic generative process—natural or not—actually makes it easy to obtain this entire bundle of features at once?*

### 4.2 Relation to the Loeb-Scale Anomalies

The original probability analysis of 3I/ATLAS was based on twelve anomalies that combine orbital alignment, planetary targeting, jet energetics, composition, polarization, mass loss and dynamical behavior (Spinelli, 2025). Those anomalies are largely independent of detailed image morphology beyond the mere existence of jets and anti-tails.

The Cassandra–Loeb image comparison adds a new, more subtle ingredient: the *temporal* ordering of information. The Cassandra images appear to encode the same complex jet geometry that was only revealed later by independent observers. If the Cassandra images are genuine, they simply extend the observational record. If they are not, then the fact that they nonetheless match the later images becomes itself an additional improbability that must be explained.

Either way, the image comparison pushes us toward the same conceptual fork highlighted in Spinelli (2025): either we have witnessed an extraordinary yet purely natural configuration of an interstellar comet, or some alternative generative process—possibly technological—is at work that naturally produces this entire suite of properties.

## 5 HiRISE images and NASA's press conference

On 2025 November 19, NASA released the long–anticipated HiRISE image of 3I/ATLAS obtained by the Mars Reconnaissance Orbiter on 2025 October 2, together with supporting material from MAVEN and Perseverance (NASA/JPL-Caltech, 2025; NASA, 2025). The image was made public 43 days after the flyby, following a government shutdown that delayed data processing and distribution. In the days leading up to the release, Loeb discussed the expected spatial resolution of the HiRISE data ($\sim$ 30 km per pixel) and the scientific importance of a side–view on the anti–tail and jets (Loeb, 2025b).

The released HiRISE frame, shown in Figure 4, is heavily pixelated and smeared along the spacecraft–motion direction. NASA's official explanation attributes the loss of sharpness to the relative motion between the comet and the orbiter during the time–delay integration of the camera (NASA/JPL-Caltech, 2025). While motion smear is a well–known effect for line–scan imagers, it is notable that several Earth–based telescopes operated by advanced amateurs now deliver images with finer apparent structure in the inner coma and jets than the released HiRISE frame. Loeb's analysis of the press conference highlights this tension and raises the question of whether additional higher–quality HiRISE products exist but have not yet been released to the public (Loeb, 2025d).

From the perspective of this paper, the HiRISE result adds another layer to the Cassandra comparison. The morphology in Figure 4—a compact bright core with an asymmetric sun–facing component roughly aligned with the velocity vector—is broadly consistent with both the leaked Cassandra images and the later ground–based jet maps, but the level of detail is surprisingly modest for a dedicated high–resolution camera at only tens of millions of kilometres from the object. Whether one interprets this as merely an instrumental limitation, an artefact of data–processing choices, or an indicator that some information is being withheld, the HiRISE data do not reduce the morphological coincidence between the Cassandra leak and the later independent images; if anything, they reinforce the basic qualitative picture of a compact nucleus with a strongly anisotropic coma.

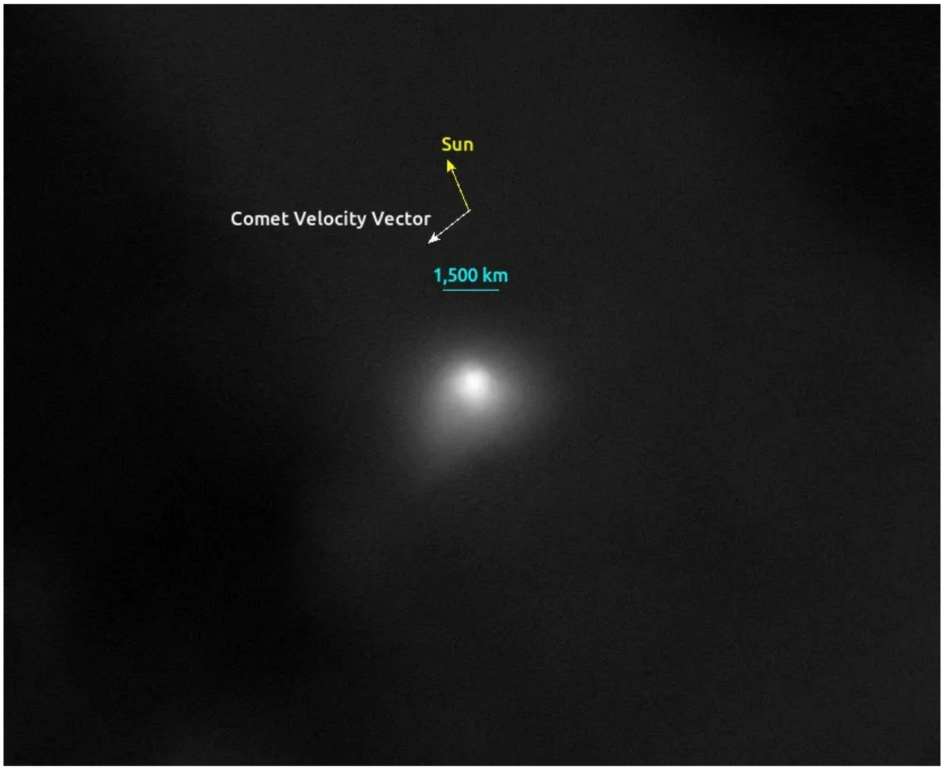



Figure 4: Annotated HiRISE image of 3I/ATLAS from the Mars Reconnaissance Orbiter on 2025 October 2, showing the comet as a compact bright condensation with an asymmetric extension in the general direction of its velocity vector and the Sun. The scale bar corresponds to 1,500 km at the comet's distance. Credit: NASA/JPL–Caltech/University of Arizona; annotation adapted by J. C. Spinelli.

# 6 Conclusions

The Cassandra leak and the later post-perihelion images of 3I/ATLAS present a consistent morphological picture: a bright nucleus, a strong sunward anti-tail, a long anti-solar tail, and multiple secondary jets, including a distinctive V-shaped pair in the upper-right quadrant when the images are suitably registered. This concordance is difficult to ascribe to chance if the Cassandra images were fabricated independently of the later data.

While morphology alone does not prove authenticity, the agreement increases the plausibility that the Cassandra leak represents genuine observations of 3I/ATLAS and should therefore be considered alongside the officially reported data. In this sense, the Cassandra images contribute an additional qualitative anomaly to the already striking bundle of Loeb-scale anomalies. The central scientific question remains: *what realistic generative process—natural or not—makes it easy to produce this entire bundle of features at once?*

Future work could attempt a more quantitative morphological comparison, for example by fitting parametric jet models to both the Cassandra and post-perihelion images and embedding the resulting parameters within the Bayesian framework of Spinelli (2025). For now, the qualitative concordance is already sufficient to sharpen the tension between traditional cometary interpretations and the technological-hypothesis alternative.

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