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# Fast Astronomical Transients in Archival Photographic Plates: Using optical aberrations as a tool for discerning real images, from plate artifacts

Ivo Busko
*Independent Researcher, Retired Developer at NASA*

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ABSTRACT

The detection of fast astronomical transients in photographic plates from the Palomar sky surveys conducted in the 1950s, was subject to the criticism that such transients could be just the effect of otherwise unaccounted for plate artifacts. In this paper, we show that transient images exhibit the coma aberration pattern expected from off-axis point sources recorded through the telescope optics, a signature that plate artifacts cannot naturally reproduce. Although the data does not by themselves establish the physical origin of the light that generated the images, they lend support to hypotheses that do not rely on instrumental effects to explain transients.

## 1. INTRODUCTION

In this paper, we present first results from a search of optical transients carried out in the context of the VASCO Project (Vanishing & Appearing Sources during a Century of Observations, B. Villarroel et al. 2020 ), but using different methodology and data. Methodology and data were described previously (I. Busko 2026a, henceforth Paper I). In short, we resort to data provided by the Archives of Photographic PLates for Astronomical USE (APPLAUSE)[1], and we search for individual transient events, as opposed to the statistical approach used by the VASCO team. Using a different data set than the digitized versions of the Palomar Observatory Sky Surveys (POSS, S. G. Djorgovski et al. 2003) used by VASCO enables us to independently test their findings, although at a cost: because the POSS was conducted as a homogeneous survey over most of the sky, with a single telescope, the resulting data set can be reliably used to build statistically complete samples from which sound statistical information can be gathered. The APPLAUSE archive, on the other hand, being a collection of photographic plates taken for different scientific purposes, and using different telescopes, does not lend itself easily to the construction of large and homogeneous data sets. This is the underlying reason why we adopted the search procedure described in Paper 1.

Regardless of the data and method used, the main problem is that a plate artifact can potentially be mistaken as a legitimate transient. Plate artifacts result from a large number of causes. Some are simple to understand, such as dust particles and micro-hairs, deposited or attached both on the plate surfaces and on the scanner bed. Also, finger prints, scratches, and blemishes introduced by careless manipulation. Other causes are more exotic in nature but no less damaging, such as ambient radiation, chemical issues during plate development, manufacture defects. An important issue is aging: plates stored for many decades inside a paper envelope can develop markings and spots caused by the envelope slowly leaching chemicals. Particles firmly attached, or even embedded in the emulsion layer, can slowly leach chemicals into the emulsion as well. Most of these artifacts can be easily filtered out after the plate is scanned, with software such as SExtractor (E. Bertin & S. Arnouts 1996). But a small but persistent subset will remain, because they mimic so well the appearance of real stars that were truly imaged by the telescope.

An often raised criticism to the proposal that transients were recorded by these old plates is that they could be just plate artifacts that somehow managed to elude the analysis and statistical tools used to find them. Although a number of works already produced sound statistical evidence that true transients exist (B. Villarroel et al. 2020; B. Villarroel et al. 2025b; S. Bruehl et al. 2026), it would be reassuring to be able to confirm their existence through independent data sets and methodologies.

[1] https://www.plate-archive.org/cms/home/

## 2. COMA OPTICAL ABERRATION

In the project described on Paper 1, we focussed on plates obtained with the *Hamburger Sternwarte Großer Schmidt-spiegel* 1.2-m camera. Being of Schmidt design, the images it produces are remarkably free of optical aberrations that can deform the image produced by a point source. However, this much sought-after feature, so useful in most astronomical research, turned out to be a liability for this project. The reason is that the sharp and very round images the camera creates from point sources, are difficult to tell apart from some types of artifacts. There is a significant population of artifacts that look very round, and sometimes even a bit sharper that star images. To the point that one cannot distinguish between them based on common measures such as radial profiles, widths, circularity figures-of-merit, and others.

However, the APPLAUSE archive hosts data from many historical telescopes, and some of those are prone, sometimes very significantly, to optical aberrations. A common type of aberration in simple telescopes is *coma* (from the latin *coma* or greek *koma* meaning "hair of a comet"). It is caused by light rays coming into the telescope at an angle with the optical axis, and thus losing their symmetry in relation to the optical surfaces. This results in elongated images that resemble a tiny comet with its tail (V. Sacek 2006).

We could in principle use the coma properties delineated in Figure 1 to tell apart images that resulted from light that traversed the telescope, from plate artifacts that have no relationship with optics.

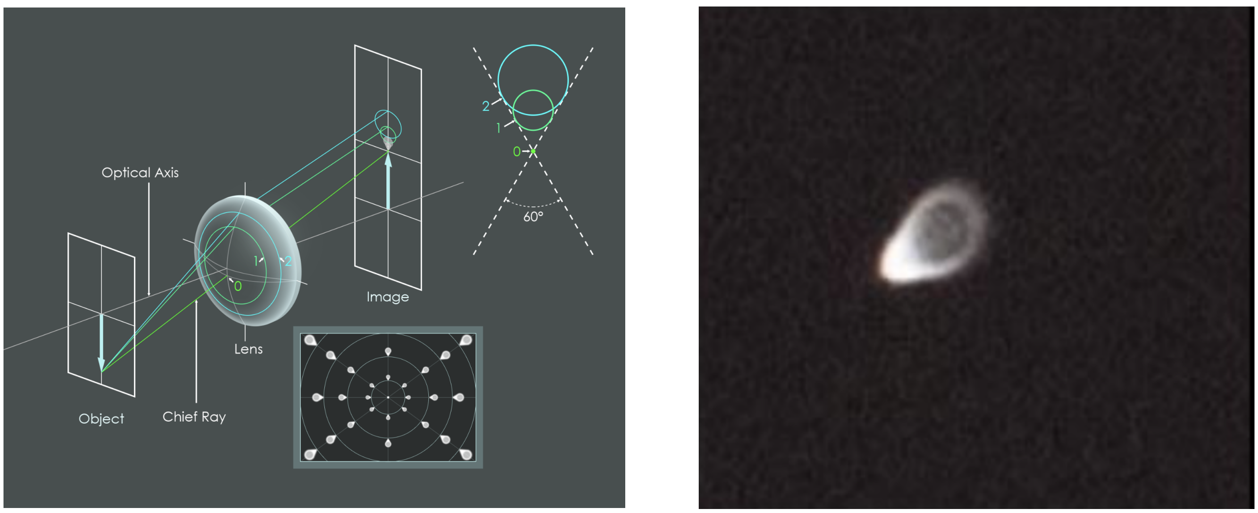


**Figure 1. Coma:** light rays from a point source, coming at an angle into the optics, result in an elongated light distribution at the focal surface. The light distribution is built from continuously enlarged circles, as one moves away from the chief ray towards the plate edge. These circles are essentially defocussed images of the point source, that is, they are images of the lens *pupil*. The locus where all these circles overlap each other has the appearance of two symmetrical "wings". The light rays passing at the very edge of the optics result in the "tail" ending in a semi-circular contour, which delineates the edge of the defocussed image of the optic's pupil. The inset on the left panel shows how the aberration is lined up towards the center of the field, and how the tail's size increases as one moves from center to edge of field. Right panel shows an actual star image. (graphics by M. Kohlpaintner 2026, coma image by S. Prahl 2019).

## 3. DATA AND METHODOLOGY

Data from the *Hamburger Sternwarte Doppel-Reflektor* 0.6-m parabolic mirror telescope was selected for this project, because its images are affected by significant coma, and because enough plate pairs appropriate for the transient search could be found at the archive holdings.

A total of 532 plate pairs, spanning the years from 1934 to 1957, was found to satisfy the Field-Of-View (FOV) overlap and matching exposure time and emulsion criteria (Paper I). To avoid contamination by space debris left over by the space programs, which do generate glints from reflected Sunlight, October 1957 was chosen as sample cutoff because it is the launch date of Sputnik. Most plates used in this work cover FOVs typically about 2.2° X 1.5°, and were scanned at a resolution of 10.583 $\mu$m/pixel. The resulting digital files are typically 12,000 x 8,000 pixels in size.

Table 1 lists some global parameters associated with the data set.

Table 2 shows the relevant parameters of the plates where transients were found.

**Table 1.** Data set parameters

| parameter | value | unit |
|---|---|---|
| Total plates: | 532 | |
| Total plate pairs: | 407 | |
| Total exptime: | 145.23 | hour |
| Total sky area: | 1871.56 | sq. deg |

**Table 2.** Plate pairs with transients

| Plate IDs[a] | UT 1[b] | UT 2[b] | Exptime (s) | Emulsion |
|---|---|---|---|---|
| 62525 - 62526 | 1949-04-20 21:56:26 | 1949-04-20 22:51:47 | 1800 | Agfa Astro Z |
| 62962 - 62963 | 1950-12-09 22:51:38 | 1950-12-09 23:06:35 | 600 | Agfa Astro Panchrom. |
| 62964 - 62965 | 1950-12-09 23:28:31 | 1950-12-09 23:44:29 | 600 | Agfa Astro Panchrom. |
| 63037 - 63038 | 1951-02-08 21:09:24 | 1951-02-08 21:29:21 | 600 | Agfa Astro |
| 63054 - 63055 | 1951-03-04 18:54:08 | 1951-03-04 19:11:06 | 720 | Agfa Astro |
| 63501 - 63502 | 1953-04-19 22:42:08 | 1953-04-19 23:08:03 | 1200 | Kodak Oa-O |

[a] unique IDs generated by APPLAUSE.

[b] UT at mid-exposure.

Note—Plate pairs have the same exposure time and emulsion on both plates.

The data analysis procedure outlined in Paper I was initially conceived with the Schmidt camera images in mind. As such, it partially relies on parameters produced by Gaussian fitting to star images, as well as shape information generated by computer vision algorithms, in an attempt to filter out artifacts and eventually produce a short list of transient candidates. These candidates have in turn to be vetted visually, since the filters are far from perfect and let a significant number of artifacts to be tagged as valid transient candidates.

For the Doppel-Reflektor data, because of the presence of coma, the processing was modified in three ways: (i) Gaussian fitting was allowed to work on a more relaxed set of bounds; (ii) filters applied on computer vision shape parameters were turned off, and (iii) the visual vetting process was speeded up. The processing procedure also applies filters on a variety of parameters generated by Sextractor and made available in the APPLAUSE-generated tables. These filters were kept in place, since they greatly help to eliminate the most egregious artifacts.

False positives among the remaining candidates were then weeded out by cross-checking against the USNO catalog (D. G. Monet et al. 2003) (the Gaia catalog, Gaia Collaboration et al. 2023, is already used by the pipeline search algorithm), and visually against the corresponding regions in POSS-II blue plates. In some more interesting plates, we actually blinked (with *ds9*, W. A. Joye 2006) the entire plate pair in an attempt to detect transients that might have eluded the automated procedure.

The visual vetting process used in this work relies on criteria based on the properties of the coma signature, and how these features actually appear on images within a range of signal-to-noise levels: (i) comatic images must appear aligned with the direction that points to the center of the plates; (ii) wings should be visible, and, if not, at least an asymmetry in the light distribution towards the correct direction of the coma must be visible; (iii) the size and visibility of the coma must be consistent with the distance to the plate's center and its overall brightness; (iv) photographic effects such as saturation and halation on bright sources, but especially possible emulsion reciprocity failure on faint sources, must to be taken into account when visually evaluating those images.. For each candidate, these features were evaluated against a set of star images in the neighborhood of the candidate, with peak flux within 0.1 magnitude of the candidate's peak flux.

**Table 3.** Transient properties

| Plate ID[a] | Source ID [a] | R.A. | Dec. | $m_v$ |
|---|---|---|---|---|
| 63054 | 40649850007759 | 2 28 28.3 | +57 07 55 | 7.1 |
| 63054 | 40649850009785 | 2 19 00.5 | +57 31 53 | 7.9 |
| 63054 | 40649850006760 | 2 16 49.5 | +57 06 38 | 9.1 |
| 63037 | 40649680004453 | 2 17 24.6 | +57 33 08 | 10.0 |
| 63501 | 40654930007682 | 13 14 07.1 | +18 08 31 | 10.2 |
| 63038 | 40649690003944[b] | 2 14 49.7 | +57 33 57 | 10.6 |
| 63501 | 40654930007722 | 13 14 08.8 | +18 08 07 | 10.4 |
| 63501 | 40654930007709 | 13 14 08.0 | +18 07 47 | 10.5 |
| 62964 | 40648950008626 | 2 24 06.1 | +57 22 13 | 10.6. |
| 62962 | 40648930008575 | 2 17 54.3 | +57 37 30 | 10.9 |
| 62525 | 40644250018738 | 13 13 37.4 | +17 13 43 | 11.9 |

[a]unique IDs generated by APPLAUSE.

[b]appearing transient; all others are vanishing transients.

It should be noted that the data analysis algorithm described in Paper I was designed around the concept of *vanishing* transients. It cannot detect *appearing* transients, that is, objects that show up on a plate but do not appear on the *previous* plate. In some cases, the finding algorithm was run backwards so as to verify the existence of these appearing transients. Because this was not done on all existing plate pairs, it is quite possible that some appearing transients were not detected.

It also should be stressed that these transients were found basically visually. This was possible because plate artifacts do not show features, at the level examined in this work, that can be easily confused with true point source comatic images. Nevertheless, the knowledge gathered with the visual vetting process is fundamental for developing a control sample that could be incorporated into a more automated process.

Findings in this report should be taken as preliminary only. A full fledged quantitative analysis based on measured image parameters will be presented in a forthcoming paper, where more data from other telescopes will be added in an attempt to address the shortcomings of the small sample included in this paper. It should be noted that the main goal of this paper is not to provide results under a statistically rigorous framework, but just to present evidence that transients are the result of points of light on the sky.

The resulting transients are listed in Table 3

## 4. RESULTS

Images of the transients are shown in Figures 2 to 9. These images are direct evidence that the transients resulted from light that actually traversed the optical train of the telescope, thus invalidating the plate artifact argument, *at least for these transients*. It does not mean that other transients already reported in the literature were not originated by plate artifacts.

Of note is the fact that transients cover a relatively wide range of brightnesses, including three very bright ones, all on the same plate on March 4, 1951. Nothing can be said about the other end of the brightness scale, however, since our sample is incomplete in a variety of senses. The weakest transient identified as such would suggest that the sample would have a limit of around $m_v \approx 11$. Concerns about confirmation bias on a basically visual identification method are valid at these lower brightnesses, but the sample also includes brighter transients that find no counterpart on known plate artifacts that superficially have the appearance of comatic images of point sources.

However, we do not know anything about the actual duration of each transient. The magnitudes in Table 3 assume that the transient behaved like a star, that is, was exposed by the same exposure time everything else on the plate was. But under the hypothesis that they are events of short duration, the actual brightness would be much larger. For example, a $m_v \approx 10.$ transient that lasted 1 sec. and was recorded on a plate with 15 min. exposure time, would have an actual brightness of $m_v \approx 2.6$.

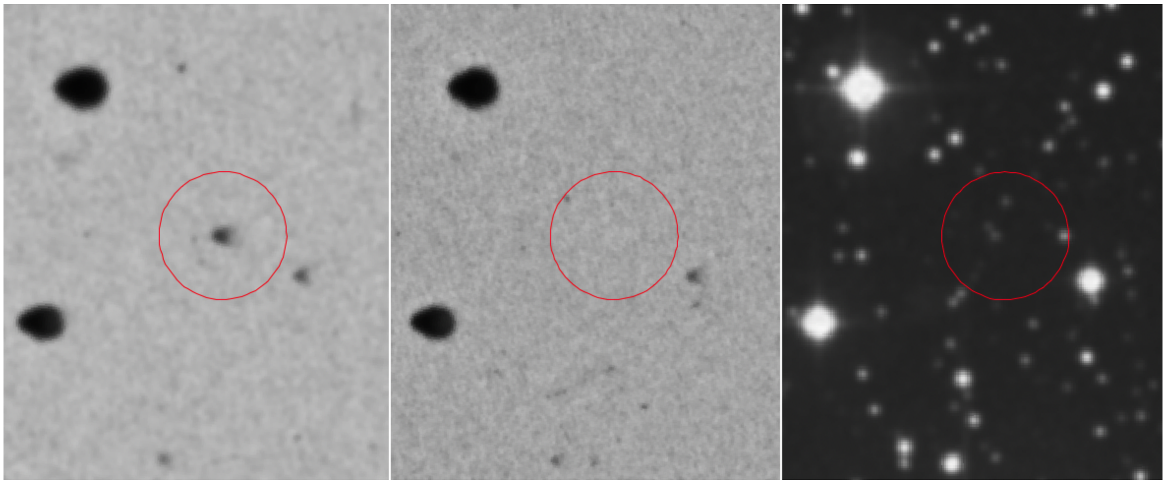

**Figure 2.** Transient 40649850006760 from plate pair 63054 (left) and 63055 (center). Negative (photographic density) scale is used to highlight faint detail. See Figure 6 for a detail of the transient itself. Right panel depicts the same field as it appears on the POSS-II blue plate.

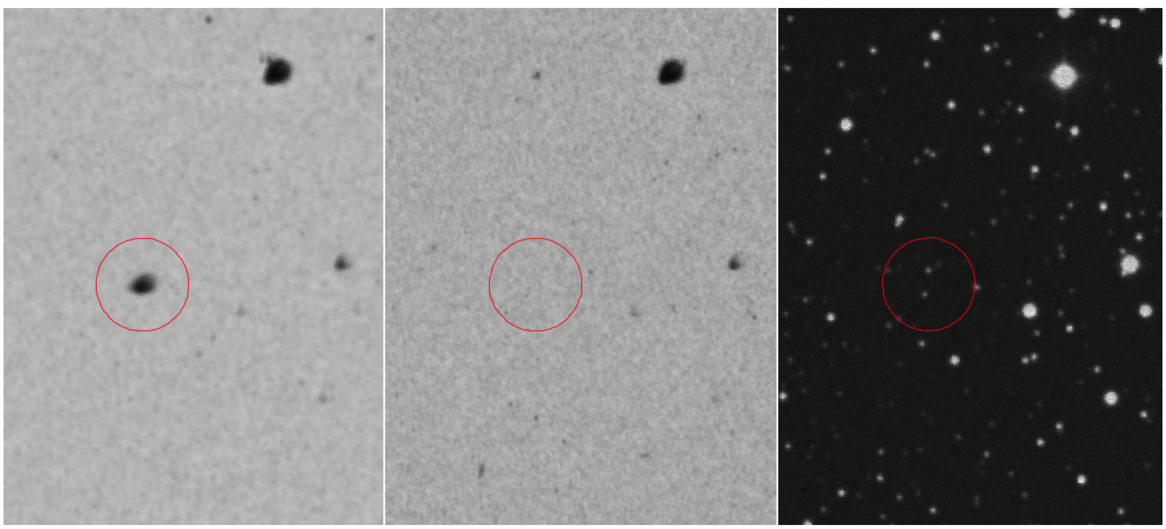

**Figure 3.** Transient 40649850009785 from plate pair 63054 (left) and 63055 (center). Negative (photographic density) scale is used to highlight faint detail. See Figure 6 for a detail of the transient itself. Right panel depicts the same field as it appears on the POSS-II blue plate.

The detected events appear clustered in both time and sky position; however, the statistical significance of this pattern cannot yet be assessed because of the non-uniform sampling of the dataset. Table 3 shows seven transients detected on a patch of sky around RA=2:17, Dec=+57, and four transients similarly detected close on the sky, around RA=13:14, Dec=+18. This all happens in a window between 1949 and 1953, other years being devoid of detections (there are about 50 plate pairs in between 1934 and 1949, and 70 plate pairs in between 1953 and 1957, the sample cutoff).

On December 9, 1950, a vanishing transient on plate 62962 is followed by another vanishing transient on plate 62964. Their mid-exposure times are separated by 30 minutes, and they are about 1.5° apart on the sky (Figures 8 and 9).

On the same vein, on February 8, 1951, a similar sequence of events shows up *in the same sky field as the December 9, 1950 transients*: a vanishing transient on plate 63037, followed by an appearing transient on the plate immediately after, 63038. Their mid-exposure times are separated by 20 minutes, and they are separated on the sky by about 35′on an almost E-W direction. Their shapes and brightnesses look similar, since they are close on the plate, thus have similar coma structure (Figures 5 and 6).

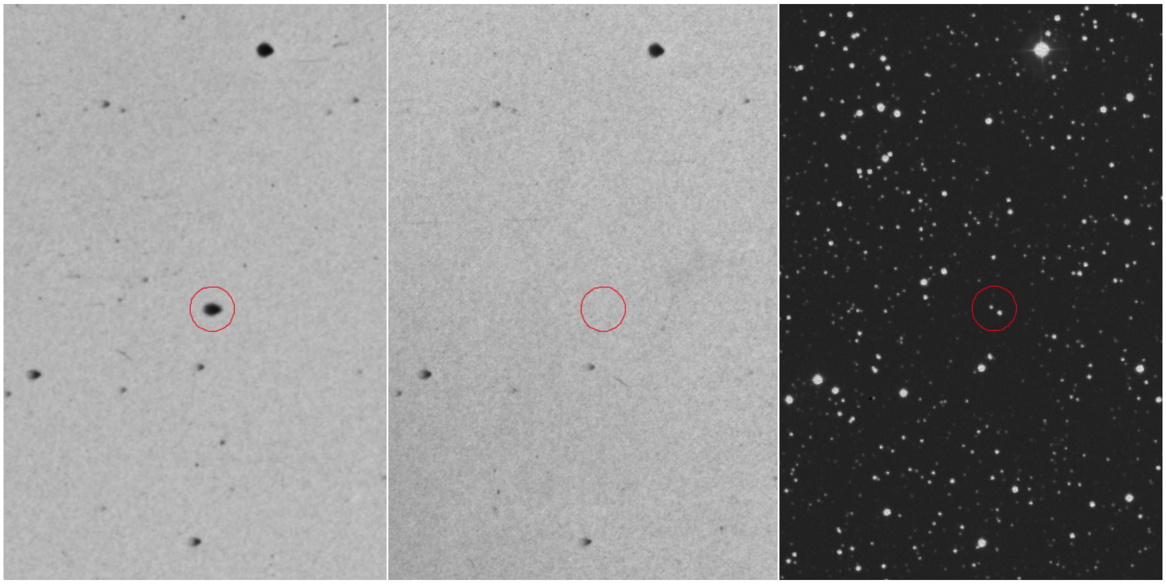

**Figure 4.** Transient 40649850007759 from plate pair 63054 (left) and 63055 (center). Negative (photographic density) scale is used to highlight faint detail. A larger, 15′X 8′field of view is show in order to display the neighborhood of the event. See Figure 6 for a detail of the transient itself. Right panel depicts the same field as it appears on the POSS-II blue plate.

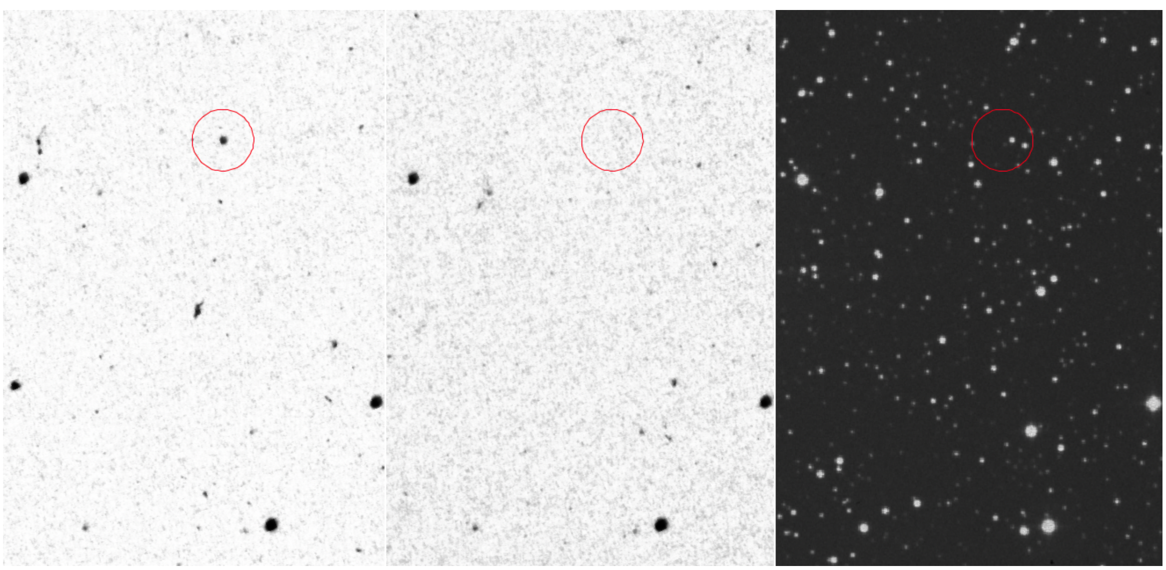

**Figure 5.** Transient 40649680004453 from plate pair 63037 (left) and 63038 (center). Negative (photographic density) scale is used to highlight faint detail. See Figure 6 for a detail of the transient itself. Right panel depicts the same field as it appears on the POSS-II blue plate.

Asteroids can be ruled out as the cause of these transients, however, since no blurring is visible on the 10 min. long exposures, and the distance travelled is inconsistent with typical asteroid speeds. The Minor Planet Center asteroid finding tool also returns empty for both date, time, coordinates data sets.

Following the above, on March 4, 1951, three very bright events were recorded again on the same patch of sky as the ones described above (Figures 2, 3, 4 and 6). Of note is the fact that the photographic image of the brightest event shows evidence of *saturation* of the emulsion response to light, and *halation*, the result of light backscatter in the emulsion layer. These further confirm that the image resulted from light acting on the emulsion, and not a plate defect.

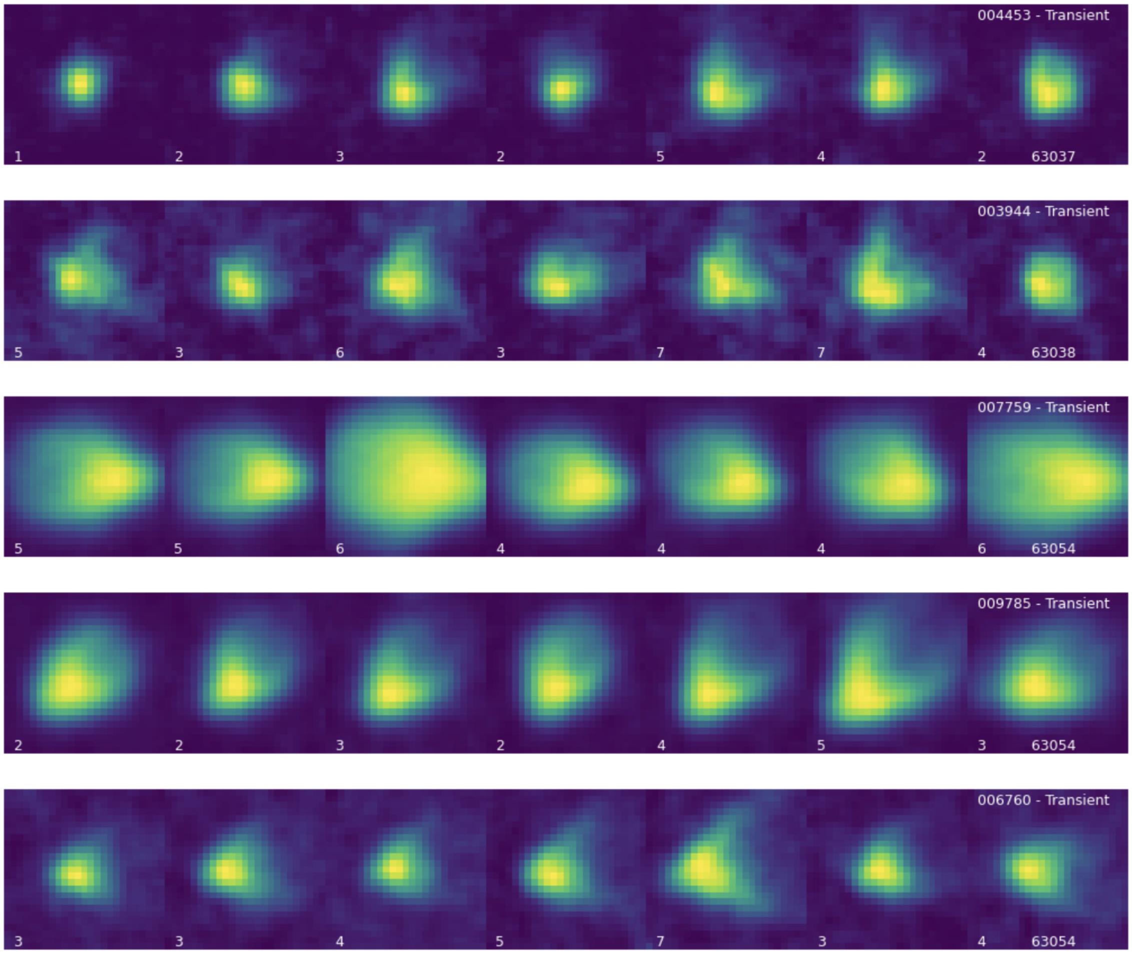


**Figure 6.** Transients displayed together with some reference stars in their respective neighborhoods. Reference stars were chosen within 0.1 magnitude of the transient's peak flux. The transient is the rightmost image on each row, identified by the last 6 digits of its source ID (as per Table 3). The numbers at the bottom indicate, left: the *annular bin*, and right: the plate ID. Annular bin is an APPLAUSE concept to codify distance to center of plate: 1 at center, 9 at the edge. Pseudo-color log photographic density scale is used to balance visibility in between the faint structures at the wings, and the bright core.

The other four transients are also remarkable, because one happened on April 20, 1949, but the other three, on April 19, 1953, showed up *in the same sky field as the April 20, 1949 transient*, all three packed together in a very small region of about 45″(Figures 10 and 11). One could argue against the classification of these three events as true transients, given their appearance, significantly narrower than stars of same peak flux. On the other hand, that might be in fact a clue that they were produced by brief pulses of light. Because the temporal power spectrum of atmospheric-induced seeing falls very quickly with frequency ($\propto f^{-8/3}$, V. I. Tatarskii 1971), most of what the photographic plate records as seeing is caused by image wander. A short flash of light will be less affected by that effect, and thus will result in a much sharper image. However, that image will still carry the coma signature. That signature might in turn be rendered less visible, in weak images, due to emulsion reciprocity failure at these short exposure times. The appearance of the three recorded events can be explained in those grounds (other weak transients in this work partially share the same properties). It seems rather unlikely that all three would be caused by plate artifacts that happen to have an asymmetry of same magnitude and, most importantly, oriented in the same direction exhibited by the coma on neighboring star images. It should be noted that the concept of transients looking sharper than stars due to short exposure times was already proposed by B. Villarroel et al. (2025a).

Given the patchy sampling of sky and timeline imposed by the data set used in this work, one cannot rule out that some, or all, those spatial and temporal groupings described above are just caused by sampling. Although that would imply that these transients are commonplace, and wherever and whenever one looks, one will be bound to easily find

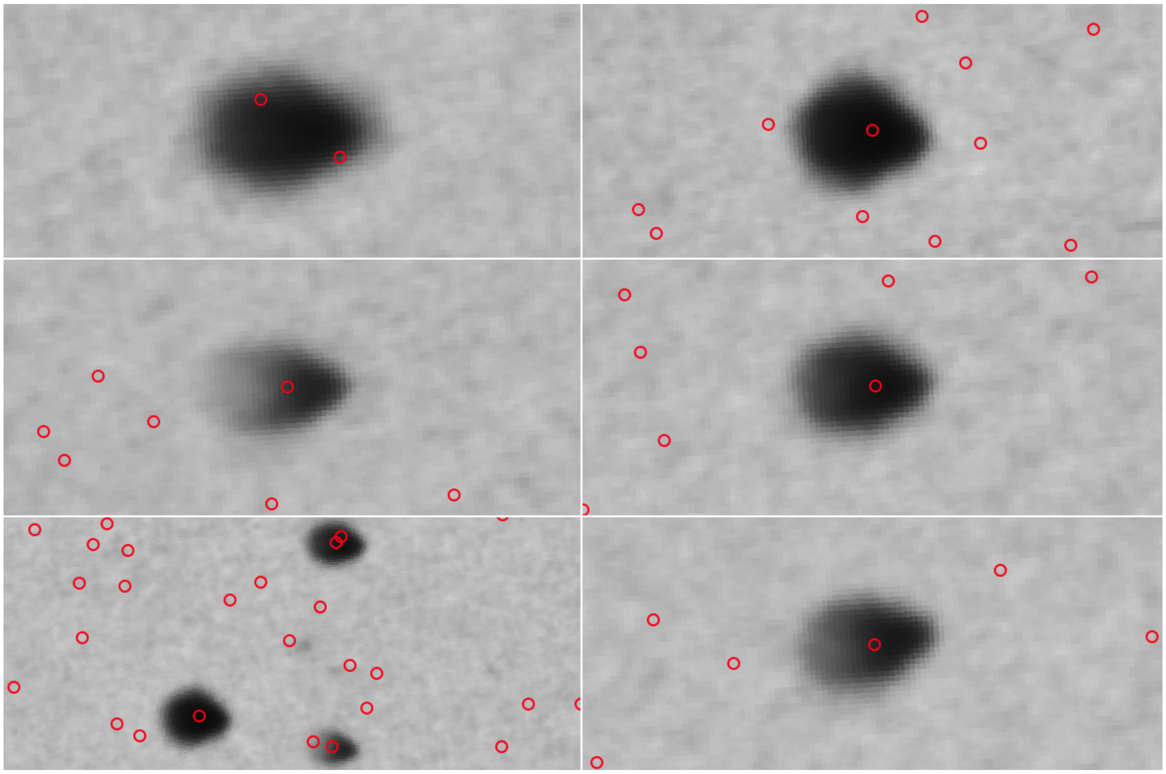

**Figure 7.** Detail of transient 40649850007759 at top left shows the position of USNO reference stars near its location. The other panels depict some typical stars near the transient location. They illustrate how their USNO catalog position relates to the comatic star image. That position is typically near the apex of the triangular wing structure, symmetrically centered on it. It is the point of peak intensity (V. Sacek 2006). This is observed in all stars on that particular plate. On the transient image, on the other hand, we do not see that, but instead we see the off-centered positions of the two faint stars visible within the circle in the POSS-II image in Figure 4. This shows that the origin of the transient is not likely to be one of those two stars. Negative (photographic density) scale is used to better highlight faint detail and structure of the coma images.

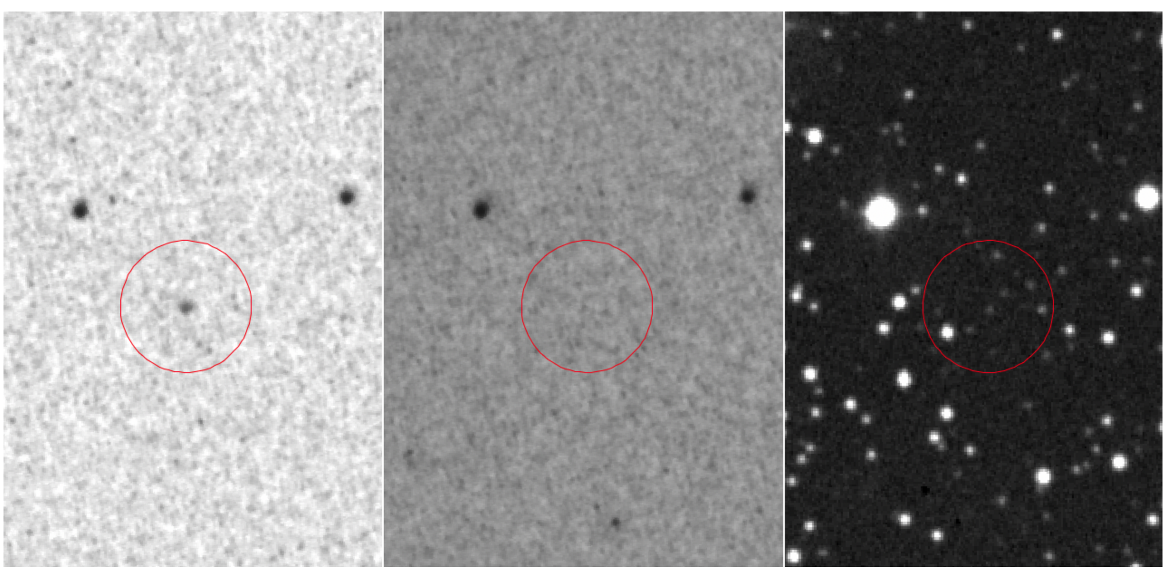

**Figure 8.** Transient 40648930008575 from plate pair 62962 (left) and 62963 (center). Negative (photographic density) scale is used to highlight faint detail. See Figure 9 for details of the transient itself. Right panel depicts the same field as it appears on the POSS-II blue plate.

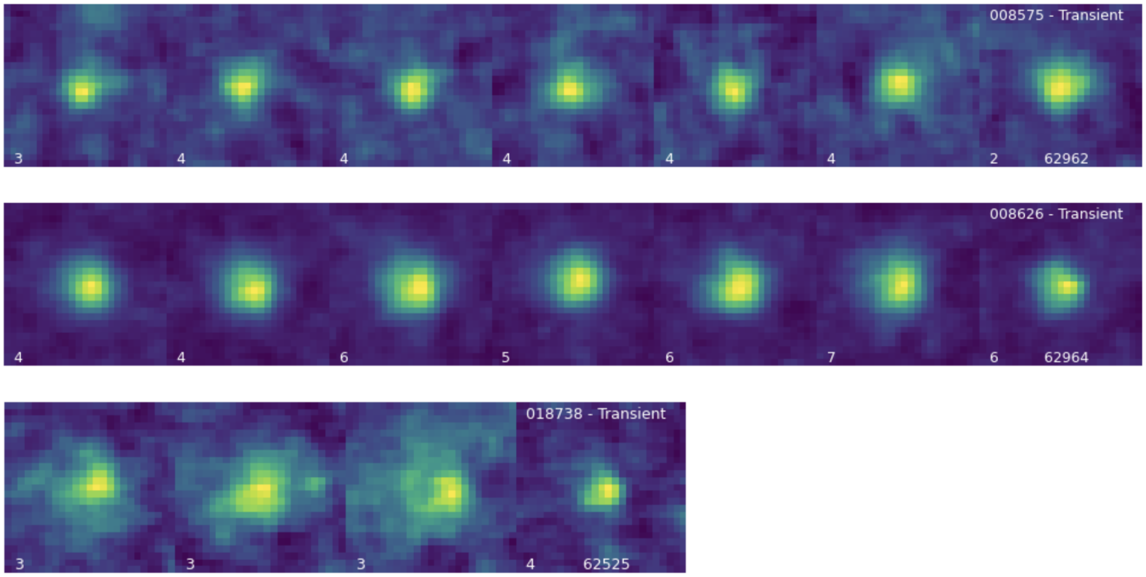


**Figure 9.** Possible transients at the limit of detection displayed together with some reference stars in their respective neighborhoods. Reference stars were chosen within 0.1 magnitude of the transient's peak flux. The transient is the rightmost image on each row, identified by the last 6 digits of its source ID (as per Table 3). The numbers at the bottom indicate, left: the *annular bin*, and right: the plate ID. Annular bin is an APPLAUSE concept to codify distance to center of plate: 1 at center, 9 at the edge. Pseudo-color log photographic density scale is used to balance visibility in between the faint structures at the wings, and the bright core.

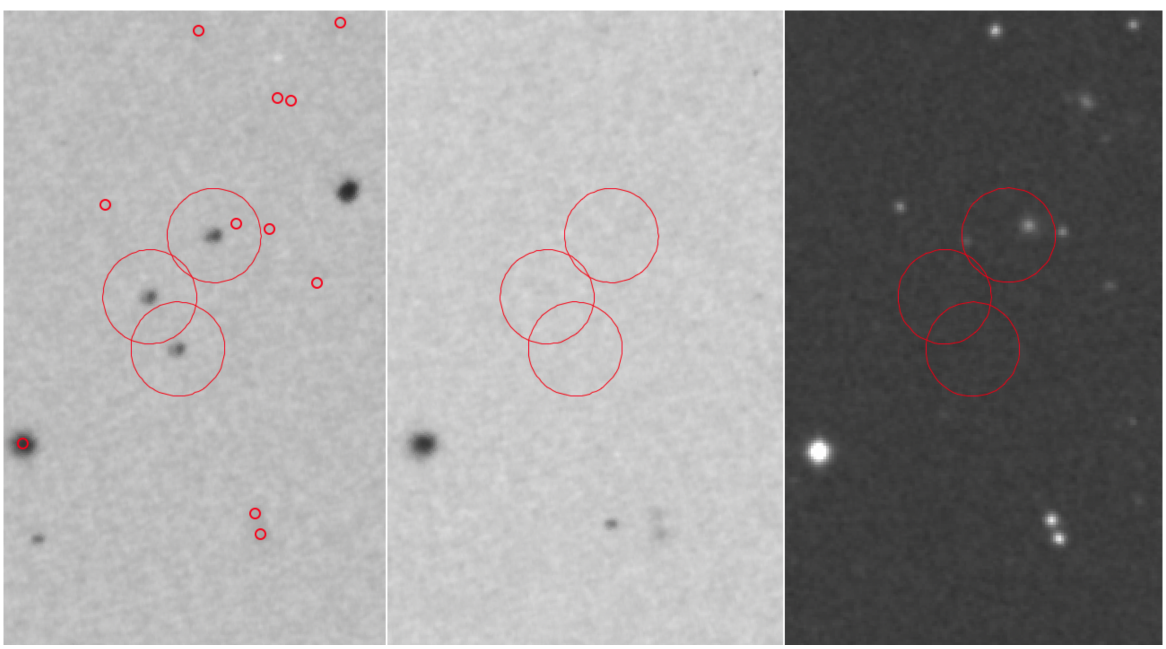

**Figure 10.** Three transients from plate pair 63501 (left) and 63502 (center). Negative (photographic density) scale is used to highlight faint detail. Small red circles indicate star positions from the USNO catalog. See Figure 11 for details of the transients themselves. Right panel depicts the same field as it appears on the POSS-II blue plate.

them. The groupings might as well be interpreted as the effect that a single, moving object, could be the cause of multiple grouped transients, although we do not have enough data to reach any firm conclusion in that regard. These topics will be better addressed on a forthcoming paper were more data from other telescopes will be added in order to increase the sample size to a point were meaningful statistical inferences can be made.

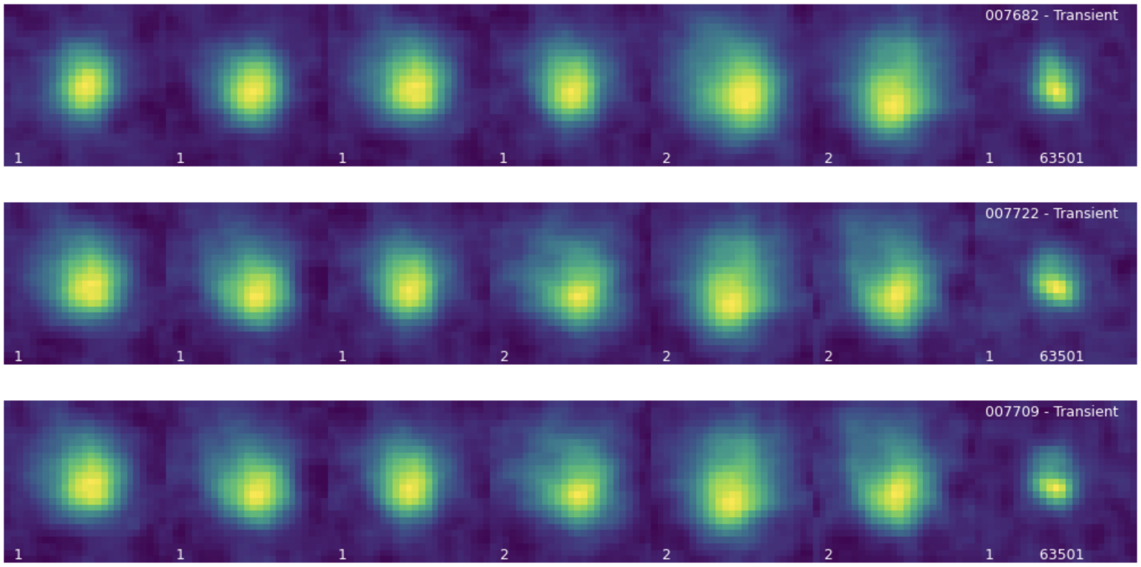


**Figure 11.** The three transients from Figure 10 displayed together with some reference stars in their respective neighborhoods. Reference stars were chosen within 0.1 magnitude of the transient's peak flux. The transient is the rightmost image on each row, identified by the last 6 digits of its source ID (as per Table 3). The numbers at the bottom indicate, left: the *annular bin*, and right: the plate ID. Annular bin is an APPLAUSE concept to codify distance to center of plate: 1 at center, 9 at the edge. Note that these transients are located at annular bin 1, near the center of the plate. Pseudo-color log photographic density scale is used to balance visibility in between the faint structures at the wings, and the bright core.

Of note are also possible associations present in our sample, with nuclear weapon testing. These associations were first observed by S. Bruehl & B. Villarroel 2025 in the POSS data. Several events in the presented sample occurred within days or weeks of atmospheric nuclear tests. Whether this reflects a genuine correlation, or a chance coincidence, cannot be assessed with the present sample.

The following presents some possible associations that might exist in our data set.

- two weak transients happened two days after Operation Ranger, conducted in the Nevada Proving Ground between January 27 and February 6, 1951, executed the last of five explosions in the test run.
- three transients, the brightest in our sample, happened on March 4, 1951, about one month after the last explosion in the Ranger test run.
- a triple transient occurred Apr 19, 1953, one day after Operation Upshot-Knothole run the 6th explosion in their test run, after other five that started on March 17.

Then again, in 1950 there were no nuclear tests in the entire world, and our sample has two transients in that year. In Aug 29 1949 the URSS conducted the only nuclear test that year, in the world, and our only transient in that year predates the test by about four months.

## 5. CONCLUSIONS

Results presented in this paper provide independent evidence for the reality of fast transients in archival photographic plates, using a data set and methodology independent of other previous work on the subject performed by the VASCO Project. Although that work produced solid evidence of the reality of the transient phenomenon, there is still some lingering skepticism about it, mostly based on the argument that such transients can be mimicked by certain photographic plate artifacts.

The search presented here, performed on data made available by the APPLAUSE Archive, yielded images of transients that contain the optical signature of telescope coma, which is strong evidence that these were created by light that passed throughout the optics of the telescope, and not by plate artifacts.

The data set consists of 525 plates produced by the Hamburger Sternwarte Doppel-Reflektor 0.6-m telescope, during the period 1934 to 1957. That telescope creates images that are mildly affected by coma. Using a slightly modified methodology as the one presented in Paper I, we found eleven transients on that data set.

The transients exhibit a remarkable degree of clustering, both in time as in space. All eleven showed up on only two small regions of the sky, even when appearing on separate nights. They also all happened in the period 1949 - 1953, even though the data set has about half of its plate pairs outside that window.

Explanations for the transient phenomenon were advanced by several authors. Hyphotheses based on plate artifacts (N. Hambly & A. Blair 2024) are not supported by the findings in this work, although we still need to further develop the comatic-image technique with better sampling and an automated identification algorithm.

Other hypothesis based on non-astronomical causes for these transients still exist (the astronomical ones were examined by E. Solano et al. 2022). B. Villarroel et al. 2021 shows that micrometeorites seen face-on are not a good explanation. Ghosting and internal reflections on the optics can be dismissed by the fact the present work relies on pairs of plates: if ghosting from star images in the field happened, it should show up on both plates and thus be automatically excluded from the results. Hypotheses based on little-known upper atmosphere effects still need to be further developed.

However, the data presented here are consistent with two non-astronomical hypotheses advanced in recent years. Although the plate sample is not complete and homogeneous enough for us to draw a statistically meaningful conclusion, the data is consistent with the association that S. Bruehl & B. Villarroel (2025) found to exist between transients and nuclear weapon testing. On the same token, the data are also consistent with the hypothesis that these transients may be Sunlight glints generated by tumbling, mirror-like objects in space, in the vicinity of Earth (B. Villarroel et al. 2025a).

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*Software:* plateanalysis (I. Busko 2026b), Source Extractor (E. Bertin & S. Arnouts 1996), *ds9*, (W. A. Joye 2006)

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