Classification of Non-Solar Artifacts in Four STEREO/EUVI and SDO/AIA Browse Images

Author: MonkeeSage

Date: 2026-11-09

Abstract

We examine five localized, non-solar features in four publicly available extreme-ultraviolet (EUV) browse images of the Sun: one from the STEREO-A EUVI 195 Å telescope (2010) and three from SDO/AIA (335 Å in 2013, 193 Å in 2017, and a 304/211/171 Å composite in 2019). We compare each feature with the artifact taxonomy published by the STEREO Science Center (SSC) [1], check whether it persists in neighbouring frames, and examine its morphology at the pixel level. We then check each feature against the underlying science data: the EUVI Level-0 frame, and the AIA Level-1 frames together with the "spikes" files that record what the ground despiking removed. All five are classified as **energetic-particle hits ("cosmic rays") on the CCD detector**. The particle-hit pixels reach about 12,000–17,000 DN. The AIA despiking removed 96–99 % of each hit's excess signal but left a faint column trail, which is what appears in the browse images. The four AIA trails run along detector columns, one-sided and away from the nearest horizontal edge of the image. One hit's trails start separately from each bright pixel of its track. This indicates charge spreading along columns inside the detector rather than the particle's own path. We discuss charge-transfer trailing as the most likely, but unconfirmed, mechanism.

Contents

1. Introduction
2. Summary
3. Data
4. Results
   - A1 — STEREO-A EUVI 195 Å, 2010-04-25
   - A2 — SDO/AIA 335 Å, 2013-02-24
   - A3 — SDO/AIA 193 Å, 2017-06-20
   - A4a / A4b — SDO/AIA 304 Å composite, 2019-06-28
5. Discussion: why do the AIA hits have one-sided trails?
6. Not objects near the Sun

References

1. Introduction

Not every feature in a solar image is solar. The SSC lists nine artifact classes for STEREO imagery [1]: beacon-compression artifacts [2], stars/planets/comets [3], background-subtraction errors [4], cosmic rays [5], spacecraft debris [6], camera and optics defects such as dust, fibers and filter light leaks [7], spacecraft rolls [8], internal reflections [9], and corrupted or blank images [10]. NASA's general guide to solar-imager anomalies adds saturation *bleeding* along detector columns, flare *blooming* and diffraction, and particle *banding* [11]. Most of these classes also apply to SDO/AIA, which uses back-illuminated 4096×4096 CCDs read out through four corner amplifiers [12–14].

Energetic particles, including solar energetic particles and galactic cosmic rays, deposit charge as they pass through a detector. They usually affect a single pixel, but at shallow angles of incidence they leave streaks over many pixels [5, 15]. AIA records thousands of such hits per frame: a mean of about 6,800 on 2017-02-28, peaking at about 27,000 [15]. Level-1 AIA data are despiked on the ground with a neighbour-comparison algorithm, which is tuned for single-pixel events [15].

2. Summary

ID	Image	Classification	Confidence
A1	EUVI 195 Å, 2010-04-25	Cosmic ray / particle hit (compression-distorted)	90–97 %

ID	Image	Classification	Confidence
A2	AIA 335 Å, 2013-02-24	Particle hit with column trail	92–98 %
A3	AIA 193 Å, 2017-06-20	Particle hit with column trail	92–98 %
A4a	AIA 304 Å composite, 2019-06-28 (upper left)	Particle hit with column trail	92–98 %
A4b	AIA 304 Å composite, 2019-06-28 (lower left)	Particle hit with column trail	92–98 %

Secondary finding (Section 5): the AIA trails are charge spread along detector columns from the hit's brightest pixels, not part of the particle's path (80–92 %). The specific mechanism, charge-transfer trailing, is less certain (45–65 %).

On the confidence intervals: they are subjective credence ranges based on the evidence in Sections 4 and 5, not statistical intervals from repeated measurement. The lower bound reflects how well the evidence supports the classification against the alternatives considered. The upper bound reflects what is still unknown. All five features have now been checked in the science data, not only the browse images. The remaining uncertainty is mostly that no single exposure can rule out every rare alternative.

3. Data

ID	Instrument / channel	Observation (UT)	Image size	Artifact centre (x, y) px
A1	STEREO-A SECCHI/EUVI 195 Å	2010-04-25 11:10:30	2048^2	(2009, 1069)
A2	SDO/AIA 335 Å	2013-02-24 23:01:40	4096^2	head (3964, 910)
A3	SDO/AIA 193 Å	2017-06-20 12:56:17	4096^2	head (32, 1265)
A4a	SDO/AIA 304 Å (red channel of 304/211/171 composite)	2019-06-28 13:46:29	4096^2	head (148, 778)
A4b	SDO/AIA 304 Å (red channel of 304/211/171 composite)	2019-06-28 13:46:29	4096^2	head (58, 3665)

Pixel coordinates are measured from the top-left corner of the browse JPEG. The EUVI filename contains `n4euA`, where the "4" marks a full-resolution science image, not a beacon image [2], so beacon compression artifacts do not apply.

Method.

1. Each feature was located in the full-resolution JPEG.
2. Its morphology was examined in nearest-neighbour enlargements.
3. Its direction and asymmetry were measured from column profiles.
4. Persistence was tested by comparing the same pixel region in the previous and next browse frames:
   - EUVI: 11:05:30 and 11:13:00
   - AIA 193: 12:41:17 and 13:09:41
   - AIA composite: 13:46:11 and 14:13:59 (filename times)
5. Each feature was then examined in the science data for the same exposure (Level-0 for EUVI, Level-1 plus spikes for AIA), as described below.

The 2013 AIA 335 Å image is no longer on the SDO website. It was retrieved from the Internet Archive, which does not hold the neighbouring 335 Å browse frames (22:47:16 and 23:17:28). A2's persistence was instead tested with the Level-1 frames taken 12 s before and after.

For A1, the browse JPEG was also compared with the Level-0 FITS file for the same exposure, which holds the unprocessed detector values and the on-board processing history in its header [20]. Level-0 FITS files

are 2048×2048 unsigned 16-bit images stored bottom row first; the coordinates quoted below are flipped to top-down for comparison with the browse image.

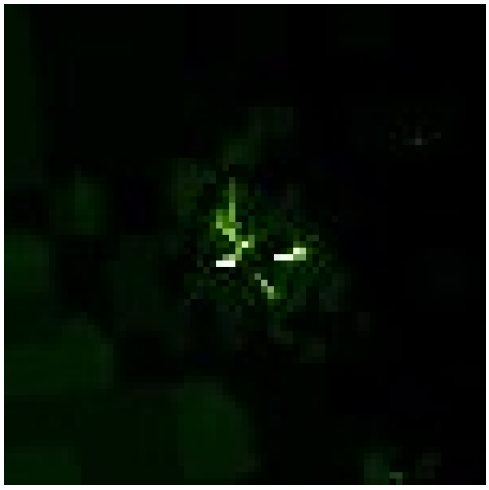
For the AIA artifacts, the Level-1 image and spikes file for each exposure were exported from the JSOC `aia.lev1_euv_12s` series [21]. The header times match the browse images exactly. For A2 the 335 Å frames 12 s before and after were exported too. Level-1 AIA images are despiked: pixels judged to be particle hits are replaced with a value estimated from their neighbours [15]. The companion spikes file is a 3×N array giving each replaced pixel's flat index into the image, its original value, and its replacement [15, 22]. We confirmed that the replacement values match the Level-1 image at every listed index. Putting the original values back ("respiking") recovers the hit as the detector recorded it. Level-1 coordinates below are also top-down. They differ by a few tens of pixels from the browse coordinates, because the browse images are re-centred on the Sun.

Crops are square regions upscaled to 600×600 px with nearest-neighbour sampling, so the original pixels are preserved without interpolation. A2 is shown at native 1:1 scale because its trail is about 490 px long. The browse figures can be regenerated with `scripts/make_figures.sh`, the Level-0 figure with `scripts/euvi_level0.py`, and the Level-1 figures and measurements with `scripts/aia_level1.py`. The FITS files used are included in `data/stereo/` and `data/aia/` (about 48 MB), so the results can be reproduced without downloading them again:

```
python3 -m venv .venv && .venv/bin/pip install astropy numpy pillow
./scripts/make_figures.sh
.venv/bin/python -I scripts/euvi_level0.py data/stereo/20100425_111030_n4euA.fts images/level0
.venv/bin/python -I scripts/aia_level1.py data/aia images/level1
```

4. Results

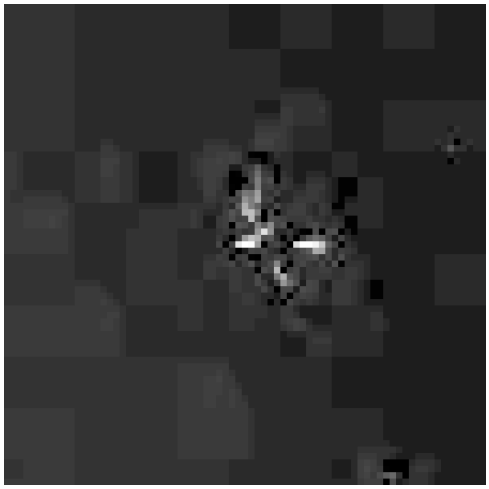
A1 — STEREO-A EUVI 195 Å, 2010-04-25 (middle-right green blob)



75×75 px region at (1972, 1032), shown at 8×. Full-size image: images/originals/20100425_111030_n4euA_195.jpg · Location overview: annotated · Source: https://stereo-ssc.nascom.nasa.gov/browse//2010/04/25/ahead/euvi/195/2048/20100425_111030_n4euA_195.jpg

Observations.

- **Shape:** a cluster, about 25 px across, of very sharp, saturated (255) line segments a few pixels long, set at different angles in a roughly star-like pattern.
- **Location:** in the faint outer corona near the right edge of the field, far from any bright solar structure.
- **Sharpness:** much sharper than anything solar nearby. The surrounding background shows the blocky texture of wavelet compression.
- **Persistence: absent** from the frames 5 minutes before and 2.5 minutes after.



Level-0 data for the same exposure: 75×75 px region at raw (1957, 1145), log-stretched after subtracting the CCD bias, shown at 8×. Source: https://stereo-ssc.nascom.nasa.gov/data/ins_data/secchi/L0/a/img/euvi/20100425/20100425_111030_n4euA.fts

Level-0 data.

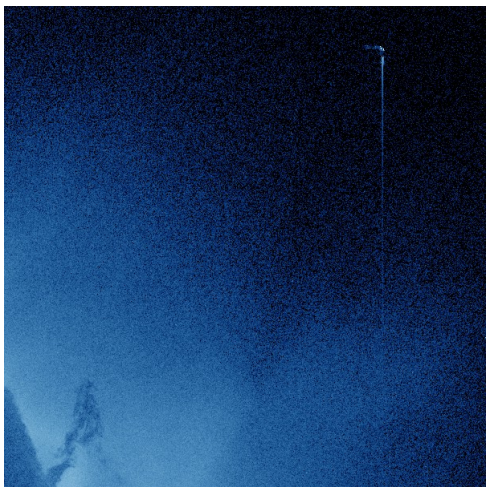
- **Same shape before ground processing:** the raw frame shows the same multi-armed pattern, in the same orientation, at raw (1994, 1182). The distortion is therefore already present in the data sent down from the spacecraft.
- **Brightest pixels in the frame:** the hit peaks at 16,382 DN, the maximum value in the whole image and higher than any pixel on the solar disk. The frame median is 758 DN. All three pixels within 10 DN of that maximum lie in this hit, on raw row 1182.
- **No on-board cosmic-ray removal:** the header records `COSMICS = 0` and `N_IMAGES = 1`. This was a single 8 s exposure that was not cosmic-ray scrubbed.
- **Heavy lossy compression:** the on-board processing steps were ”IP Trim”, ”Divide by 2” and **ICER5** (`IP_PROG3 = 95`), with a compression factor of 27.2 (`COMPFACT`).

Discussion.

- **Ruled out:**
  - Dust on the CCD [7] and the COR2 fiber [7] are persistent and fixed on the detector.
  - Stars and planets [3] persist and drift slowly. EUVI also rarely records them.
  - Debris [6] appears as diffuse, out-of-focus blobs in coronagraphs, not as sharp in-focus pixels in the EUV imager.
  - Light leaks [7] are faint, extended streaks.
- **What fits:** a cosmic-ray hit, consistent with the SSC example images [5]. The fragmented, multi-armed shape matches the SSC note that ”even the full resolution data have some compression applied to them, resulting in a small amount of distortion of the brightest cosmic rays” [5].
- **Compression:** almost all EUVI images are compressed on board with the ICER wavelet compressor [16]. A 2010 status report lists ICER3 as the usual 195 Å setting [17], but this frame's header shows the more aggressive ICER5 [20]. Lossy wavelet compression at this level is the most likely cause of both the armed, cross-like structure around the very bright hit and the blocky texture of the surrounding background.
- **Smoothing:** the browse-image smoothing that the SSC removed in July 2011 [5] does not apply here, because EUVI's 2048² browse images are at native detector resolution [18].

Classification: Cosmic ray / energetic-particle hit, morphology distorted by on-board compression. **Confidence: 90–97 %.** The feature appears in one frame only, has detector-scale sharpness, and matches SSC examples. The Level-0 data shows that it holds the brightest pixels of the frame, in an exposure that had no on-board cosmic-ray removal and heavy ICER5 compression. The remaining doubt is that a single exposure cannot rule out every rare alternative, such as a brief point-like glint from debris. Such an event would be unusual for an EUV imager.

A2 — SDO/AIA 335 Å, 2013-02-24 (upper-right blue streak)



600×600 px region at (3496, 860), native 1:1 scale. The dark feature at the lower left of the crop is solar limb structure, not part of the artifact. Full-size image: images/originals/20130224_230140_4096_0335.jpg · Location overview: annotated · Source: https://web.archive.org/web/20250124020907if_/https://sdo.gsfc.nasa.gov/assets/img/browse/2013/02/24/20130224_230140_4096_0335.jpg

Observations.

- **Head:** a short, hooked, saturated head about 15 px long.
- **Trail:** a faint trail 1–2 px wide running straight down a single column for about 490 px (y ≈ 910 → 1400).
- **Asymmetry:** within 50 px of the head, the signal below it is about 4× the signal above it.
- **Location:** off-limb, in the dim corona.



Level-1 data for the same exposure, 600×600 px region at (3496, 765), native scale. Left: Level-1 as distributed (despiked). Right: respiked with the original values from the spikes file. Same log stretch for both. The scattered dots on the right are ordinary single-pixel hits that despiking removed. Data: JSOC `aia.lev1_euv_12s`, T_OBS 2013-02-24T23:01:40.078 [21]

Level-1 and spikes data.

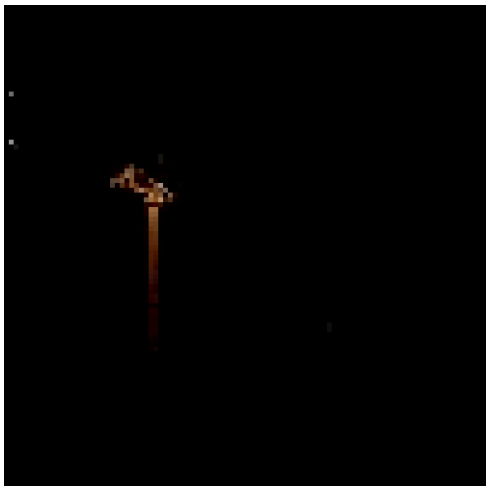
- **The hit:** respiking shows an L-shaped track about 20 px long, with its head at Level-1 (3967, 915). Its brightest pixel originally held 16,857 DN, at the ceiling of values found in the spikes files (≈16,000–17,800 DN). The coronal background here is about 2 DN.
- **Despiking:** 920 of the 930 pixels in the hit were flagged as spikes, removing 97 % of its excess signal. Even so, the brightest pixel left in the *entire* despiked frame (9,868 DN) is an unflagged pixel of this hit.
- **Trail:** in the respiked data the column below the head averages 471 DN over the first 50 px, against 2 DN above it. Its brightness falls to half within about 14 px, leaving a faint tail. Despiking cut the near part of the trail to about 14 DN, and that residue is the streak seen in the browse image.
- **Persistence (12 s cadence):** in the frames 12 s before and after, no pixel within 20 px of the head exceeds 207 DN and 454 DN respectively. Those values are typical of ordinary single-pixel spikes. The whole-frame maxima of those frames are only 635 DN and 595 DN.

Discussion.

- **Head:** the hooked track is typical of a particle crossing the detector at a shallow angle [5, 15].
- **Comet:** ruled out. The feature is absent 12 s before and after, which no comet could do, and its tail points along a detector column rather than away from the Sun.
- **Persistent defect:** ruled out by the 12 s neighbours.
- **Saturation bleeding from a bright source:** ruled out. There is no solar source here; the bright pixels are the particle track itself. See Section 5 for the trail.

Classification: Energetic-particle hit with a column-direction trail. **Confidence: 92–98 %.** The hit appears in one 2.9 s exposure only, contains the brightest pixels of the frame, and was almost entirely flagged by the AIA despiking algorithm, which was designed to find particle hits.

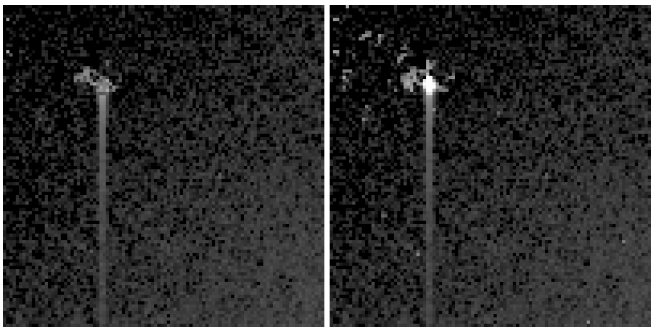
A3 — SDO/AIA 193 Å, 2017-06-20 (upper-left orange blob and streak)



100×100 px region at (0, 1225), shown at 6×. Full-size image: images/originals/20170620_125617_4096_0193.jpg · Location overview: annotated · Source: https://sdo.gsfc.nasa.gov/assets/img/browse/2017/06/20/20170620_125617_4096_0193.jpg

Observations.

- **Head:** an irregular, multi-pixel head about 14 px wide.
- **Trail:** a trail about 35 px long running straight down the column.
- **Asymmetry:** within 50 px, the signal below the head is about 26× the signal above it.
- **Location:** in the empty sky beyond the corona, near the left edge of the image.
- **Persistence: absent** from the frames 15 minutes before and 13 minutes after.



Level-1 data for the same exposure, 100×100 px region at (0, 1239), shown at 6×. Left: Level-1 as distributed (despiked). Right: respiked. Data: JSOC `aia.lev1_euv_12s`, T_OBS 2017-06-20T12:56:17.843 [21]

Level-1 and spikes data.

- **The hit:** respiking shows a single very bright point at Level-1 (30, 1264), surrounded by a small splash of fainter pixels. The point originally held 17,051 DN, at the spikes-file ceiling. The local background is about 23 DN.
- **Despiking:** 73 of the 111 hit pixels were flagged, removing 96 % of the excess signal. The head was cut to 441 DN.

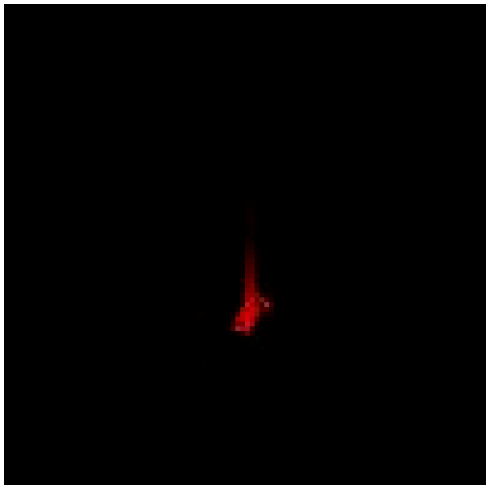
- **Trail:** the trail survives despiking almost unchanged: about 27 DN respiked and 24 DN despiked, averaged over the first 50 px below the head, against 3 DN above it. Its brightness falls to half within about 18 px and to 10 % by about 66 px.

Classification: Energetic-particle hit with a column-direction trail. **Confidence: 92–98 %.**

A4a / A4b — SDO/AIA 304/211/171 composite, 2019-06-28 (upper-left and lower-left red blobs and streaks)



A4a: 150×150 px region at (73, 755), shown at 4×.

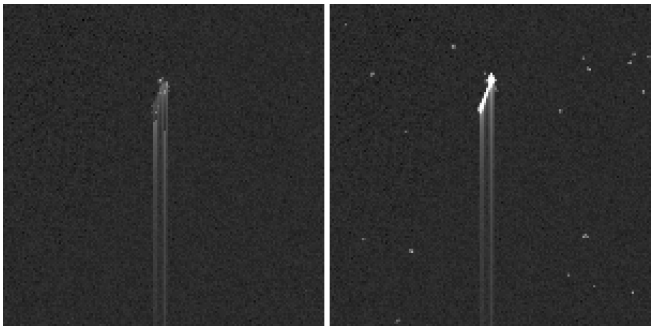


A4b: 100×100 px region at (8, 3600), shown at 6×.

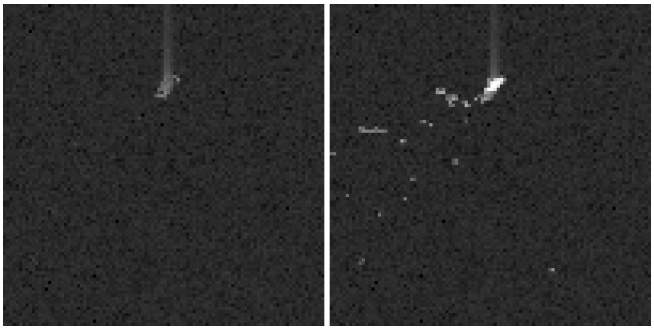
Full-size image: images/originals/20190628_140035_4096_304211171.jpg · Location overview: annotated · Source: https://sdo.gsfc.nasa.gov/assets/img/browse/2019/06/28/20190628_140035_4096_304211171.jpg

Observations.

- **A4a:** a head at (148, 778) with a trail about 110 px long running *down* the column. Within 50 px, the signal below the head is about 100× the signal above it.
- **A4b:** a head at (58, 3665) with a trail about 35 px long running *up* the column. Within 50 px, the signal above the head is about 13× the signal below it.
- **Channel:** both features are purely red. They appear only in the 304 Å channel, which the image label shows was exposed 8 s after the 211 Å and 171 Å exposures (13:46:29 vs 13:46:21).
- **Persistence:** both are **absent** from the frames about 14 minutes before and after.



A4a in Level-1 data, 150×150 px region at (91, 779), shown at 4×. Left: despiked. Right: respiked.



A4b in Level-1 data, 100×100 px region at (33, 3680), shown at 6×. Left: despiked. Right: respiked. Data: JSOC `aia.lev1_euv_12s` 304 Å, DATE-OBS 2019-06-28T13:46:29.129, the time printed on the browse image [21]

Level-1 and spikes data.

- **A4a:** respiking shows a straight diagonal track about 15 px long, with its head at Level-1 (166, 816) and a peak of 11,874 DN. Despiking removed 99 % of its excess signal. What remains (890 DN) is still the brightest pixel in the entire despiked 304 Å frame. **Several parallel trails** run down the columns, each starting from a different bright pixel along the track. Over the first 50 px below the head they average 914 DN respiked and 22 DN despiked.
- **A4b:** respiking shows a bright compact blob at Level-1 (83, 3705), peaking at 16,069 DN, with a spray of fainter flagged pixels below and to its left. Despiking removed 99 % of its excess signal. Its trail runs *up* the column and is fainter: about 4 DN above the head versus 1 DN below it, over 50 px. Its brightness falls to half within about 21 px.

Discussion.

- **Rules out a real source:** a real off-limb source would appear in the overlapping coronal channels as well. A feature that appears in only one channel and only one frame is characteristic of a hit on one camera during one exposure.
- **Confirmed in the science data:** both features are particle-hit pixels at thousands of DN on a background near 0 DN. The despiking algorithm flagged both as spikes.

Classification (both): Energetic-particle hits with column-direction trails. **Confidence: 92–98 %.**

5. Discussion: why do the AIA hits have one-sided trails?

Ordinary particle tracks point in random directions. All four AIA features instead have a trail **along the column (vertical) axis**, and in each case the trail points **toward the horizontal mid-line of the image**:

ID	Head y (px)	Image half	Trail direction
A2	910	top	down
A3	1265	top	down
A4a	778	top	down
A4b	3665	bottom	up

If all four trail directions were independent and random, a pattern this consistent would be unlikely. The Level-1 data adds three further observations:

1. **The trails are not part of the particle's path.** In A4a the track itself is a ~15 px diagonal, yet several separate trails run straight down the columns, one from each bright pixel along it (see the A4a figure). A particle crossing the detector leaves one track in one direction. Column-aligned trails starting at each bright pixel point instead to charge from those pixels spreading along the columns inside the detector.
2. **The trails start at the brightest pixels.** Three of the four heads (A2, A3 and A4b) reached 16,000–17,000 DN, the highest values recorded anywhere in the spikes files. That is consistent with saturated pixels.
3. **Each trail is bright near the head and fades quickly.** In the respiked data each trail falls to half its brightness within 10–21 px of the head, then continues as a faint tail. In the despiked data the bright near part is largely removed, but the faint tail survives because the despiking algorithm compares each pixel with its eight neighbours [15], and a smooth trail does not stand out from them. This explains why A2's trail looks about 490 px long in the browse image while most of its signal lies in the first 20 px.

What the browse images are made from. For the 2017 and 2019 images, at most 6 % of the isolated single-pixel spikes near each artifact are visible in the browse JPEG, against a chance baseline of 0 %. Those browse images were therefore made from despiked Level-1 data, and what they show of each artifact is the residue that despiking left. The 2013 browse image shows 37 % of nearby spikes, against a chance baseline of 18 %. It therefore appears to have been made from data that was not despiked, or not fully.

Mechanism. Two detector effects spread charge along columns:

- **Saturation bleeding** [11]: charge overflowing a full pixel spills into its column neighbours. It is usually described as extending both ways along the column.
- **Charge-transfer inefficiency (CTE) trailing**: radiation-damage traps capture part of a bright charge packet during readout and release it later into pixels farther from the readout register [19].

The AIA CCD is split into four 2048×2048 quadrants, each read out through its own corner amplifier [14]. If the parallel transfer runs toward the top edge in the upper half and toward the bottom edge in the lower half, then every trail here lies on the side *away from* its readout register. That is the CTE signature, and a one-sided pattern like this is hard to explain by bleeding alone. A CTE tail also has the observed shape: bright just behind the source, then a long faint tail.

The CTE explanation remains unconfirmed because we have not verified that the Level-1 orientation (which matches the browse orientation to within a few tens of pixels) matches the readout direction of each AIA camera. Level-1 processing does not resample the image relative to Level-0 [15, 22], but we found no source documenting how Level-0 rows map to the CCD's readout registers.

Confidence that the trails are charge spread along detector columns from the hit's brightest pixels, rather than part of the particle tracks: 80–92 %. Confidence that the specific mechanism is CTE trailing: 45–65 %. Neither changes the primary classification of any feature.

The EUVI hit (A1) shows no such trail. Its distortion is better explained by on-board ICER compression [5, 16, 20].

6. Not objects near the Sun

Features like these are regularly mistaken for real objects near the Sun, and sometimes promoted as UFOs or alien spacecraft. In 2003 the SOHO team responded to such claims with a tongue-in-cheek guide to making a ”UFO”. The guide enlarges and smooths one of the cosmic-ray marks found in almost every SOHO EUV image into a saucer [23]. In 2012 a ”jointed spaceship” in a SOHO/LASCO C2 image was identified by the Naval Research Laboratory as ”merely a collection of streaks left by cosmic rays”, pointing out that ”these artifacts do not persist from image to image” [24]. Other artifact classes are misread the same way. A geometric ”object” in STEREO HI2-B data in December 2011 turned out to be an internal reflection of Venus [25], and corrupted images can superimpose data from different telescopes [10].

Five independent lines of evidence show that the features studied here are energetic-particle hits rather than objects in space:

1. **They exist for a single exposure.** A2 is absent from the frames 12 s before and after; the others are absent minutes before and after. A real object moves continuously and appears in consecutive frames,

as comets do in SOHO and STEREO images [3, 23]. A particle hit lasts only for the exposure in which it strikes.

2. **They are sharper than the telescope can image.** Anything in the sky is seen through the telescope optics, which blur a point to about 1.5 arcsec, roughly 2.5 AIA pixels [12]. In A2, A4a and A4b the brightness falls from 11,900–16,900 DN to under 210 DN between one pixel and the next. Only charge deposited directly in the detector can have edges that sharp.
3. **They follow the detector, not the sky.** All four AIA trails run exactly along detector columns, and in A4a several trails start separately from each bright pixel (Section 5). A physical object would have no reason to line up with the pixel grid.
4. **They appear in one camera only.** The A4 features are in the 304 Å exposure but not in the 211 Å and 171 Å exposures taken 8 s earlier with an overlapping field of view.
5. **They are what particle hits look like, and they are common.** The AIA despiking algorithm, built to recognise particle hits, flagged 96–99 % of the signal in each feature. The same frames each contain between 15,713 and 51,876 flagged spikes [21], so a few large ones in any image are expected.

Taken literally, the features would also be implausibly large. One AIA pixel spans about 435 km at the Sun's distance (0.6 arcsec at 1 AU), so A2's browse-image trail of about 490 px would be an object roughly 210,000 km long, about 15 % of the Sun's diameter, if it were near the Sun.

References

1. STEREO Science Center, ”Image artifacts.” https://stereo-ssc.nascom.nasa.gov/artifacts/artifacts.shtml
2. STEREO Science Center, ”Image artifacts – Beacon data.” https://stereo-ssc.nascom.nasa.gov/artifacts/artifacts_beacon.shtml
3. STEREO Science Center, ”Image artifacts – Stars, planets, and comets.” https://stereo-ssc.nascom.nasa.gov/artifacts/artifacts_planets.shtml
4. STEREO Science Center, ”Image artifacts – Background subtraction.” https://stereo-ssc.nascom.nasa.gov/artifacts/artifacts_background.shtml
5. STEREO Science Center, ”Image artifacts – Cosmic rays.” https://stereo-ssc.nascom.nasa.gov/artifacts/artifacts_cosmic_rays.shtml
6. STEREO Science Center, ”Image artifacts – Debris.” https://stereo-ssc.nascom.nasa.gov/artifacts/artifacts_debris.shtml
7. STEREO Science Center, ”Image artifacts – Telescope and camera defects.” https://stereo-ssc.nascom.nasa.gov/artifacts/artifacts_camera.shtml
8. STEREO Science Center, ”Image artifacts – Spacecraft rolls.” https://stereo-ssc.nascom.nasa.gov/artifacts/artifacts_rolls.shtml
9. STEREO Science Center, ”Image artifacts – Internal reflections.” https://stereo-ssc.nascom.nasa.gov/artifacts/artifacts_reflections.shtml
10. STEREO Science Center, ”Image artifacts – Corrupted and blank images.” https://stereo-ssc.nascom.nasa.gov/artifacts/artifacts_corrupted.shtml
11. Hill, S. (2019), ”Artifacts and Other Imaging Anomalies Taken by NASA's Solar Imagers,” NASA *The Sun Spot* blog. https://science.nasa.gov/blogs/the-sun-spot/2019/02/08/artifacts-and-other-imaging-anomalies-taken-by-nasas-solar-imagers/
12. Lemen, J. R., Title, A. M., Akin, D. J., Boerner, P. F., et al. (2012), ”The Atmospheric Imaging Assembly (AIA) on the Solar Dynamics Observatory (SDO),” *Solar Physics* 275, 17–40. https://doi.org/10.1007/s11207-011-9776-8
13. Boerner, P., Edwards, C., Lemen, J., Rausch, A., et al. (2012), ”Initial Calibration of the Atmospheric Imaging Assembly (AIA) on the Solar Dynamics Observatory (SDO),” *Solar Physics* 275, 41–66. https://doi.org/10.1007/s11207-011-9804-8
14. Clapp, M., Lang, J., Pool, P., Morris, D., et al. (2017), ”Systems approach to the design of the CCD sensors and camera electronics for the AIA and HMI instruments on Solar Dynamics Observatory,” *Proc. SPIE* 10565 (ICSO 2010). https://doi.org/10.1117/12.2309196
15. Young, P. R., Viall, N. M., Kirk, M. S., Mason, E. I., Chitta, L. P. (2021), ”An Analysis of Spikes in Atmospheric Imaging Assembly (AIA) Data,” *Solar Physics* 296, 181. https://doi.org/10.1007/s11207-021-01929-8 (arXiv: https://arxiv.org/abs/2108.02624)
16. Wuelser, J.-P., et al. (2007), EUVI status presentation, STEREO Science Working Group, March 2007. https://stereoftp.nascom.nasa.gov/meetings/SWG/SWG_Mar_2007/wuelser/swg.pdf
17. Howard, R. A. (2010), SECCHI status report, STEREO Science Working Group, 23 March 2010. https://stereo.nascom.nasa.gov/meetings/SWG/SWG_Mar_2010/swg_secchi_status_20100323_howard.pdf

18. Wuelser, J.-P., Lemen, J. R., Tarbell, T. D., Wolfson, C. J., et al. (2004), ”EUVI: the STEREO-SECCHI extreme ultraviolet imager,” *Proc. SPIE* 5171, 111. https://doi.org/10.1117/12.506877; see also Howard, R. A., et al. (2008), ”Sun Earth Connection Coronal and Heliospheric Investigation (SECCHI),” *Space Science Reviews* 136, 67–115. https://doi.org/10.1007/s11214-008-9341-4
19. Townsley, L. K., Broos, P. S., Nousek, J. A., Garmire, G. P. (2002), ”Modeling charge transfer inefficiency in the Chandra Advanced CCD Imaging Spectrometer,” *Nuclear Instruments and Methods in Physics Research A* 486, 751–784. https://doi.org/10.1016/S0168-9002(01)02156-8
20. STEREO Science Center, SECCHI Level-0 data archive, EUVI-A file `20100425_111030_n4euA.fts`. https://stereo-ssc.nascom.nasa.gov/data/ins_data/secchi/L0/a/img/euvi/20100425/20100425_111030_n4euA.fts
21. Joint Science Operations Center (JSOC), Stanford University, SDO/AIA data series `aia.lev1_euv_12s`, image and spikes segments for records 78809615, 78809622 and 78809629 (335 Å, 2013-02-24), 157692406 (193 Å, 2017-06-20) and 194794212 (304 Å, 2019-06-28). Exported via http://jsoc.stanford.edu/ajax/exportdata.html
22. aiapy documentation, `aiapy.calibrate.respike`. https://aiapy.readthedocs.io/en/stable/api/aiapy.calibrate.respike.html
23. Boyle, A. (2003), ”Scientists show how to make a UFO,” msnbc.com / NBC News, 24 January 2003. https://www.nbcnews.com/id/wbna3077760
24. Wolchover, N. (2012), ”UFO Spaceship Orbiting the Sun, or a Camera Glitch?,” Life's Little Mysteries / Live Science, republished by NBC News, 26 April 2012. https://www.nbcnews.com/news/amp/wbna47190227
25. STEREO Science Center, ”Triangular shaped object in STEREO data explained.” https://stereo-ssc.nascom.nasa.gov/artifacts/triangle/index.shtml