Starshade Technology Workshop

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University of Colorado
December 1, 2016

Recent Progress, Needs and Opportunities

In context of Rendezvous Mission

Definition of Mission

Very Poorly Defined

Based on EXO-S design which is known to have problems.

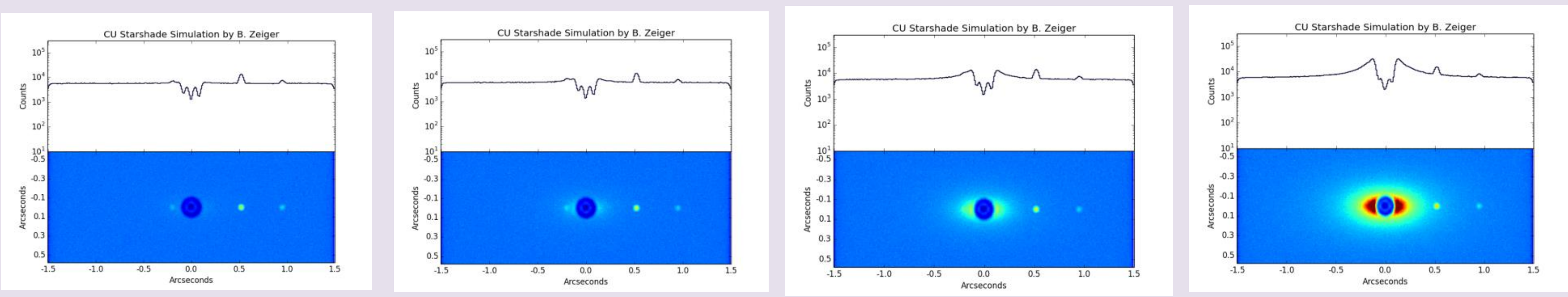
Should be spectroscopy driven.
That's the "Search for Life" that everyone wants.

But that makes our sources effectively 100x fainter

Drives the design at a fundamental level.

Science Capabilities

WFIRST Telescope, 0.1″ IWA Starshade
Earths @ 0.1″ 0.2″; Jupiter @ 0.5″; Saturn @ 1″
Includes local zodiacal light and dark noise



10^{-9} suppression 0.3 Zodis

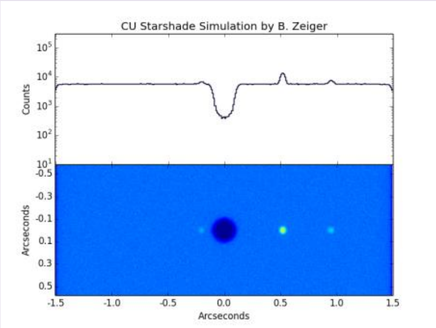
10^{-9} suppression 1 Zodi

10^{-9} suppression 3 Zodis

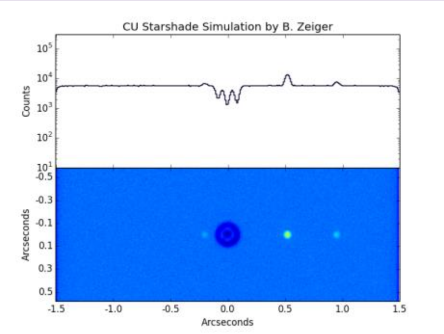
10^{-9} suppression 10 Zodis

Technical Requirements

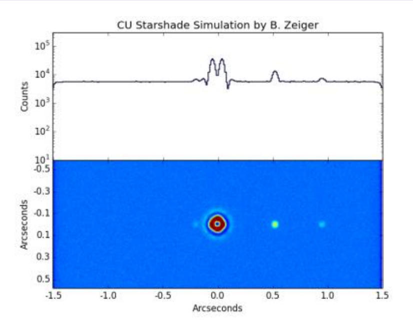
WFIRST Telescope, 0.1″ IWA Starshade
Earths @ 0.1″ 0.2″; Jupiter @ 0.5″; Saturn @ 1″
Includes local zodiacal light and dark noise



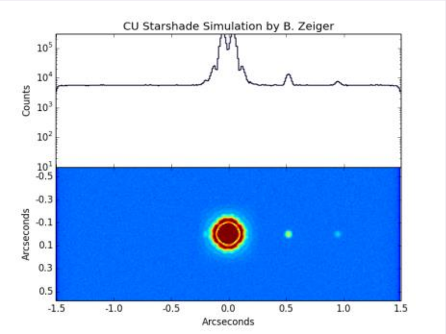
Total suppression
No exozodi



10^{-9} suppression
No exozodi



10^{-8} suppression
No exozodi



10^{-7} suppression
No exozodi

Development and Demonstration

Its always been about showing they work

I have 47 years of experience in development of Space Observatories
There are multiple technologies I invented and championed through flight.

And this I know:

The key to success is building an experience base.

Just Do It

Starshade Critical Technology

Enabling Technologies

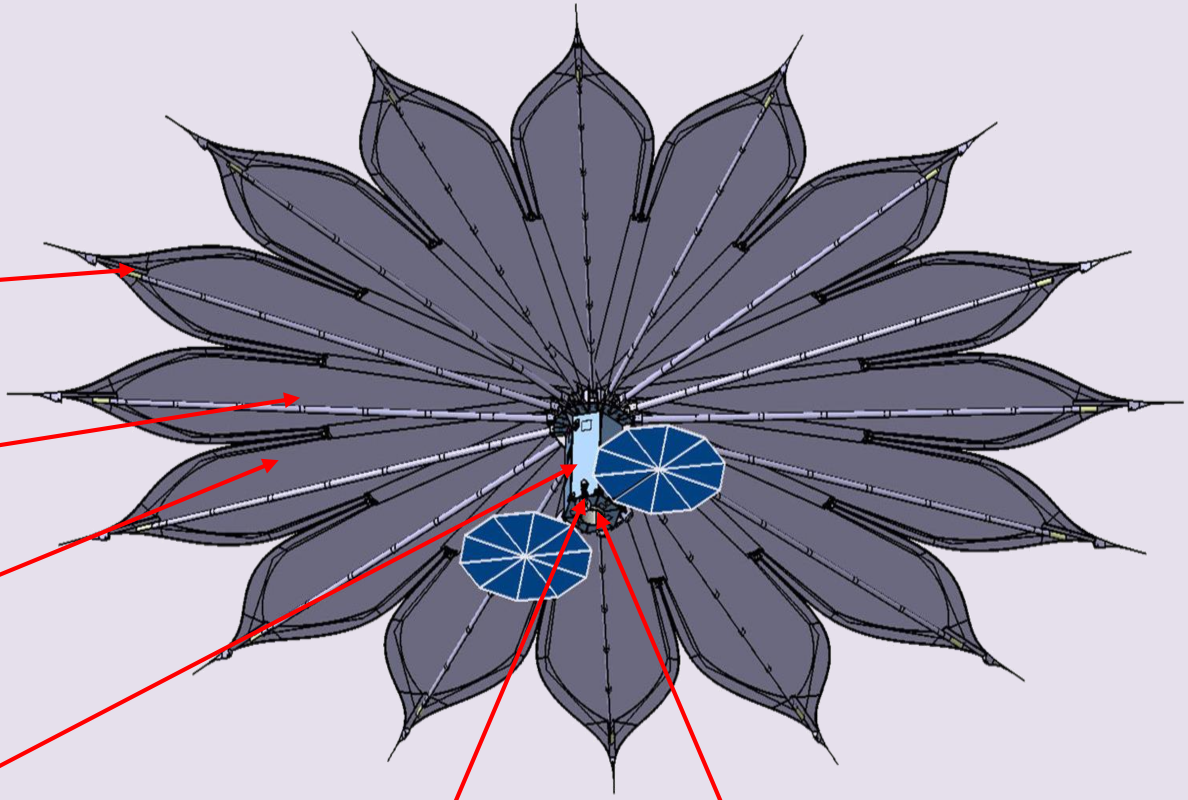
Precision Shape Control
- Maintain edge position
- Maintain structure shape

Thin Edge Treatment
- Maintain edge stability
- Minimize stray light

Precision Deployment
- Minimize jitter
- Maintain petal location

Opaque Membrane
- Maintain opacity
- Lightweight

2 Axes Formation Flying
- Maintain 1m alignment
- Minimize jitter

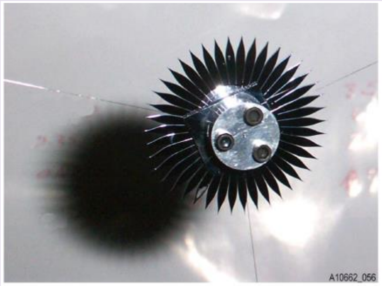


Enhancing Technologies

Solar Electric Propulsion
- NEXT engine
- Increase observable targets
- Reduce propellant mass

Lightweight S/C Structures
- Increase observable targets
- Reduce overall mass

Lab Studies



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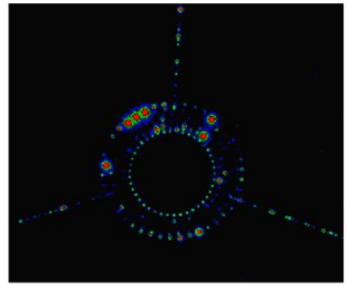

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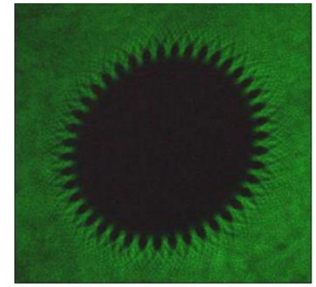
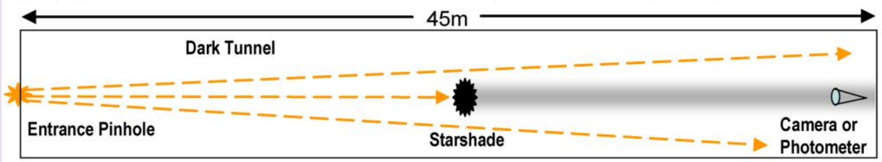


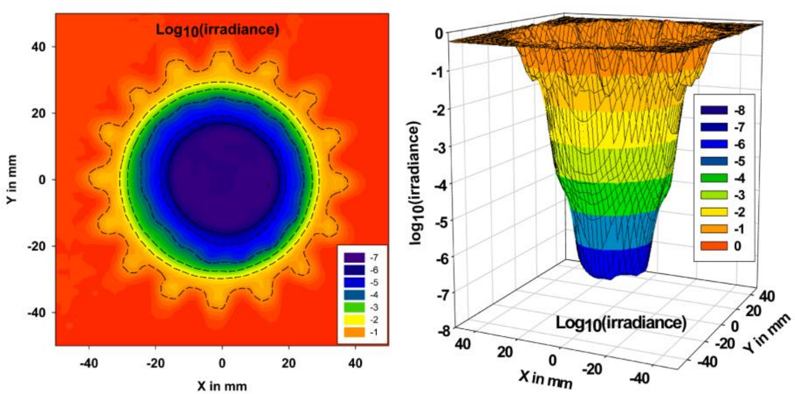
c)

Figure D-12 a): A test starshade, 35mm tip to tip made from silicon by lithographic techniques and suspended by three thin wires with a = b = 8mm, n = 6, and 42 petals; b) image of starshade back-illuminated by diverging beam of sunlight with approximately the same Fresnel number as expected in flight; clearly visible are scattering off support wires, two rings of bright points that correlate with tips of petals and gaps at bases of petals; c) when illuminated with coherent light (a green HeNe laser), one can see that diffraction by the starshade is primarily in the azimuthal direction.

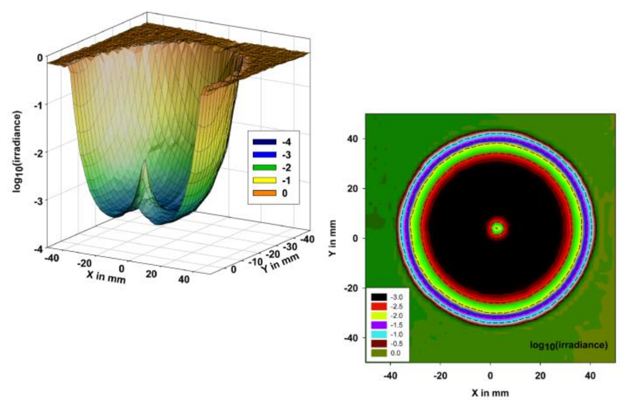


d) Schematic of test beamline; a heliostat feeds sunlight into the dark tunnel; a photon counting photometer scans the shadow to measure its depth; a camera can image the diffraction and scatter by defects around the starshade.

e) Students near one end of dark tunnel at University of Colorado



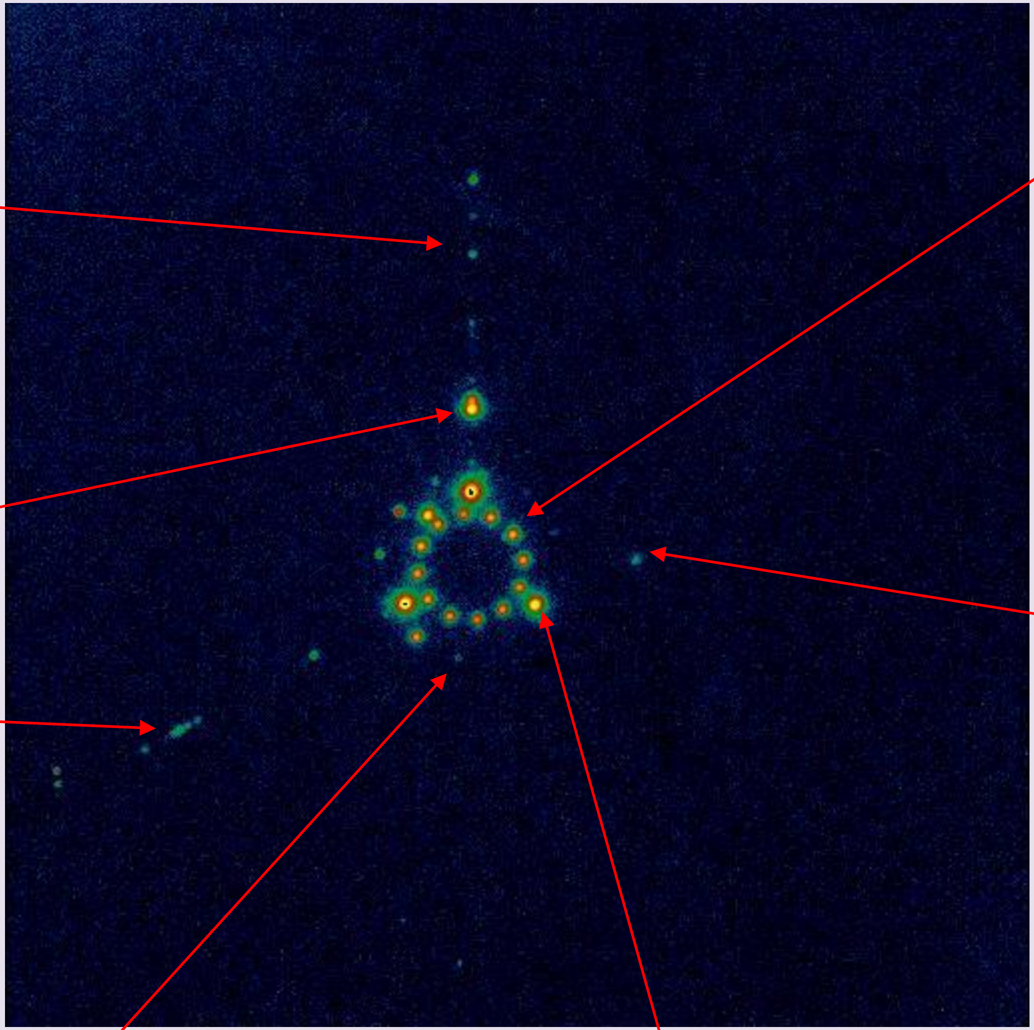
f) Photometer mapping of shadow from 16 petal silicon starshade in white light shows suppression of several orders of magnitude of irradiance within a few millimeters, with an ultimate suppression level of < 1 x 10^{-7}.



g) Map of shadow from a precision circular disc in white light showing amplitude of Poisson's spot at a predicted irradiance level 1% of incident level, verifying the photometric accuracy of measurement facility.

CU/NIST starshade, 60s

500 micron entrance pinhole, iris=6mm, 7/30/07 data



mount wire

Diffraction where Petal bases meet

Dust on wire

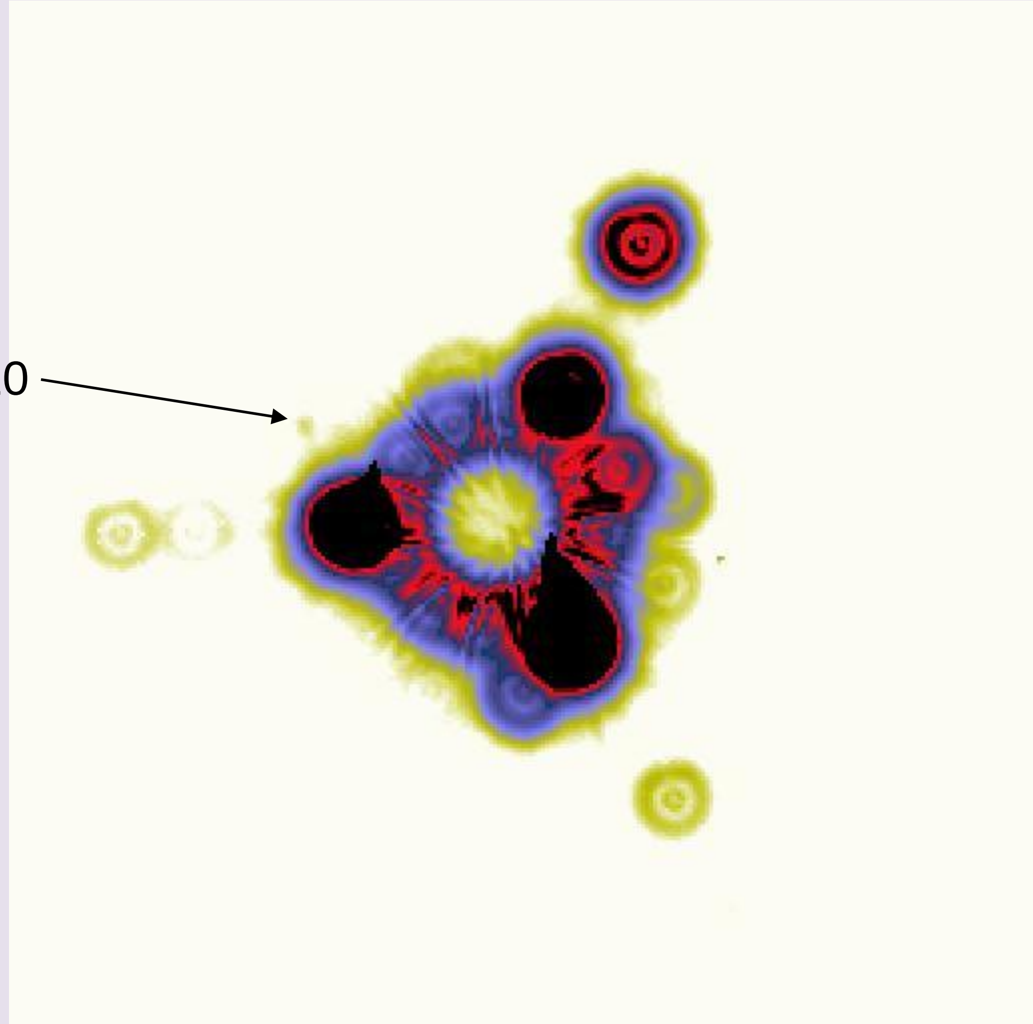
Planet @ $2x10^{-9}$ contrast

mount wire

Broken petal tip

Diffraction where wires cross petal edges

6/19/07 Image27- 600sec



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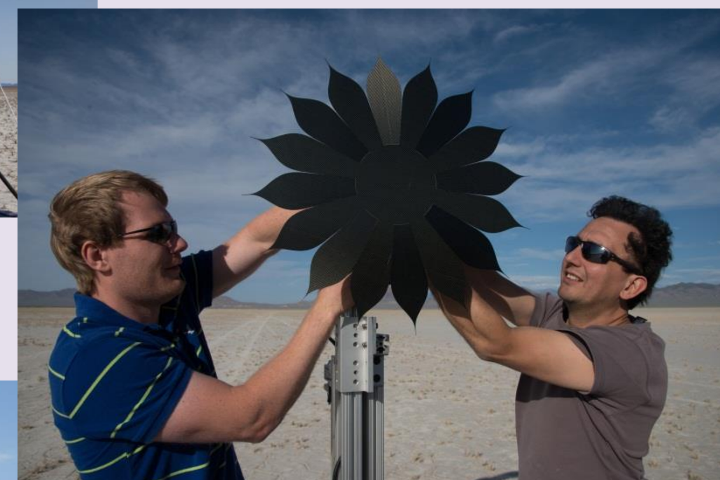
TDEM Field Test #1

- The first of three field tests that will be carried out on TDEM contract

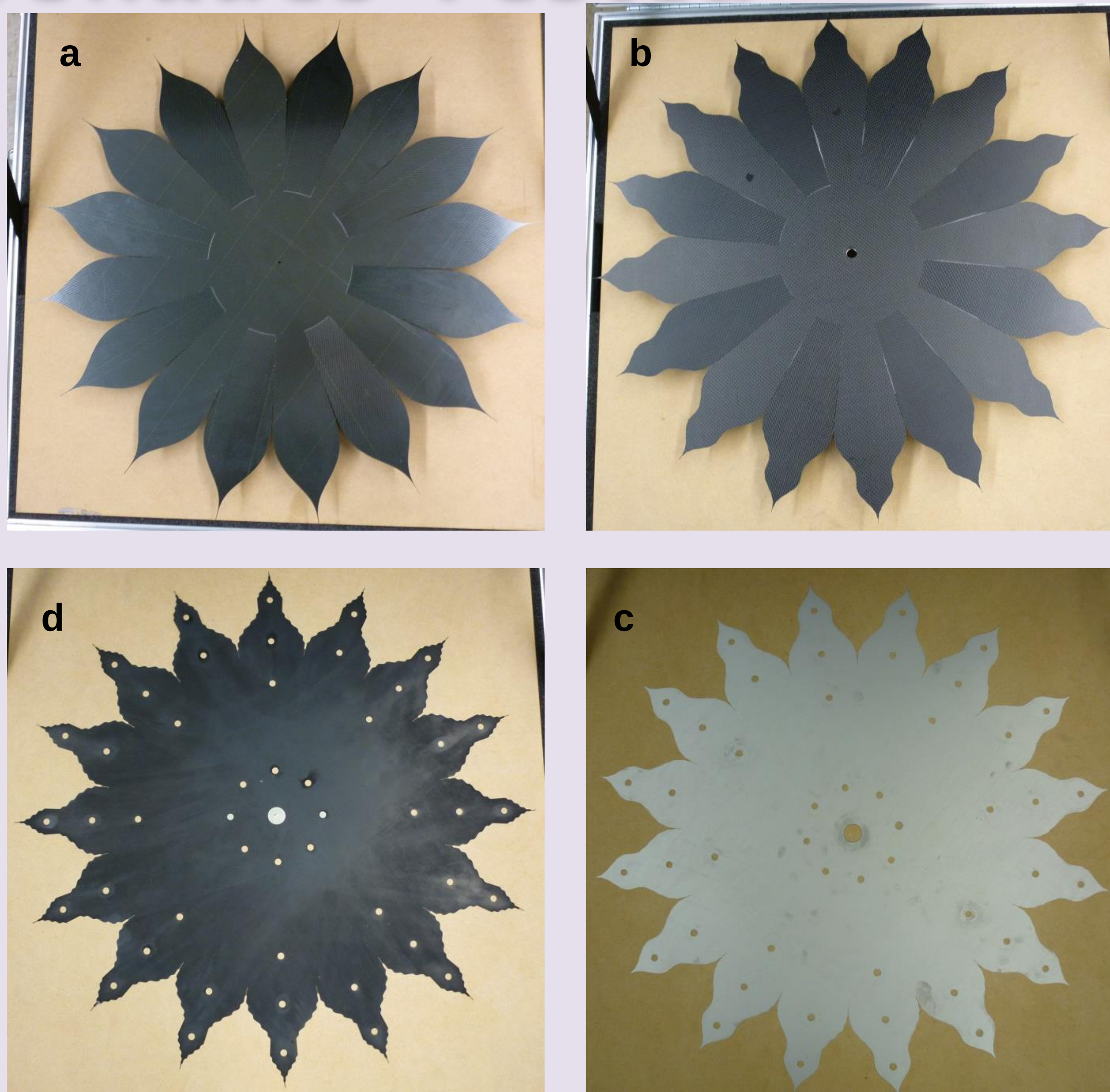
- Testing carried out over 5 nights From May 28th to the morning of June 2nd

- Testing range is 2km range with the Starshade in the middle

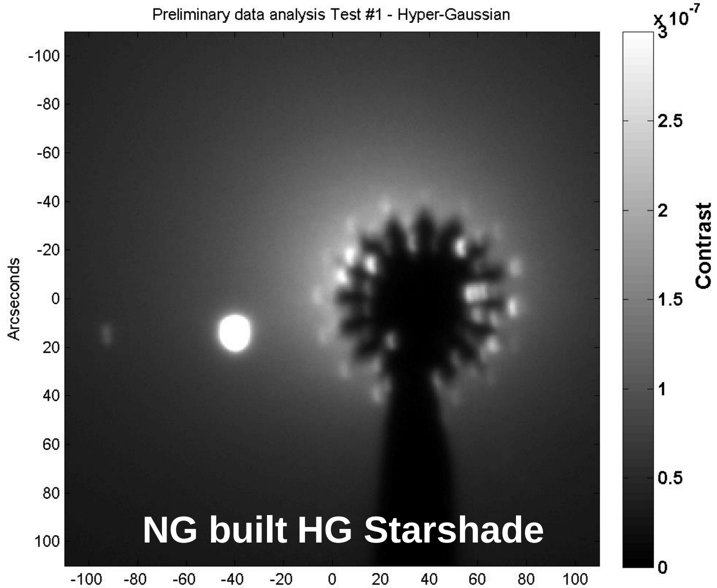


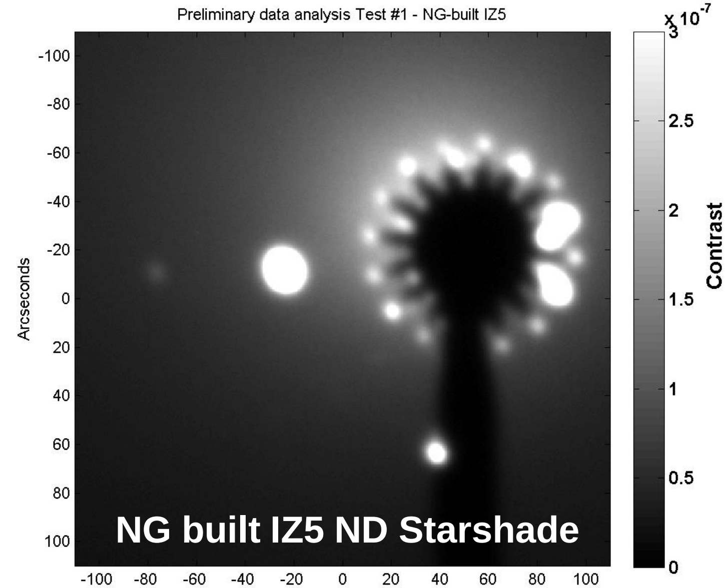
Starshades Tested

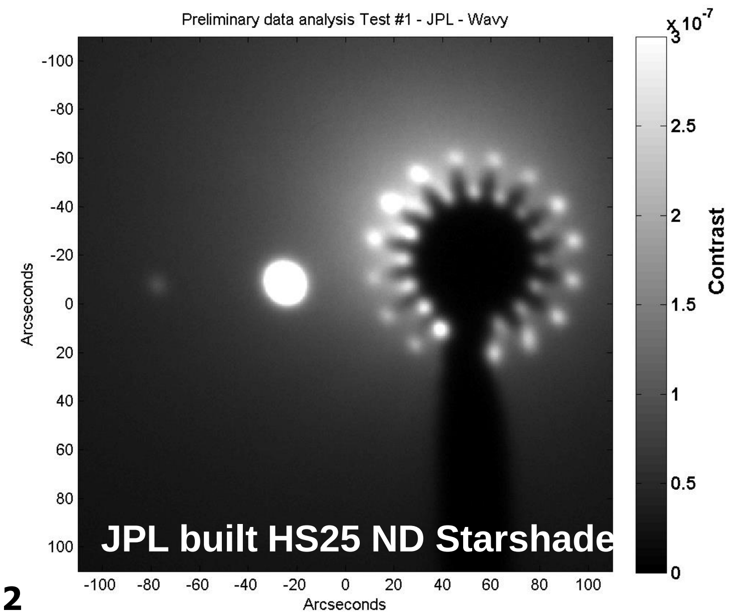
- 4 Starshades were tested
  a. Hypergaussian built by Northrop Grumman, Same starshade as tested previously
  b. Numerically determined IZ5, built by Northrop Grumman to JPL prescription
  c. Numerically determined IZ5, built by JPL to identical prescription
  d. Numerically determined HS25, built by JPL

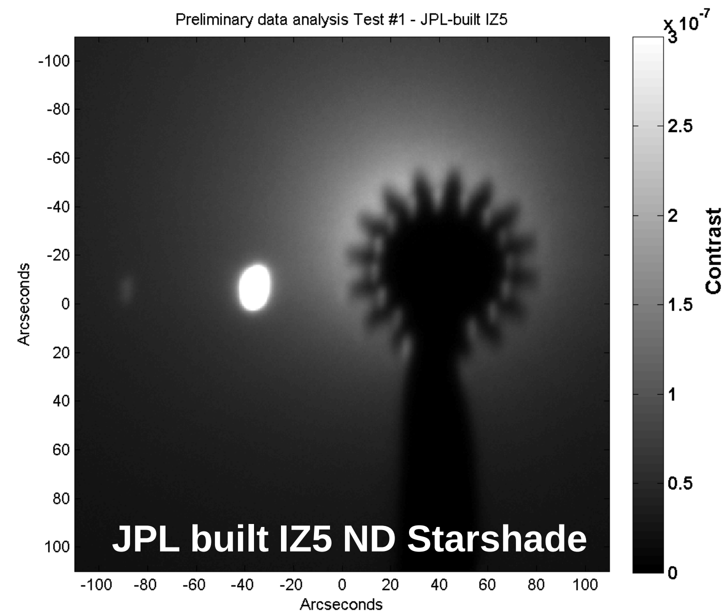


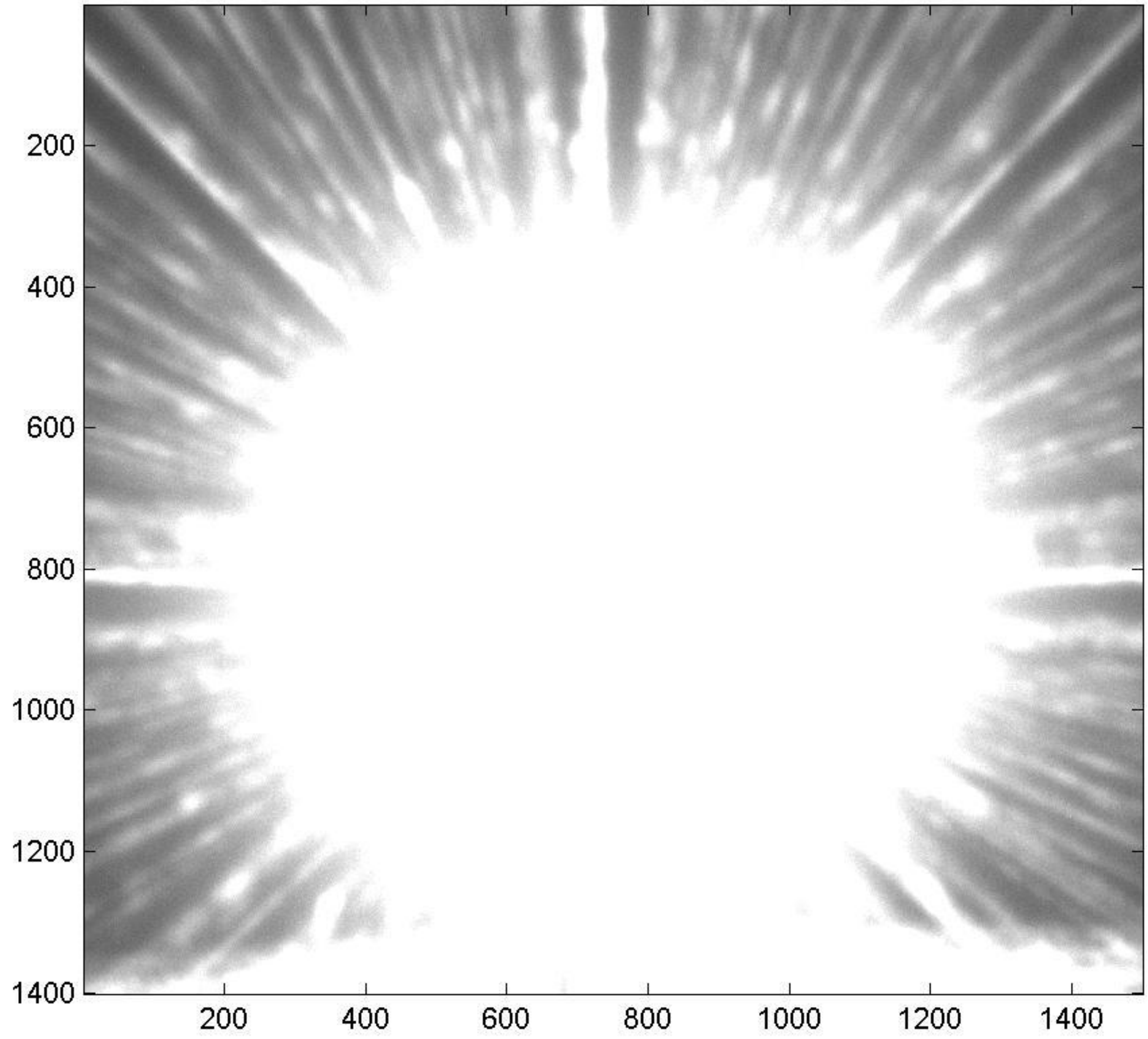
Starshade Images







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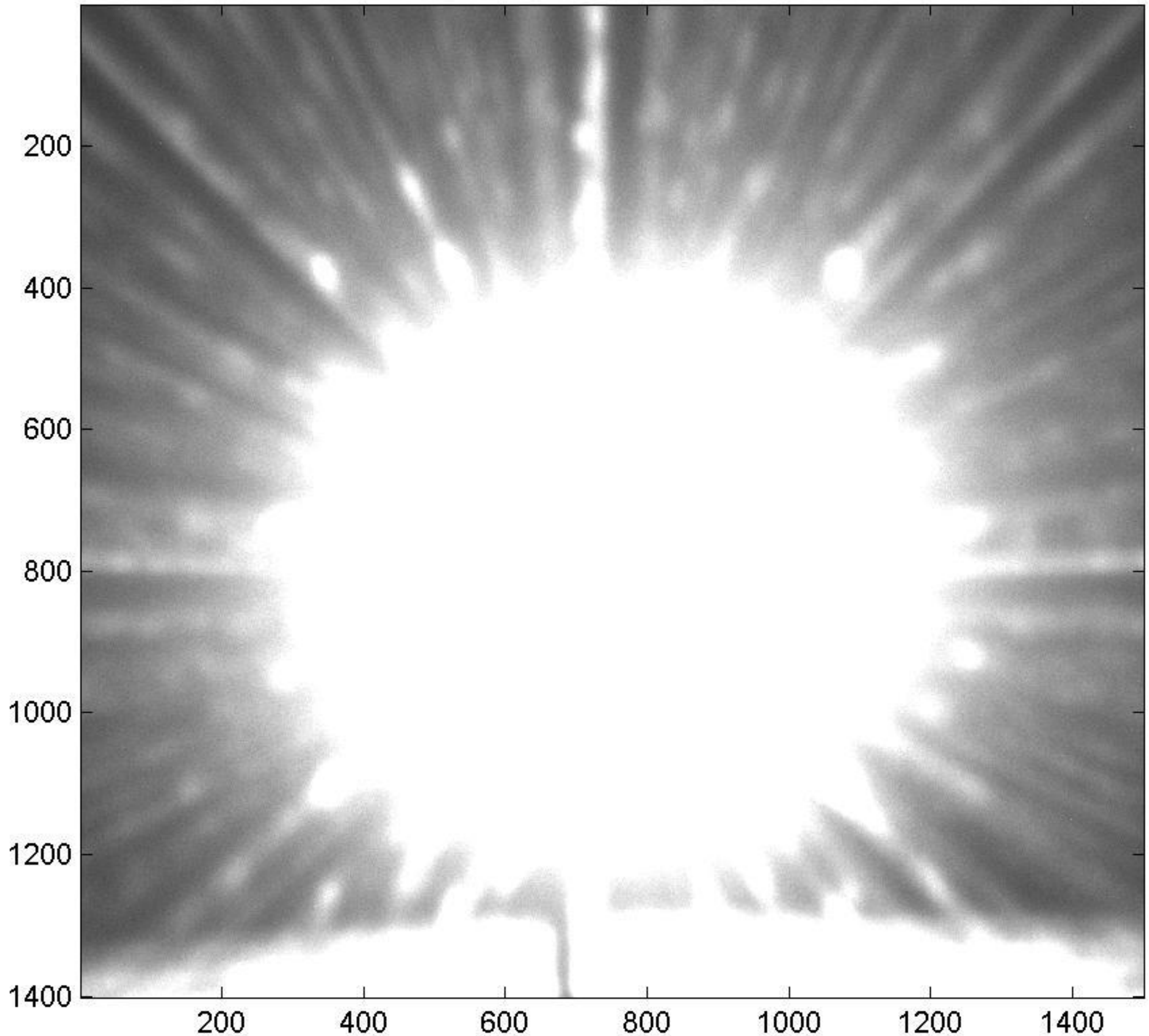
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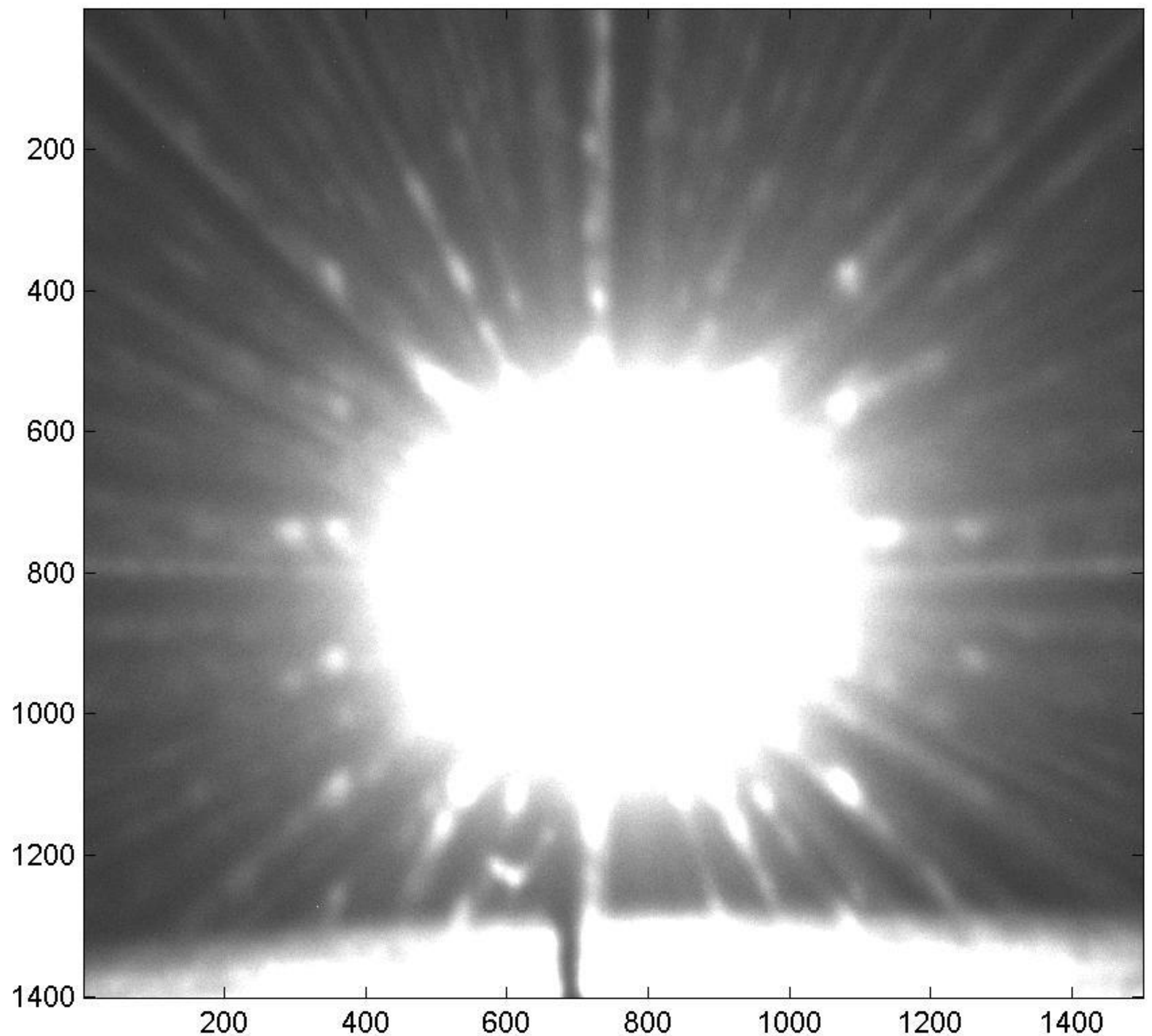

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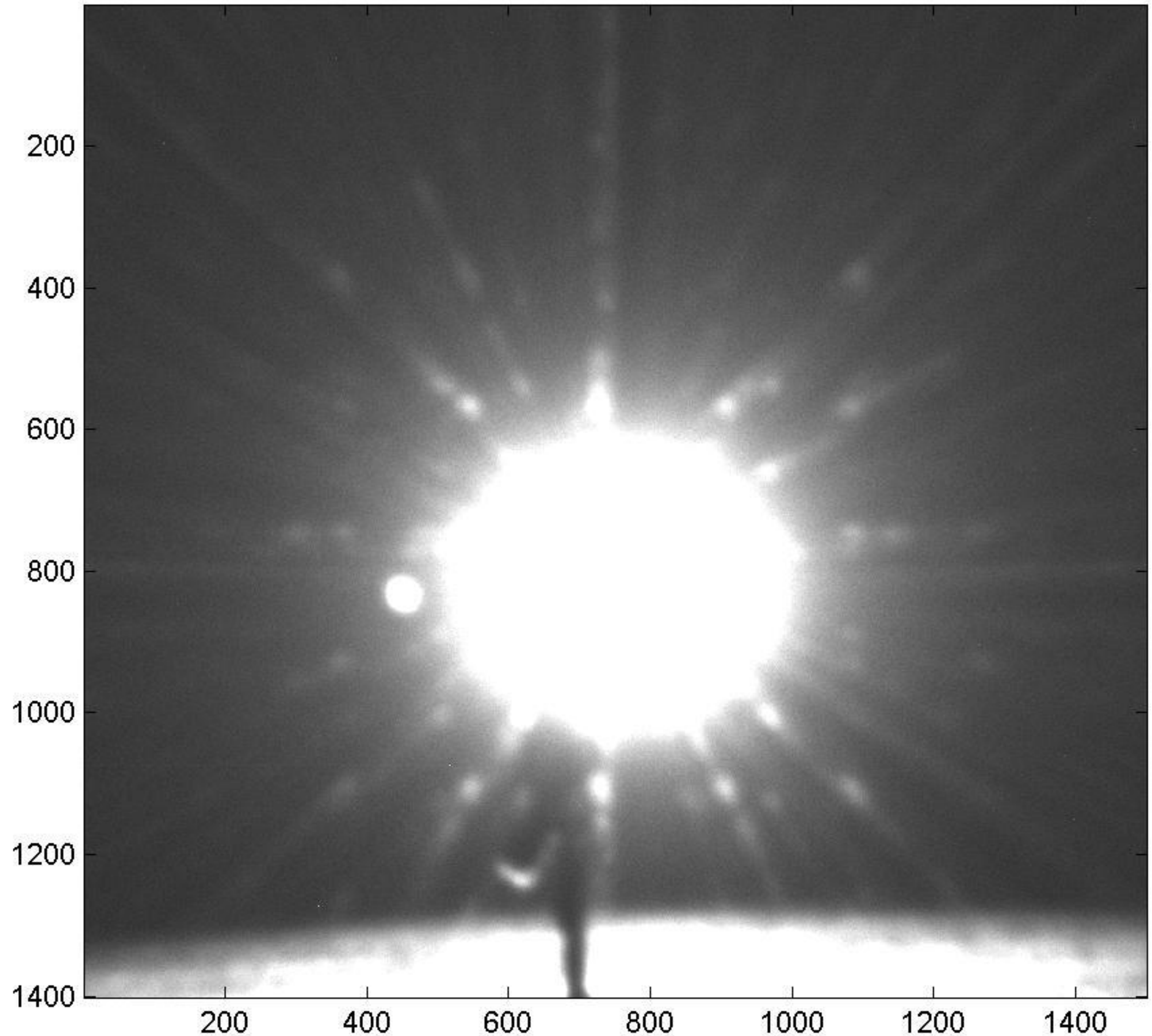
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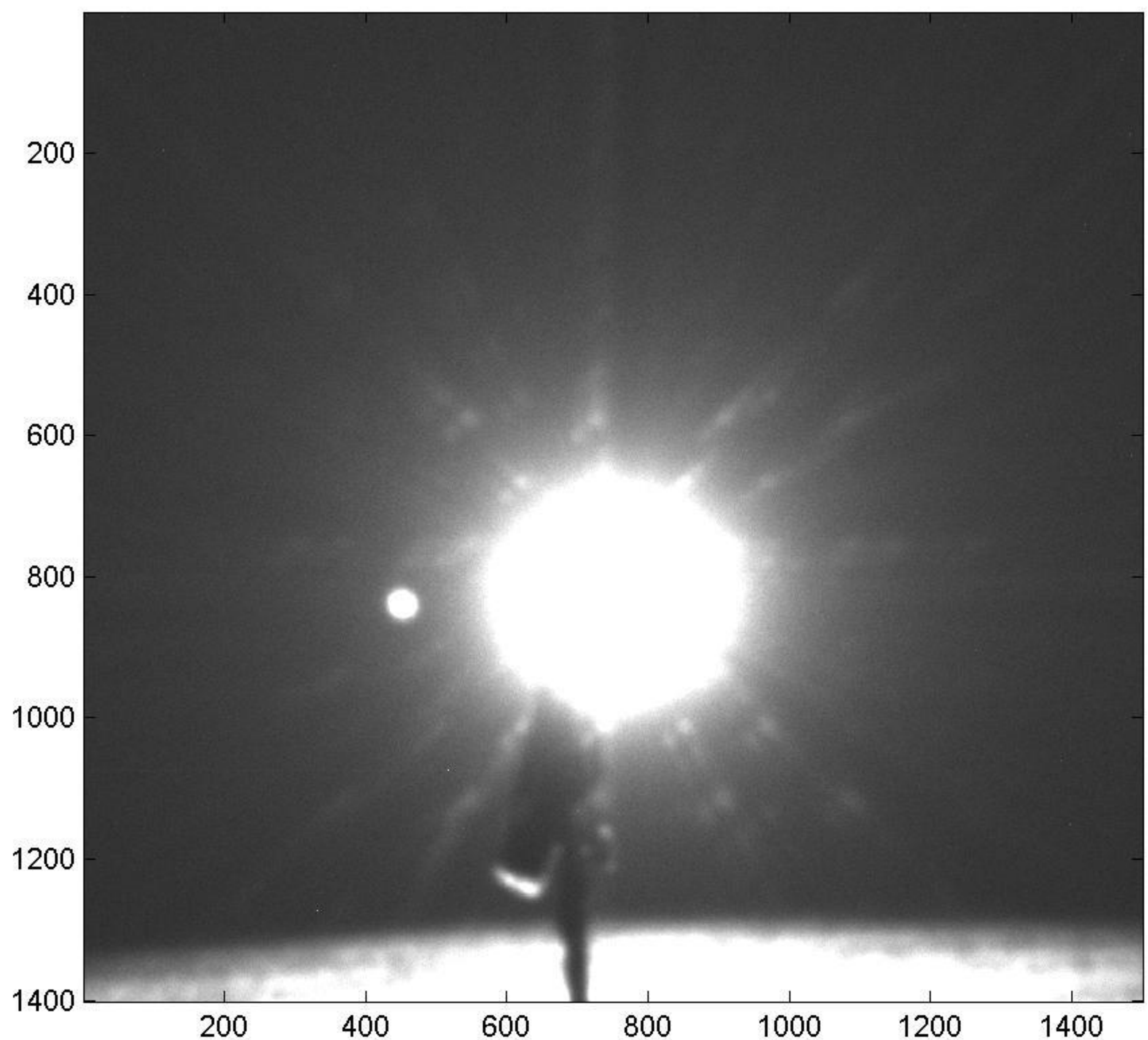

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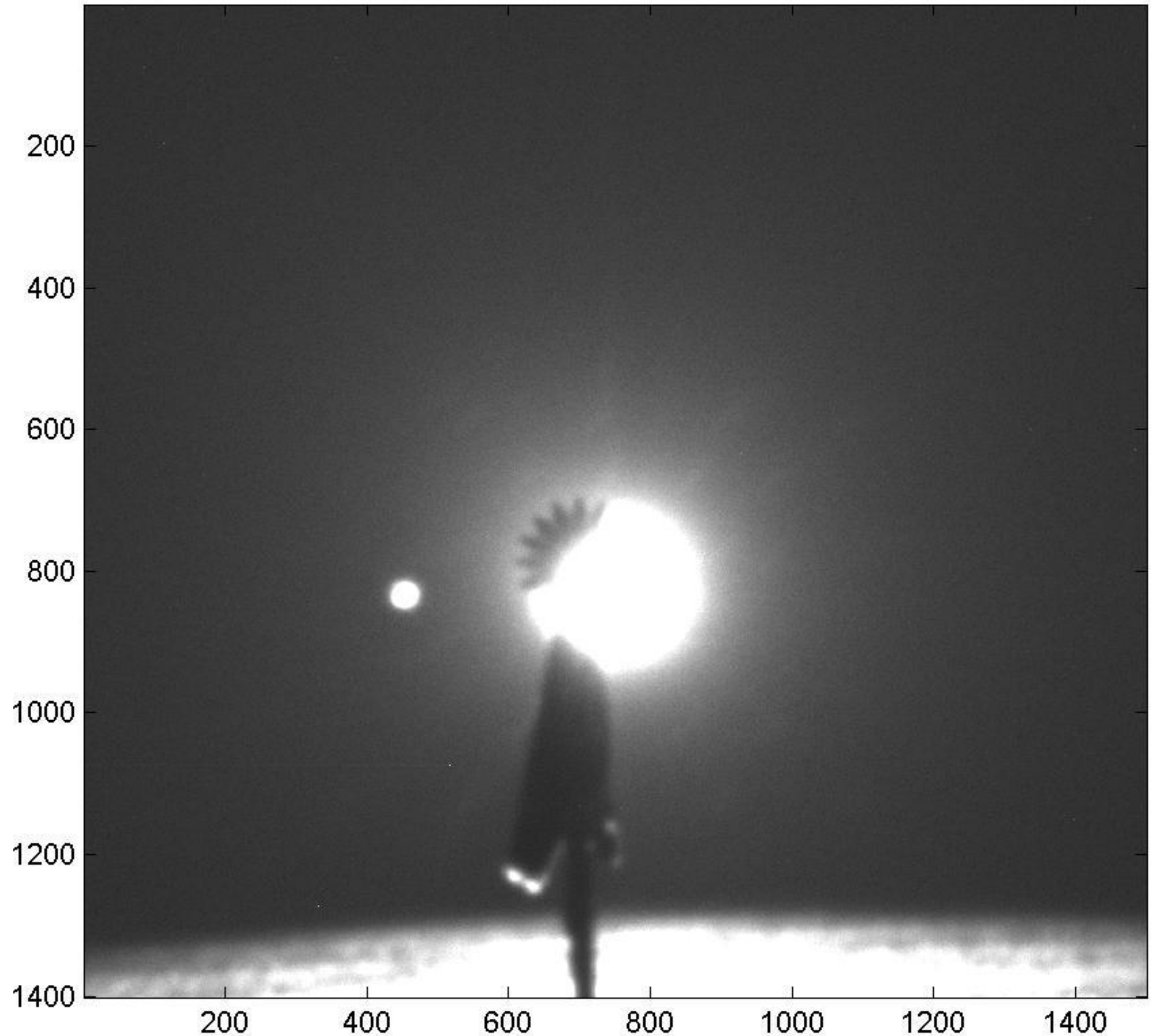

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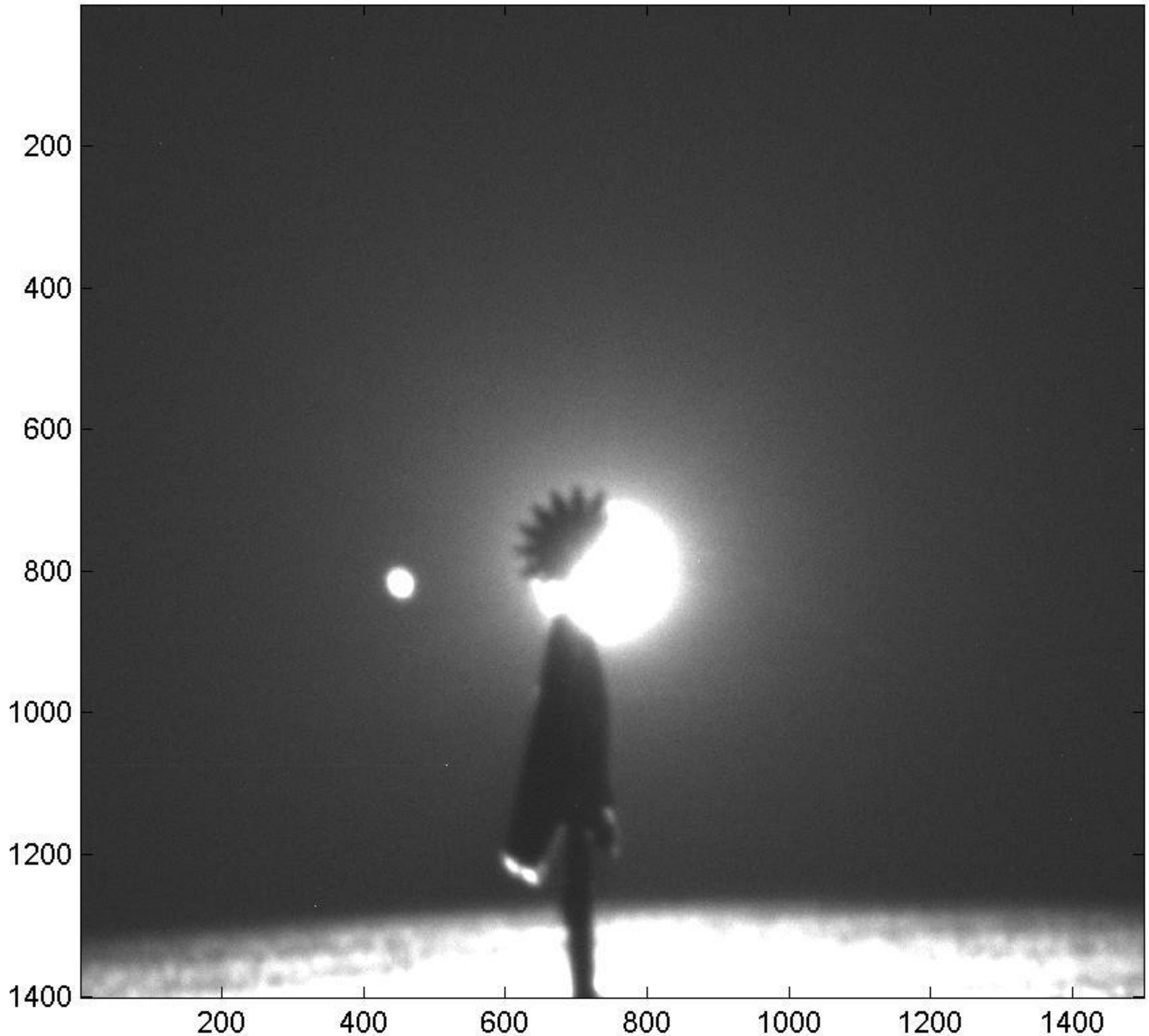
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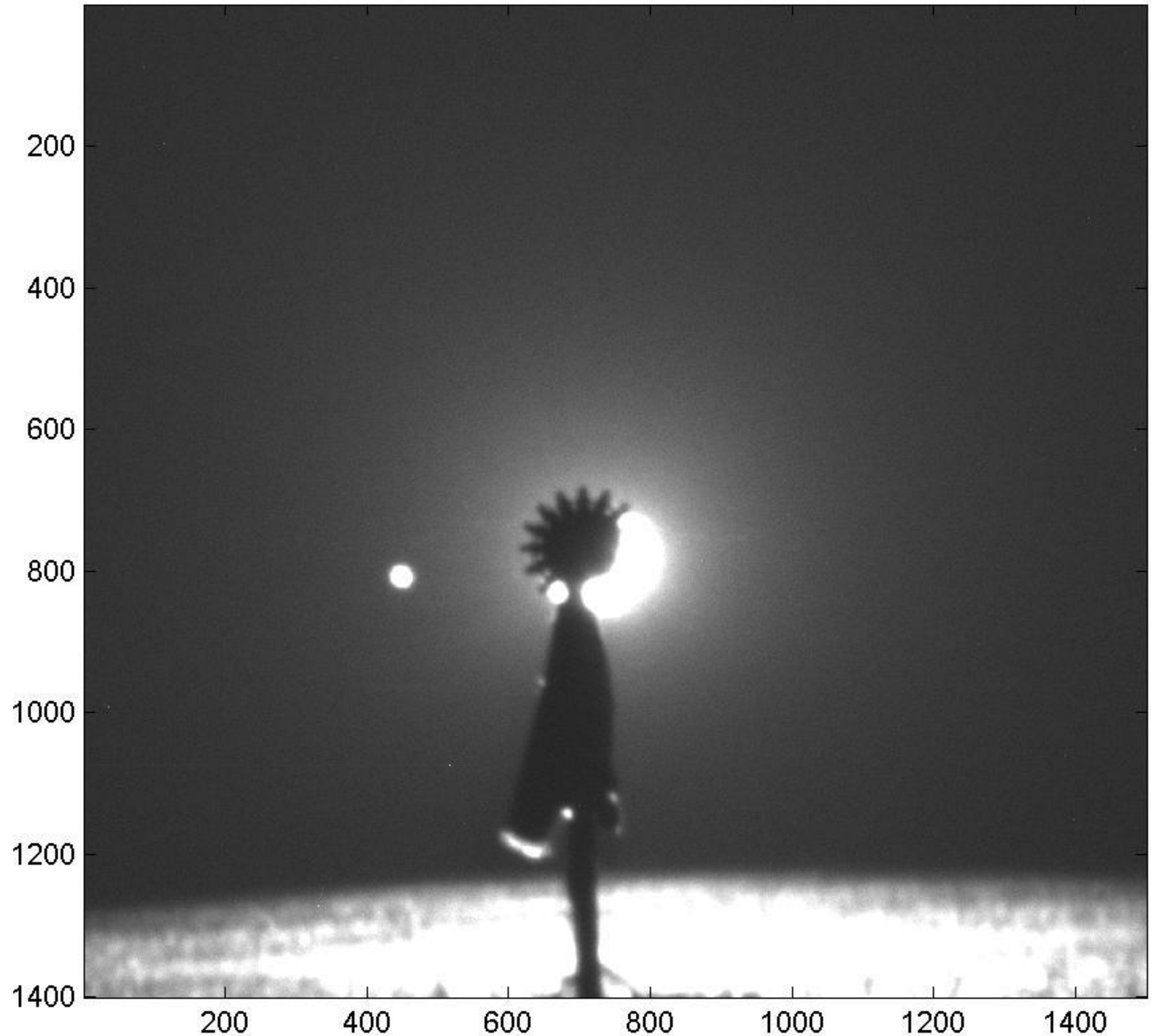
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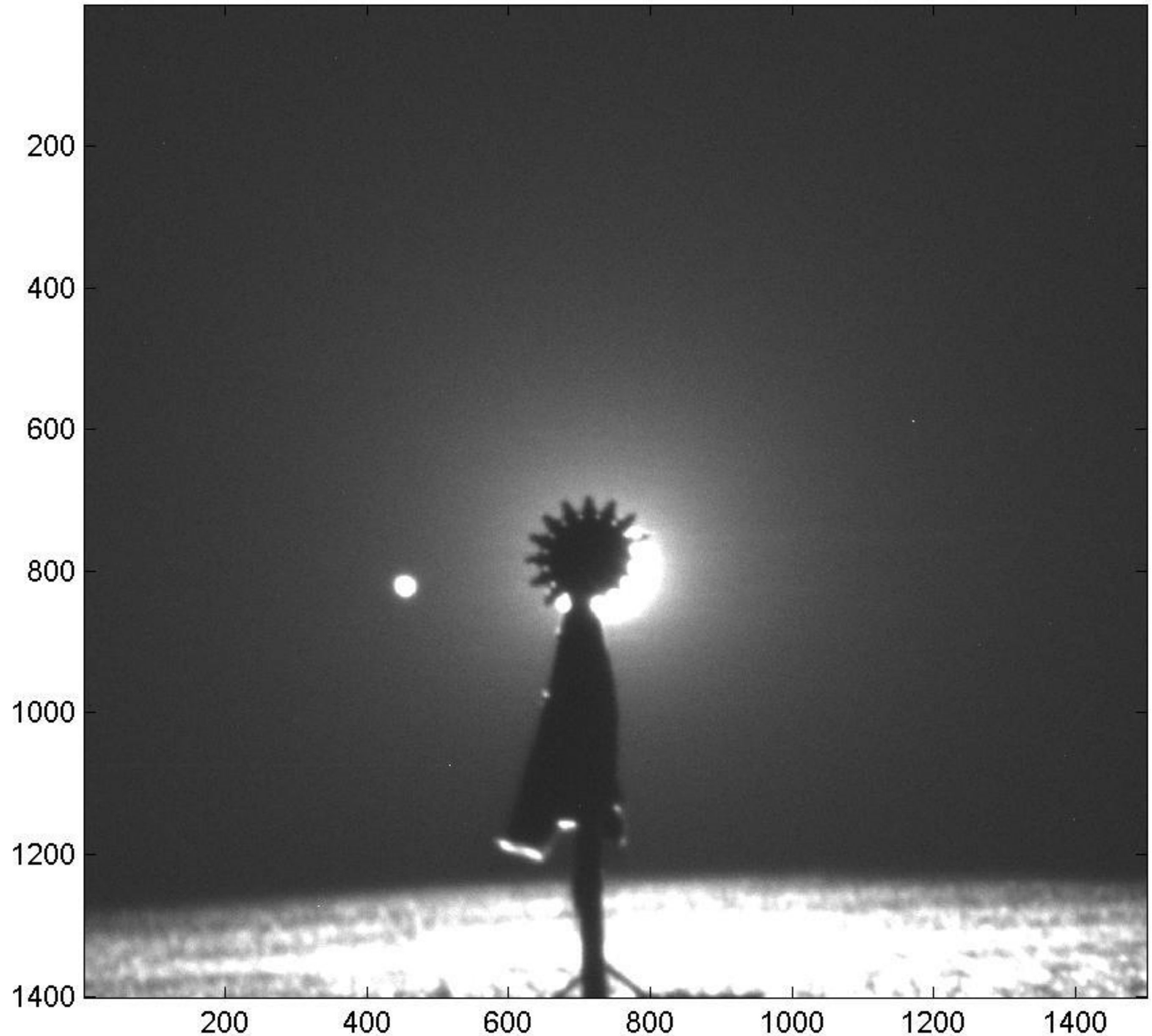
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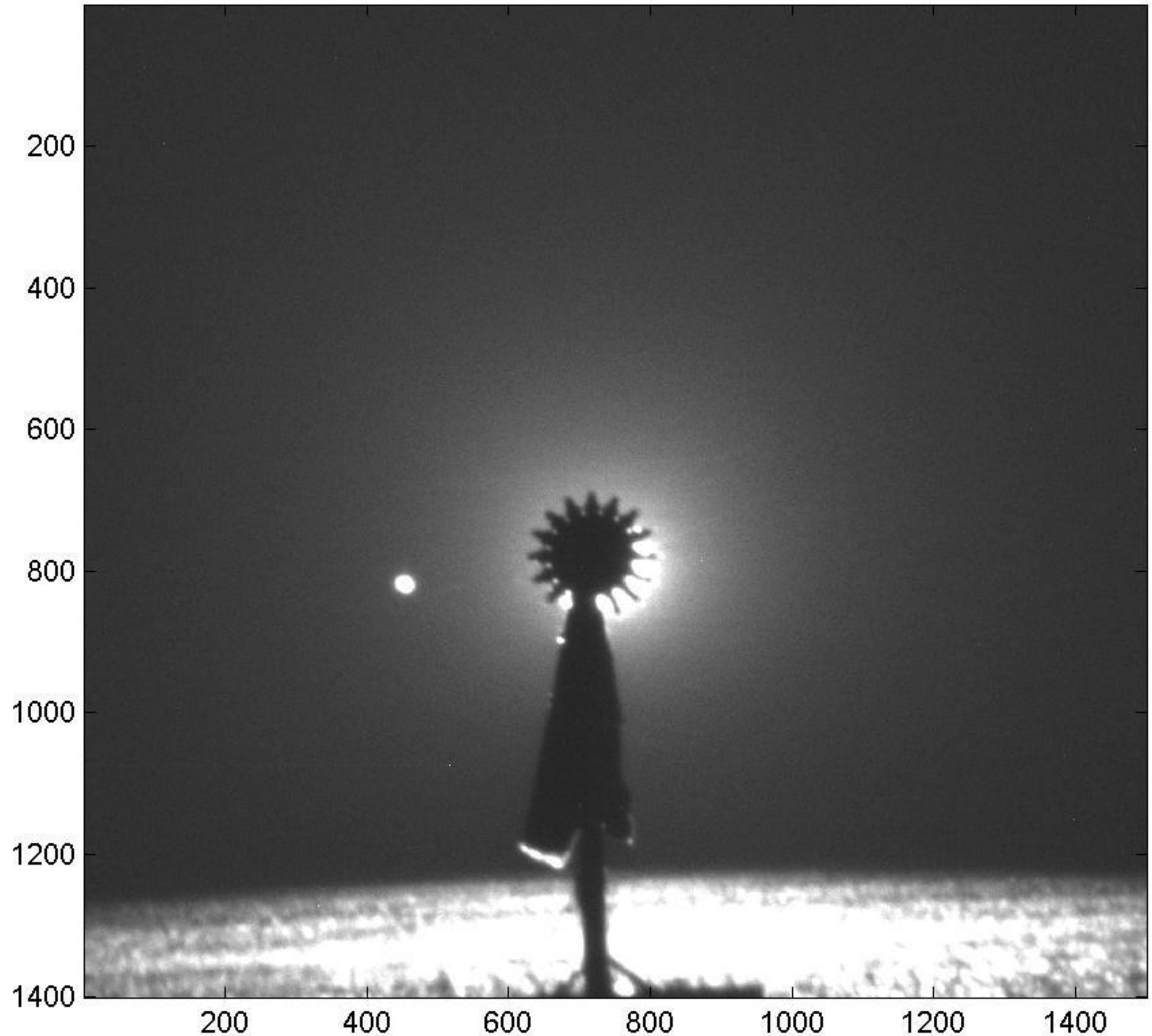
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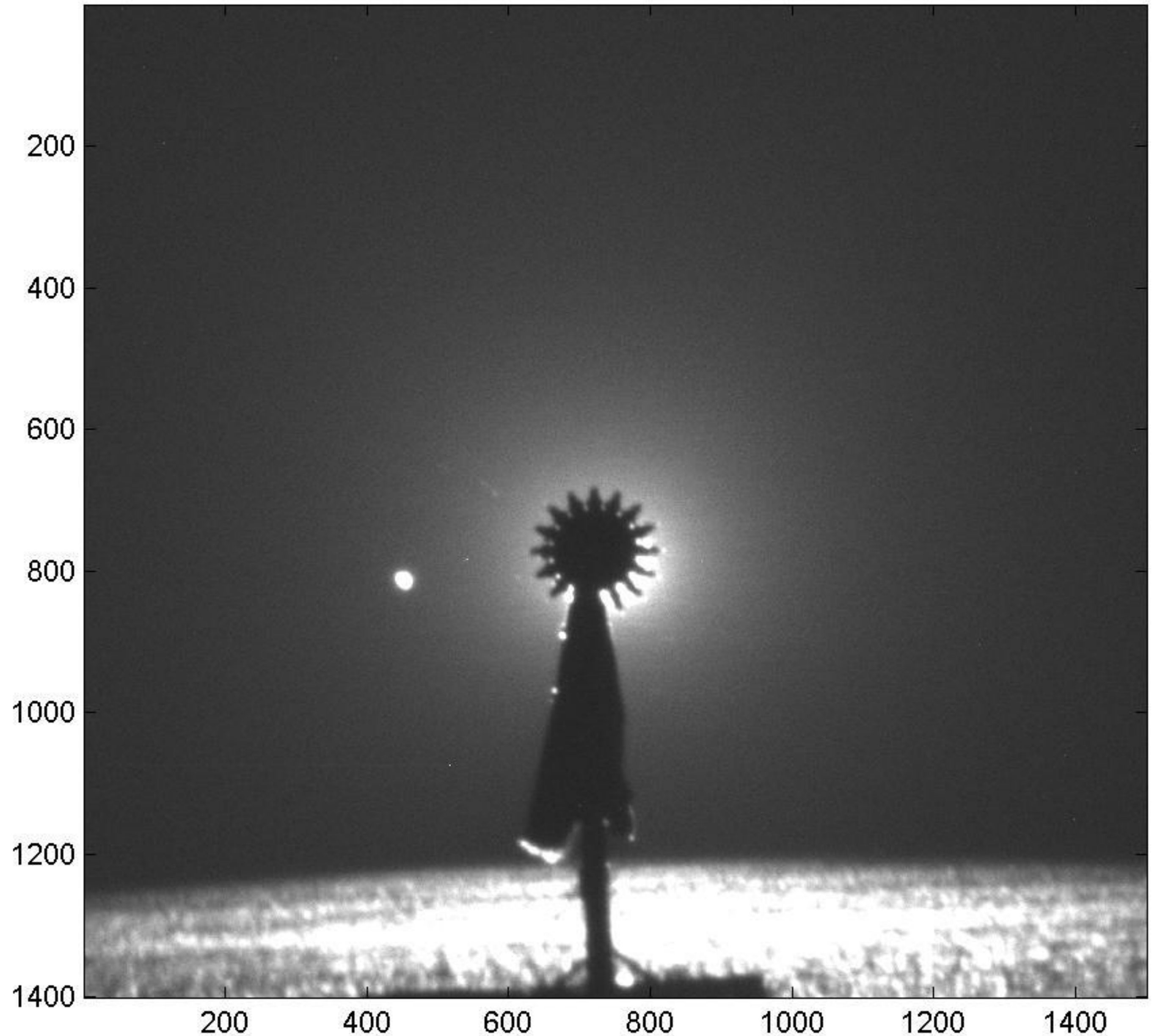
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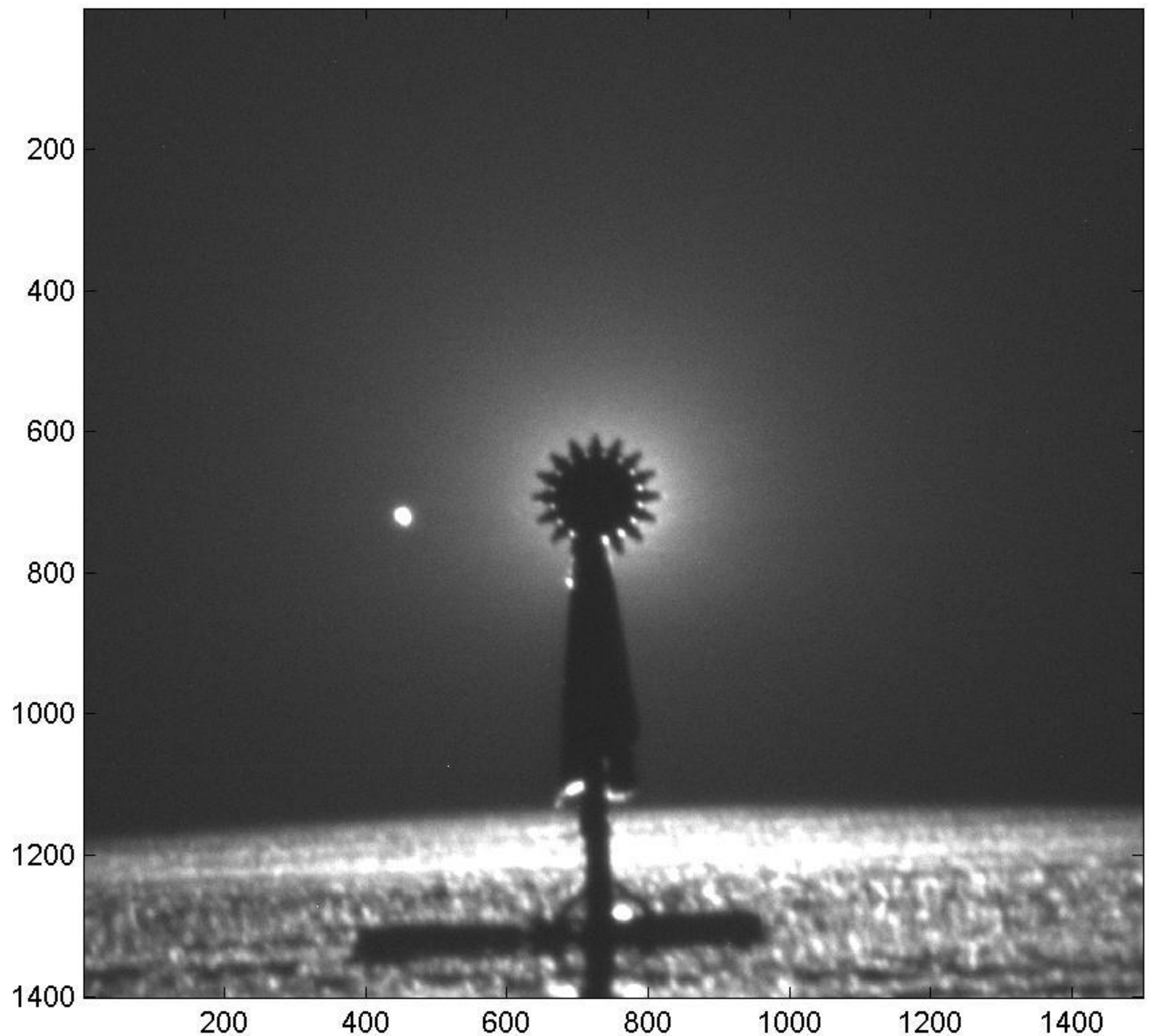
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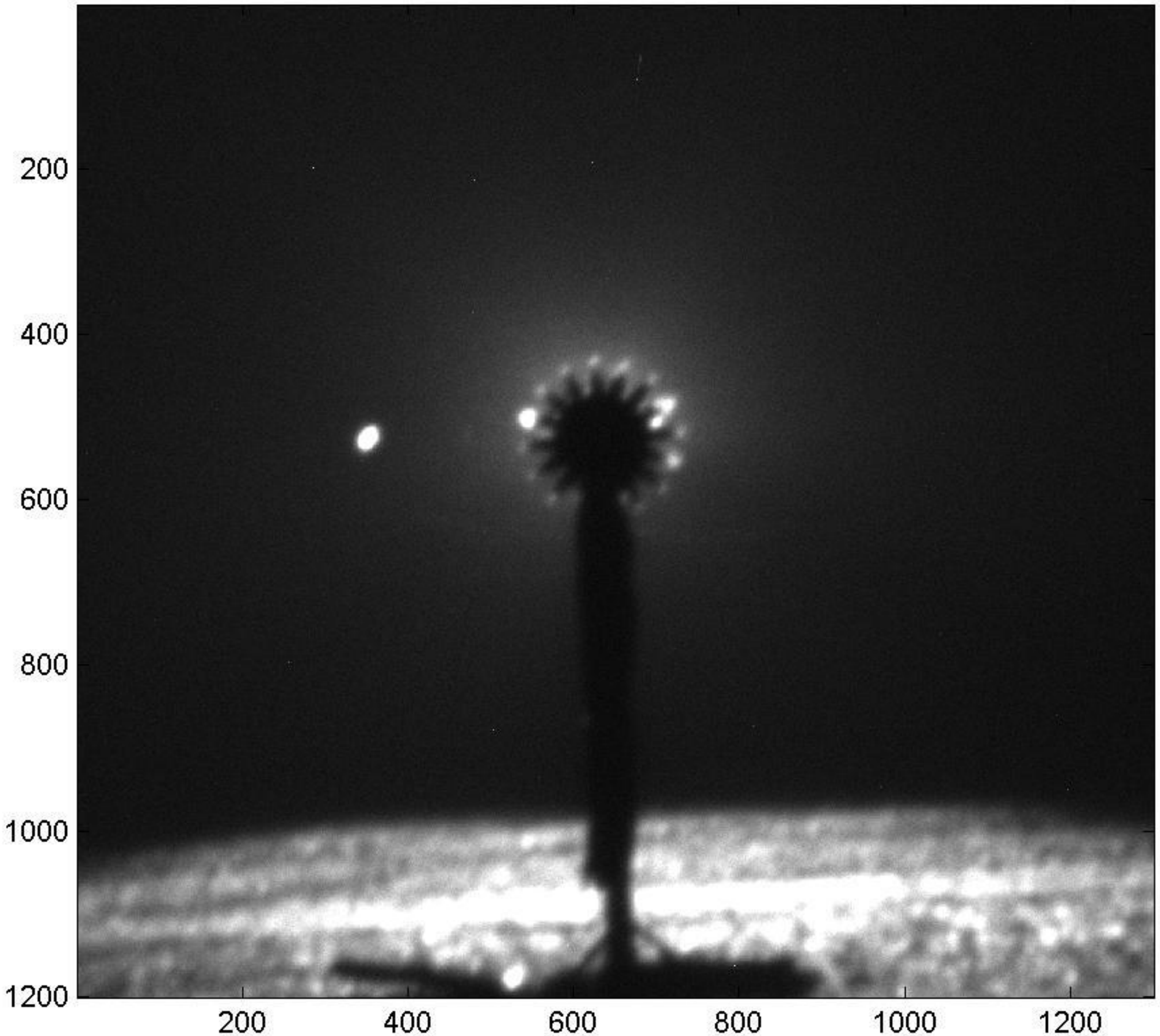
THE VALUE OF PERFORMANCE.

NORTHROP GRUMMAN

Sequence 2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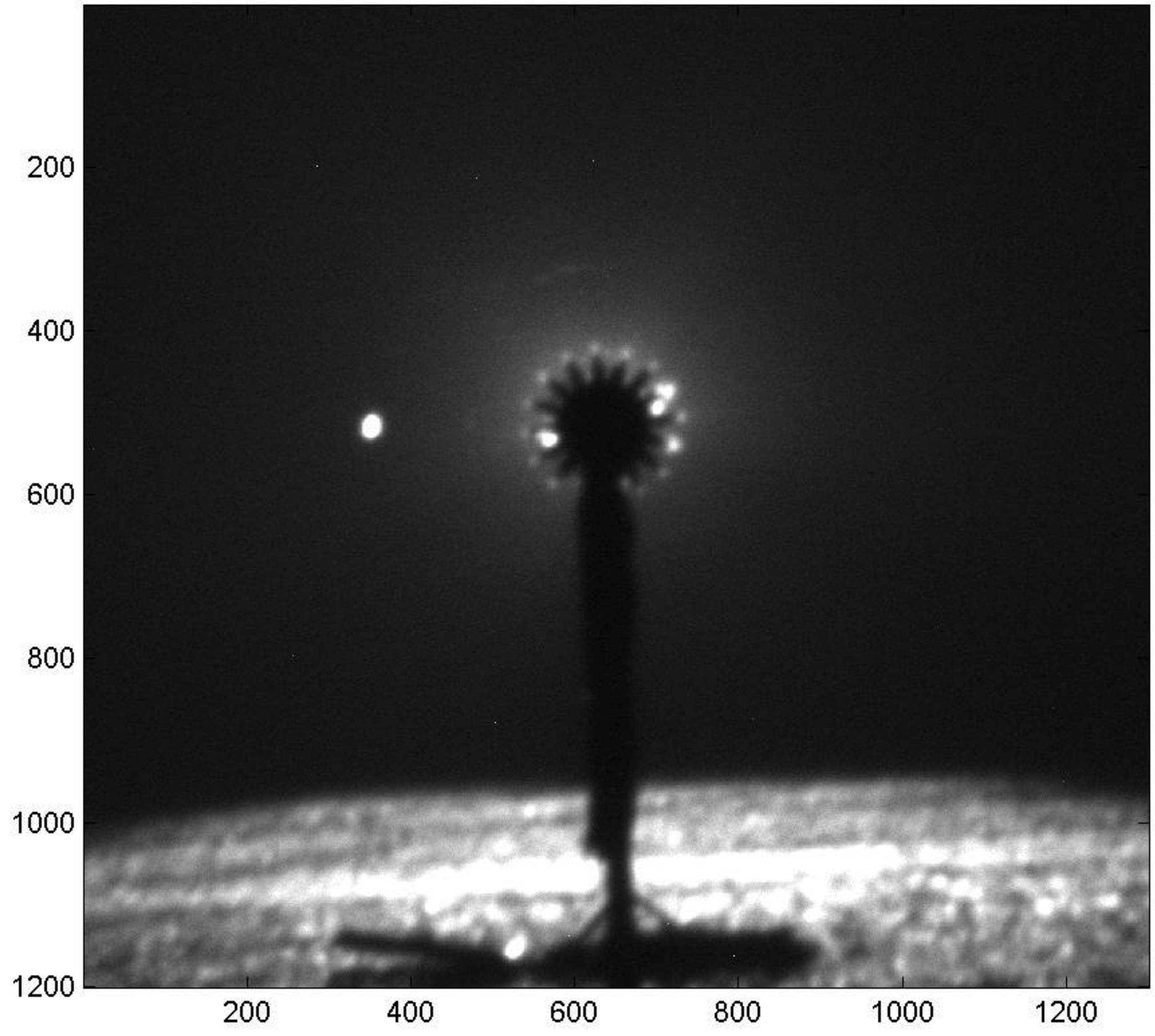
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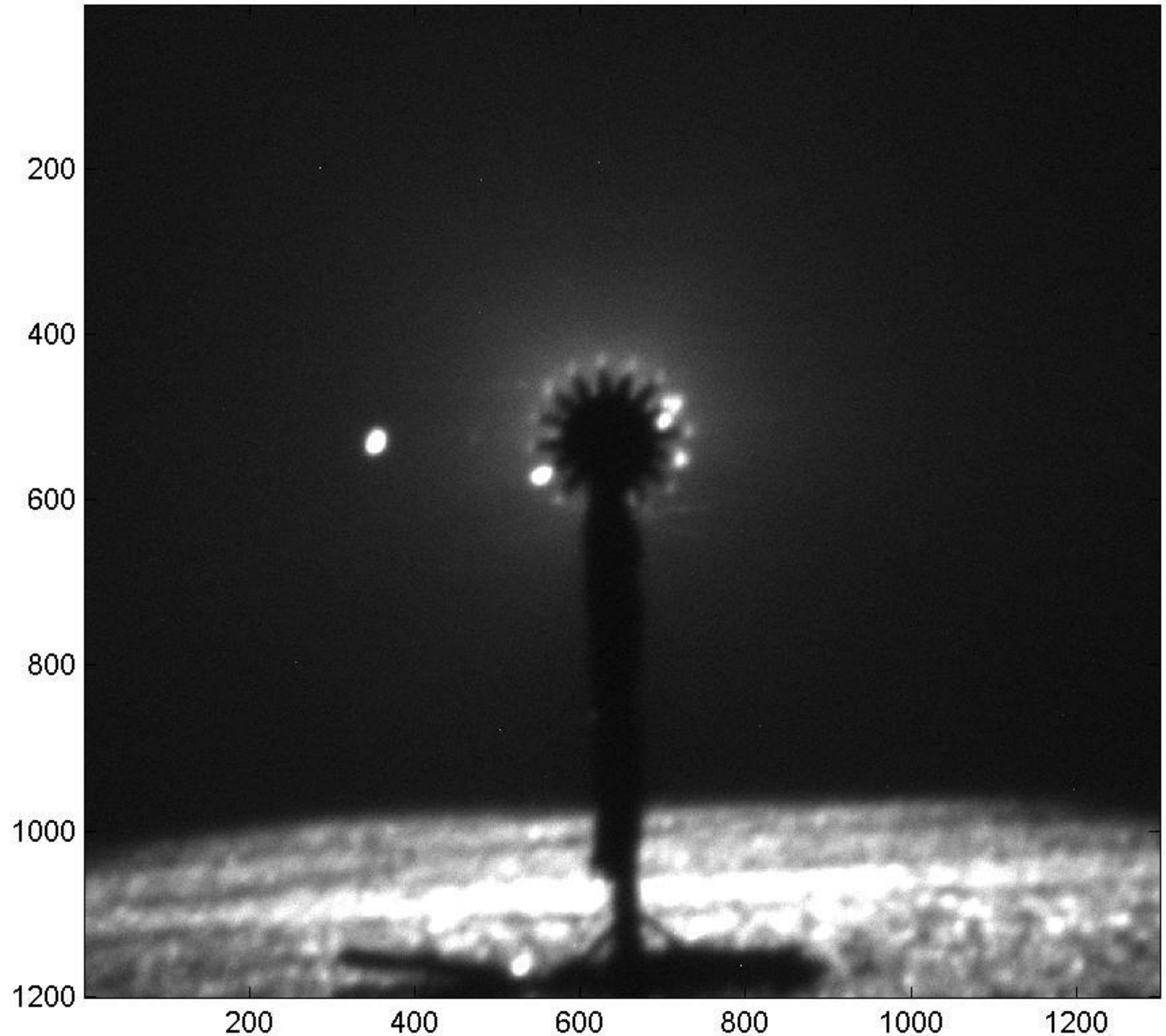

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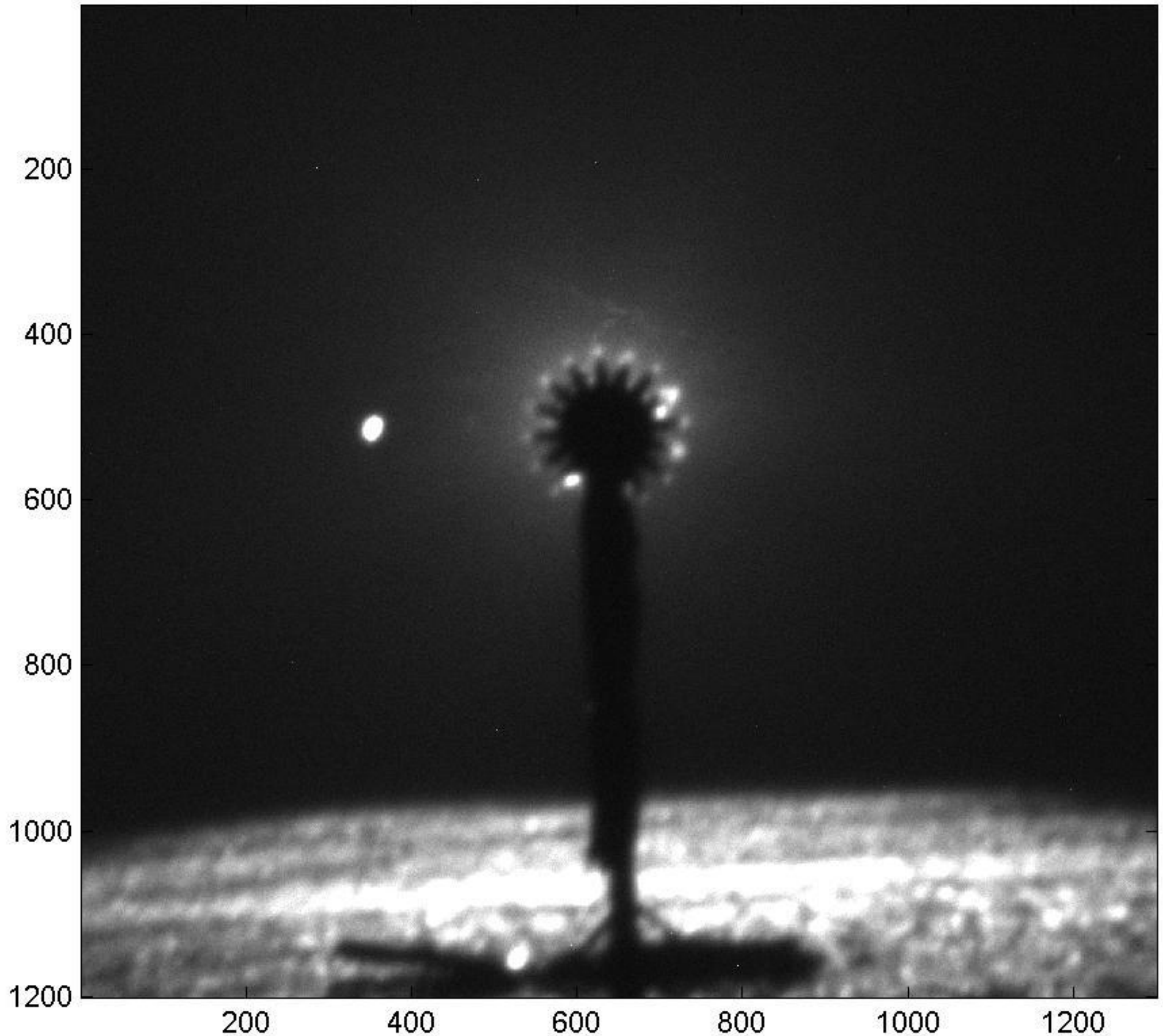
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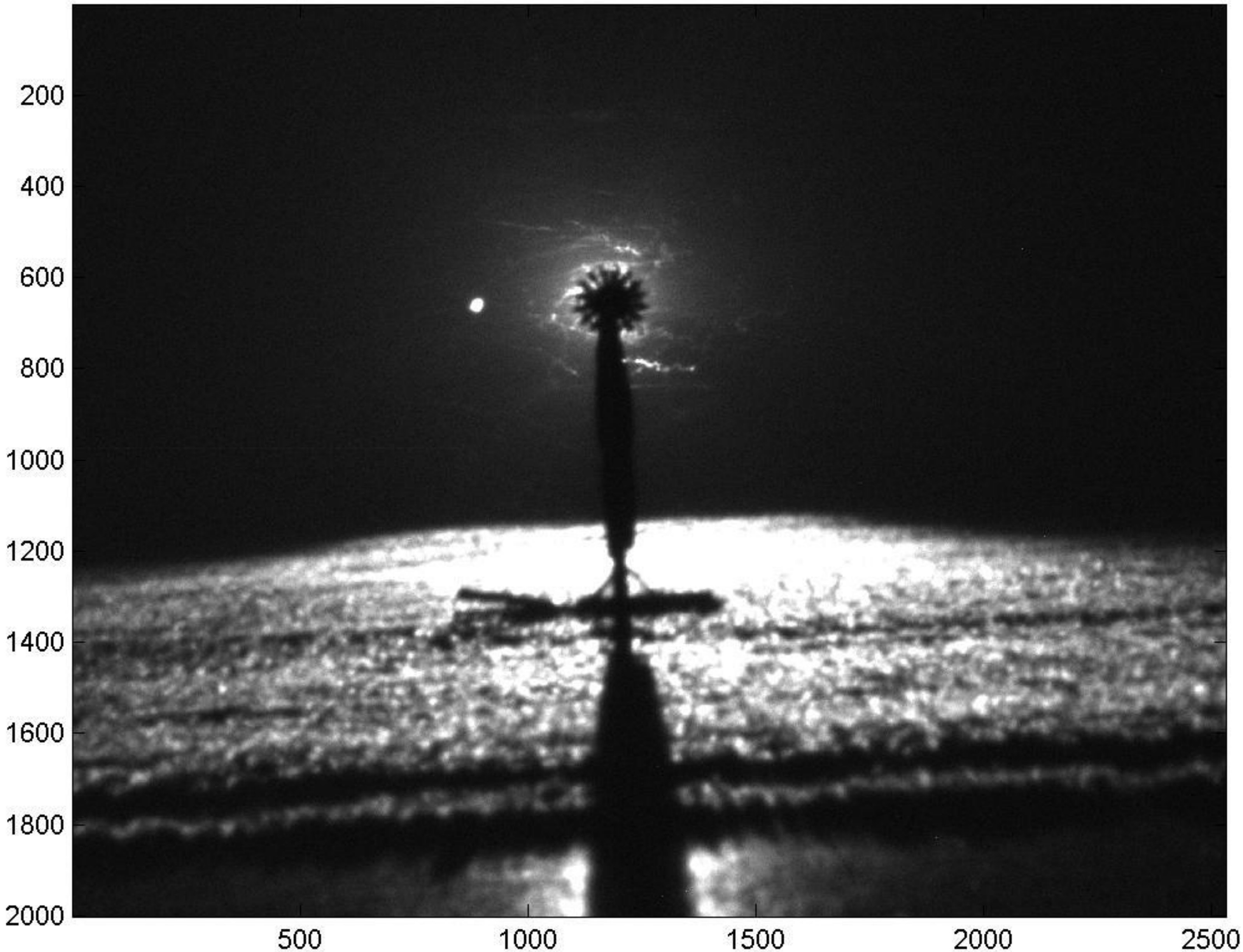

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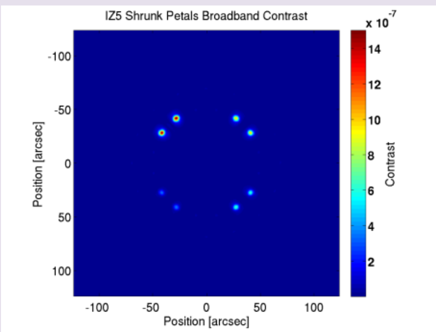
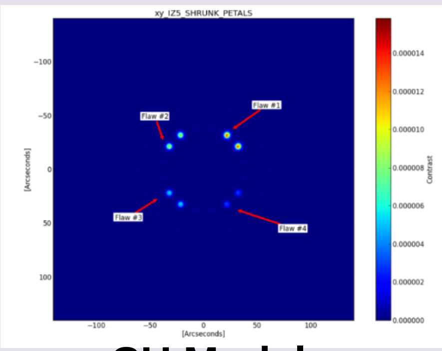
Model Validation

But Models Cannot Be Validated
They are always wrong.

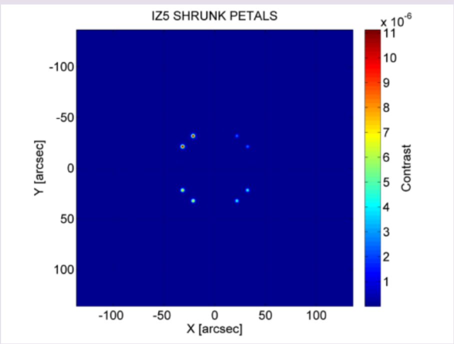
What needs validation is performance.
Models must be adjusted to follow lab results



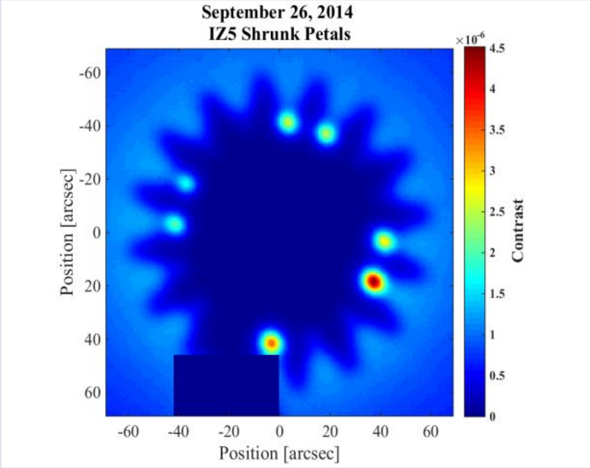
NG Model



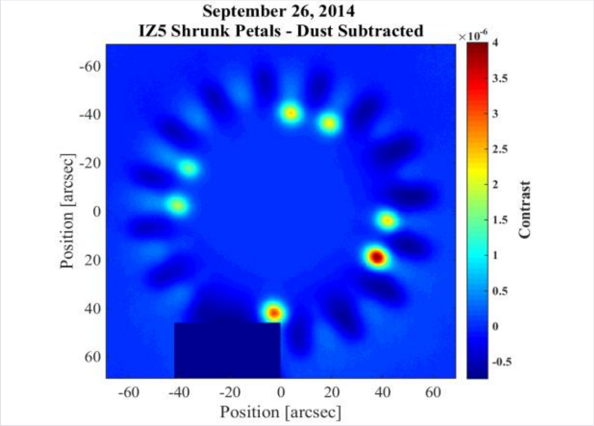
CU Model



JPL Model



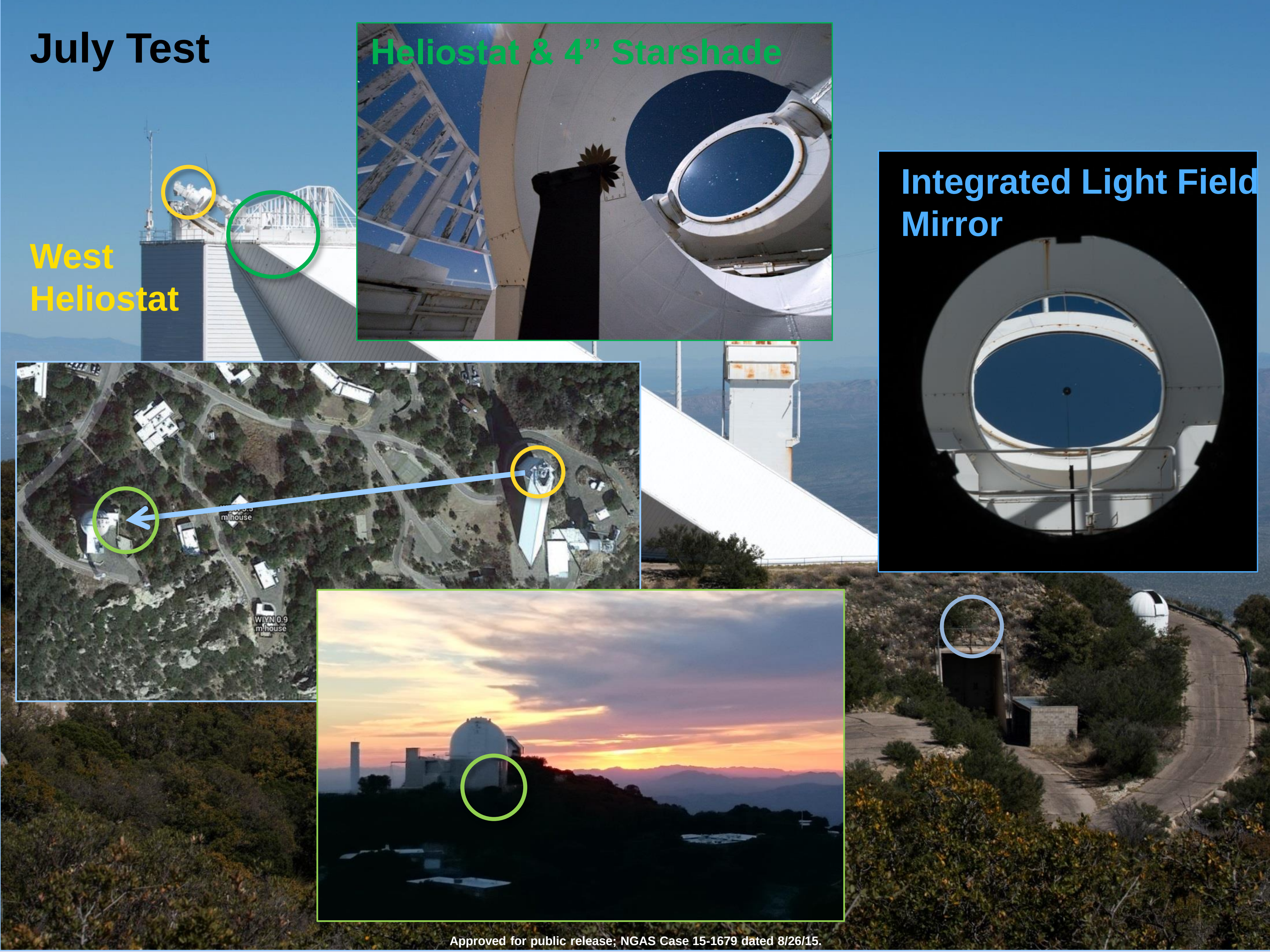
Measured



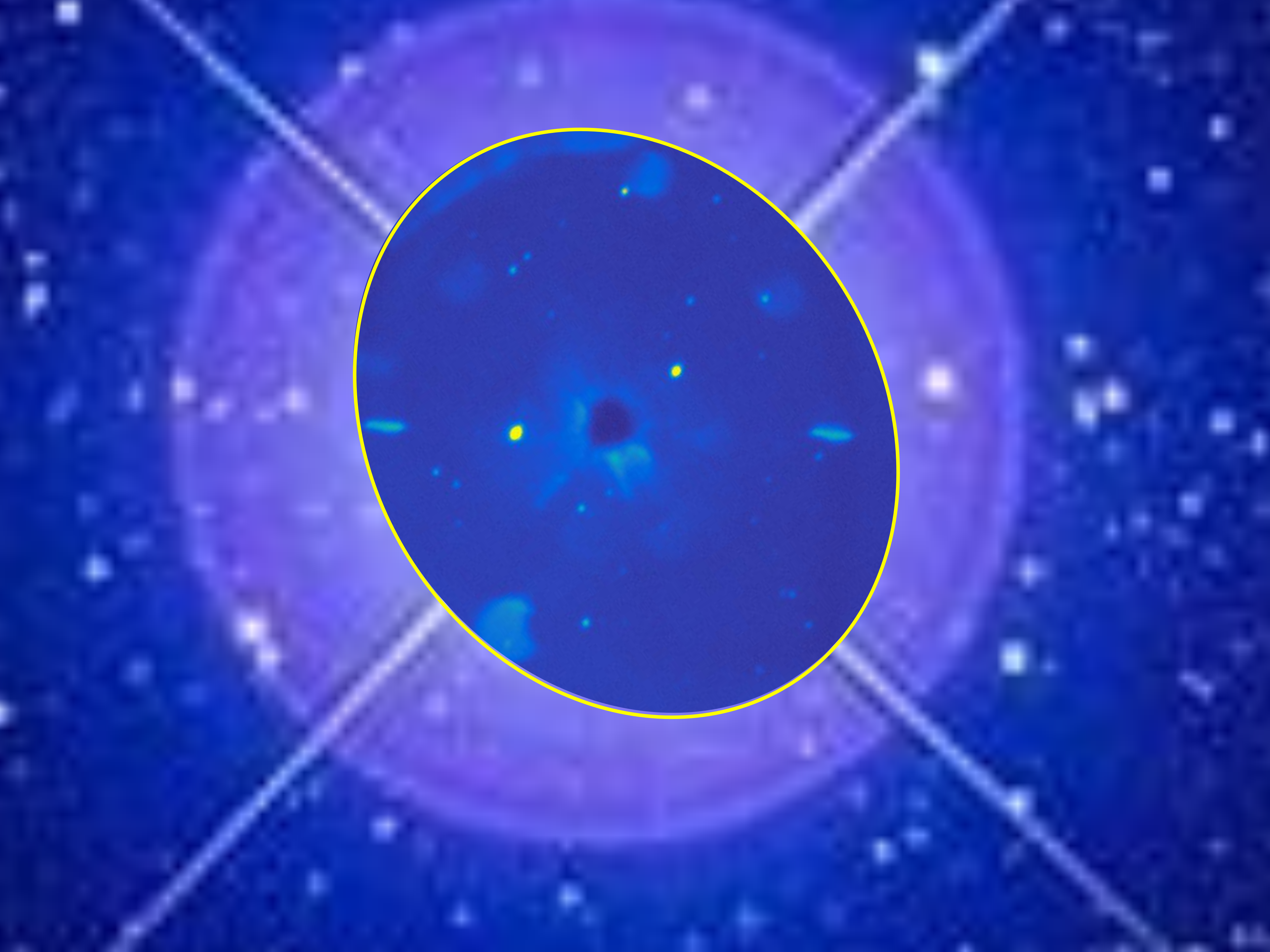
Measured & Dust Subtracted

Approved for public release; NGAS Case 15-1679 dated 8/26/15.

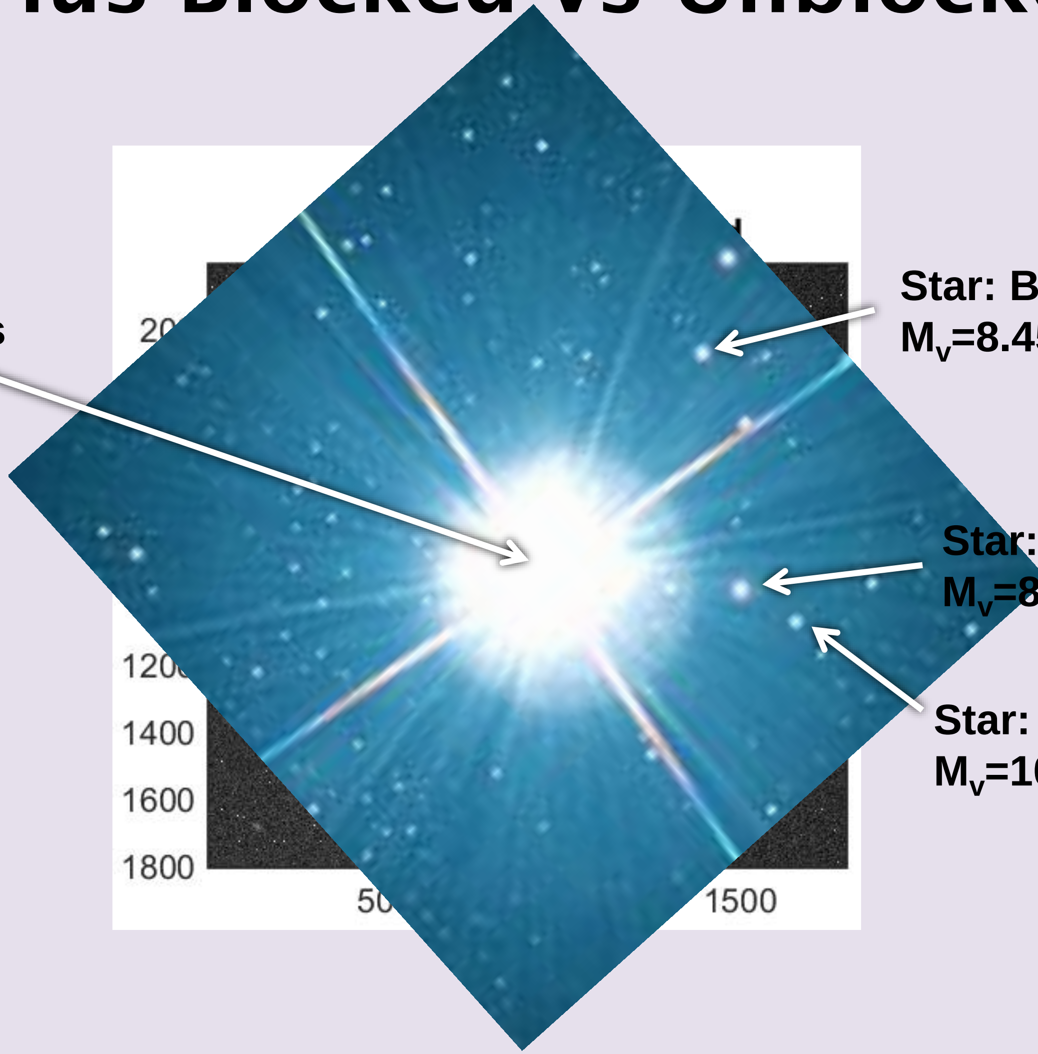
July Test



Approved for public release; NGAS Case 15-1679 dated 8/26/15.



Sirius Blocked vs Unblocked

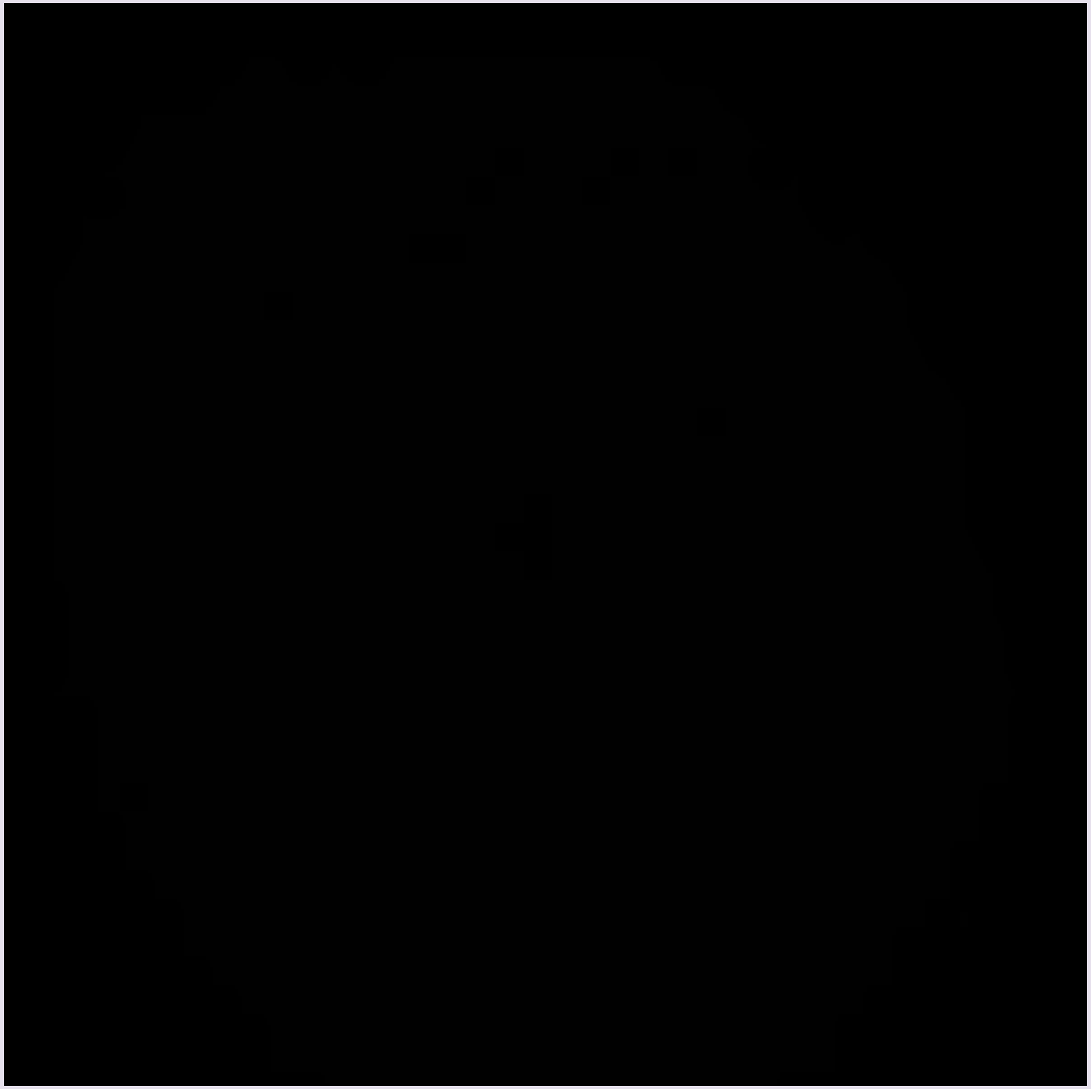


- 12 astronomical magnitudes shown in this image

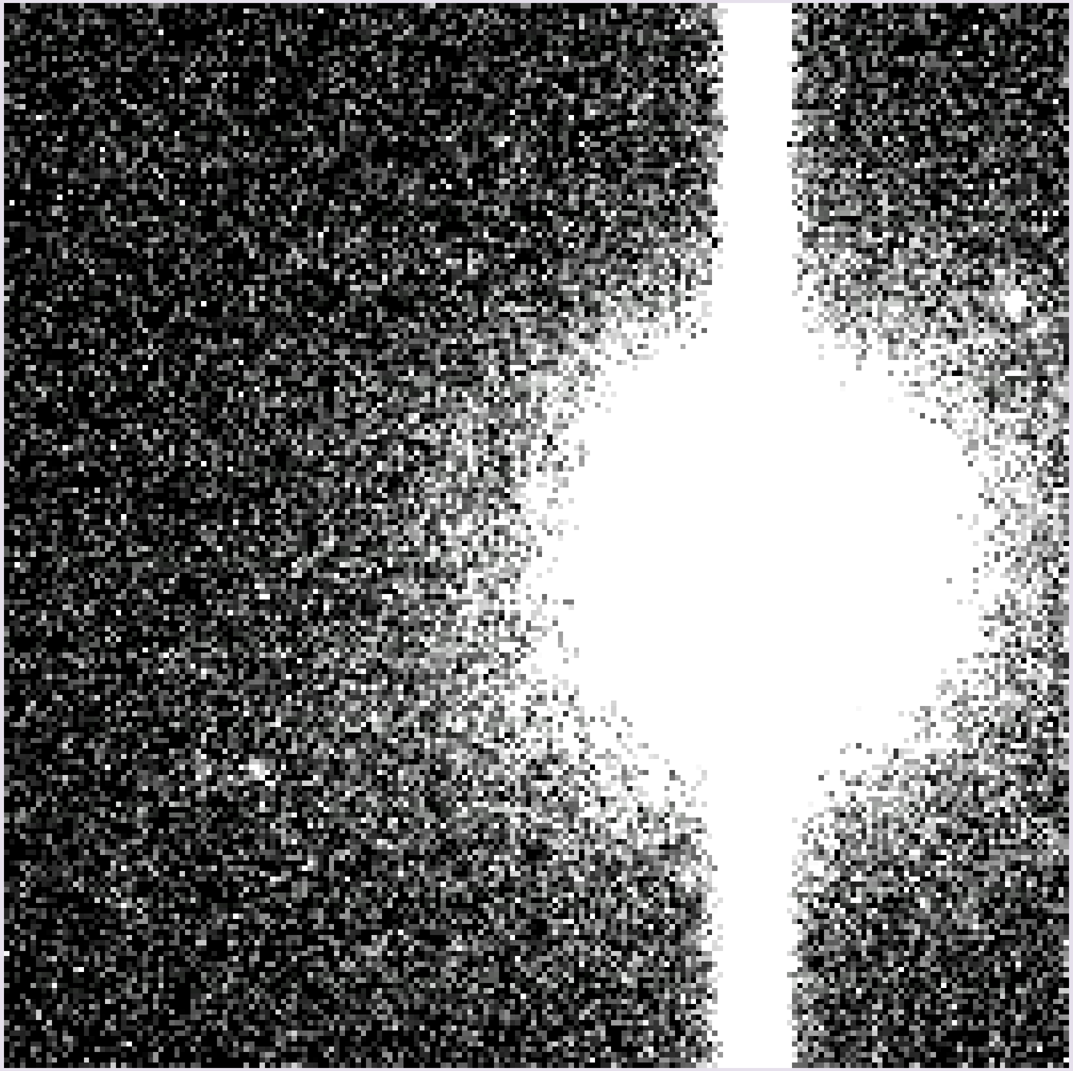
S. Warwick, et al. (2015)

Approved for public release; NGAS Case 15-1679 dated 8/26/15.

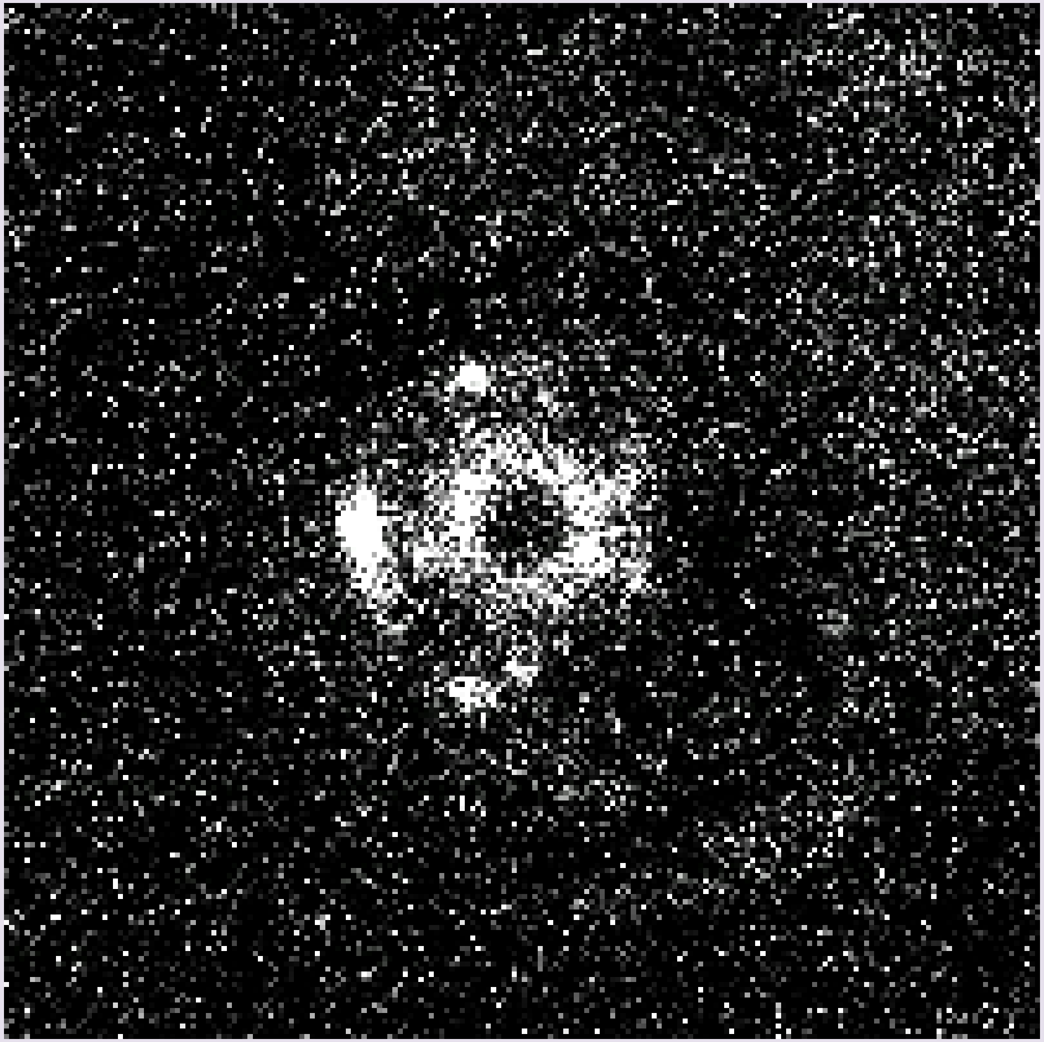
ET Phone Home



Flashlight



Antares



Needs and Opportunities

We have no support as of the end of this month.

Therefore there is no opportunity to move forward.