


The impact of satellite trails on Hubble Space Telescope observations

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HUBBLE
SPACE TELESCOPE

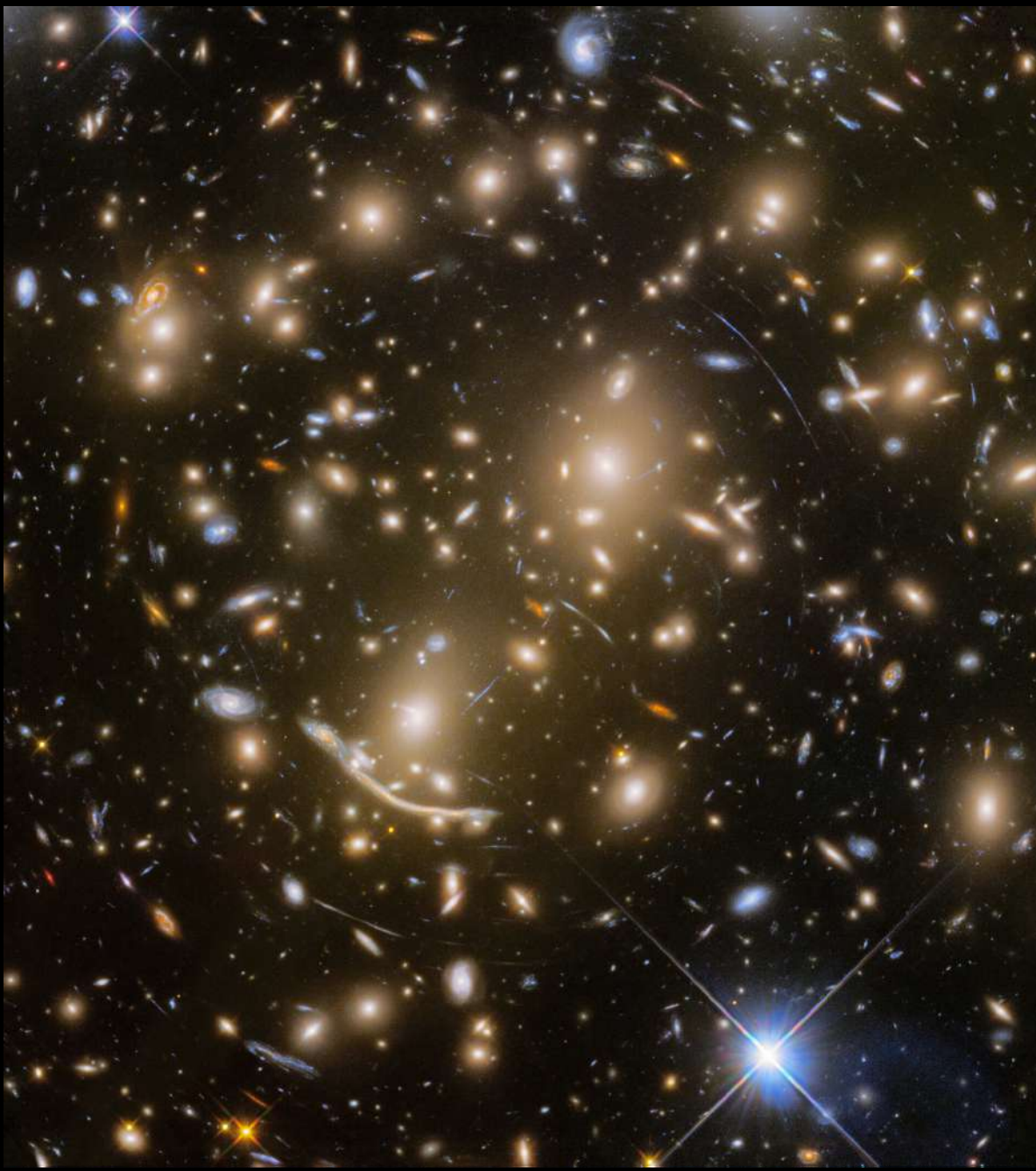




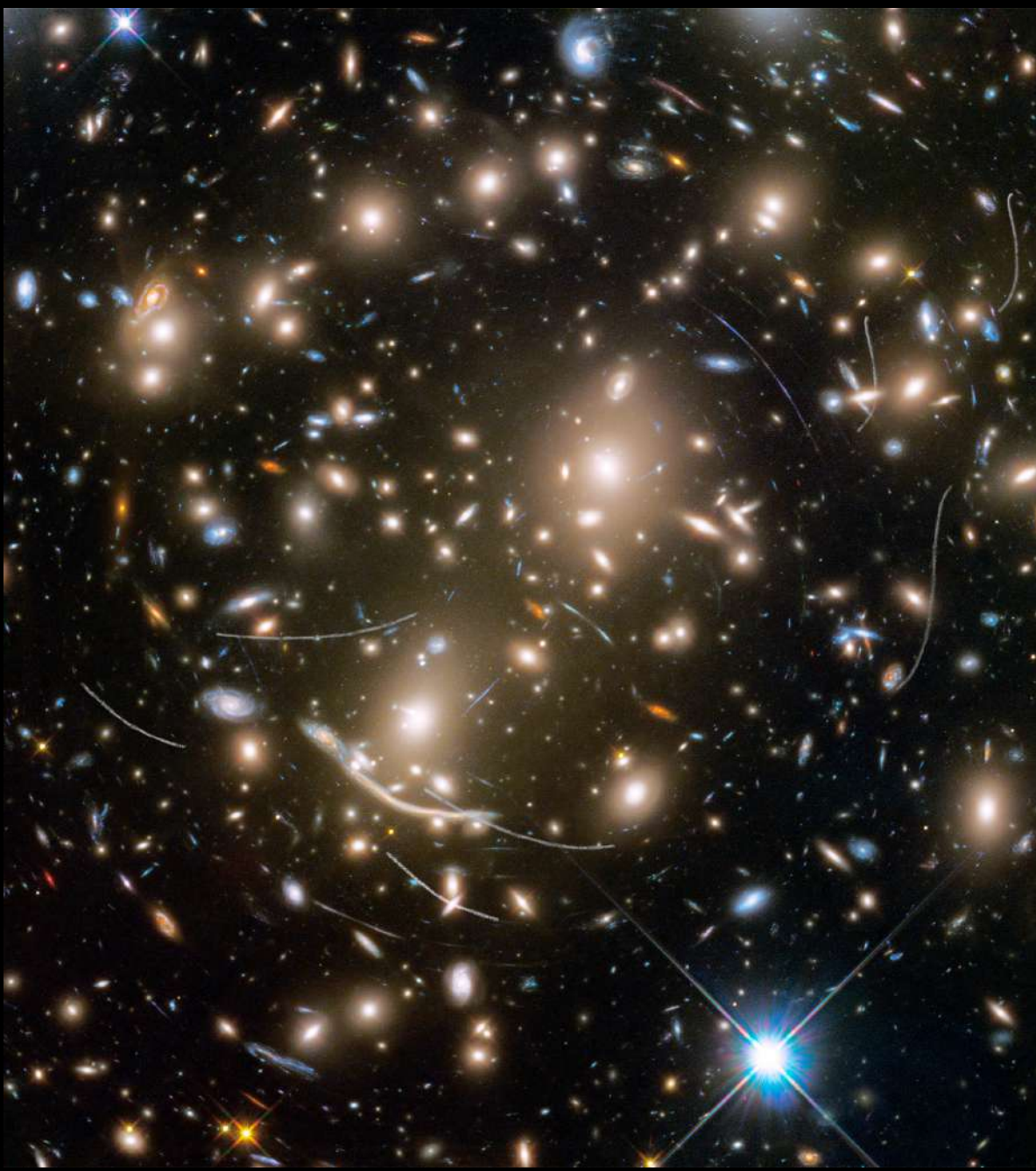
30 YEARS OF HUBBLE SPACE TELESCOPE

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Frontier Fields Cluster Abell 370, HST ACS
Credit: NASA, ESA/Hubble



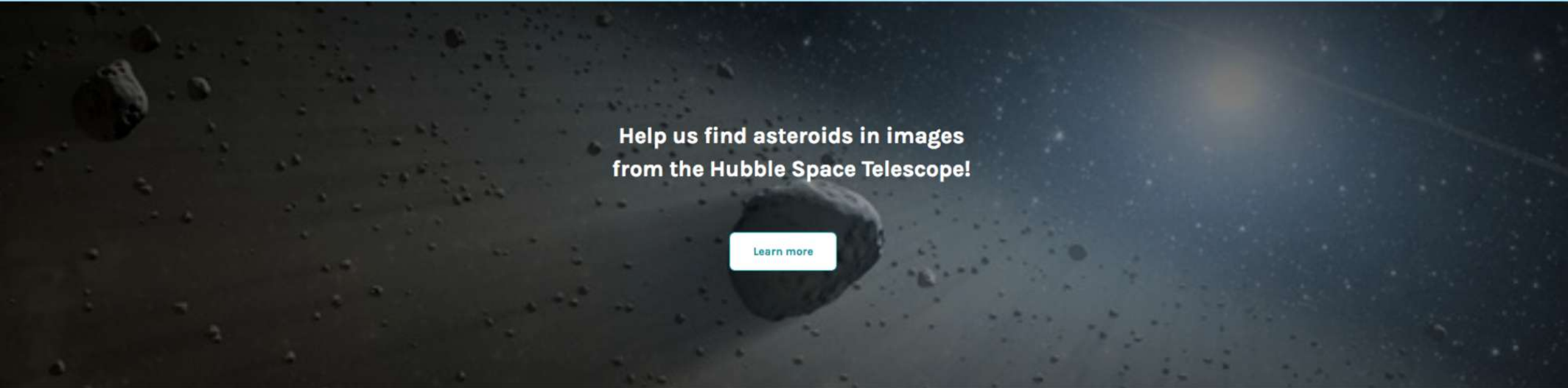
Asteroids observed serendipitously in image of Frontier Fields cluster Abell 370
Credit: NASA, ESA/Hubble



Frontier Fields cluster Abell 370
Trail probably Chinese Long March
4C Y33 third stage passing 34km
above HST.
Satellite ID by J. McDowell
Image credit: Judy Schmidt



Happy international asteroid day! [The current dataset has finished](#) and the science team is working on analysing your classifications.



Help us find asteroids in images from the Hubble Space Telescope!

[Learn more](#)

Get started

If you are for the first time on this project, choose "Training". Otherwise, move on to "Classify" and hunt for asteroids in Hubble images!

[Training](#)



TASK

TUTORIAL

Is there an asteroid trail visible in the images?

Yes

No

Impossible to tell

NEED SOME HELP WITH THIS TASK?

Done & Talk

Done



FIELD GUIDE



Participation

Classification Stats

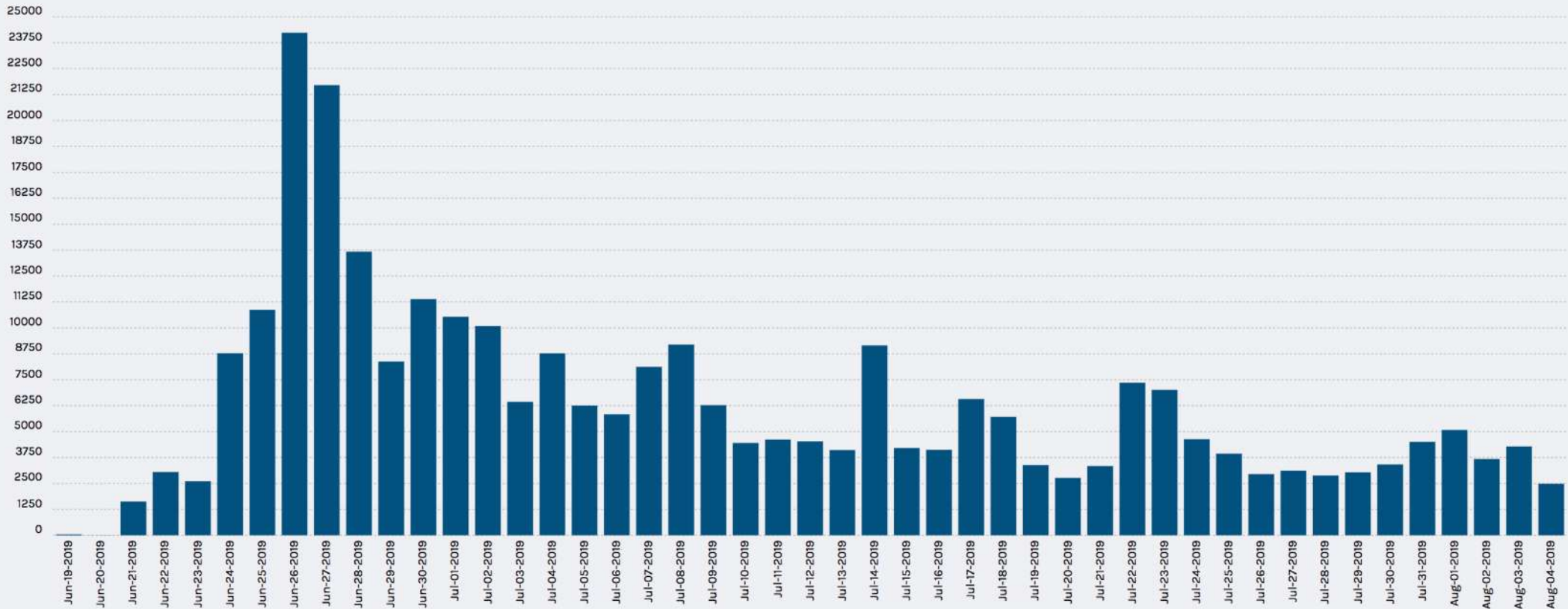
Classifications per for

Current date range: Jun-19-2019 to Aug-04-2019

[Reset date range](#)

Apr-01-2019

Oct-25-2019



Happy International Asteroid Day! The current dataset has finished and the science team is working on analysing your classifications.

Hubble Asteroid Hunter Talk

Search or enter a #tag

Subject 37652046




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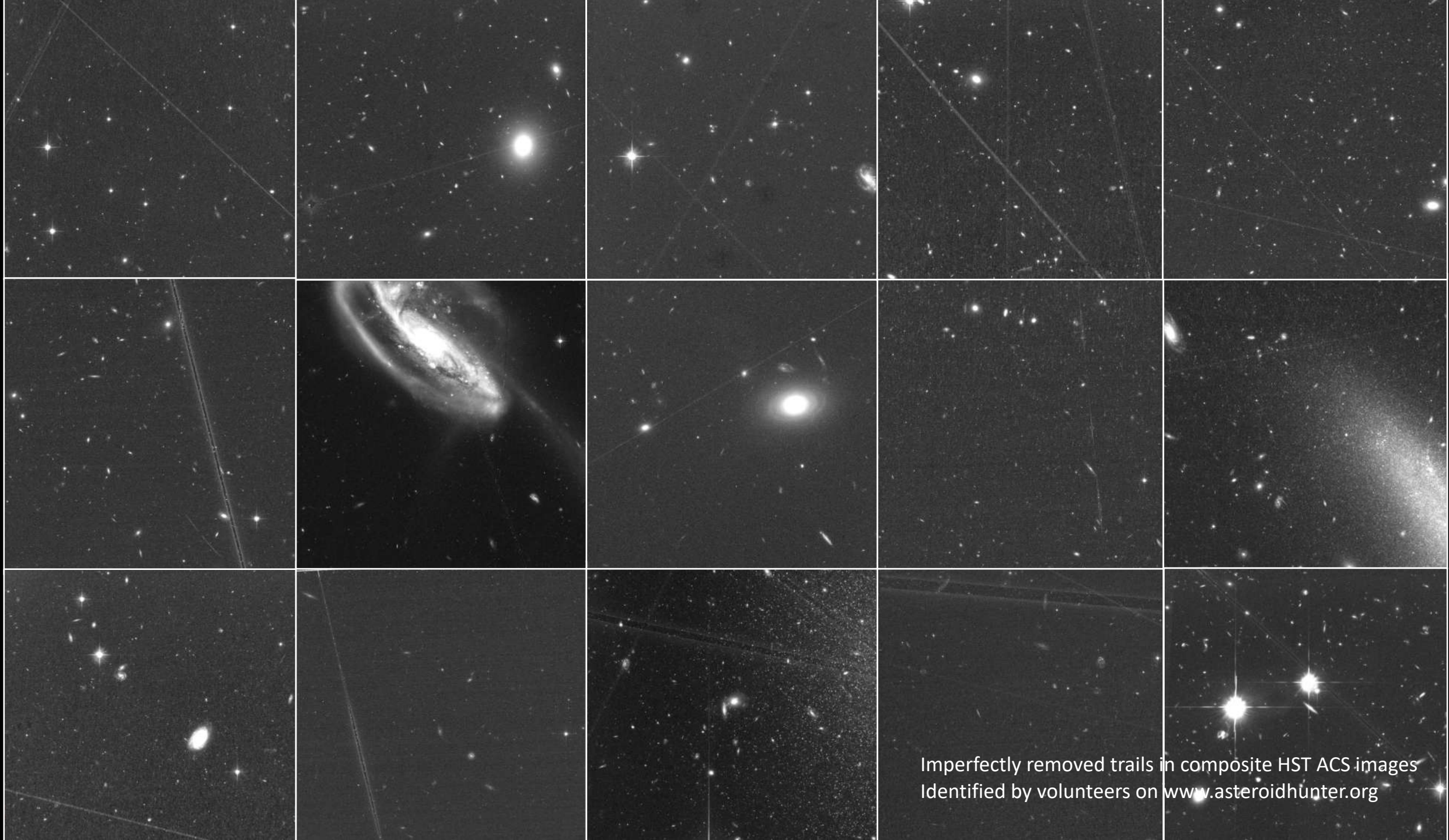
Comments:

 [fauxwise](#) @fauxwise

December 16th 2016, 11:51 am

Not clear what the grey line across the image could be. Perhaps a common [satellite](#)?

[View the discussion](#)

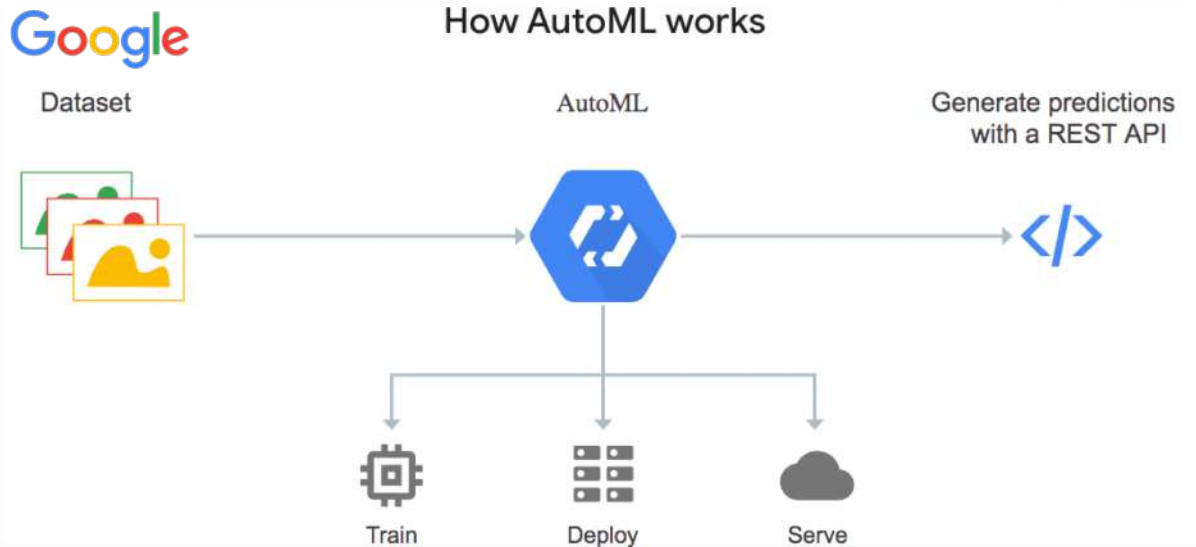
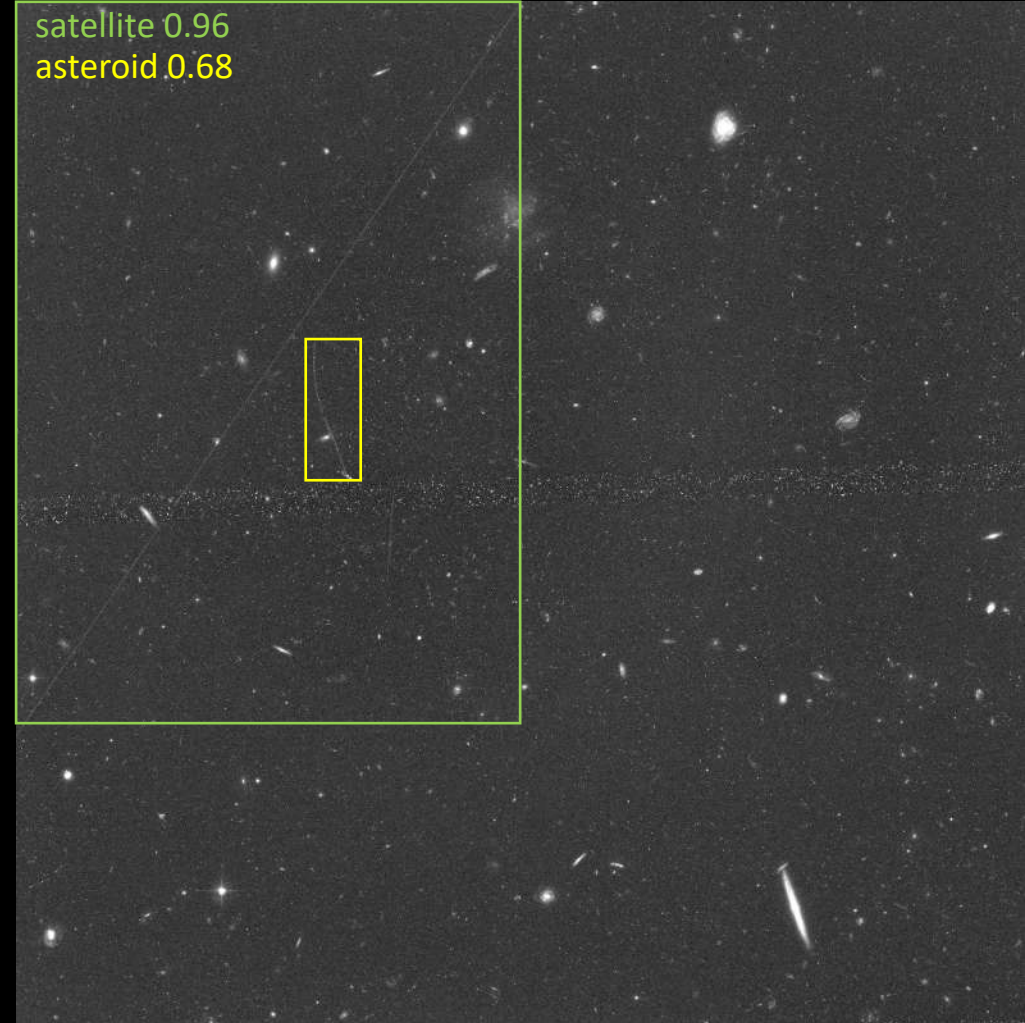
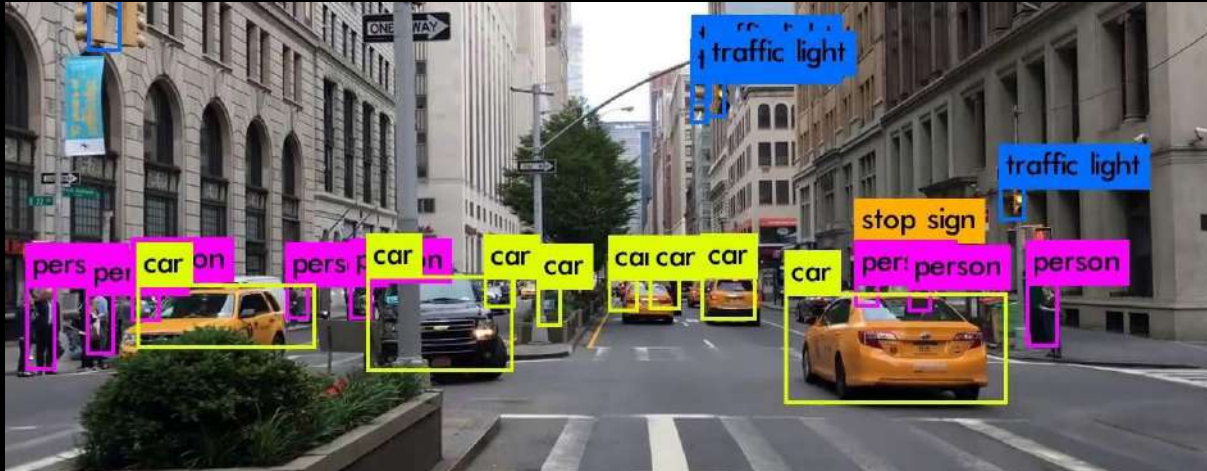


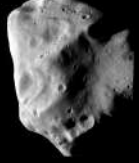
Imperfectly removed trails in composite HST ACS images
Identified by volunteers on www.asteroidhunter.org



Using deep learning to identify trails

* In collaboration with Google



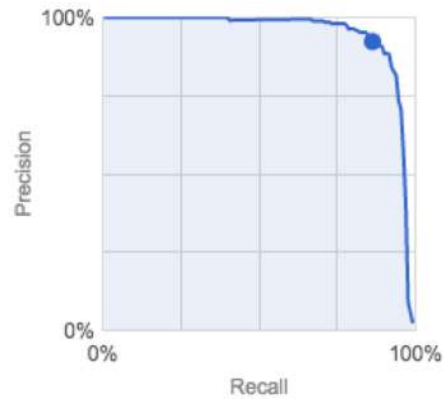


Using deep learning to identify trails

* In collaboration with Google

satellite

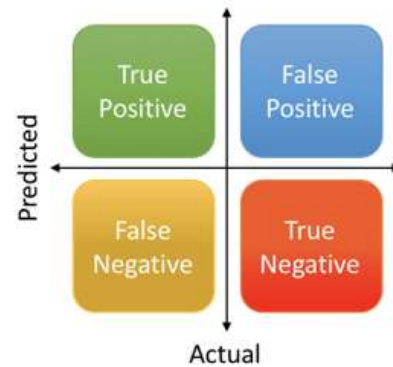
Total images	3,855
Test items	253
Total objects	263
Object to image avg	1.04
Precision ?	92.28%
Recall ?	86.31%



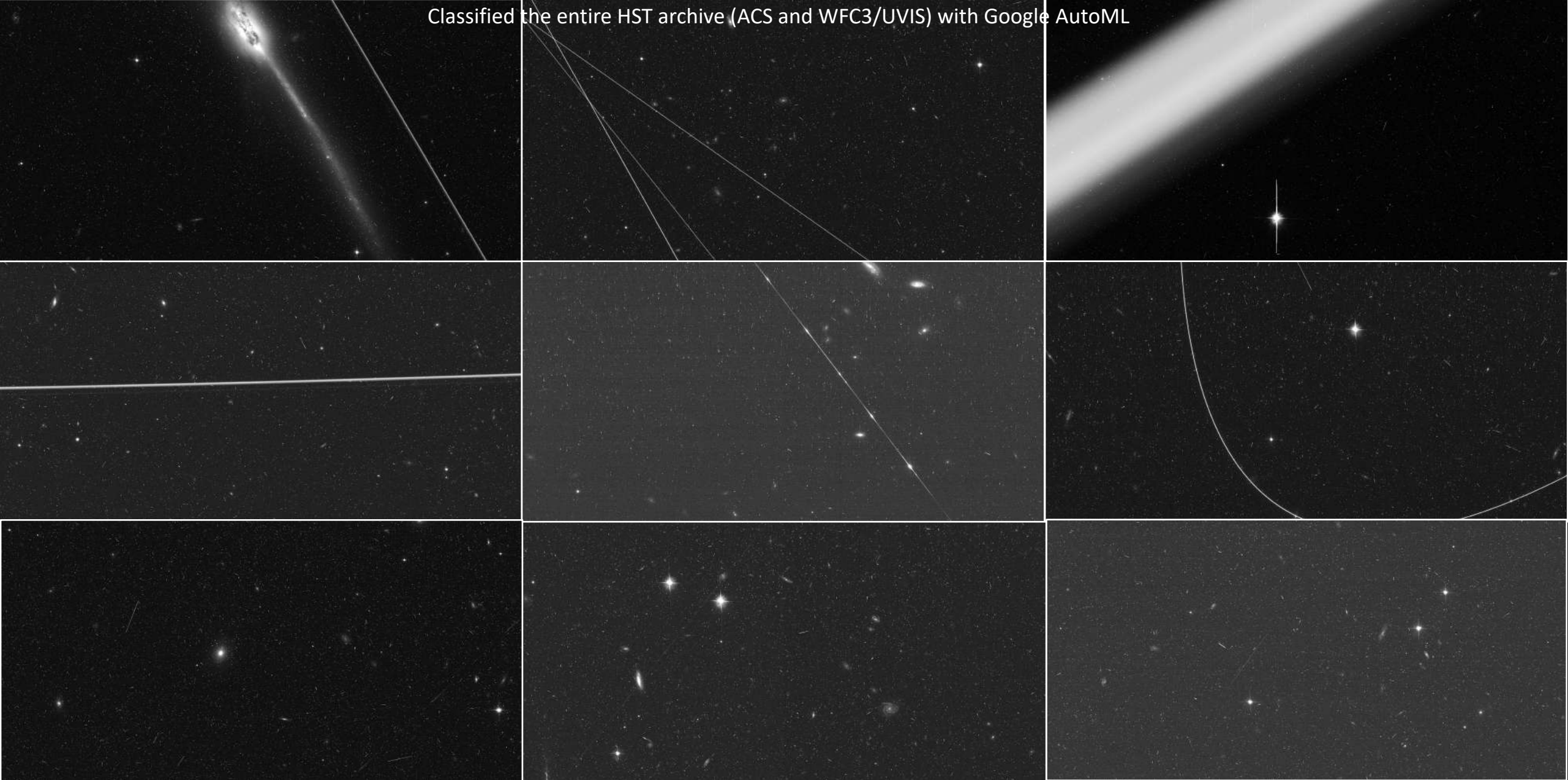
$$\text{Precision} = \frac{\text{True Positive}}{\text{Actual Results}} \quad \text{or} \quad \frac{\text{True Positive}}{\text{True Positive} + \text{False Positive}}$$

$$\text{Recall} = \frac{\text{True Positive}}{\text{Predicted Results}} \quad \text{or} \quad \frac{\text{True Positive}}{\text{True Positive} + \text{False Negative}}$$

$$\text{Accuracy} = \frac{\text{True Positive} + \text{True Negative}}{\text{Total}}$$



Classified the entire HST archive (ACS and WFC3/UVIS) with Google AutoML





Fraction of HST images with satellite trails

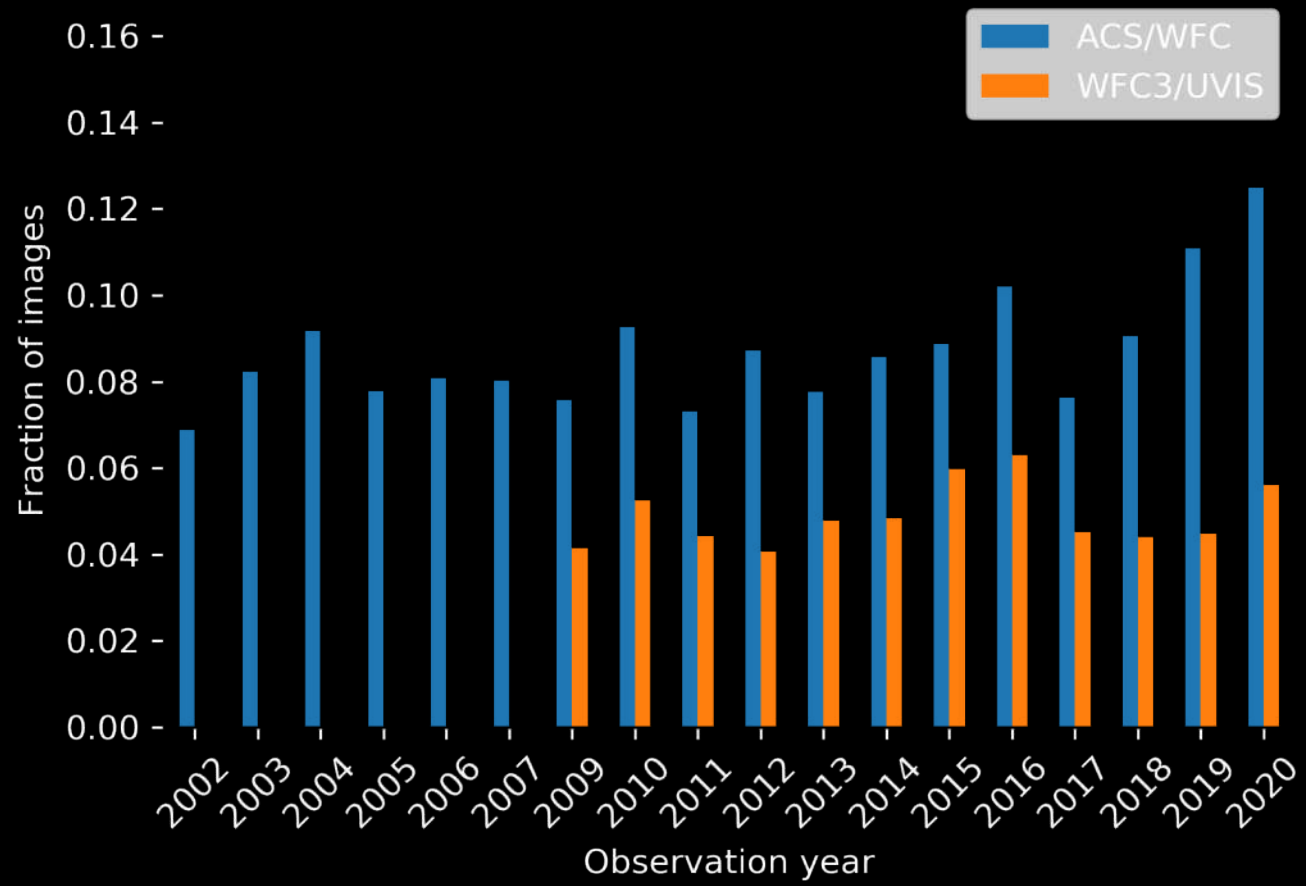


7.8% of Hubble composite images (~35 min exp. time) are crossed by satellite trails



2.5% of individual exposures of 10 min (2.7% ACS and 1.9% of WFC3 impacted)

HST images with satellite trails by instrument



ACS FOV = 202"x202" / WFC3 FOV = 160"x160"

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Fraction of HST images with satellite trails



7.8% of Hubble composite images (~35 min exp. time) are crossed by satellite trails

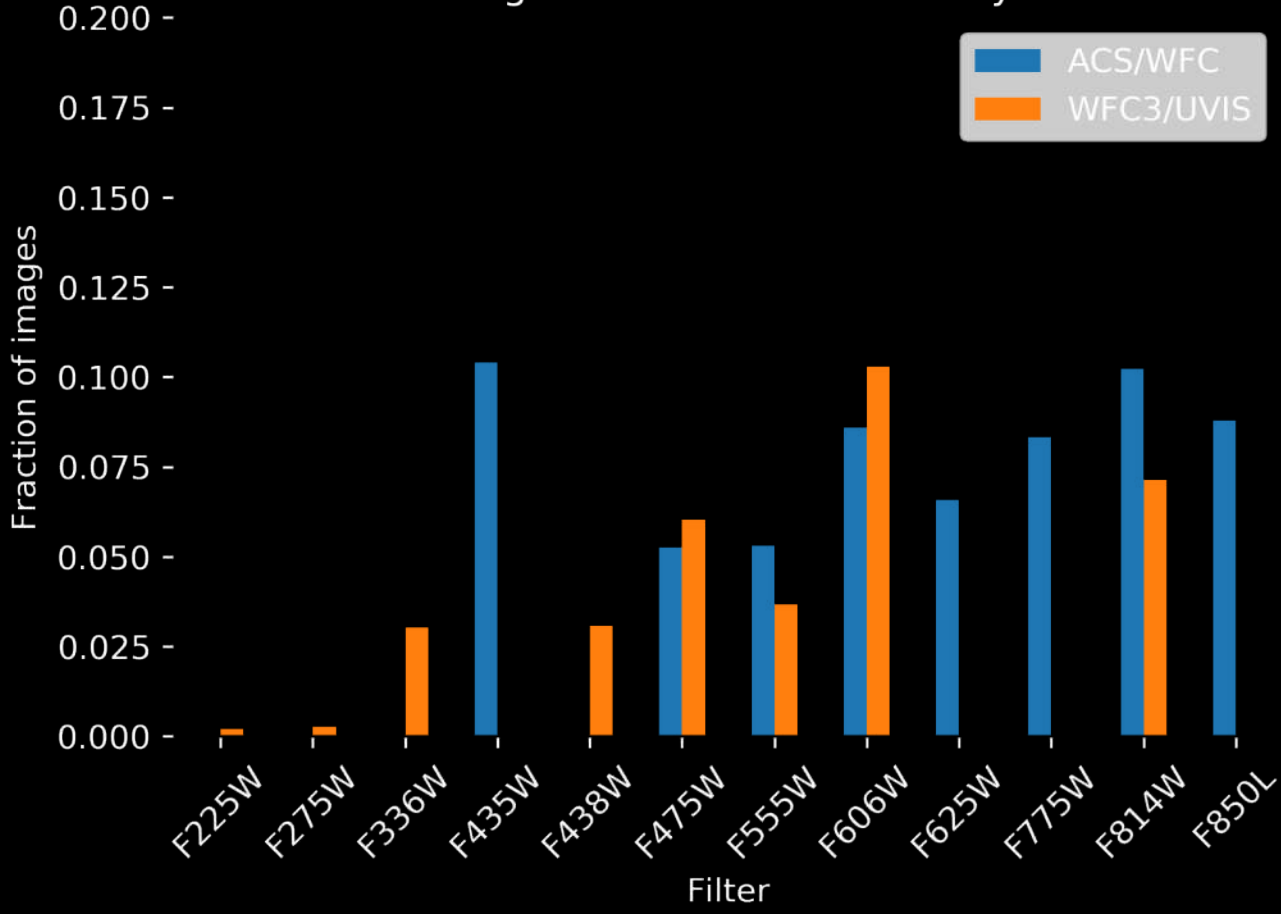


2.5% of individual exposures of 10 min (2.7% ACS and 1.9% of WFC3 impacted)



The fraction depends on filter. No satellites in UV

HST images with satellite trails by filter



ACS FOV = 202"x202" / WFC3 FOV = 160"x160"

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Fraction of HST images with satellite trails

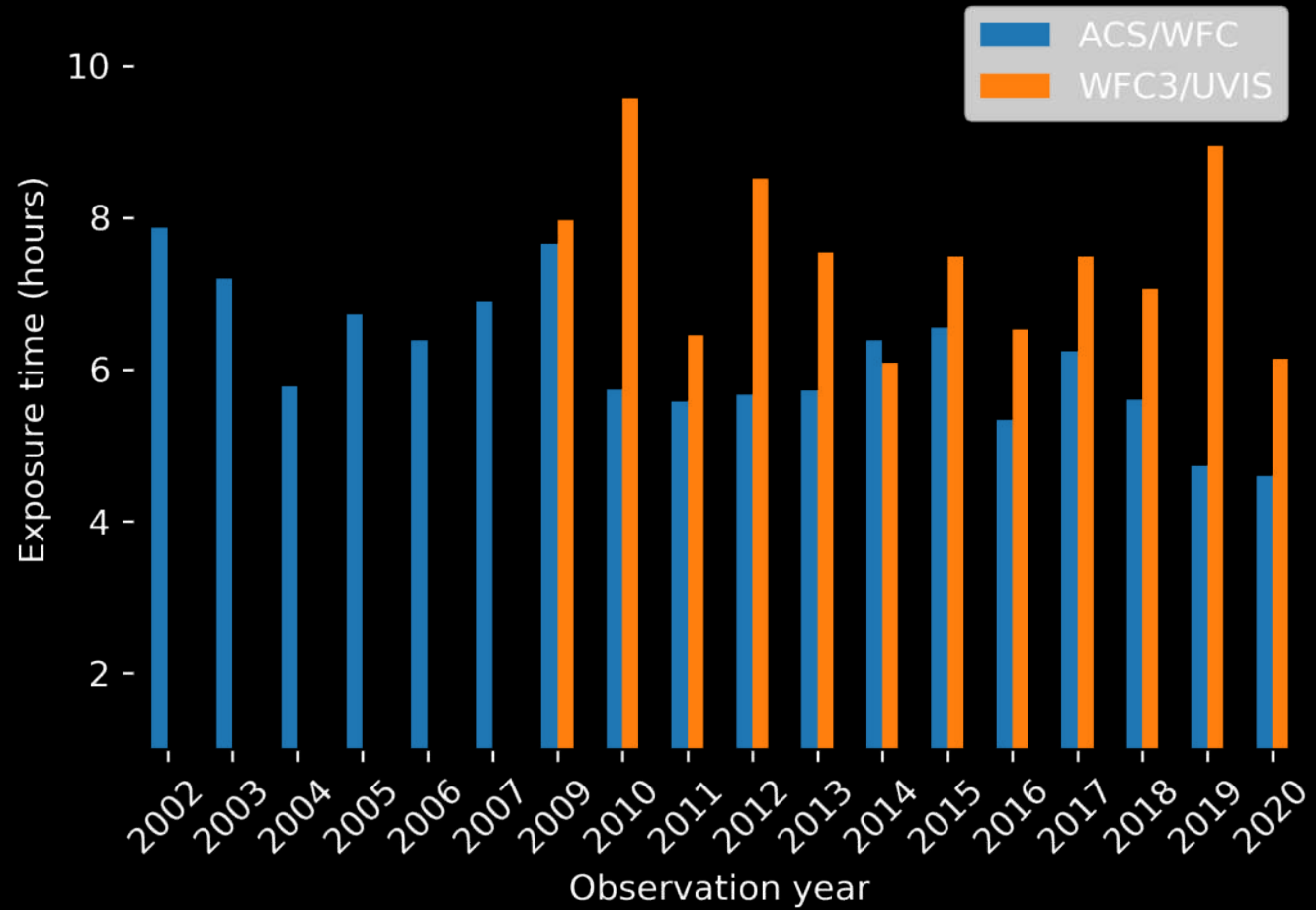


6 hours of exposure for a satellite to cross the field-of-view for ACS (7.7 for WFC3)



Decreased 30% from 2002-2020

Observation time for a satellite to cross the field-of-view



ACS FOV = 202"x202" / WFC3 FOV = 160"x160"

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Fraction of HST images with satellite trails



6 hours of exposure for a satellite to cross the field-of-view for ACS (7.4 for WFC3)

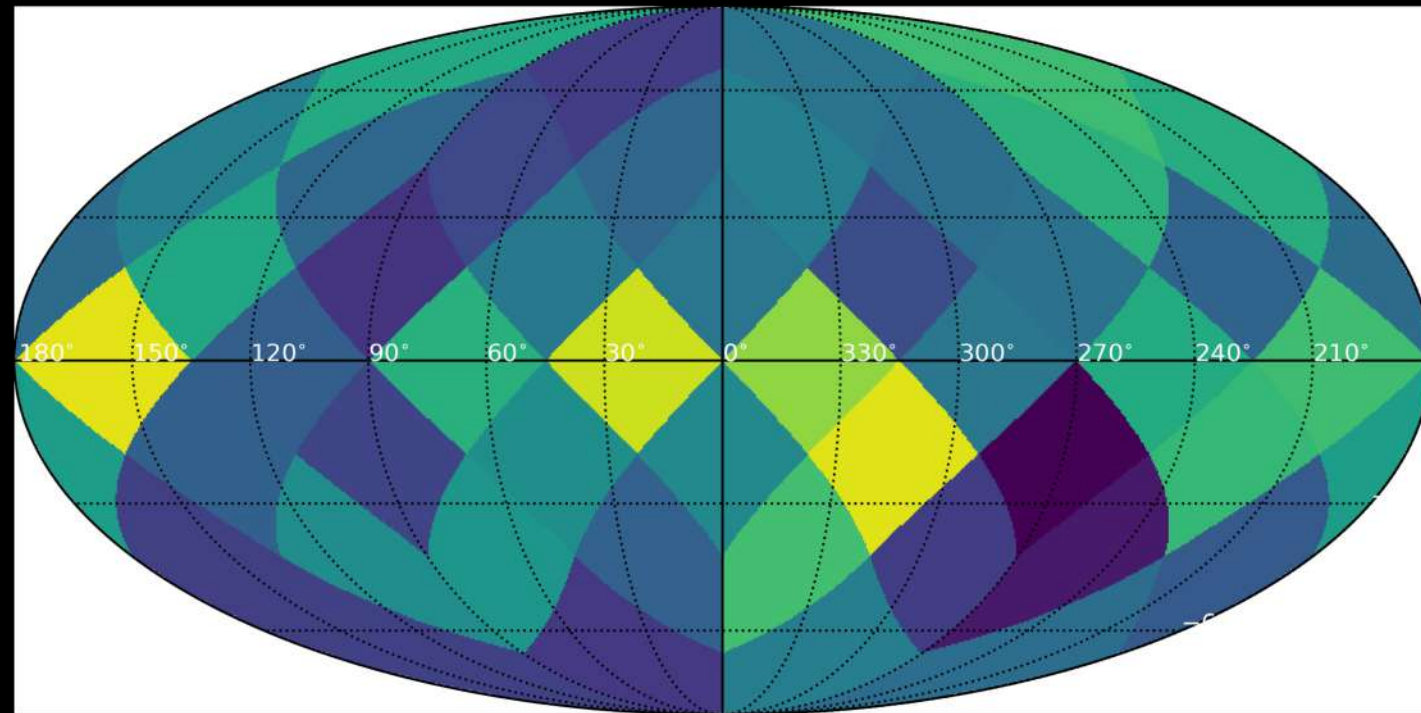


Decreased 30% from 2002-2020



Fraction depends on telescope pointing. Satellites more likely at $\delta \sim 0^\circ$ and $\delta > 50^\circ$

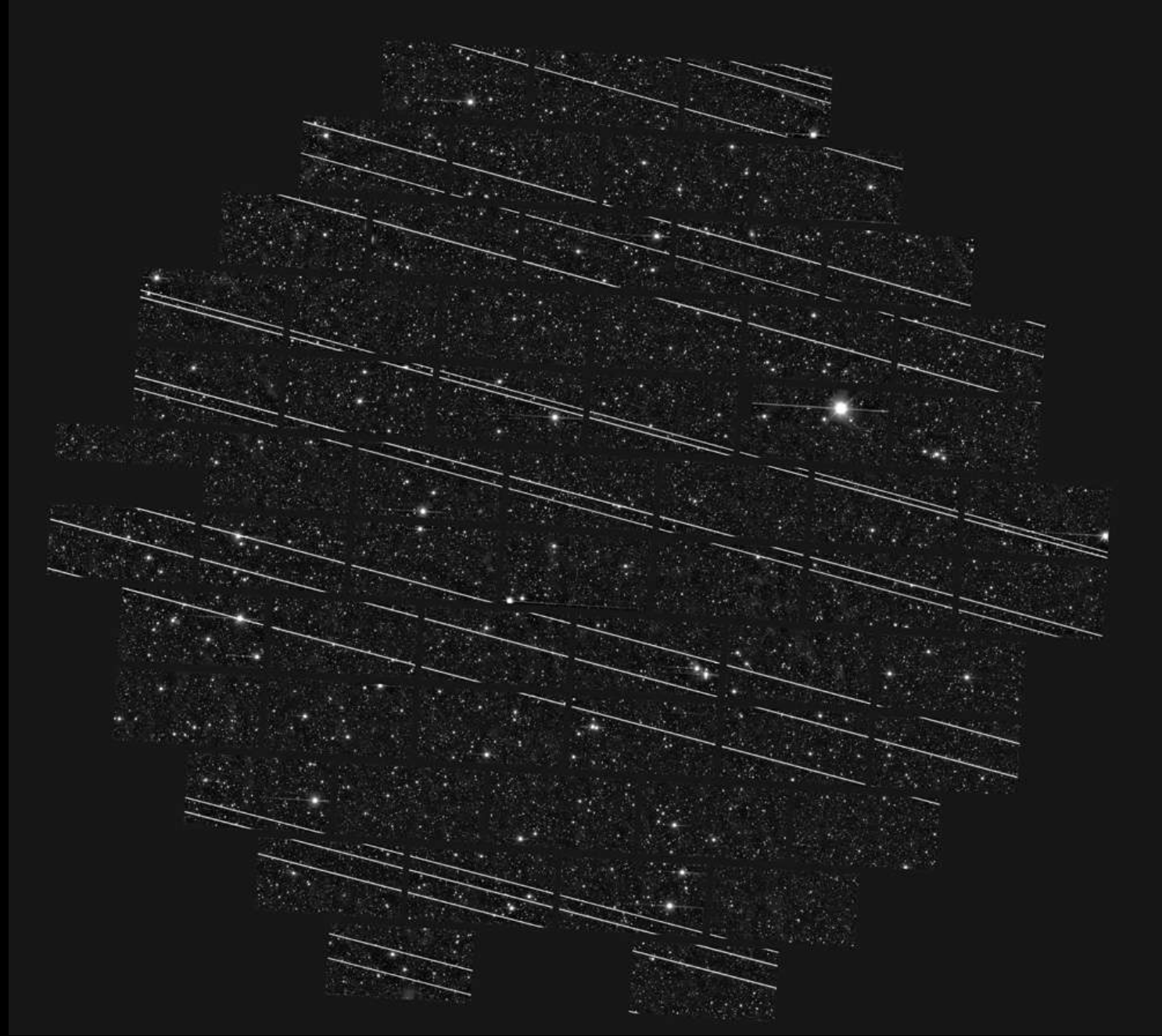
Observed fraction of satellites by HST per sky area



ACS FOV = 202"x202" / WFC3 FOV = 160"x160"

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Starlink satellites crossing Dark Energy Camera images. Credit: DELVE Survey/CTIO/AURA/NSF

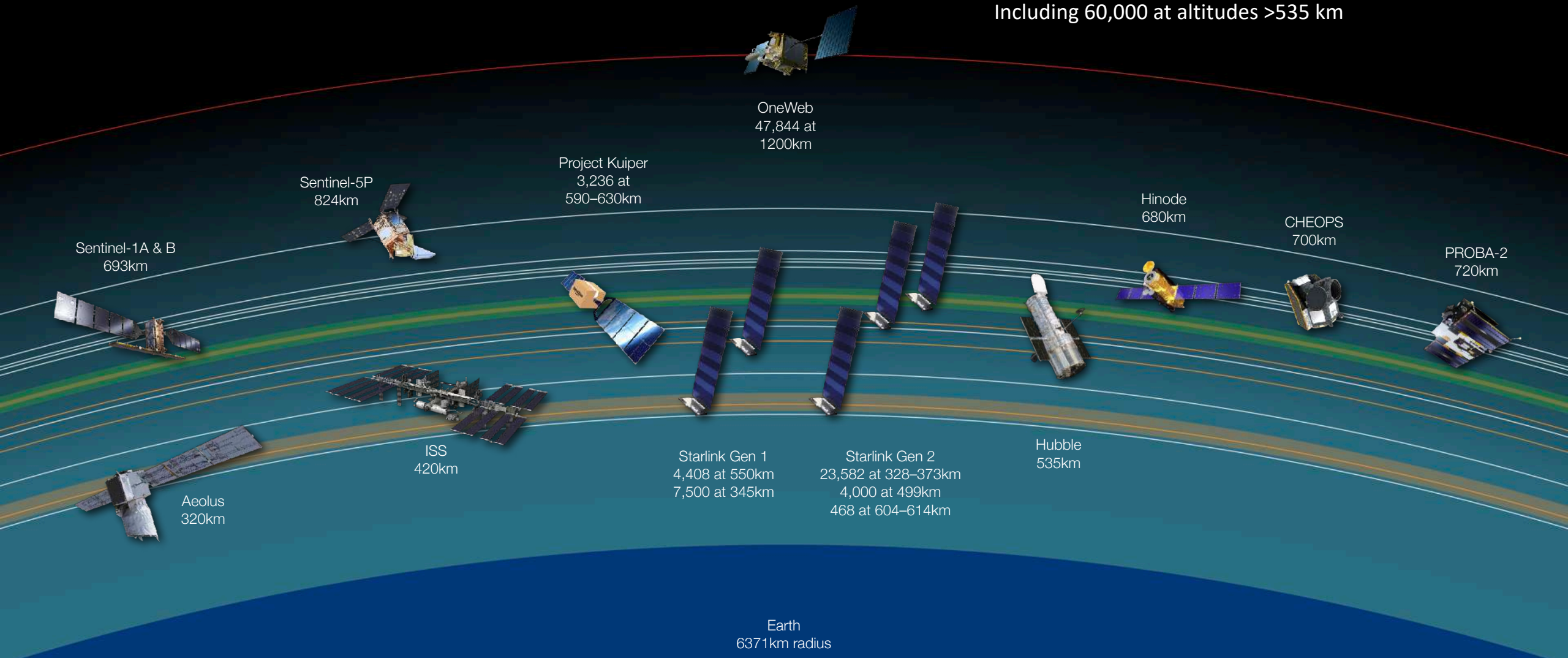
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Selection of space science missions in low-Earth orbit

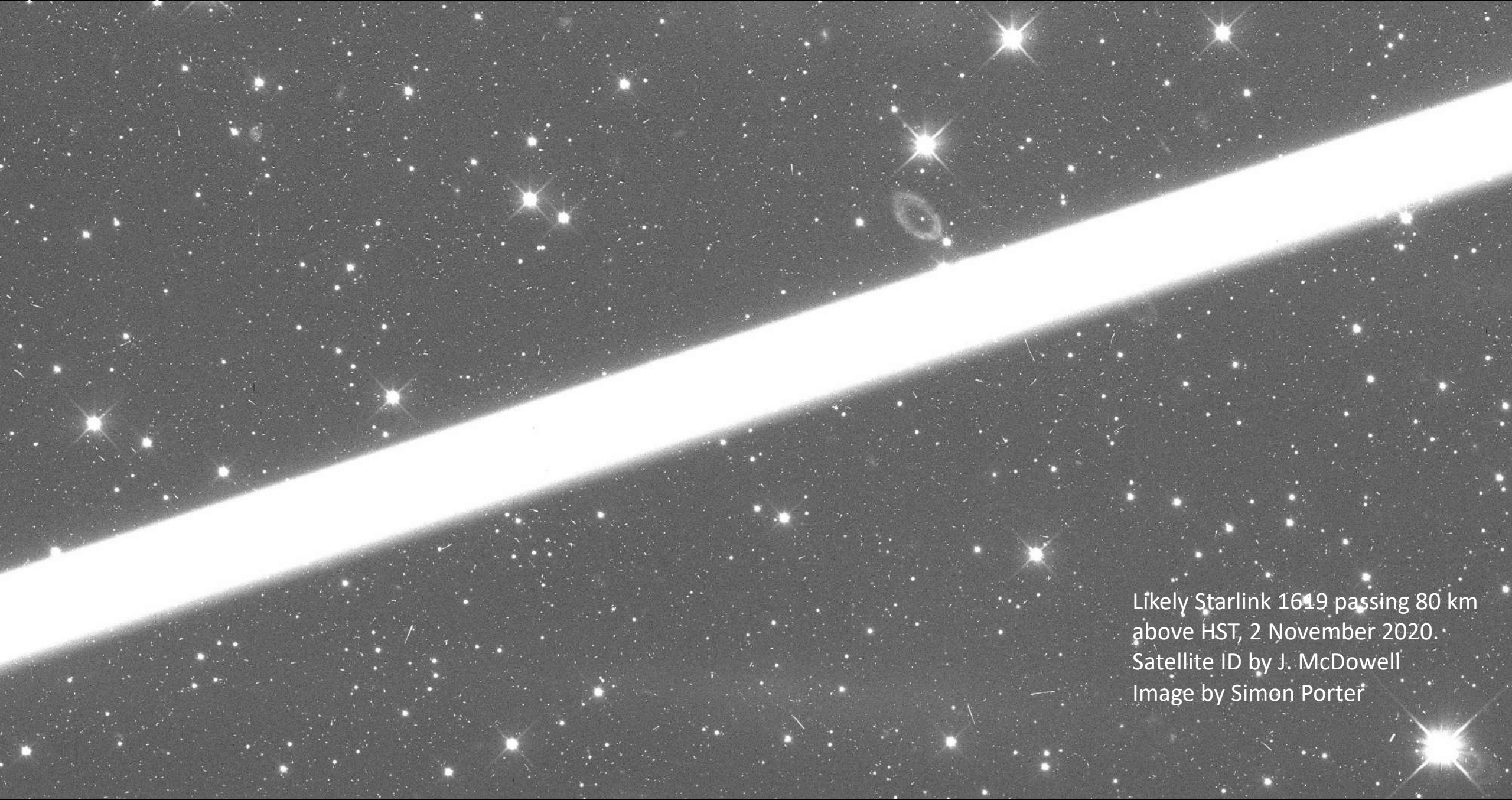
plus ~91,000 LEO internet satellites

Including 60,000 at altitudes >535 km



Courtesy of M. McCaughrean

Earth & orbits are to scale; spacecraft are not



Likely Starlink 1619 passing 80 km
above HST, 2 November 2020.
Satellite ID by J. McDowell
Image by Simon Porter





Impact of mega-constellations on HST observations

The probability that a satellite crosses the field-of-view of Hubble is:

$$P \approx \frac{N_{sat}}{4\pi} \times f \times FoV \times \omega \times \Delta t$$

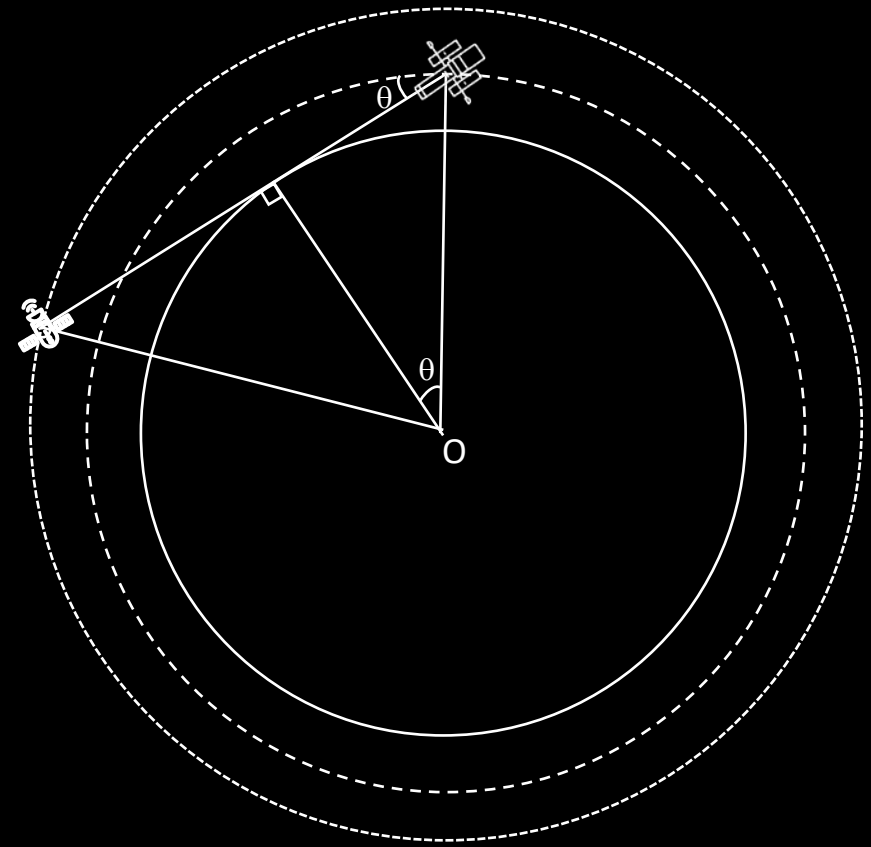
$\frac{N_{sat}}{4\pi}$ – number density of higher orbit satellites

f – fraction of satellites visible to Hubble and illuminated (~7%)

FoV – size (width) of the field-of-view

ω – angular velocity of the satellite

Δt – average exposure time





Impact of mega-constellations on HST observations

The probability that a satellite crosses the field-of-view of Hubble is:

$$P \approx \frac{N_{sat}}{4\pi} \times f \times FoV \times \omega \times \Delta t$$

$\frac{N_{sat}}{4\pi}$ – number density of higher orbit satellites

f – fraction of satellites visible to Hubble and illuminated (~7%)

FoV – size (width) of the field-of-view

ω – angular velocity of the satellite

Δt – average exposure time

$P \approx 20\%$ for 10 minute exposures!

Possibly future HST observation with megaconstellations. Credit: Fabian Neyer



Take home messages



Trails in science data
Telescopes in LEO such as Hubble already affected



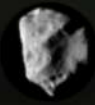
Citizen science + AI can be used to explore images for satellite/space debris
➔ collaboraton to identify the artificial objects in the images



Megaconstellations
➔ large increase in the trail incidence
➔ Increased potential for collisions



Thank you!



Hubble Asteroid Hunter

Language English

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from the Hubble Space Telescope!

[Learn more](#)



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