

A photograph of the Earth's aurora (Northern Lights) as seen from the International Space Station (ISS). The aurora displays vibrant green and purple hues against the dark background of space. The curved horizon of the Earth is visible, and a portion of the ISS structure is seen in the foreground, silhouetted against the bright light of the aurora.

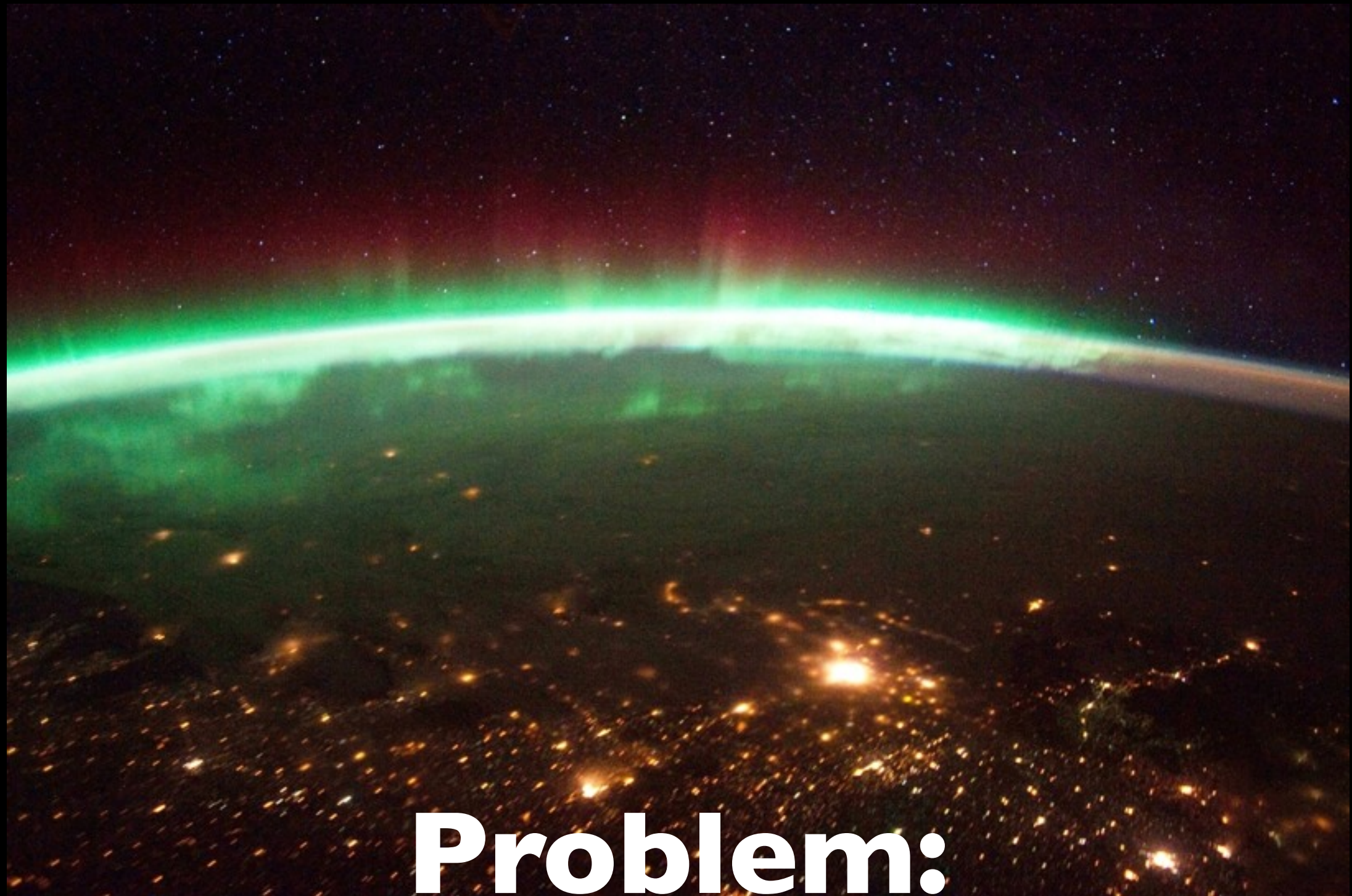
Localizing Auroras with ISS Image Time Series

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Problem:

Use ISS image sequences as a low-cost method to determine camera orientation and extract aurora coverage on Earth

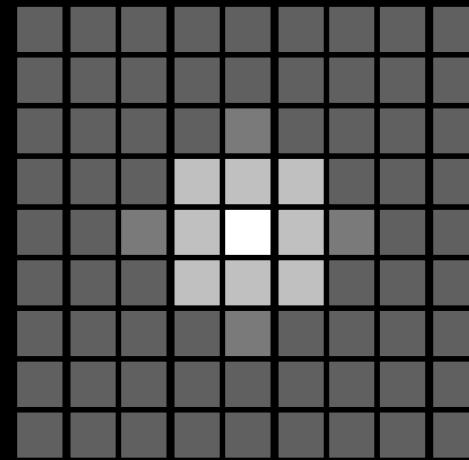
1st Attempt: Brute Force Algorithm

Brute force algorithm

Known bright star coordinates
(RA, DEC)

Star centroiding & hot pixel
filtering algorithm

Choose 3 parameters:
RA, DEC, rotation angle
(neglect plate constant
distortion*)



SNR Condition:
Mean (3x3 pixel box)
> SNR x Median
(9x9 pixel box)

Spherical projection to
(x, y) pixel coordinates

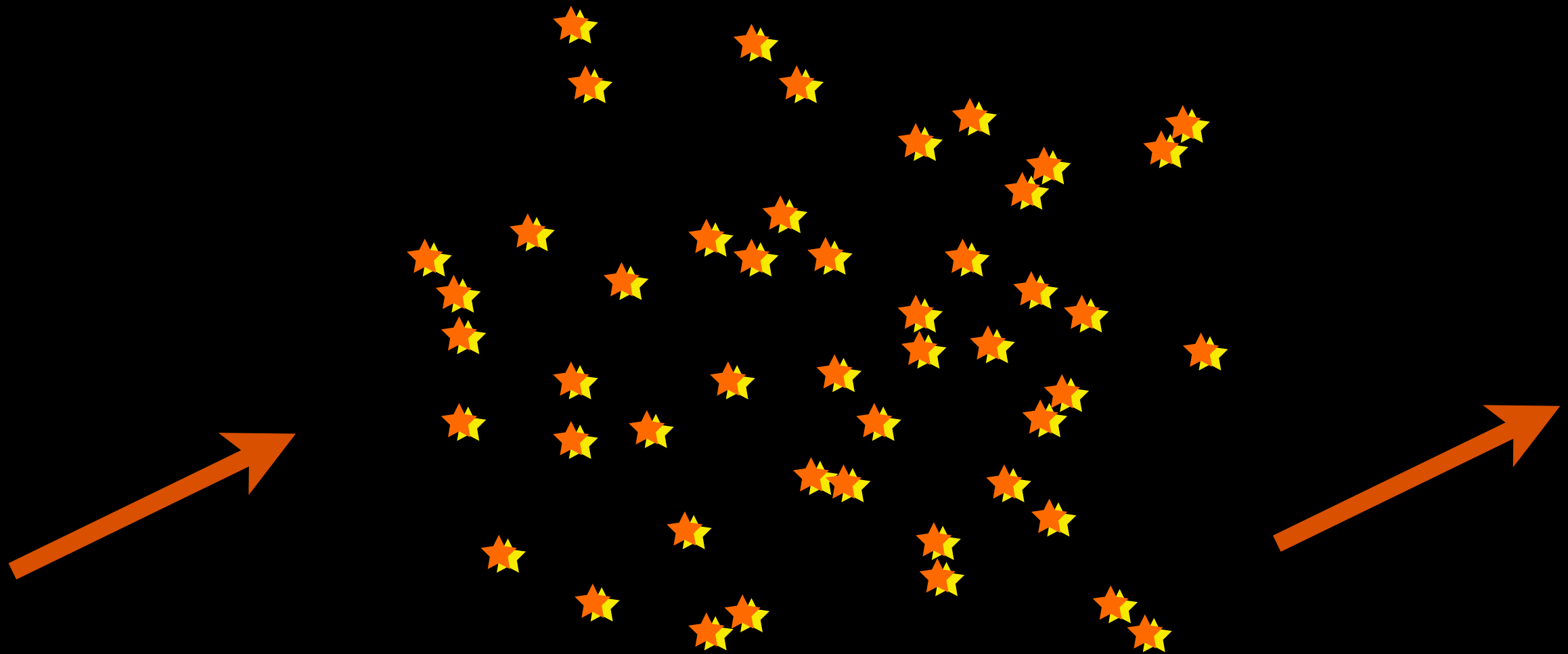
(x, y) pixel coordinates
of stellar centroids

Sum distances to nearest neighbour

3D least squares optimization



Resolution of least squares 3D search grid must be much smaller than the inter-stellar spacing



Resolution of least squares 3D search grid must be much smaller than the inter-stellar spacing



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$> 10^{12}$ image centres must be searched for least squares optimization on 50 stars in 70 degree FOV



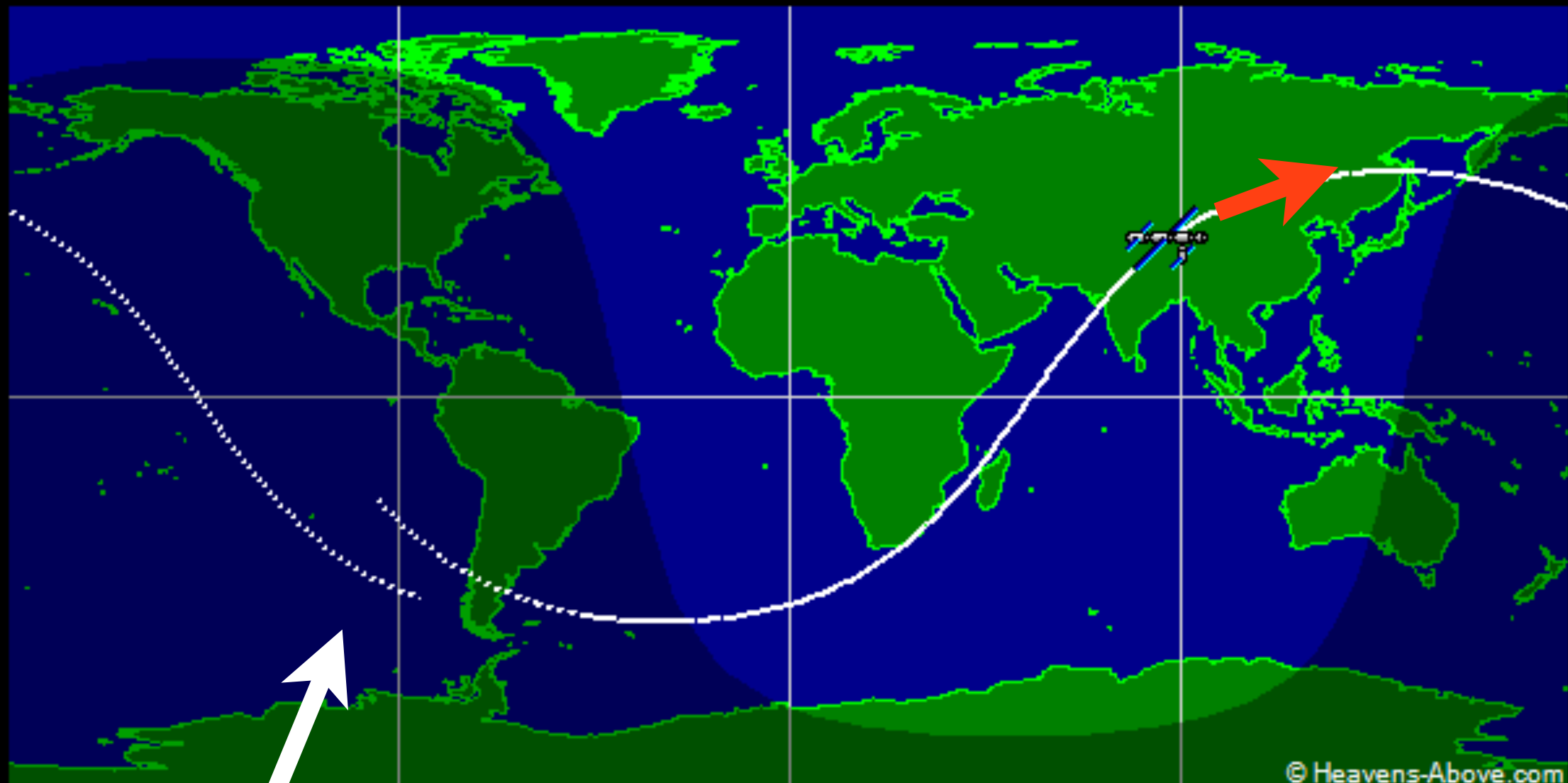
Resolution of least squares 3D search grid must be much smaller than the inter-stellar spacing

Requires a more refined method...

2nd Attempt: Incorporation of time domain information

Spherical geometry of Star Trails

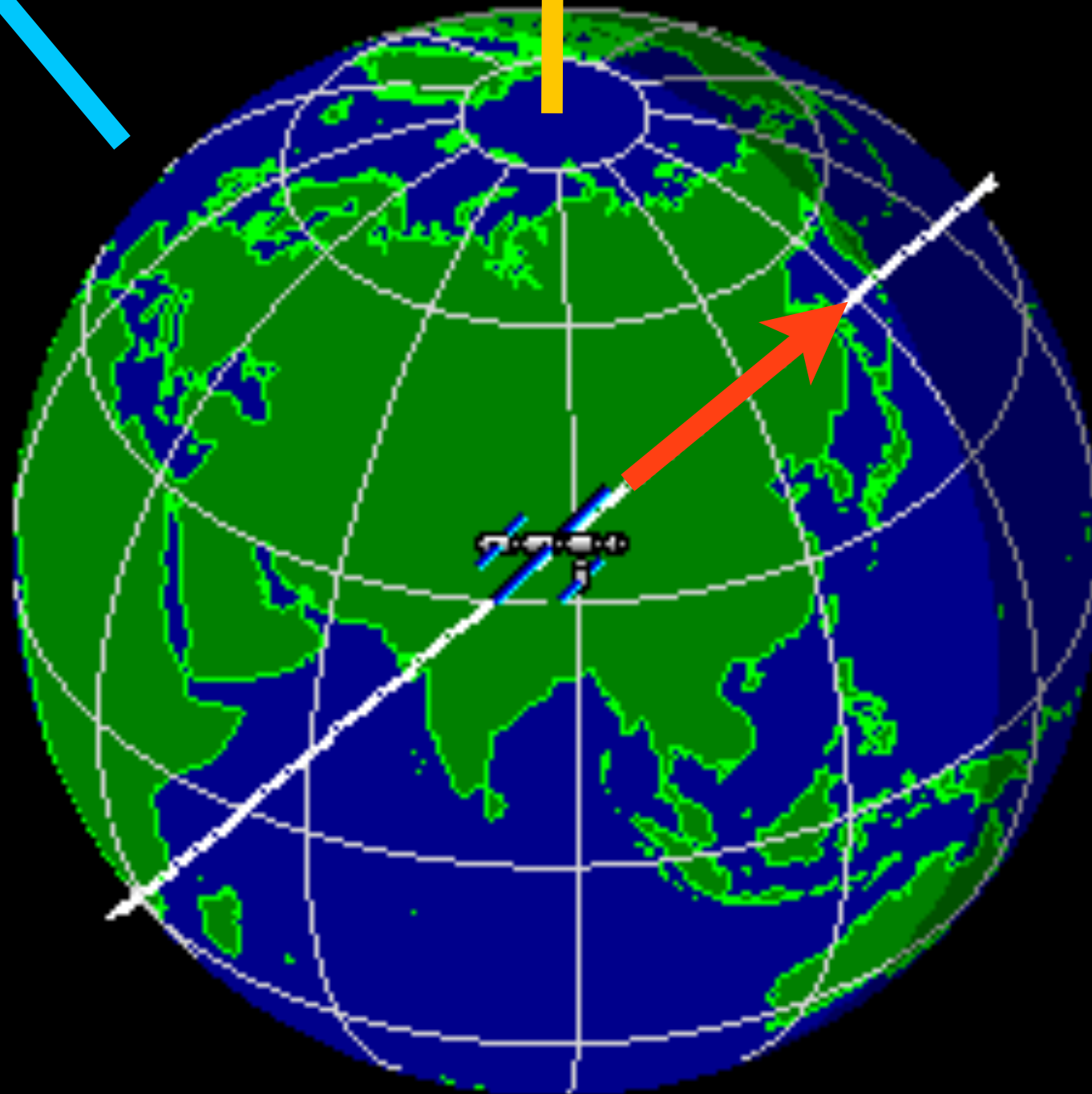
ISS Orbit



Precession due to rotation of Earth during ~90 min ISS period

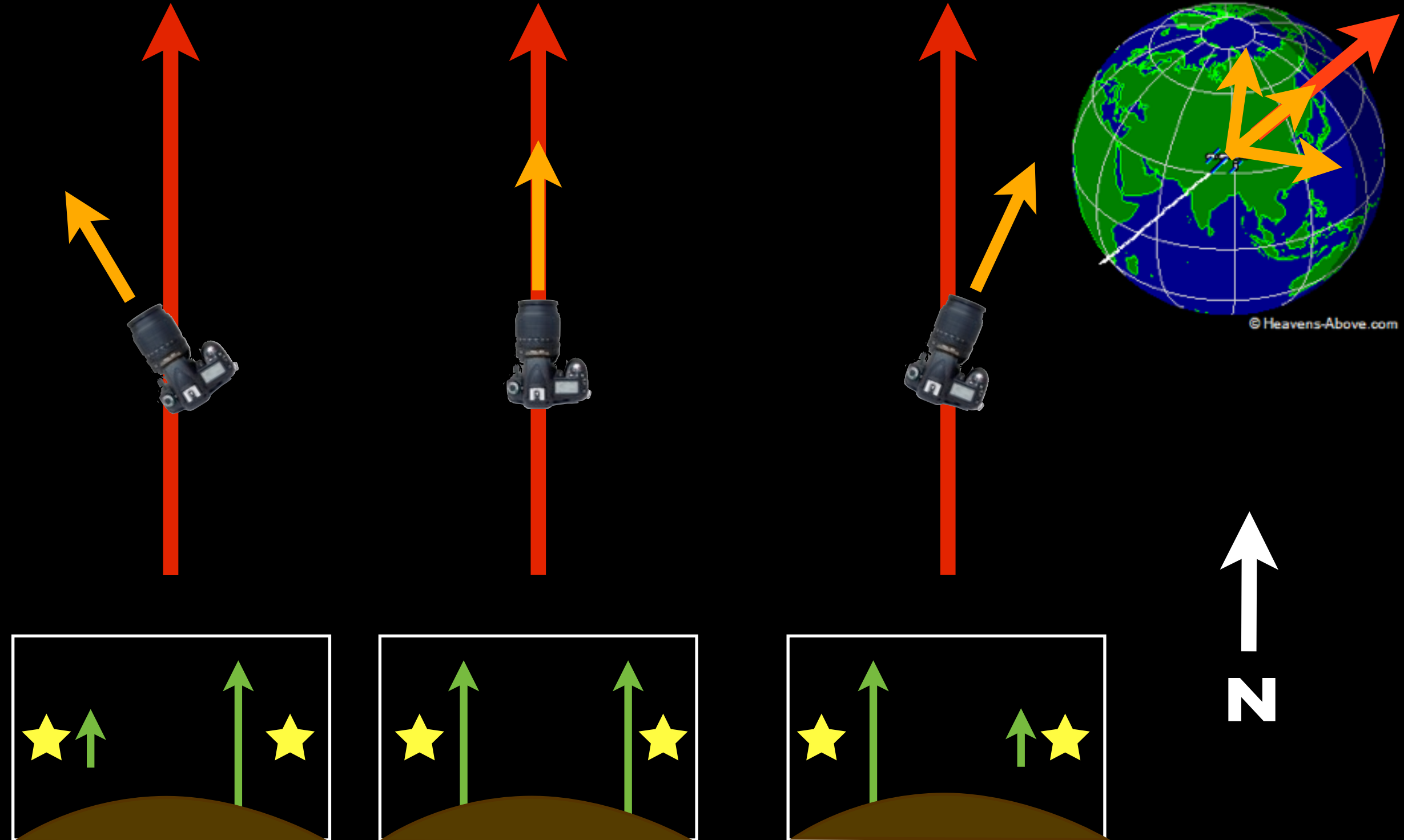
ISS revolution axis

Earth revolution axis



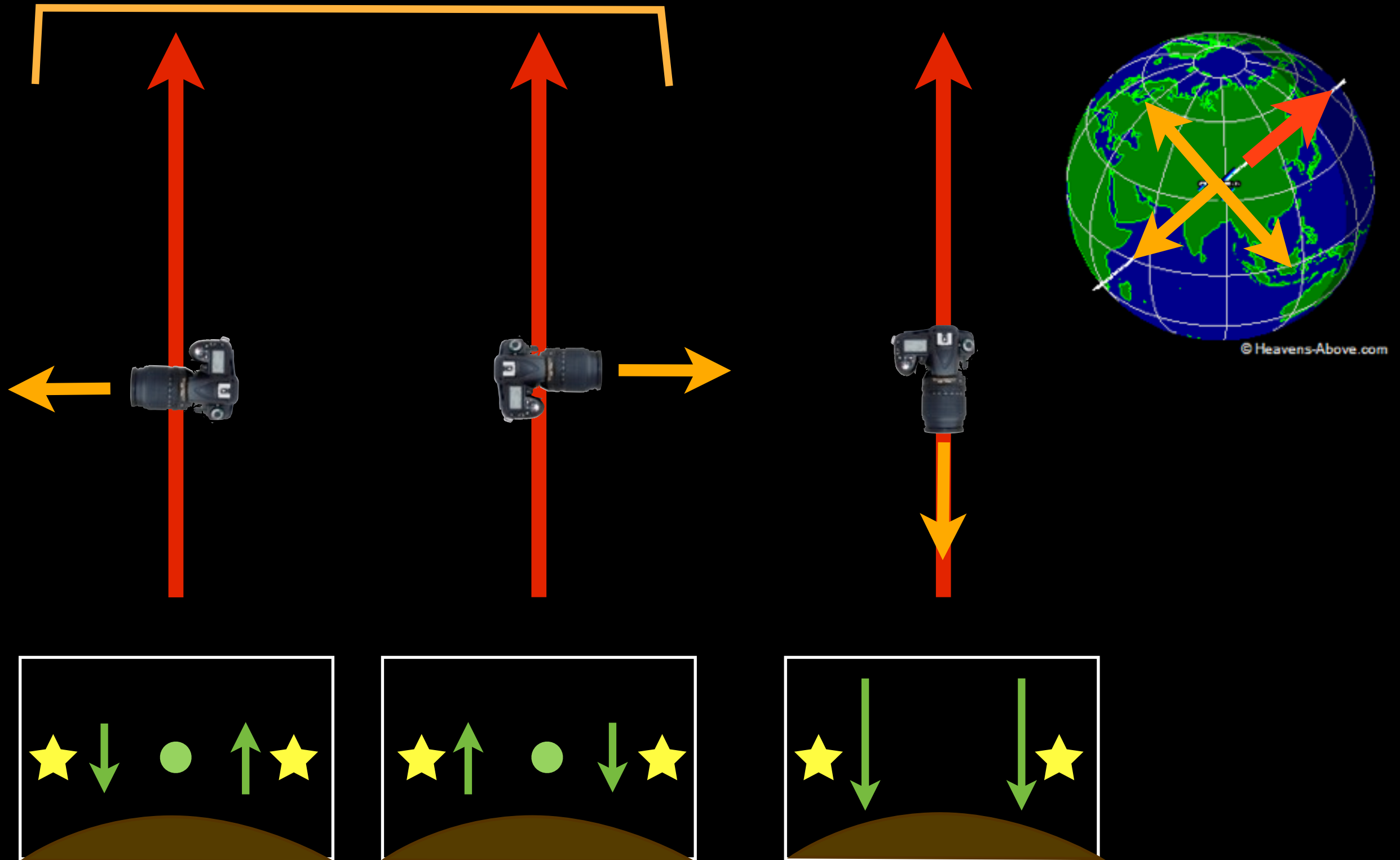
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Direction of ISS velocity given by $d/dt(\text{nadir})$



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Optical and ISS revolution axes coincide



Star Trail Computational Method

Orientation via Star Trails



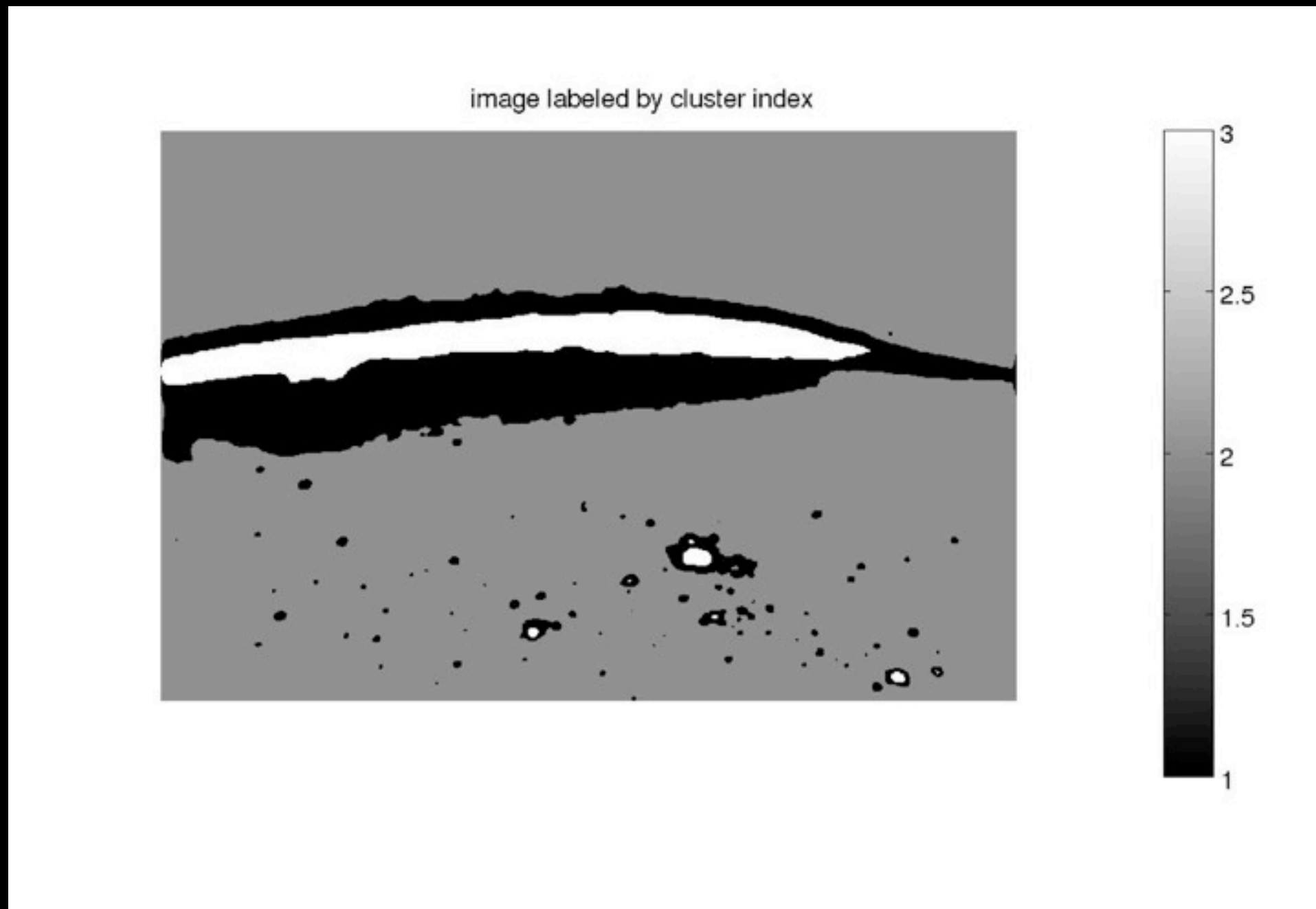
Remove Earth from image via K-means image segmentation

Orientation via Star Trails



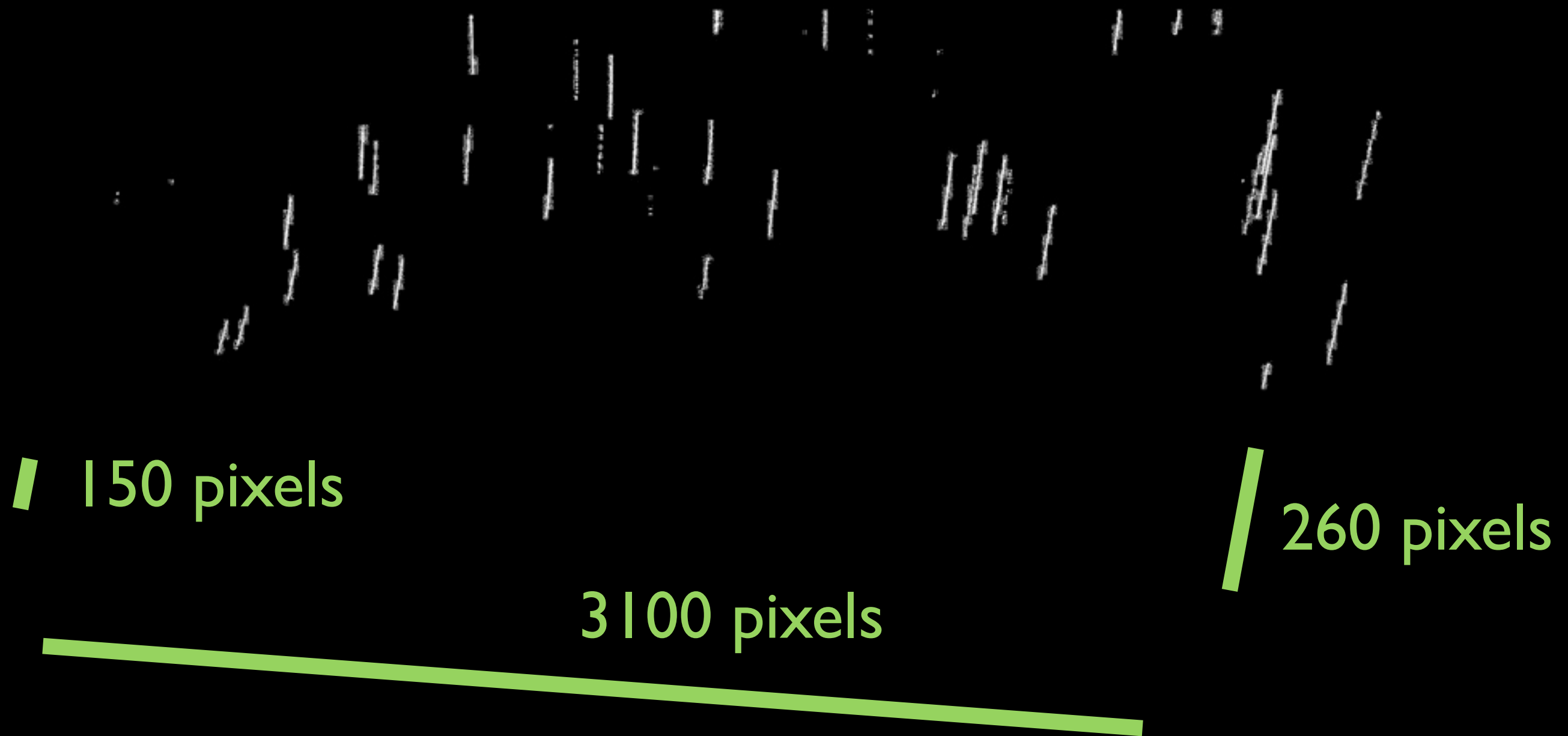
Remove Earth from image via K-means image segmentation

Orientation via Star Trails



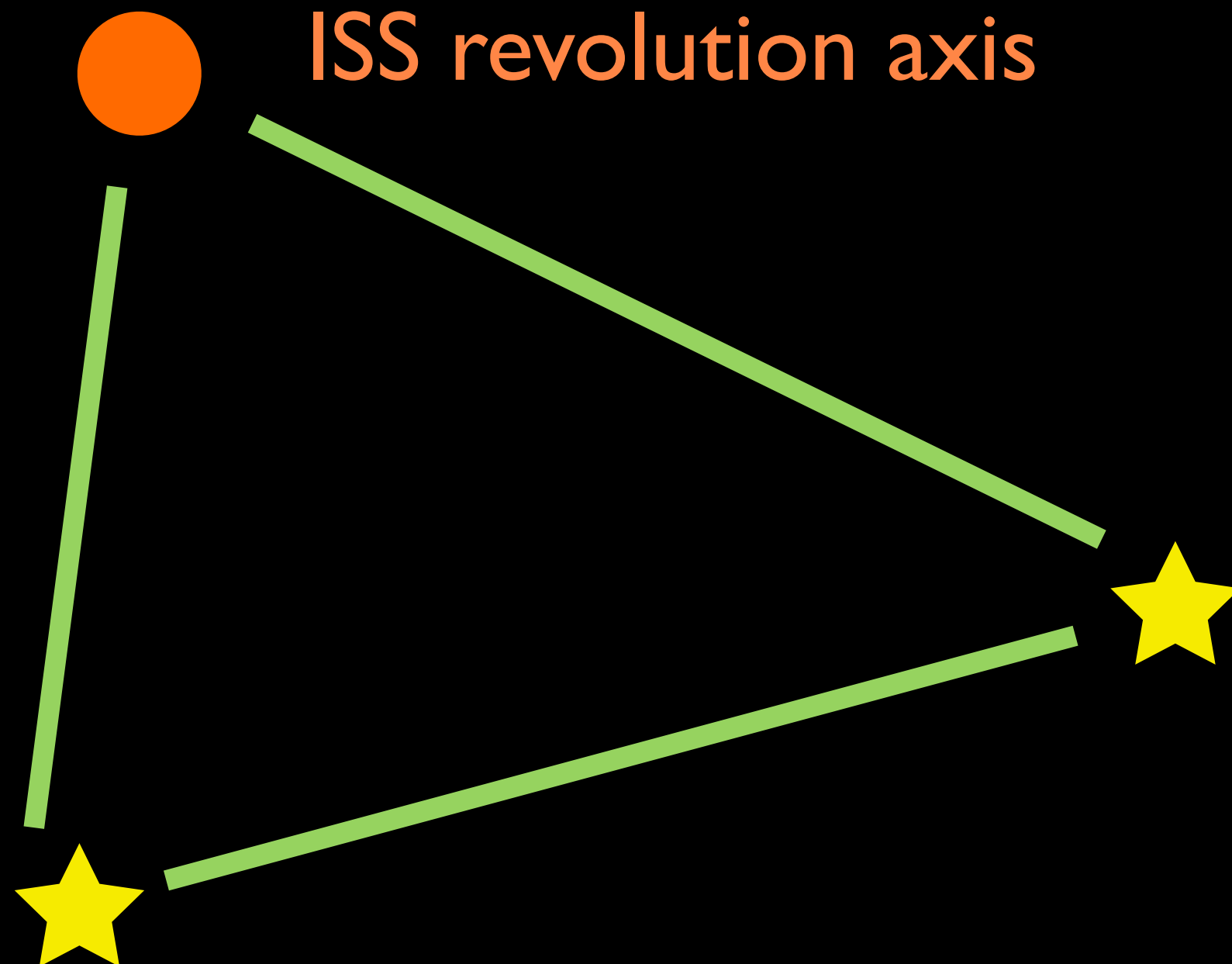
Remove Earth from image via K-means image segmentation

Star Trails



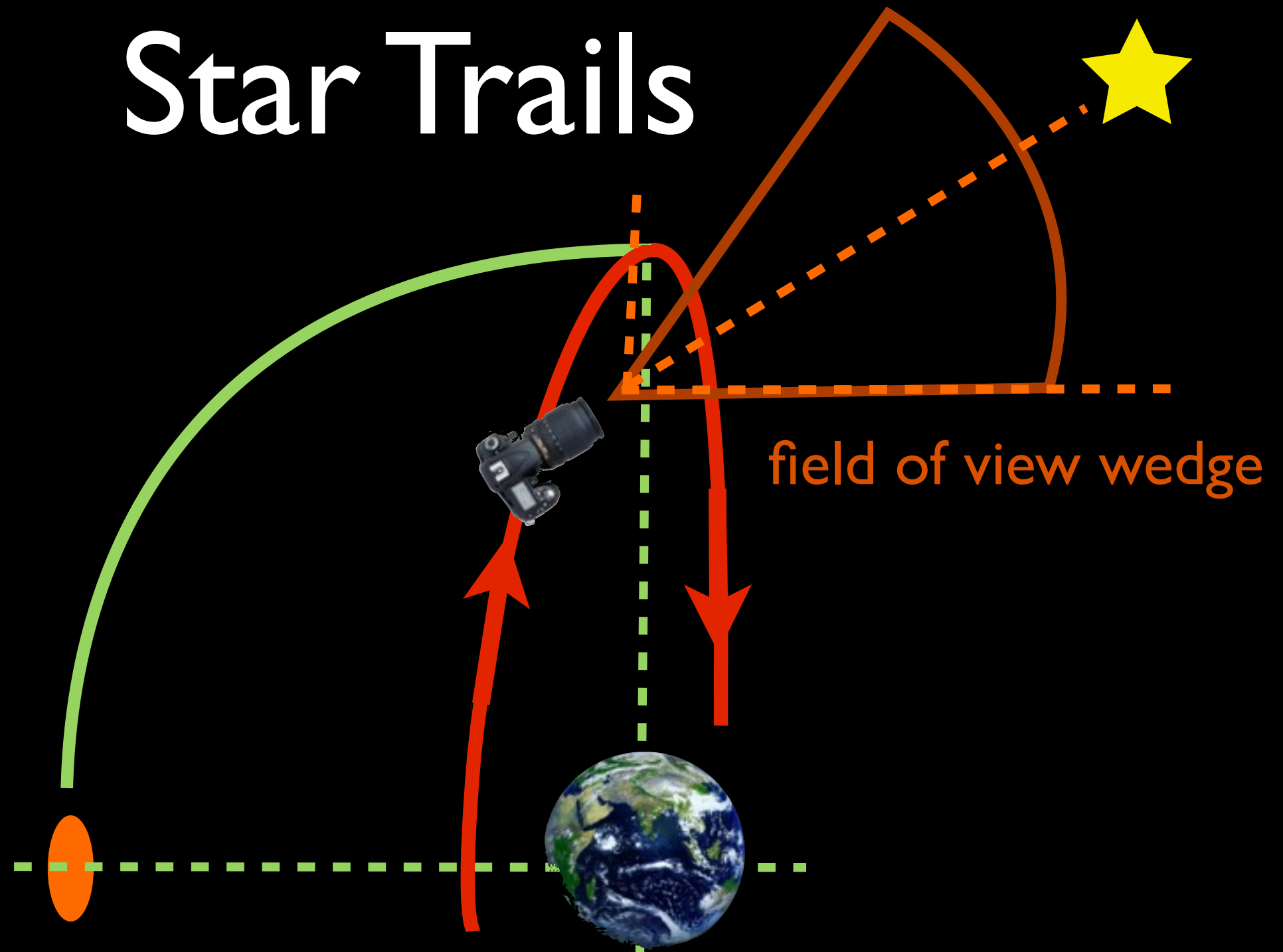
Angular distance to pole is a function of pixel velocity

Star Trails



Angular distance to pole is a function of pixel velocity

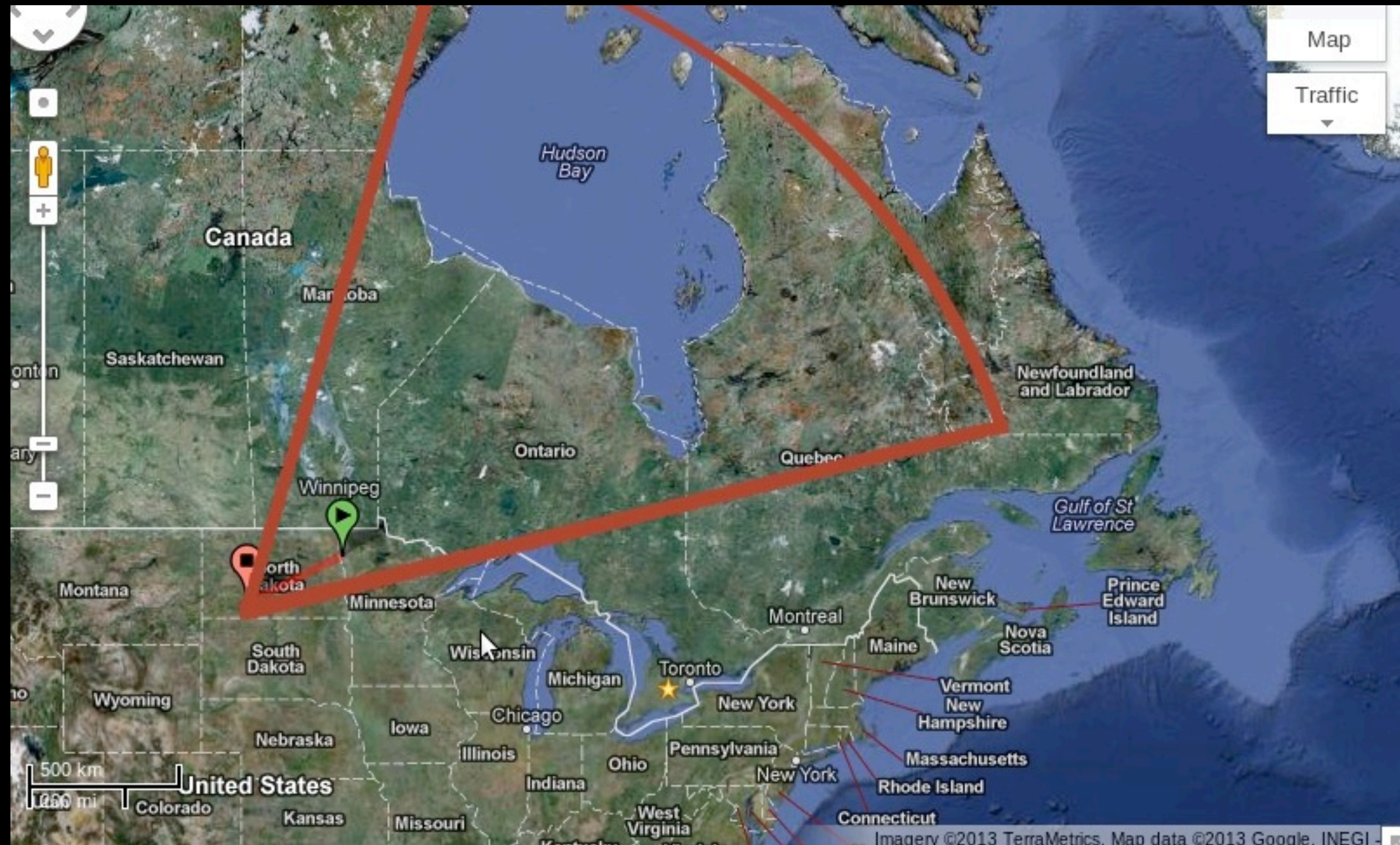
Star Trails



ISS revolution axis

Angular distance to pole is a function of pixel velocity

Field of View Wedge



Aurora Extraction



Isolate aurora via K-means image segmentation

Aurora in FoV Wedge



Star Trail Method Summary

Direction of ISS velocity given by $d/dt(\text{nadir})$

Rotation of camera given by lengths of star trails

Pitch of camera given by altitude and direct image
measurement

Efficient camera orientation method; can extrapolate the
location of the aurora