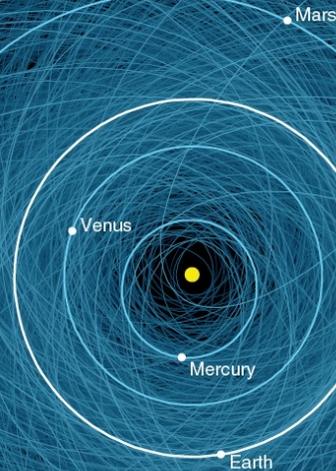


**EXERCISE ONLY!!**



# 2021 PDC Exercise Day 1: April 26, 2021 (Today) Newly Discovered Asteroid Poses Risk of Earth Impact in Six Months

Paul Chodas (CNEOS/JPL/NASA, on Behalf of IAWN)

2021 Planetary Defense Conference, April 26-30, 2021

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**EXERCISE ONLY!!**



## EXERCISE

# Asteroid 2021 PDC: Discovery & Tracking



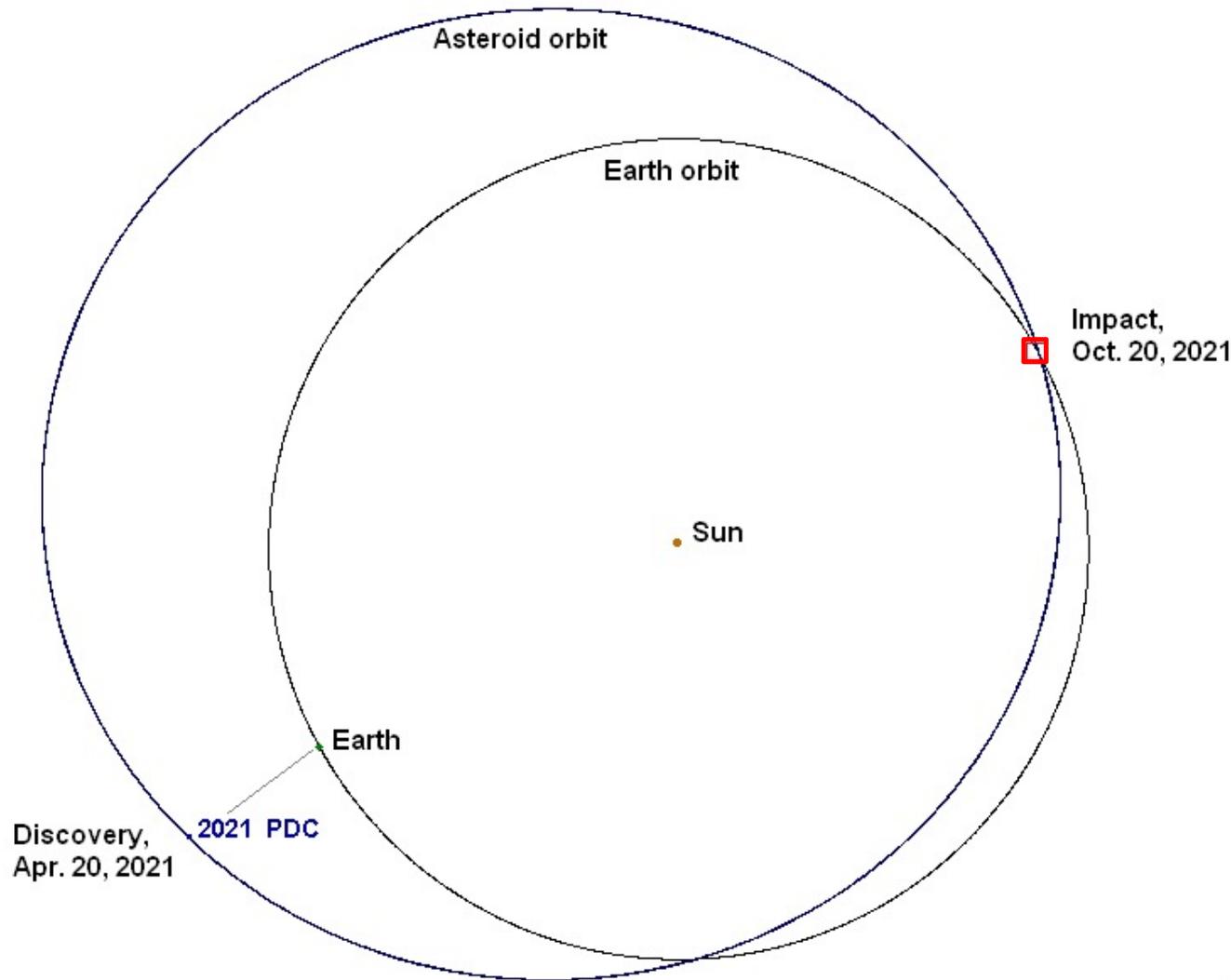
- Asteroid discovered on April 19, 2021 by the Pan-STARRS survey in Hawaii
- Confirmed the following night; designated “**2021 PDC**” by the Minor Planet Center
- It is tracked nightly, providing observations essential for computing its trajectory
- 2021 PDC is distant (35 million miles) and faint (magnitude 21.4), and it will remain so until this September, when it will start to approach very close to Earth
- Within days, impact monitoring systems at NASA and ESA both assess that 2021 PDC could impact Earth on October 20, 2021, only six months from now
- Today, after only a week of tracking, the impact probability has reached **5%**
- The size of 2021 PDC is highly uncertain. Based on its brightness and a typical range of reflectivities, its nominal size range is estimated to be **80 to 200 meters (300 to 700 feet)**. But an analysis considering all the uncertainties gives a full potential size range of **35 to 700 meters (100 to 2300 feet)**
- 2021 PDC meets the threshold criteria for action by both IAWN and SMPAG
- For more info: <https://cneos.jpl.nasa.gov/pd/cs/pdc21/day1.html>

**EXERCISE ONLY!!**



EXERCISE

# Orbit of Asteroid 2021 PDC



Mostly outside Earth's orbit, but the two orbits intersect

2021 PDC takes 1.4 years to complete one orbit about the Sun

Between discovery and the possible impact, 2021 PDC traverses less than half an orbit

Not shown here, but the asteroid orbit is inclined  $16^\circ$  to Earth's

**EXERCISE ONLY!!**



## EXERCISE

# The Uncertainty Region and Impact Probability



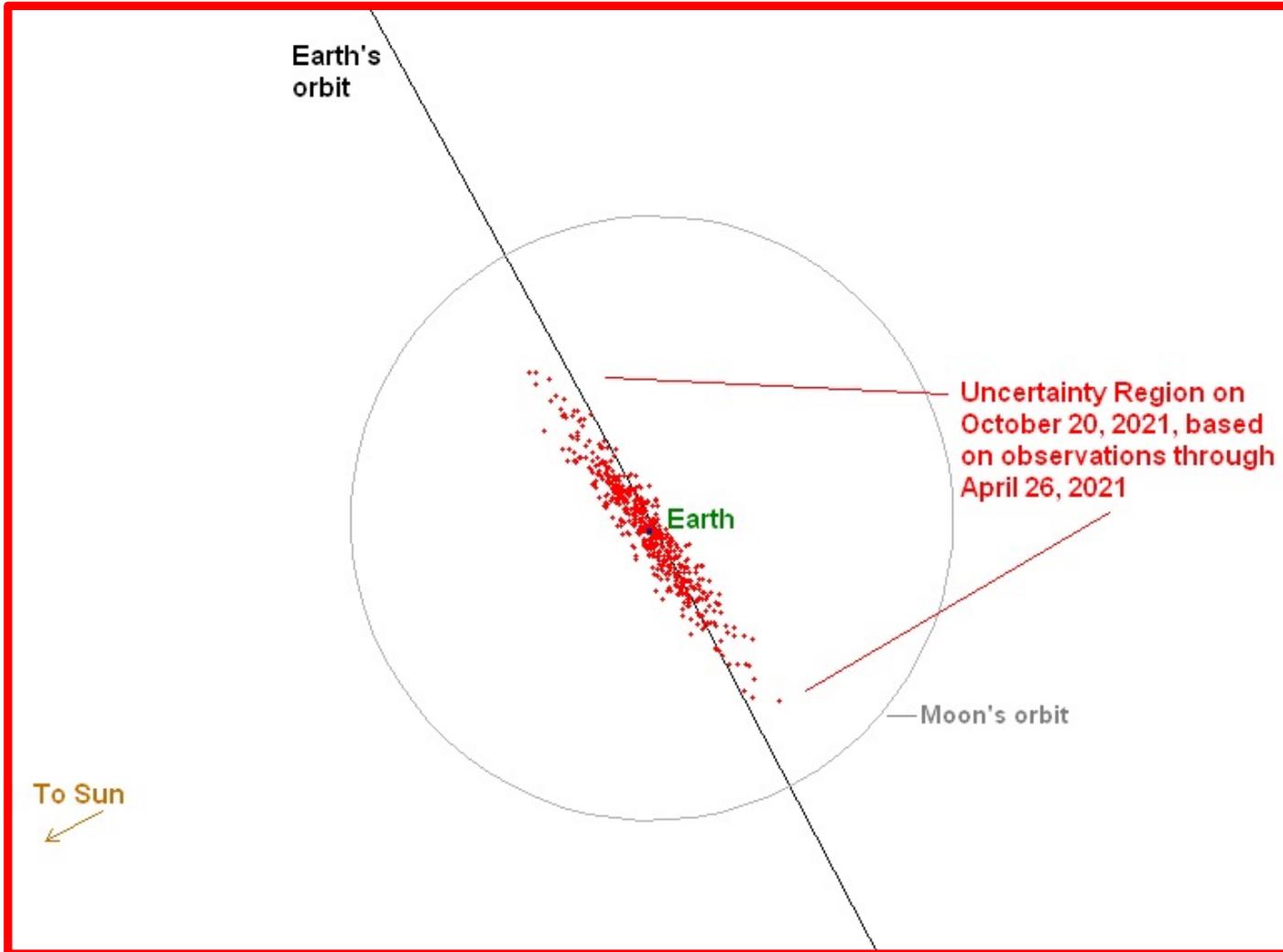
- To assess the chance of impact, we need to predict the position of the asteroid when Earth crosses its path on October 20
- Predictions of future positions are always uncertain at some level
- Calculate an “Uncertainty region” around the predicted position; the region can be visualized by filling it with tracer points (think of them as “virtual” asteroids)
- Since 2021 PDC has been tracked for only a week, its uncertainty region on October 20 will be very large, in fact much larger than the Earth
- If the Earth passes through the uncertainty region impact is possible; counting the fraction of tracer points that impact yields a rough estimate of the impact probability
- Calculating where the tracer points impact on the Earth gives us the potential impact region

**EXERCISE ONLY!!**



EXERCISE

# 2021 PDC Position Uncertainty at Potential Impact on October 20, 2021



The **red dots** show possible positions of 2021 PDC on October 20, 2021, computed using just 1 week of tracking data since discovery

5% of the red dots intersect Earth

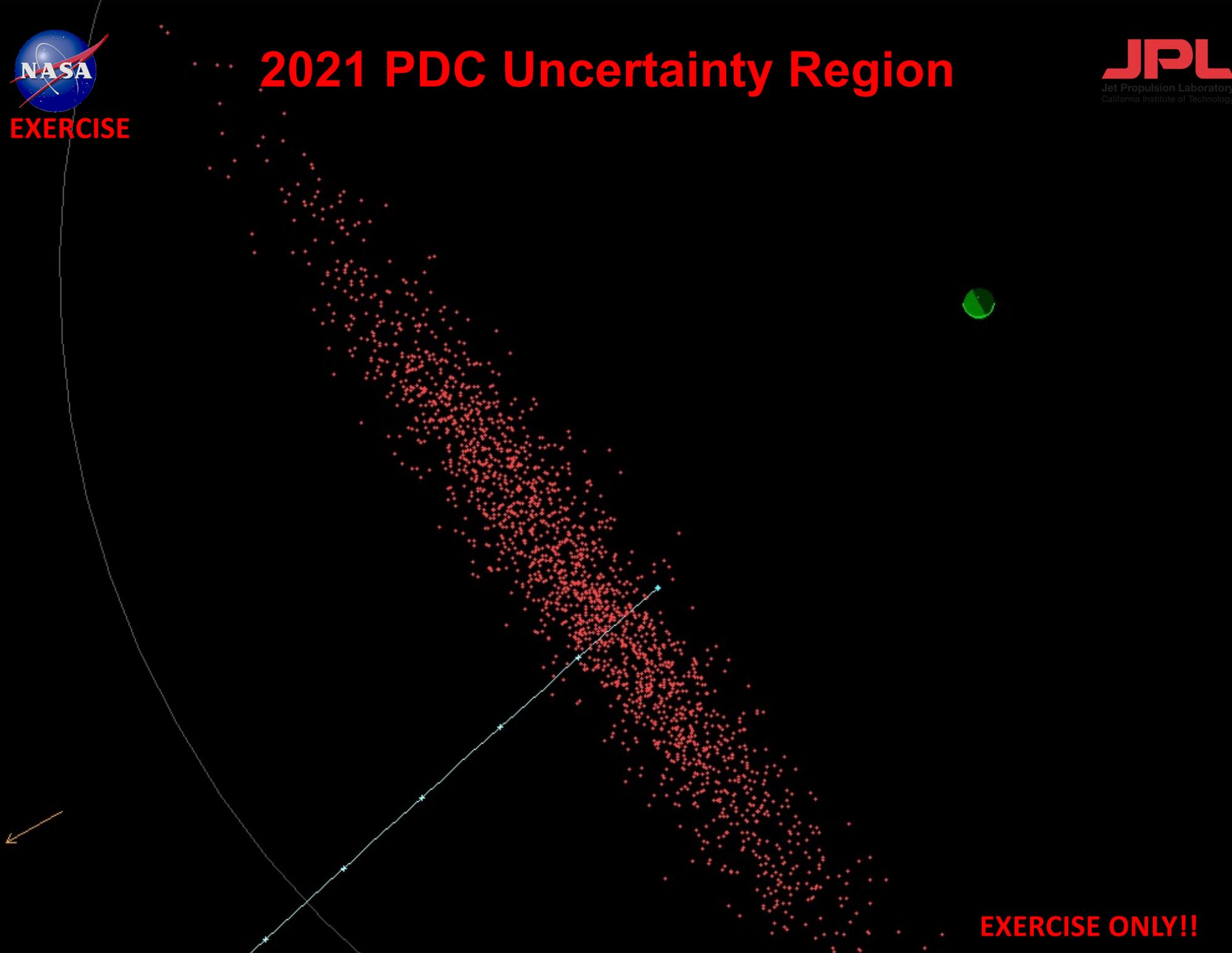
As more observations are made, the uncertainty region will shrink

**EXERCISE ONLY!!**



EXERCISE

# 2021 PDC Uncertainty Region

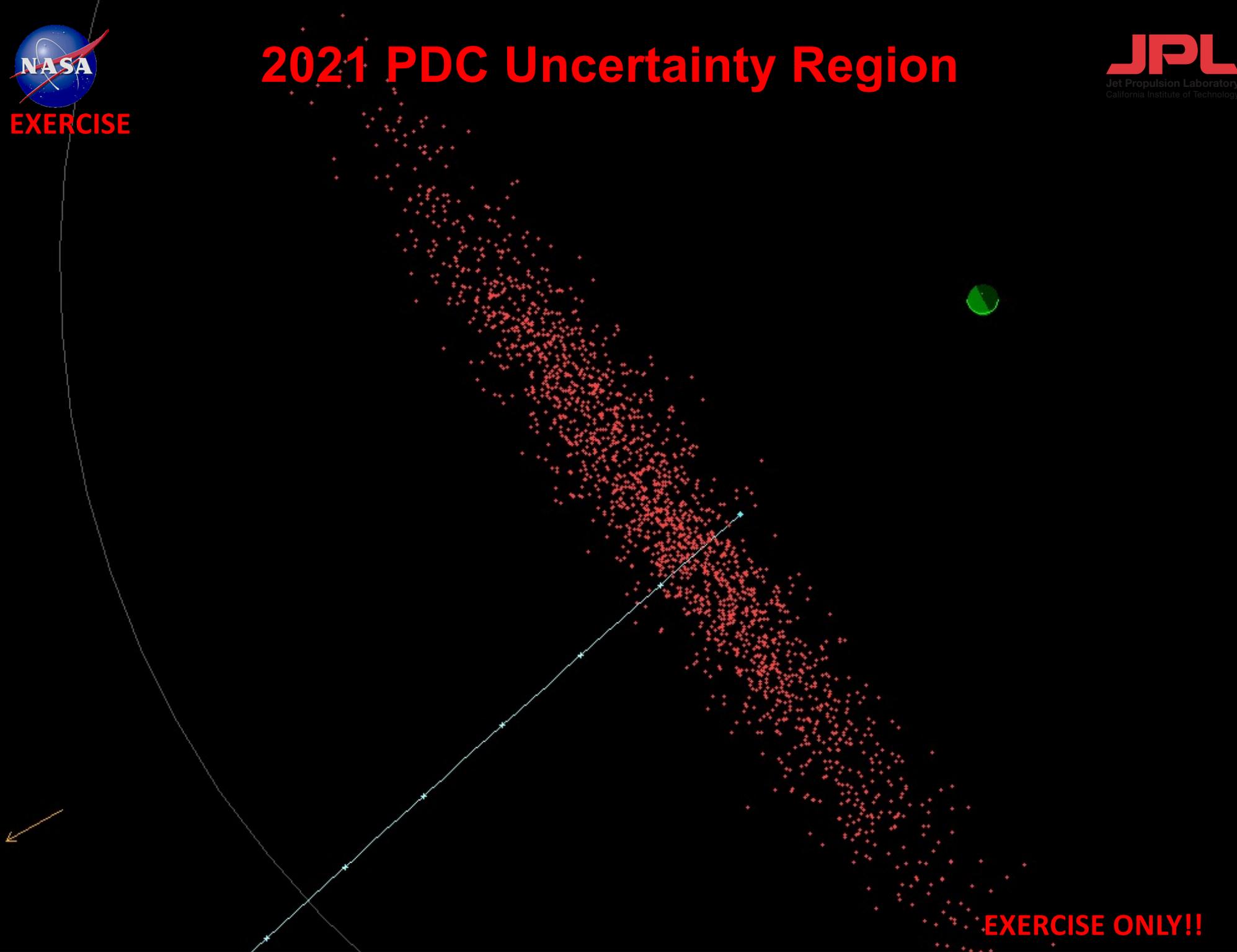


EXERCISE ONLY!!



EXERCISE

# 2021 PDC Uncertainty Region

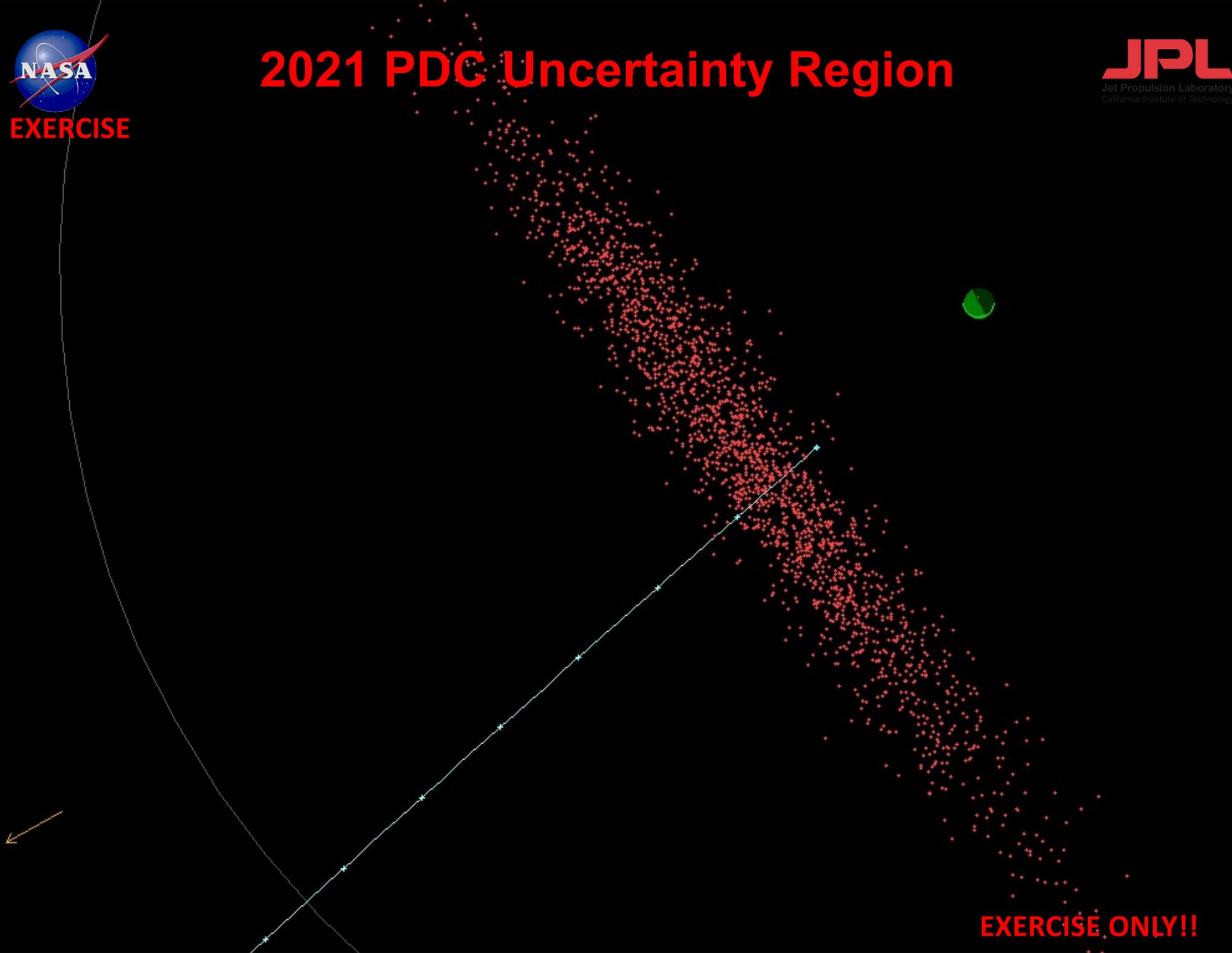


EXERCISE ONLY!!



EXERCISE

# 2021 PDC Uncertainty Region

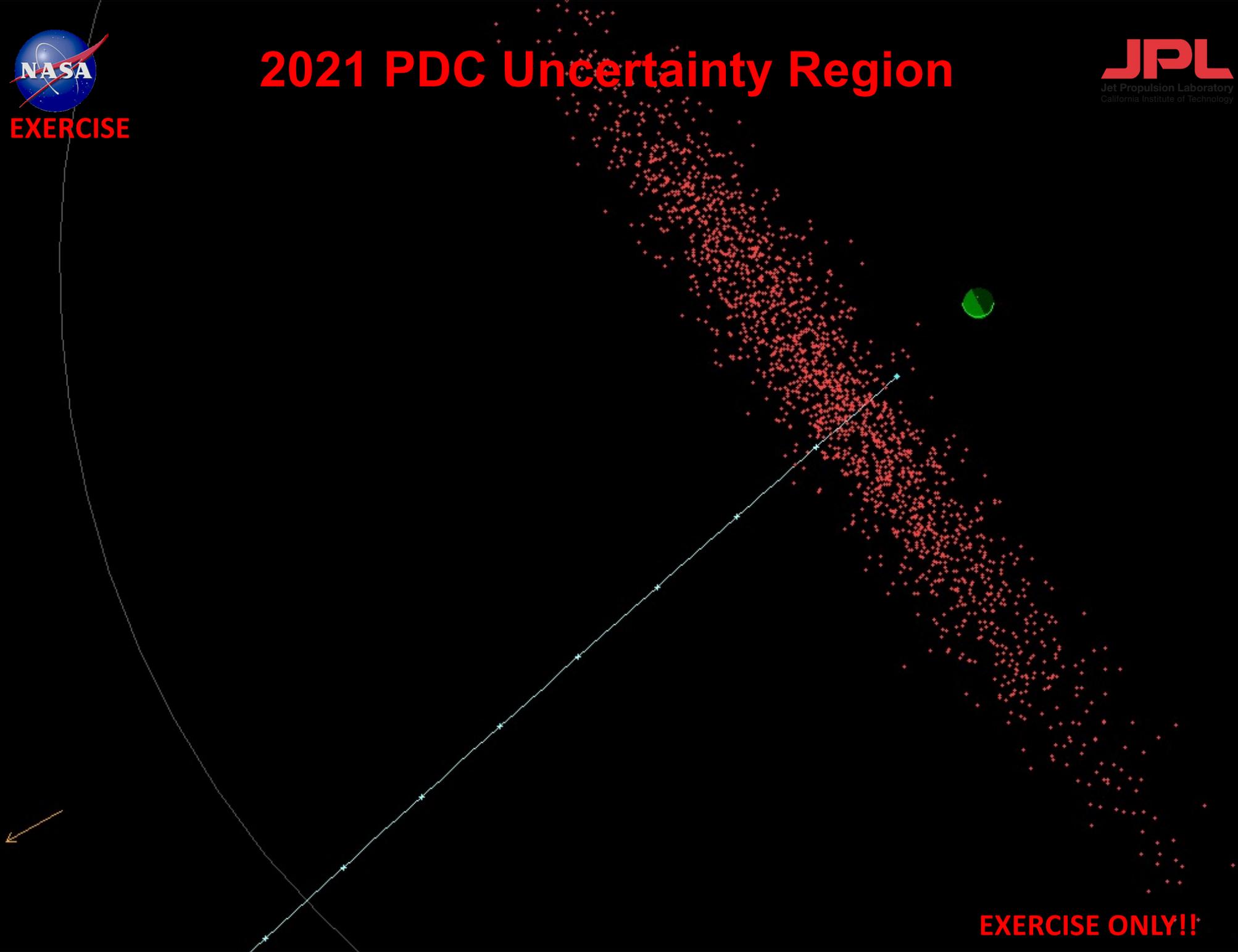


EXERCISE ONLY!!



EXERCISE

# 2021 PDC Uncertainty Region

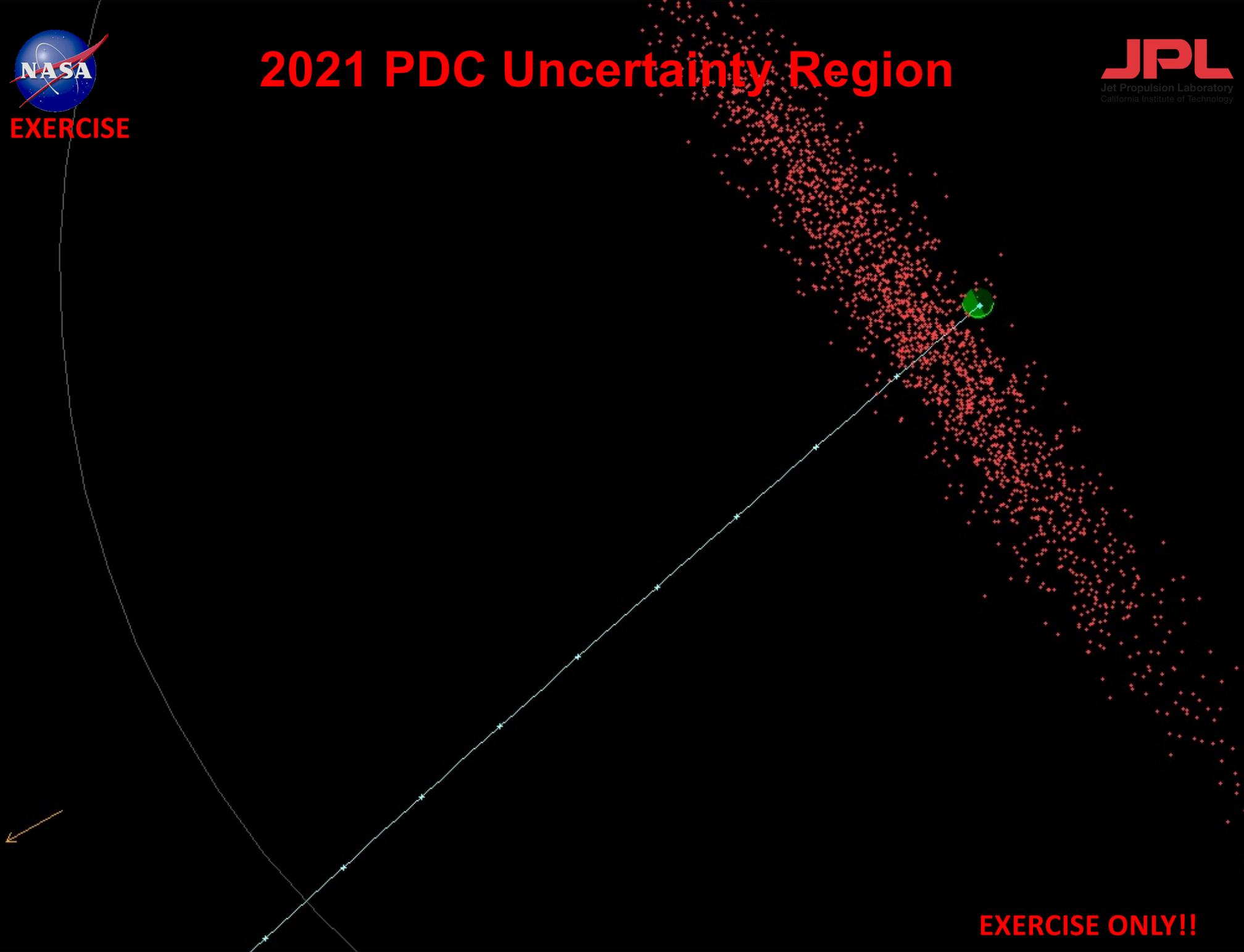


EXERCISE ONLY!!



EXERCISE

# 2021 PDC Uncertainty Region



EXERCISE ONLY!!

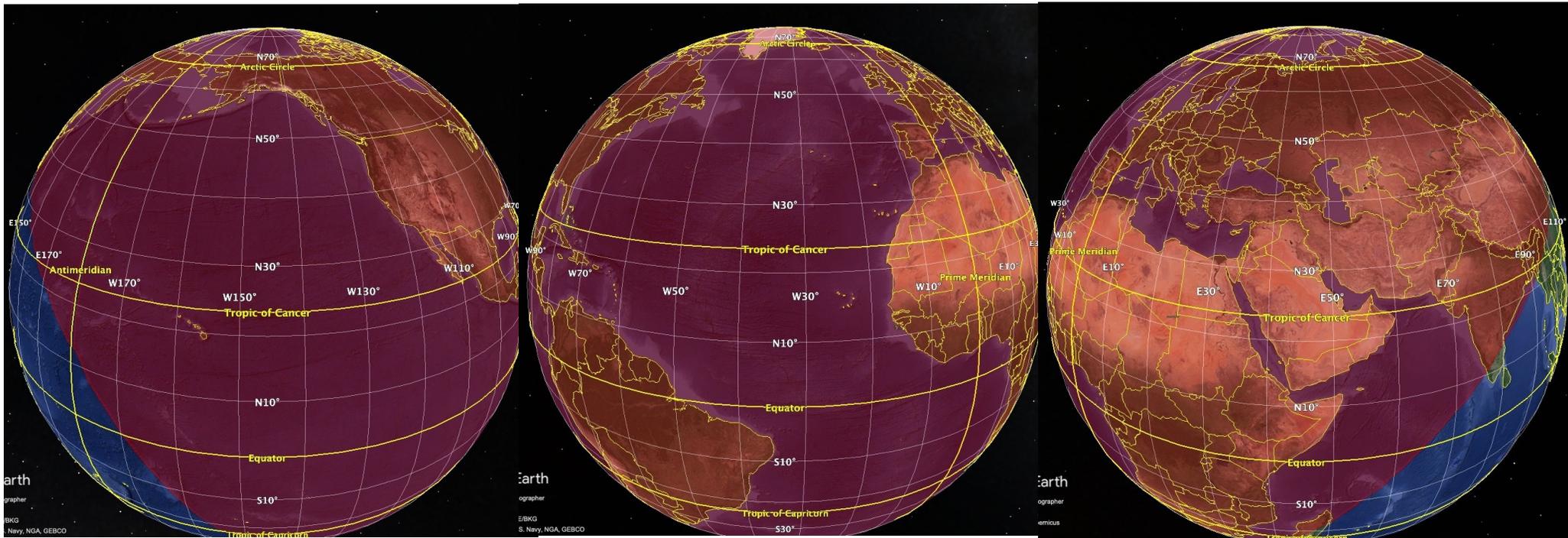


## EXERCISE

# Where Could 2021 PDC Impact?



- Based on current orbit knowledge, 2021 PDC could impact anywhere within a region that covers 2/3 of the Earth surface, shaded here in red/purple:



- The region covers more than a hemisphere because Earth's gravity causes near-limb trajectories to bend inwards and impact

**EXERCISE ONLY!!**



# Observation Plans for 2021 PDC



## EXERCISE

- The International Asteroid Warning Network (IAWN) is helping coordinate the international observation efforts for 2021 PDC
- 2021 PDC has only been tracked for a week: continued tracking is essential for obtaining the most accurate possible orbit and impact assessments
- Orbit accuracy depends critically on the length of time over which an asteroid is tracked (the “data arc”): the longer the data arc the more accurate the orbit
- For 2021 PDC, pre-discovery (“precovery”) observations were found in images taken on the 2 days before the asteroid was discovered, extending the data arc
- The impact probability will likely change dramatically over the next week:
  - If the asteroid IS on an impact trajectory, observations over the next week could push the impact probability up to about 30%
  - If the asteroid IS NOT on an impact trajectory, the probability might still increase for a time, but will eventually drop to zero
- 2021 PDC will continue to be observable until October, although it will be very faint and observations will be more difficult as it will approach the twilight sky

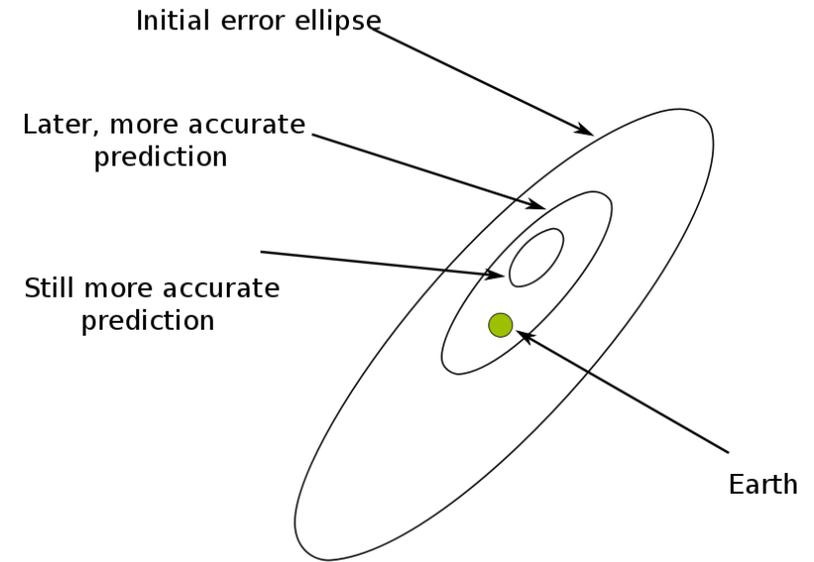
**EXERCISE ONLY!!**



## EXERCISE

# Will Impact Probability Increase or Decrease?

- As an asteroid is tracked, its orbit will become increasingly accurate and the uncertainty region will shrink
  - If the region shrinks away from the Earth, impact probability goes down
  - If the region shrinks and Earth remains inside, the impact probability will grow
- We can generally predict when future observations will be made, and therefore when the uncertainty region will shrink, but we can't predict whether the Earth will remain inside
- Most likely, the region will shrink entirely away from the Earth, and the impact probability will drop to zero
- But if the shrinking uncertainty region continues to include the Earth, the impact probability will keep rising and it would become 100% if the region shrinks onto the Earth





## EXERCISE

# Why Is the Size of 2021 PDC So Uncertain?

- Measurements of an asteroid's optical brightness can be used to estimate its intrinsic brightness or “**absolute magnitude**”,  $H$
- Estimating size based on  $H$  requires its albedo (surface brightness), which is not known and can vary widely from one asteroid to another:

- Examples for 2021 PDC:

|                            |       |
|----------------------------|-------|
| Extremely bright surface   | 60 m  |
| Bright surface             | 80 m  |
| Average surface brightness | 140 m |
| Dark surface               | 200 m |
| Extremely dark surface     | 400 m |

- Incorporating uncertainty in  $H$  leads to the full size range, 35 – 700m
- Ways to a more accurate size:

Observe with space-based IR, and/or  
Observe with planetary radar, and/or  
Send a reconnaissance mission

**EXERCISE ONLY!!**



# Possible Impact Effects: Nominal Size Range



## EXERCISE

| Diameter of Impacting Asteroid | Type of Event                      | Approximate Impact Energy (MT) | Average Time Between Impacts (Years) |
|--------------------------------|------------------------------------|--------------------------------|--------------------------------------|
| 5 m (16 ft)                    | Bolide                             | 0.01                           | 1                                    |
| 10 m (33 ft)                   | Superbolide                        | 0.1                            | 10                                   |
| 25 m (80 ft)                   | Major Airburst                     | 1                              | 100                                  |
| 50 m (160 ft)                  | Local Scale Devastation            | 10                             | 1000                                 |
| 140 m (460 ft)                 | Regional Scale Devastation         | 300                            | 20,000                               |
| 300 m (1000 ft)                | Continent Scale Devastation        | 2,000                          | 70,000                               |
| 600 m (2000 ft)                | Below Global Catastrophe Threshold | 20,000                         | 200,000                              |
| 1 km (3300 ft)                 | Possible Global Catastrophe        | 100,000                        | 700,000                              |
| 5 km (3 mi)                    | Above Global Catastrophe Threshold | 10,000,000                     | 30 million                           |
| 10 km (6 mi)                   | Mass Extinction                    | 100,000,000                    | 100 million                          |

**EXERCISE ONLY!!**



**EXERCISE**

# Possible Impact Effects: Full Size Range



| Diameter of Impacting Asteroid | Type of Event                      | Approximate Impact Energy (MT) | Average Time Between Impacts (Years) |
|--------------------------------|------------------------------------|--------------------------------|--------------------------------------|
| 5 m (16 ft)                    | Bolide                             | 0.01                           | 1                                    |
| 10 m (33 ft)                   | Superbolide                        | 0.1                            | 10                                   |
| 25 m (80 ft)                   | Major Airburst                     | 1                              | 100                                  |
| 50 m (160 ft)                  | Local Scale Devastation            | 10                             | 1000                                 |
| 140 m (460 ft)                 | Regional Scale Devastation         | 300                            | 20,000                               |
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**EXERCISE ONLY!!**