

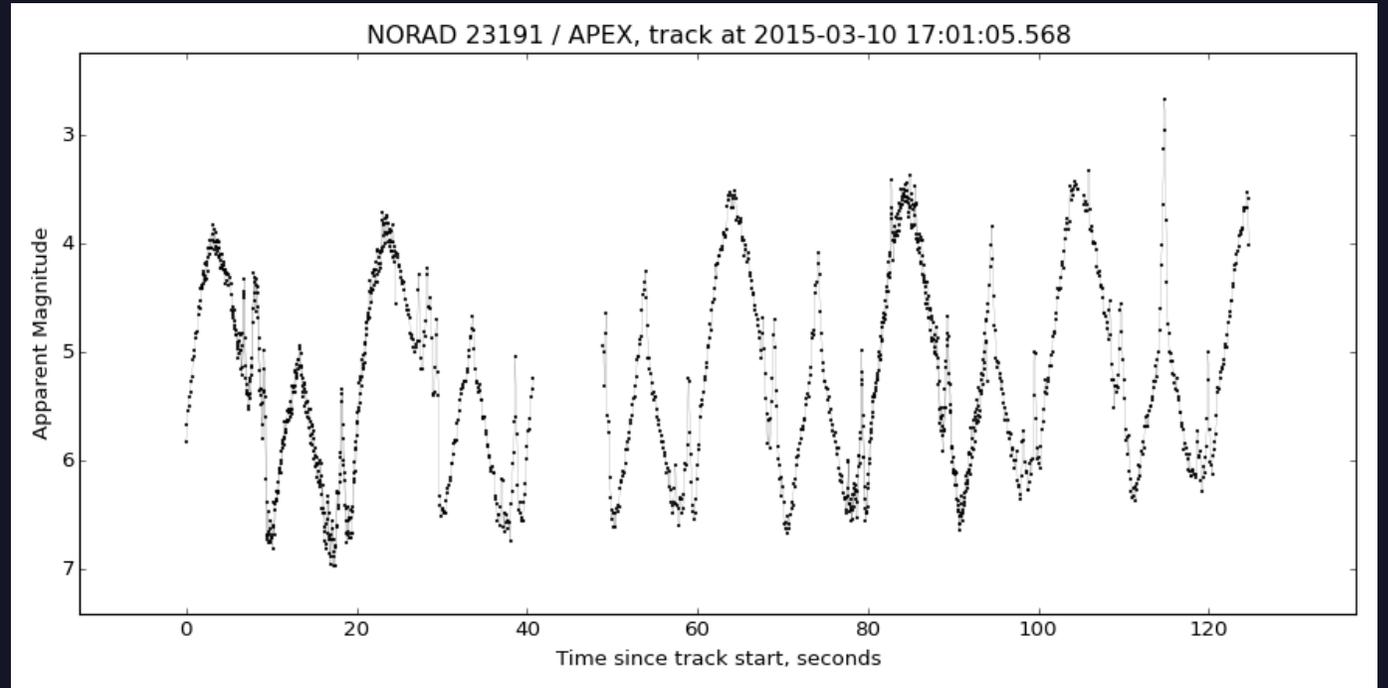
Novel Applications of Light Curve Analysis for SSA Applications

Laurence Blacketer

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What is a Light Curve?

Brightness against Time



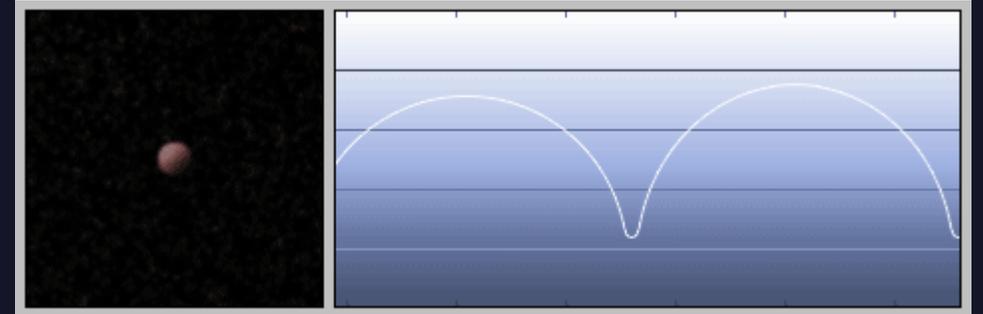
(Data from: <http://mmt.favor2.info>)

The History of Light Curve Analysis

- An **advantage** of light curve analysis is a **strong heritage** of application to objects in space.
- A key example is **asteroids**. Analysis of the light curves of asteroids have historically been used to attempt to determine properties such as:
 - **Rotation Period**
 - **Attitude motion**
 - **Shape**

Asteroid Characterisation Example: 'Oumuamua

- Light curve analysis is **still an important technique** for estimating properties of asteroids.
- Discovered on 19 October 2017 from the Haleakalā Observatory on Maui, Hawaii.
- Light curve analysis was used to estimate 'Oumuamua's **shape** and **attitude motion**.
- However, there can be **multiple solutions**.



Light Curve Analysis of Spacecraft

- **Unlike with asteroids**, the shapes of artificial satellites are **known**:
 - Cylindrical objects (rocket bodies)
 - 'Box-Wing' spacecraft
- We may also be able to make **good assumptions** of the **reflective properties** of the **materials**.

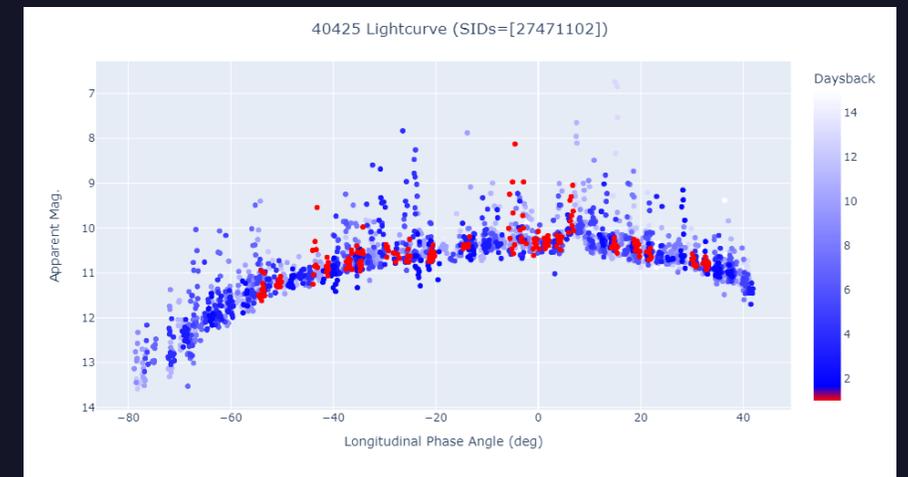
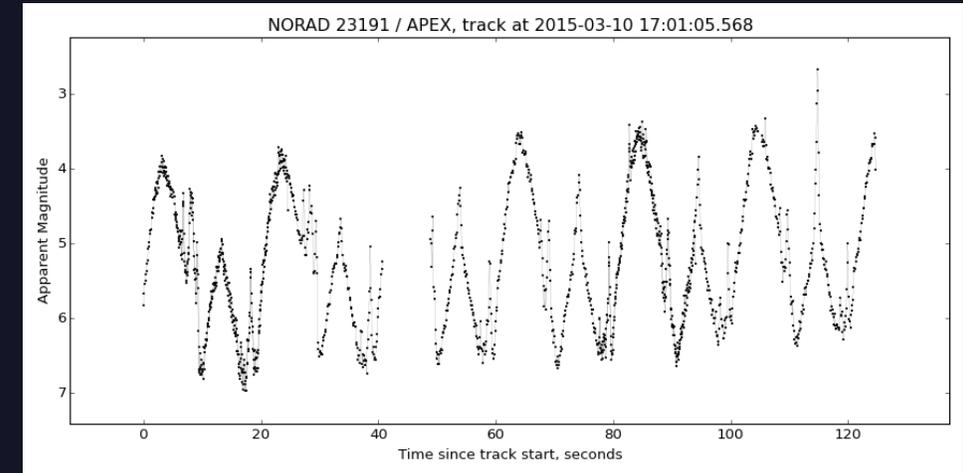


The Historical Limitations of Light Curve Analysis of Spacecraft

- Historically, **optical telescopes** were very **costly**.
- **Data volume** was **low**.
- **Computational power** was **limited**.

How are Light Curves used Operationally?

- Within the US Space Surveillance Network (SSN), **optical is primarily used to track 'deep space' objects.** Above Low Earth Orbit (LEO, 2000+ km) up to Geostationary Earth Orbit (GEO, ~35,800 km).
- Operationally, light curves are **used primarily for two applications:**
 - **Spin determination / Spin stability analysis**
 - **Anomaly detection**
 - **Primarily in GEO**

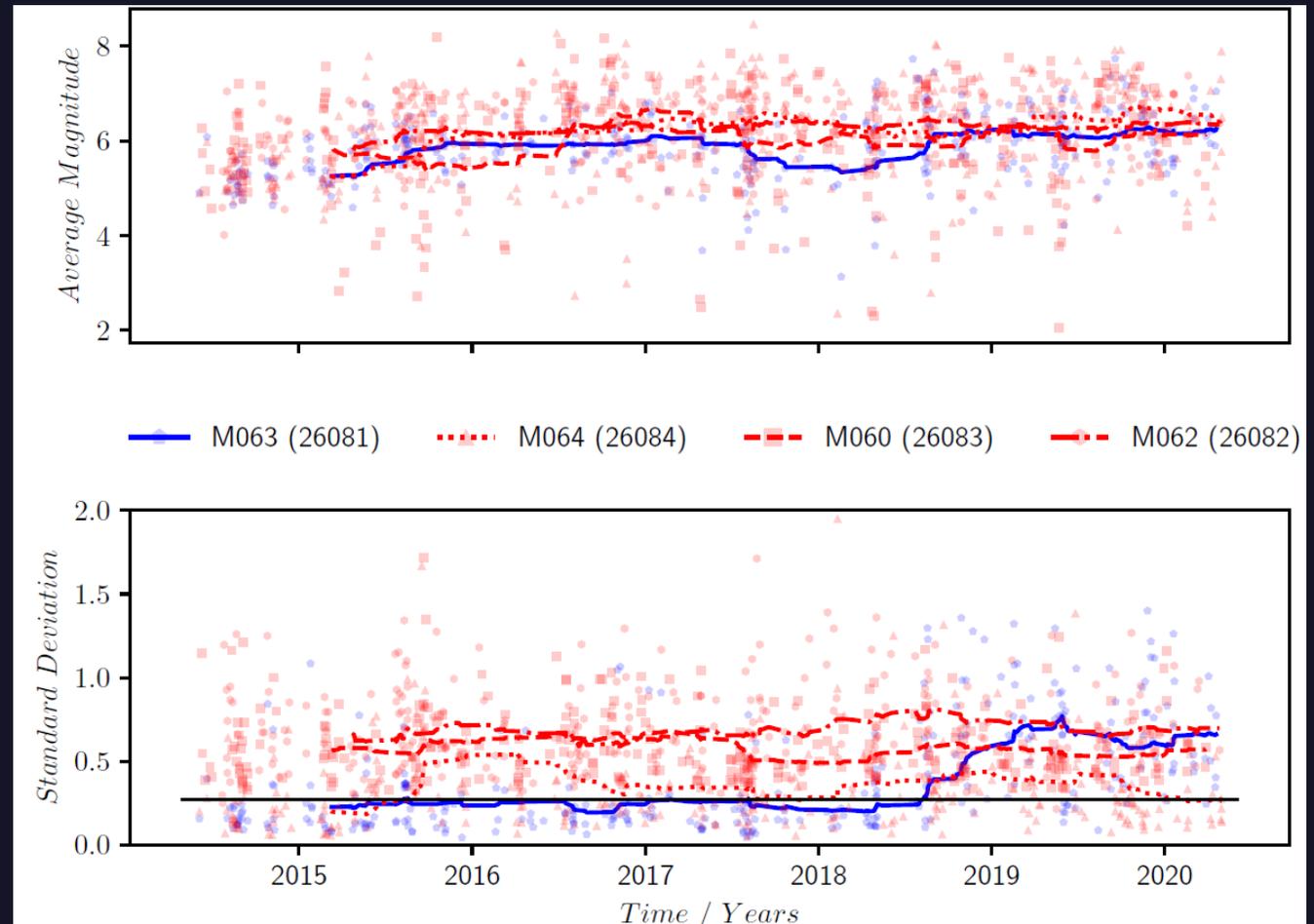


Example Application 1:

Operational Status Determination

Example Application 1: Operational Status

- 4 Globalstar satellites launched:
08/02/2000
- **3 satellites** are listed as **active**
- **1 satellite** has **conflicting data**.
- The **running average** of the **standard deviations** of each light curve are almost entirely above a **threshold of 0.27**, with the exception of 1 object.



(Data from: <http://mmt.favor2.info>)

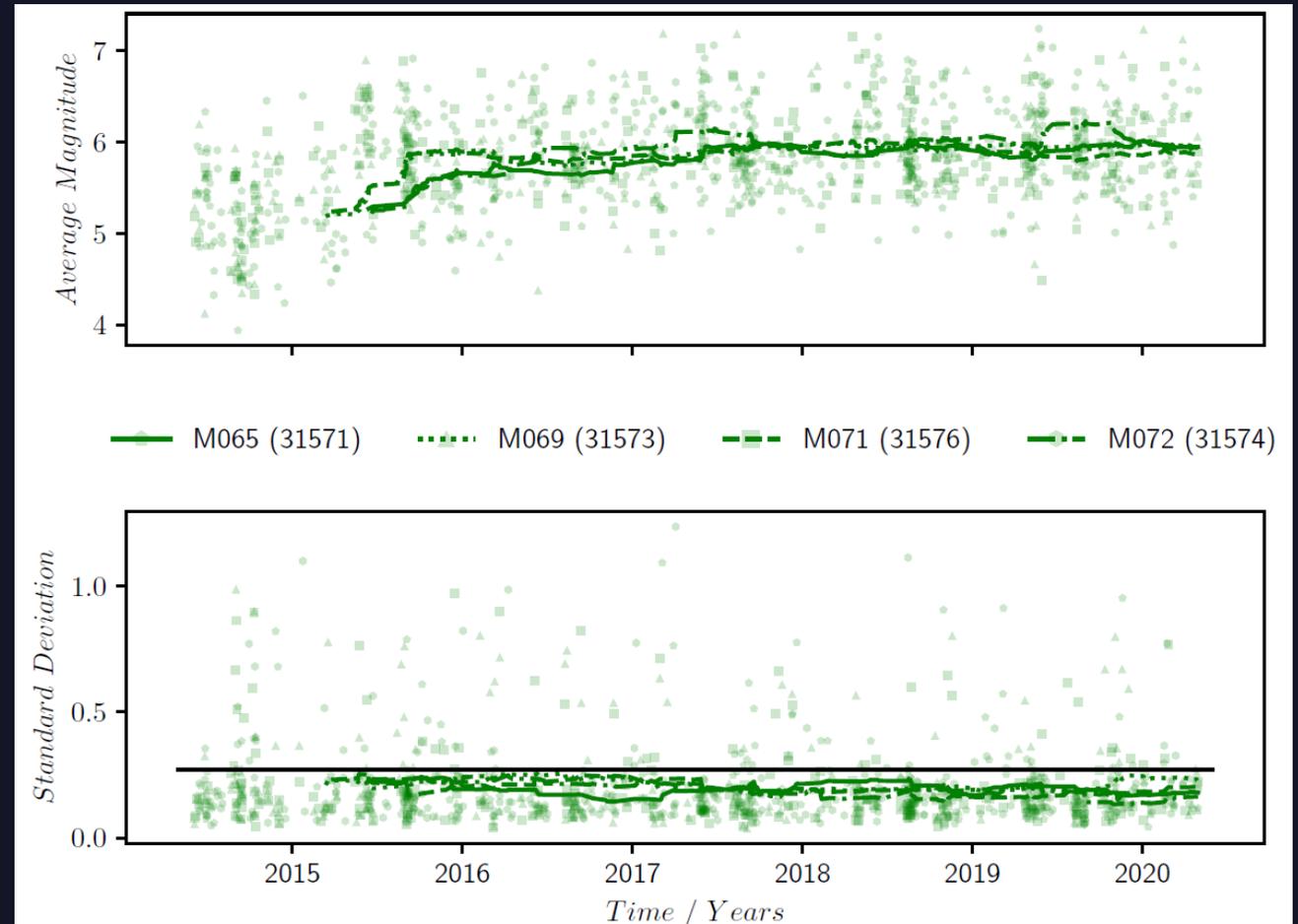
Example Application 1: Operational Status

- 4 Globalstar satellites launched:

29/05/2007

- **All satellites** are listed as **active**.

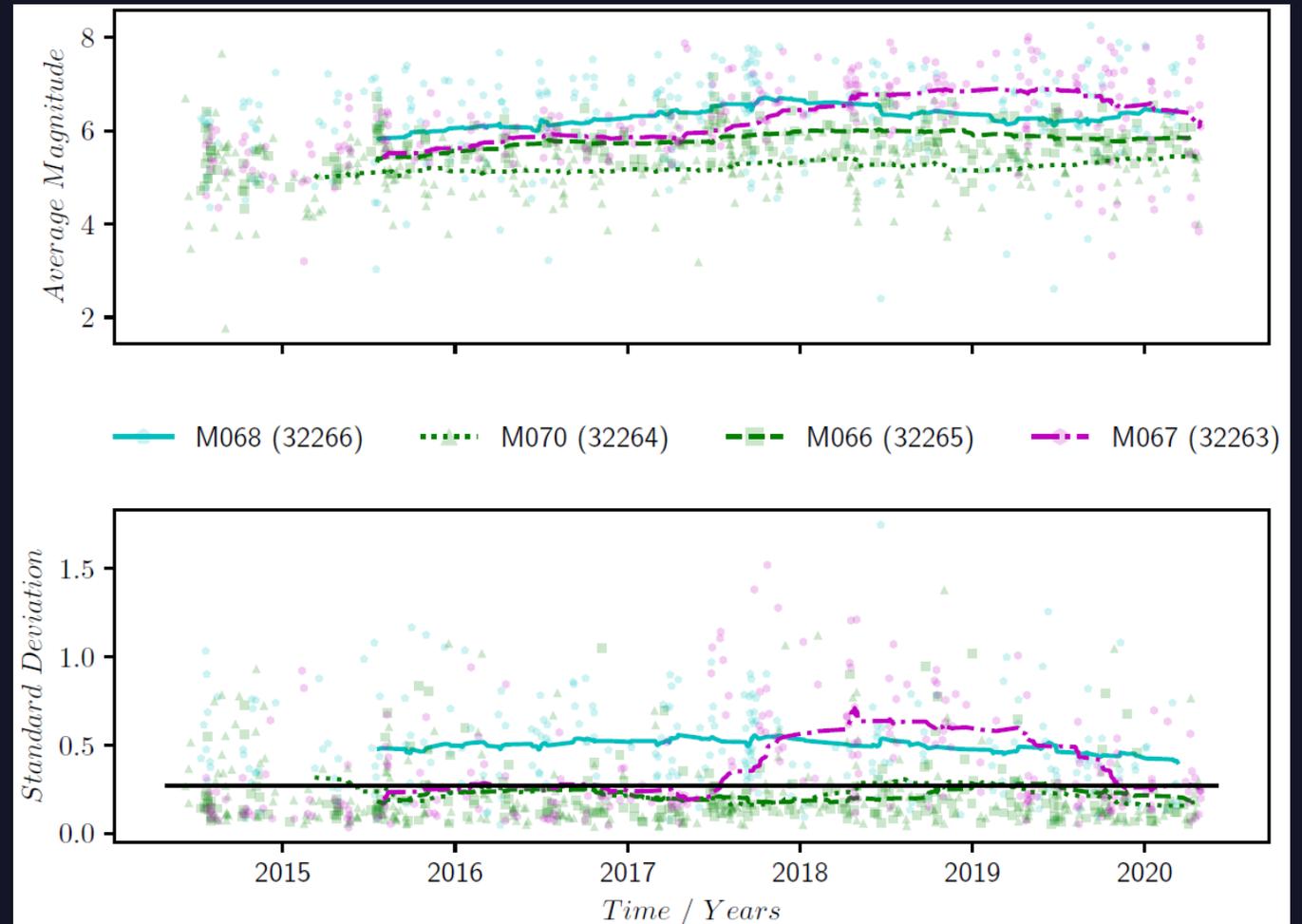
- The running average of the standard deviations of each light curve is below a threshold of 0.27.



(Data from: <http://mmt.favor2.info>)

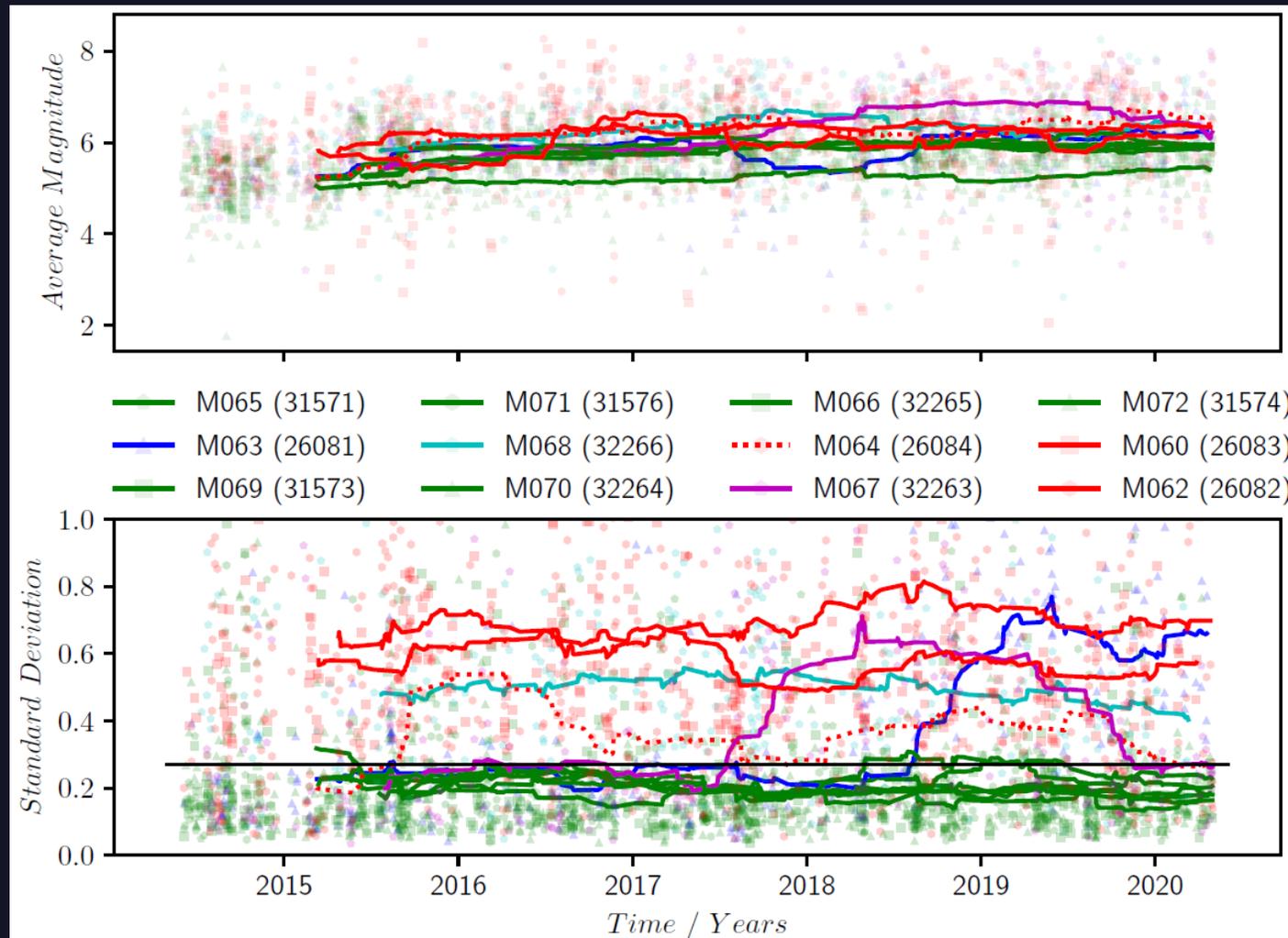
Example Application 1: Operational Status

- 4 Globalstar satellites launched:
20/10/2007
- **2 satellites** are listed as **active**
- **2 satellites** have **conflicting data.**
- The running average of the standard deviations of each light curve is below a threshold of 0.27.



(Data from: <http://mmt.favor2.info>)

Example Application 1: Operational Status



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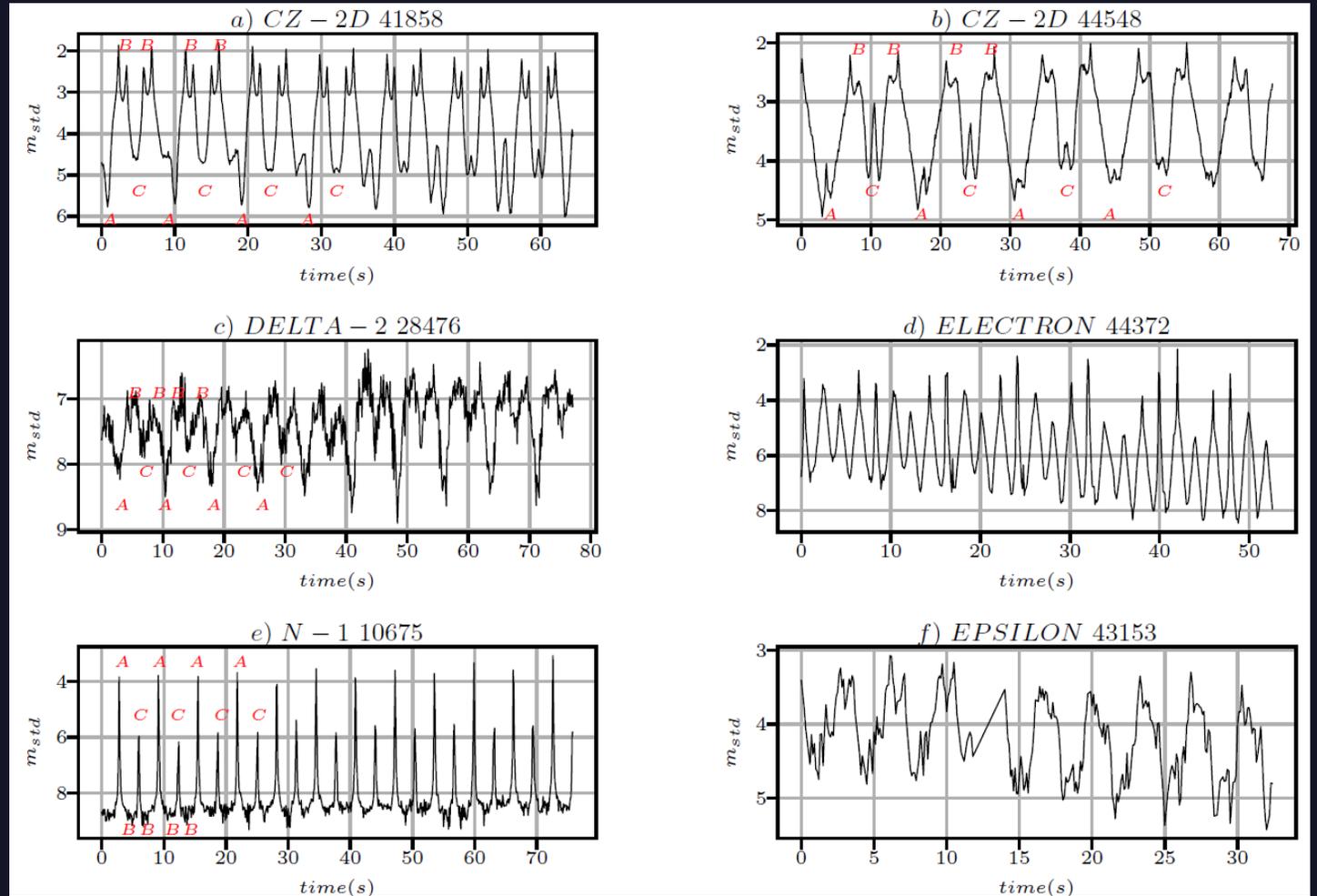
Example Application 2:

Light Curve Inverse Modelling

(Spin Axis Determination)

Example Application 2: Spin Axis Determination

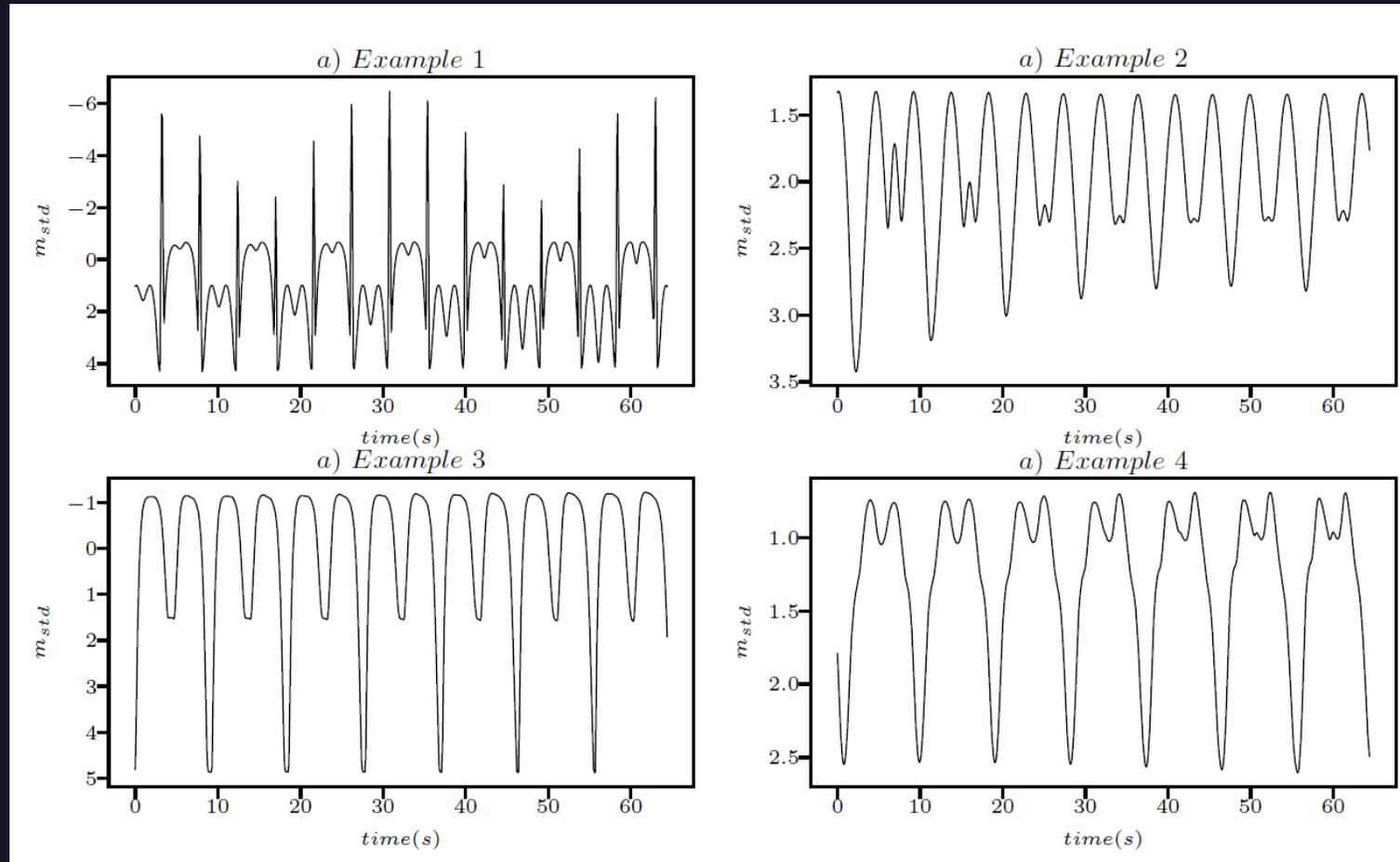
Examples of rocket body light curves.



(Data from: <http://mmt.favor2.info>)

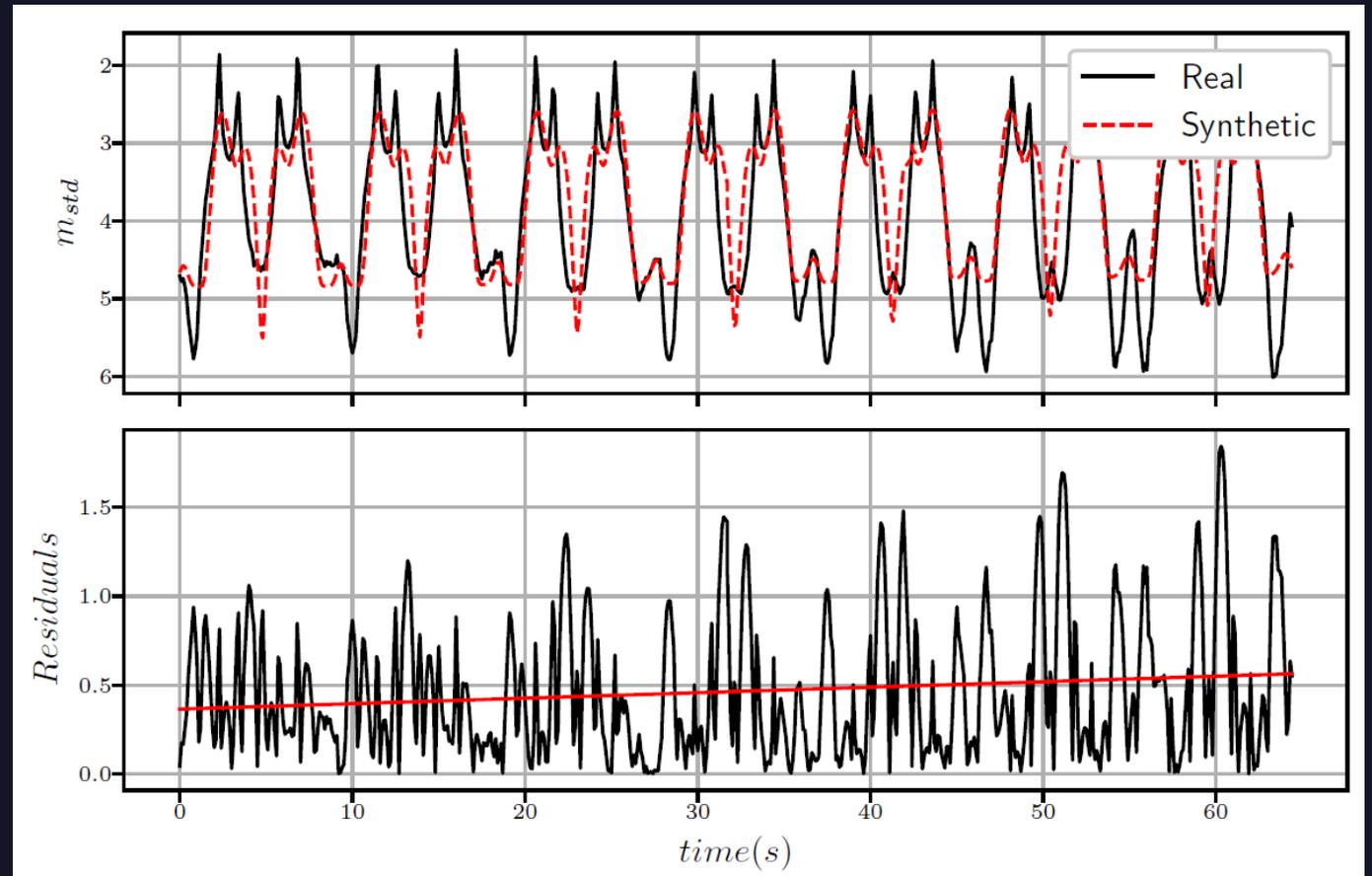
Example Application 2: Spin Axis Determination

- Examples of **Synthetic** rocket body light curves.
- Brightness calculated using a **Bidirectional Reflectance Distribution Function (BRDF)**.
- Assumed **'flat spin'** attitude state, all input parameters randomised.



Example Application 2: Spin Axis Determination

- Best-fitting synthetic light curve.
- Determined using a **brute force** fitting approach.



Example Application 2: Spin Axis Determination

Summary:

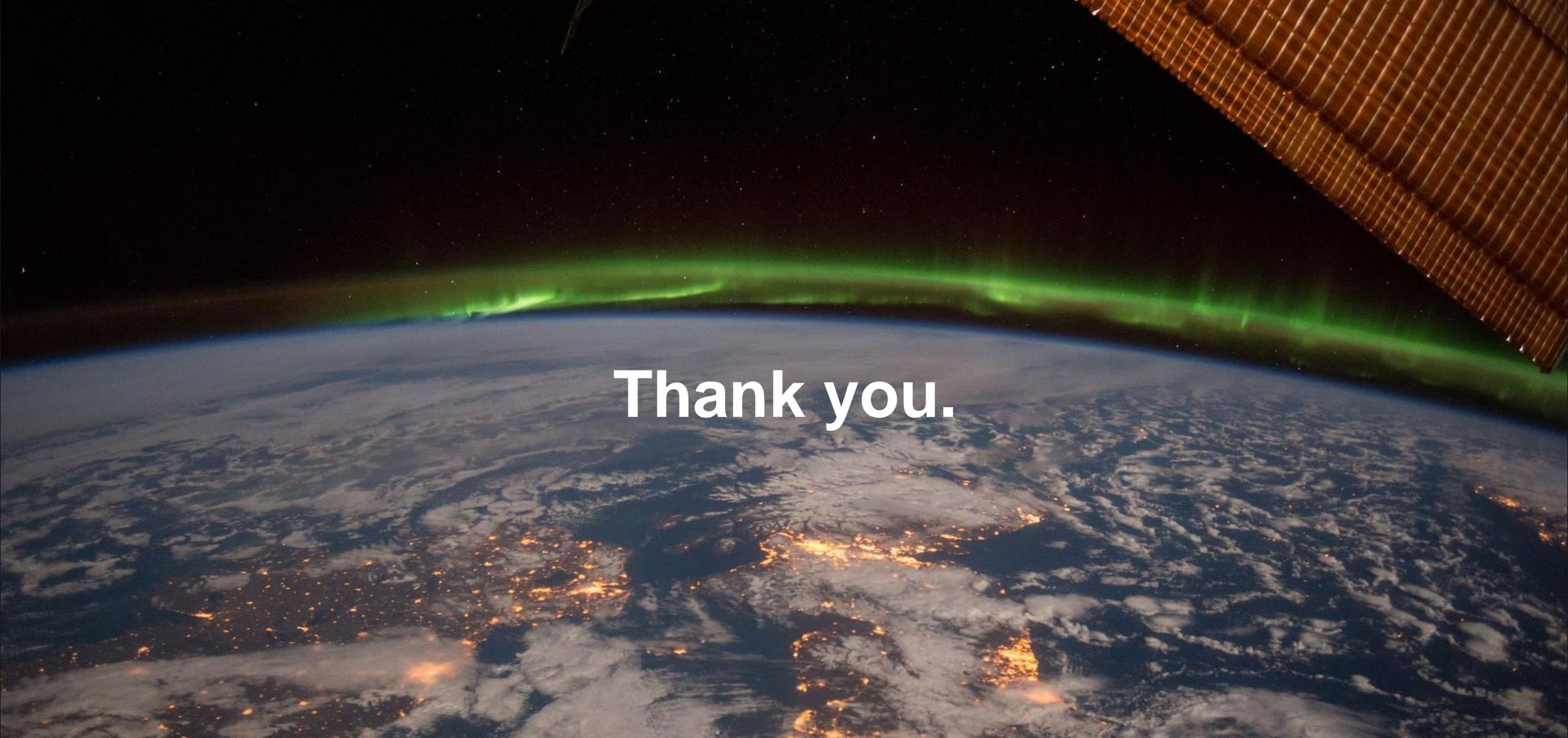
- **Inverse modelling** of rocket body light curves using a **synthetic light curve model** can be used to **estimate the angular velocity vector** of a **rotating rocket body**.
- This may be useful for **Active Debris Removal (ADR)** or **re-entry prediction** applications.
- However, there is a **lack** of available **truth data**.

Other possible inverse modelling applications:

Changes in configuration, attitude state determination (stable), changes in attitude state (stable), etc...

Conclusion

- The **availability of light curve data** has **increased** dramatically in recent years, and is likely to **continue to increase** into the future.
- Presently, light curve data is **not used to its maximum potential** in operational settings.
- Some examples of ways this can be improved is:
 - **Applying novel techniques for anomaly detection.**
 - **Apply novel analysis techniques that make use of improved volumes of data and improved computational power.**

A photograph taken from space showing the Earth's horizon. A vibrant green aurora borealis stretches across the sky above the horizon. Below the horizon, the Earth's surface is visible, showing clouds and city lights at night. In the upper right corner, a portion of a satellite or space station structure is visible, featuring a grid of solar panels.

Thank you.