Space Debris: Extraction of the Rotational State from Multistatic Light Curves

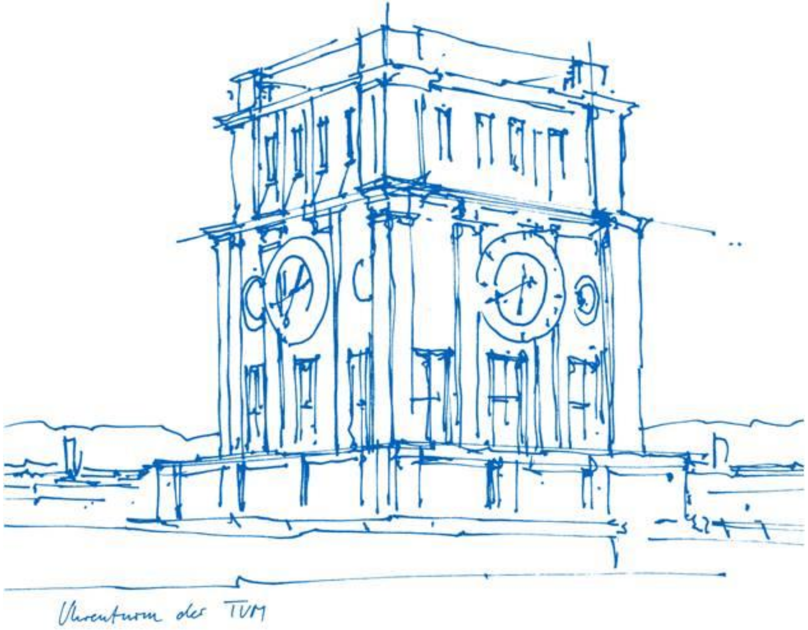
Manik Reichegger, Anja Schlicht, Urs Hugentobler

Technical University of Munich

TUM School of Engineering and Design

Forschungseinrichtung Satellitengeodäsie | FESG

Yebes, November 10th 2022

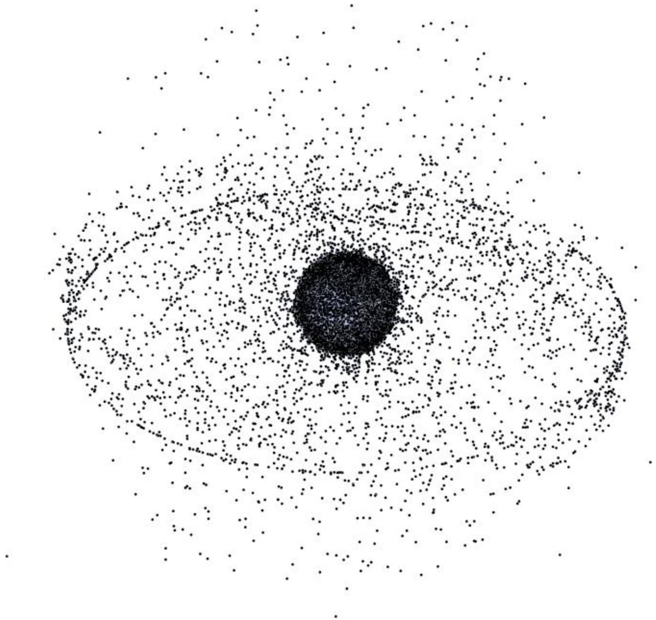


Motivation

- Rapid growth of space debris increases collision risk in space

  → Attitude determination of space debris is necessary to recover larger debris parts (robotic arms, harpoons, etc.)

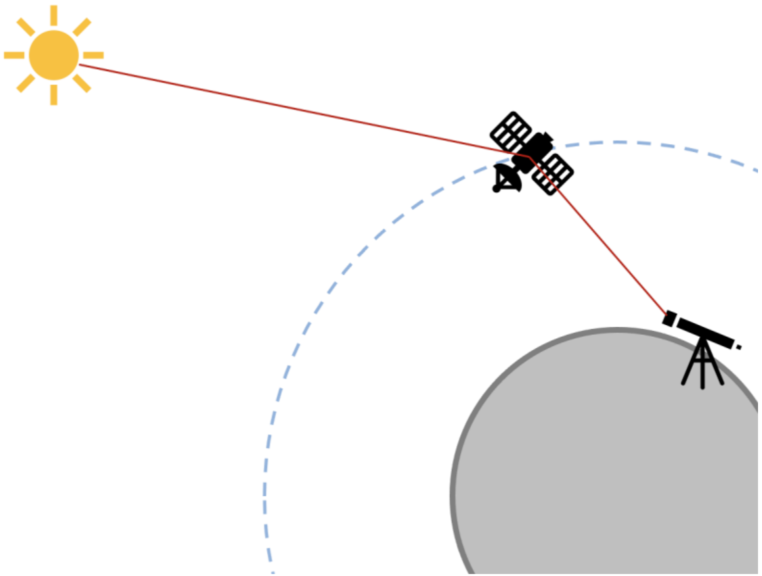
Idea: observe the change in brightness of the backscattered light over time to determine rotation parameters



www.earthobservatory.nasa.gov

Introduction - What are Light Curves

- Change in the orientation of the object causes a variation in the intensity of the reflected sunlight
- Brightness change over time can help to determine rotation parameters like rotation speed and rotation axis
- This data can help to define the current orientation in orbit which is necessary in the case of a possible return operation



Previously Realized Activities - Standard Procedure

1) Observe object with known geometry by one station and extract light curve

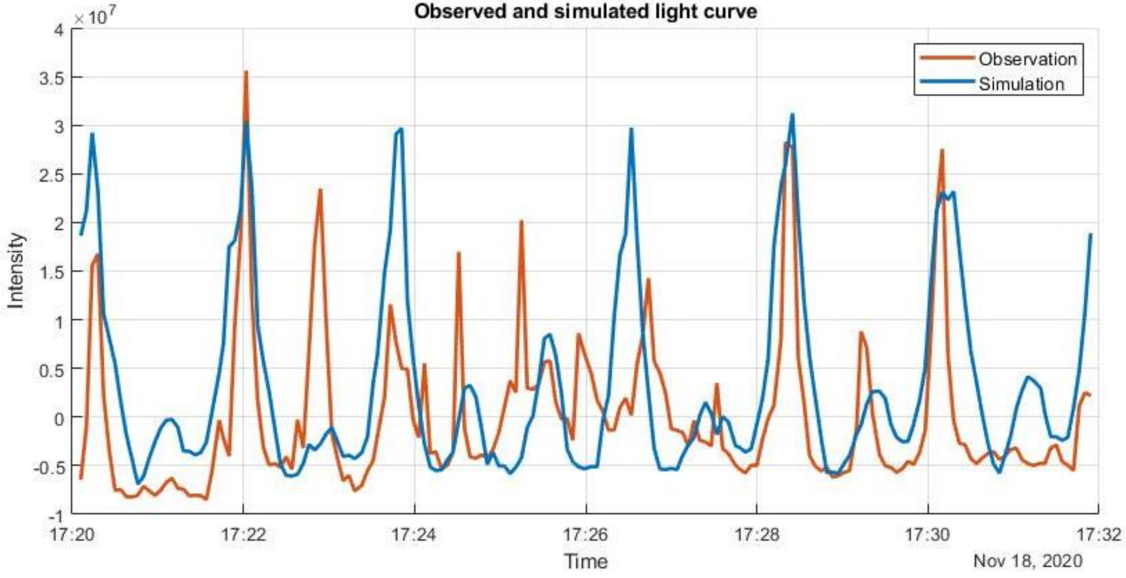
2) Spectral analysis of the light curve to extract rotation rate

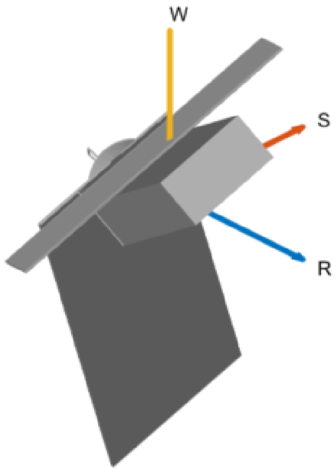
3) Determination of the start attitude, rotation axis and surface properties (comparison with a large number of simulations)

4) Correlation determination of simulations and the corresponding observed light curve

→ Find the **most reasonable** light curve

Previously Realized Activities - Result of the TUM





Best fitting light curve with the most probable attitude at the start of the pass

Problems of this Method

- Problematic with this procedure are the ambiguities

  → Spectral analysis reveals several dominant rotation periods and rotations around different rotation axes, as well as different starting attitudes lead to similar light curves

- Another problem is that very small changes in the input parameters can lead to completely different simulated light curves

Possible Solution:

Multistatic observations will resolve some of the unobservable parameters by a suitable observation geometry and eliminate some ambiguities

Null Spaces - Analysis of the Content of Information

- Introducing the Fisher information matrix – analytical expression for the null space vectors, which show the undetectable rotation axes

  → determine which attitude information is detectable from a single brightness measurement and which information lies in the kernel of the matrix

- The information matrix provides if a relative orientation error can be captured for a given a priori orientation
- The two null space vectors span a region containing all axes about which a rotation cannot be detected from a single observation

Null Spaces - Analysis of the Content of Information

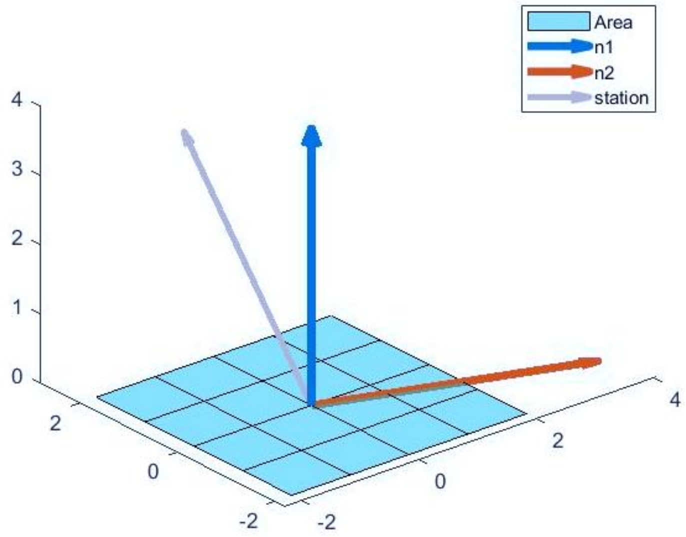
- The goal is to determine the two vectors that span the non-analyzable region

  → The first vectors is the surface normal vector (if isotropic reflection properties)

  → The second vector can be chosen orthogonal to the normal and eigenvector

- Several well distributed observatories, as well as a change in observing geometry, can minimize unanalyzable regions

Plot of the two nullspaces n1 and n2 in bodyframe - orbit altitude 500km



Planned Researches

- Analysis of the:
    - **complementarity** of multistatic light curves
    - **distribution of ground stations**
    - **shape, optical parameters** and **size** of the object
    - **orbit altitude** of the object
    - sensitivity of light curves with respect to the **initial attitude**
    - **change in geometry** between sun, object, and observer due to orbital motion separately from the **change in orientation** of the object due to rotation

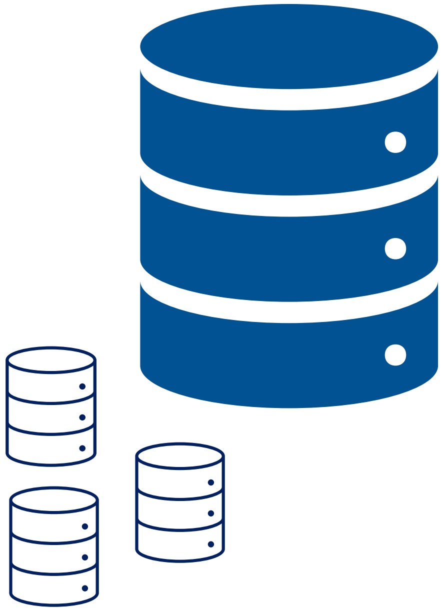
Stations Involved in the Project

- Graz
- Munich
- Uedem
- Wettzell
- Zimmerwald

The observatories use CCD or CMOS sensors as well as single photon detectors for light curve observations

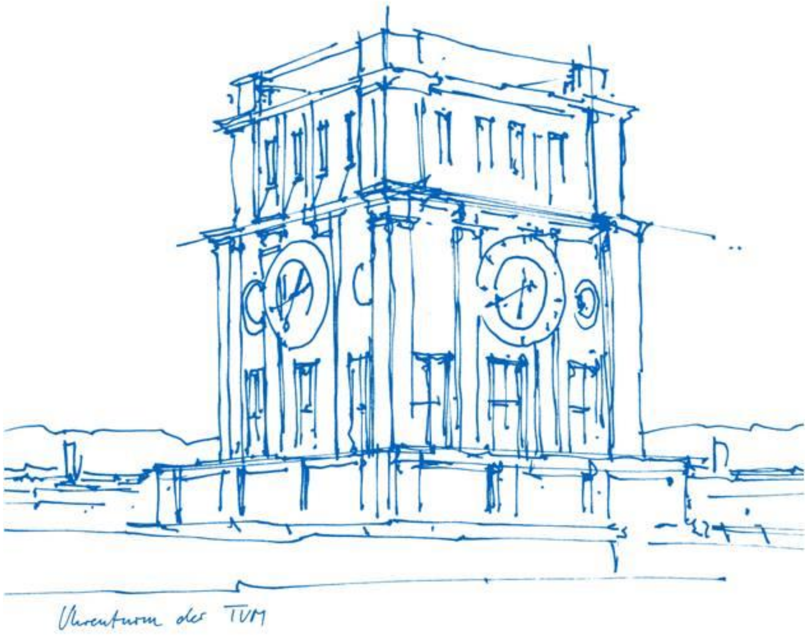
Building up a Data Base

- Light curve
- Brightness matrix
- Used software
- Sensitivity of the individual measurement instruments
- Measurement conditions
- CAD model, properties and orbit of the object



Participation at the Development of the Data Base

If there is interest and other observatories would like to participate in the observations and provide some measurements for the database, we would be very interested in a possible collaboration



Thank you for your attention!