Group 4: Orbital Elements

Miguel Angel Azanza Cuerva

Nicolae Constantinescu

Technische Universität München

TUM School of Aerospace and Geodesy

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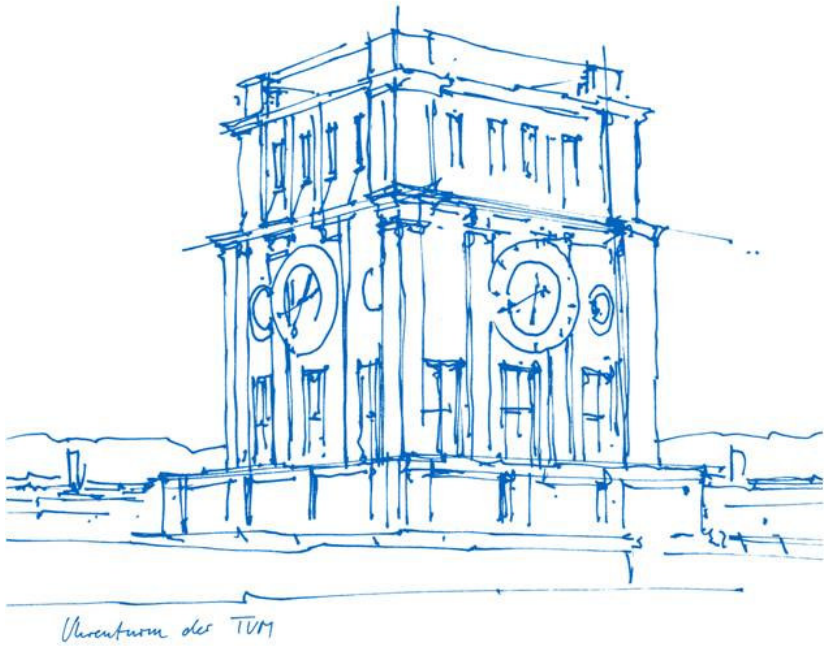


Outline

- Task Description
- Procedure Explanation
- Presentation of Results
- Encountered Problems
- Conclusions

1. Task Description

Objective

- Examine and understand the process of determining the orbit of an asteroid using observational data.
- Use a series of asteroid images to derive precise coordinates (astrometry).
- Calculate the orbital elements of the asteroid using orbit determination software.

Context

- Asteroids are dimmer and move slower than space debris, requiring special tracking techniques.
- Space debris orbits Earth at high speed in low Earth orbit, while asteroids orbit the Sun and are observed against the backdrop of fixed stars.
- Asteroids' slower movement and dimmer visibility necessitate multiple exposures and precise astrometric analysis to determine their positions and orbits.

2. Procedure Explanation. (1)

- Register at the ESA NEO Image Archive: https://neo.ssa.esa.int/image-database.

- Search for and download asteroid images in .fits format. The downloaded images will form the basis for the astrometric and orbit determination process.

- For our test, we have observed two different asteroids from 2 differet locations, during the same day:

- First observation carried out on the 30th of September 2024: ***J04 - ESA Optical Ground Station, Tenerife (20:00-21:30);***

- Second Observation Carried out the 30th of September 2024: ***Z84 - Calar Alto-Schmidt (21:30-22:30);***

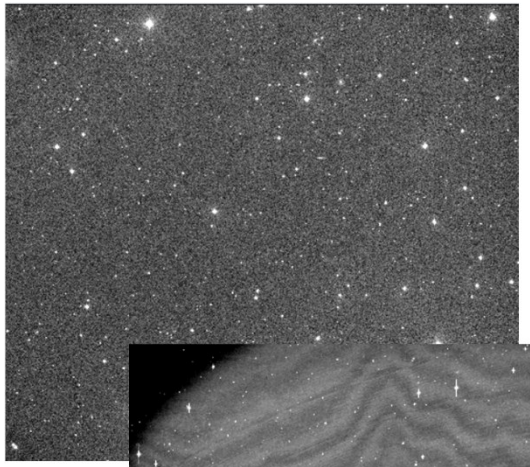


Fig.1: Image from 1st observation

Fig.2: Image from 2nd observation

2. Procedure Explanation. (2)

- Align the images and play them in sequence to detect the asteroid's movement relative to the fixed background stars.
- Use ***Astrometrica*** or another software to blink the images and visually confirm the asteroid's trajectory. ***(Blinking)***
- For the blinking procedure to be done properly, we have to introduce parameters such as the ***time and date*** when the picture was taken, ***right ascension*** and ***declination***.

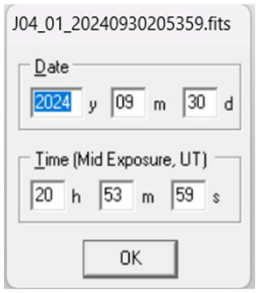
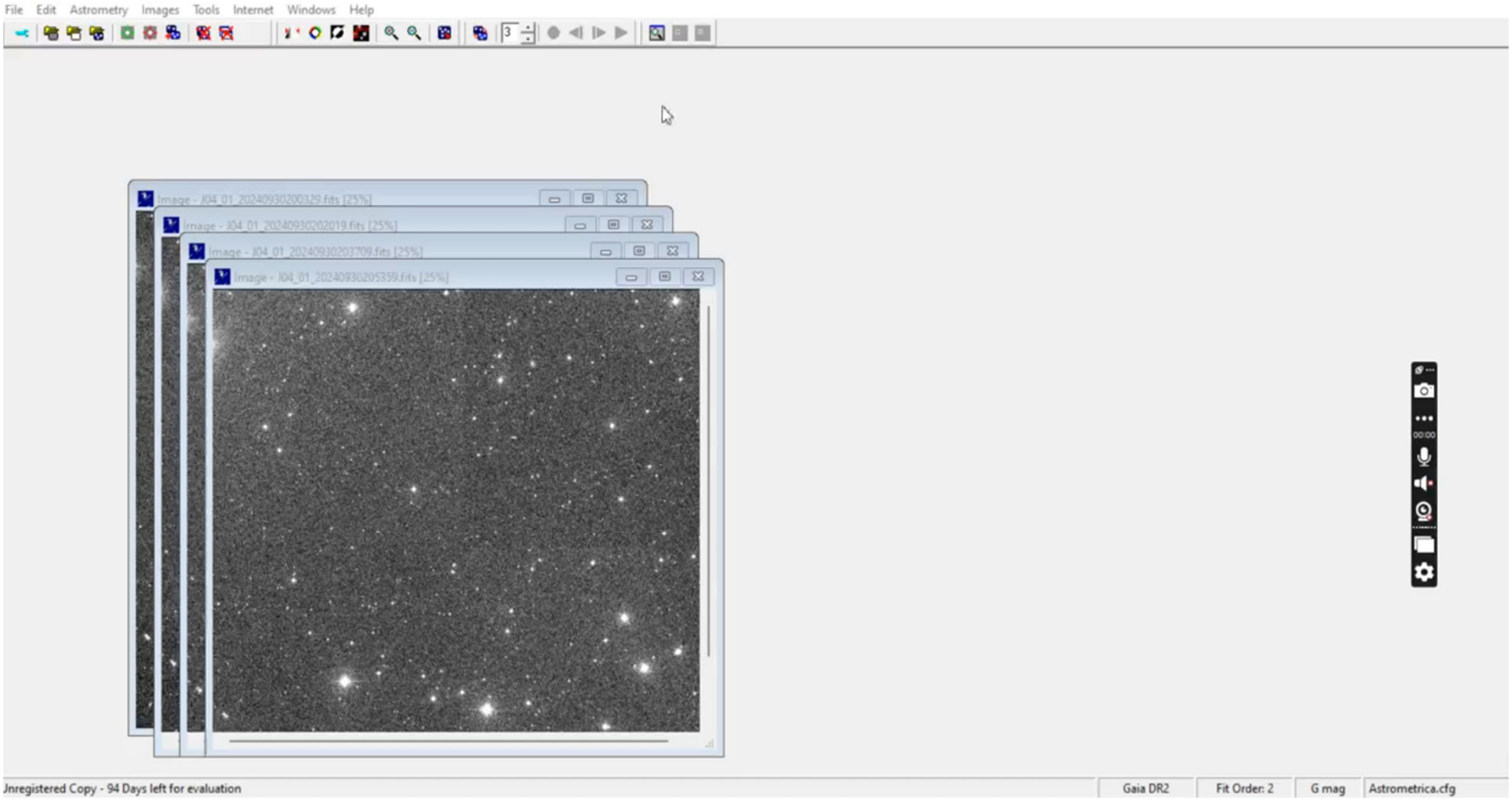


Fig.3: Setting the date & time for all sample pictures

Fig.4: Setting the coordinates for all sample pictures

	Observation 1	Observation 2
Right Acension (deg)	350.1951	347.0200
Declination (deg)	12.1681	-26.7299

2. Procedure Explanation. (3)



Recording 1: The Blinking process and extraction of objects

2. Procedure Explanation. (4)

- Upload the **MPC/ADES report** to the Find **Orb tool** (https://www.projectpluto.com/fo.html).
- Input the astrometric data to calculate the asteroid's ***orbital elements*** (e.g., semi-major axis, eccentricity, inclination).
- Generate ***ephemerides*** (predicted positions over time).
- Visualize the ***asteroid's orbit***.

```
# version=2017
# observatory
! mpcCode XXX
# submitter
! name Nick
# observers
! name Nick
# measurers
! name Nick
# telescope
! design
! aperture 0.0
! detector CCD
# software
! astrometry Astrometrica 4.13.0.451
! photometry Astrometrica 4.13.0.451
permID |provID     |trkSub  |mode|stn |obsTime               |ra         |dec        |rmsRA|rmsDec|astCat  |mag  |rmsMag|band|photCat |photAp|logSNR|seeing|exp |rmsFit|nStars|notes|remarks
       |           |      X-1| CCD|XXX |2024-09-30T20:03:29Z  |350.21351  |+12.34420  |0.53 |0.07  |   Gaia2|15.41|0.121 |   G|   Gaia2|13.4  |1.01  |1.8   |  30|0.54  |     5|     |
       |           |      X-1| CCD|XXX |2024-09-30T20:20:19Z  |350.21502  |+12.34377  |0.50 |0.05  |   Gaia2|16.54|0.344 |   G|   Gaia2|13.4  |0.52  |1.8   |  30|0.50  |     5|     |
       |           |      X-1| CCD|XXX |2024-09-30T20:37:09Z  |350.21657  |+12.34330  |0.54 |0.06  |   Gaia2|15.31|0.114 |   G|   Gaia2|13.4  |1.07  |1.7   |  30|0.54  |     5|     |
       |           |      X-1| CCD|XXX |2024-09-30T20:53:59Z  |350.21811  |+12.34287  |0.50 |0.06  |   Gaia2|16.09|0.182 |   G|   Gaia2|13.4  |0.81  |1.7   |  30|0.50  |     4|     |
       |           |      X-2| CCD|XXX |2024-09-30T20:53:59Z  |350.35934  |+12.31410  |0.50 |0.06  |   Gaia2|11.57|0.095 |   G|   Gaia2|13.4  |2.50  |1.7   |  30|0.50  |     4|     |
       |           |      X-3| CCD|XXX |2024-09-30T20:53:59Z  |350.20784  |+12.30143  |0.50 |0.06  |   Gaia2|12.02|0.095 |   G|   Gaia2|13.4  |2.34  |1.7   |  30|0.50  |     4|     |
       |           |      X-4| CCD|XXX |2024-09-30T20:53:59Z  |350.06612  |+12.33164  |0.50 |0.06  |   Gaia2|15.64|0.156 |   G|   Gaia2|13.4  |0.92  |1.7   |  30|0.50  |     4|     |
```

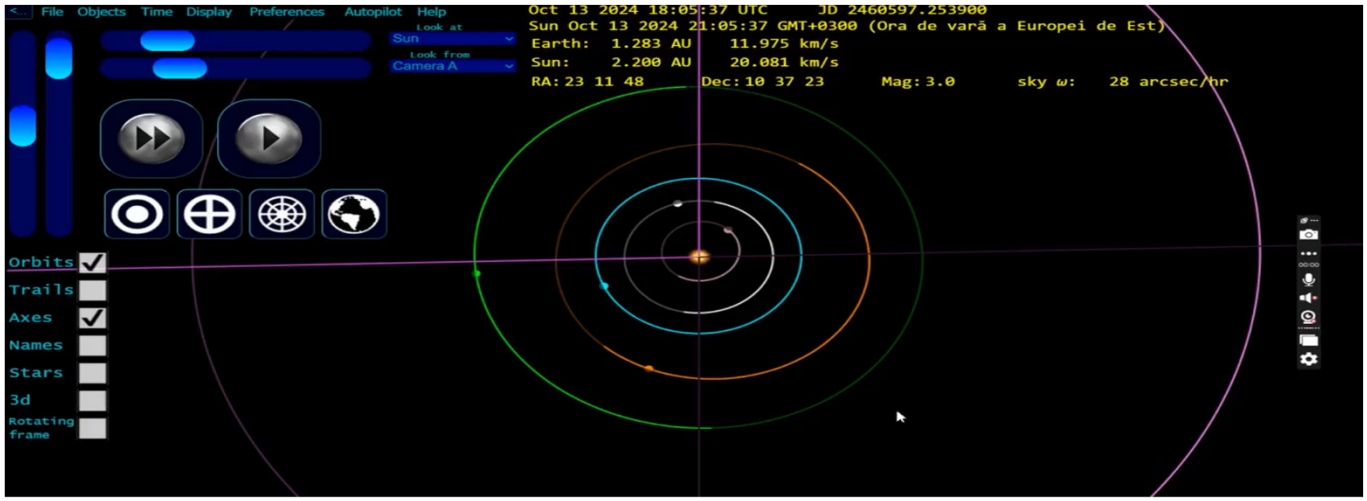
Fig.5: ADES Report

3. Presentation of Results (2)

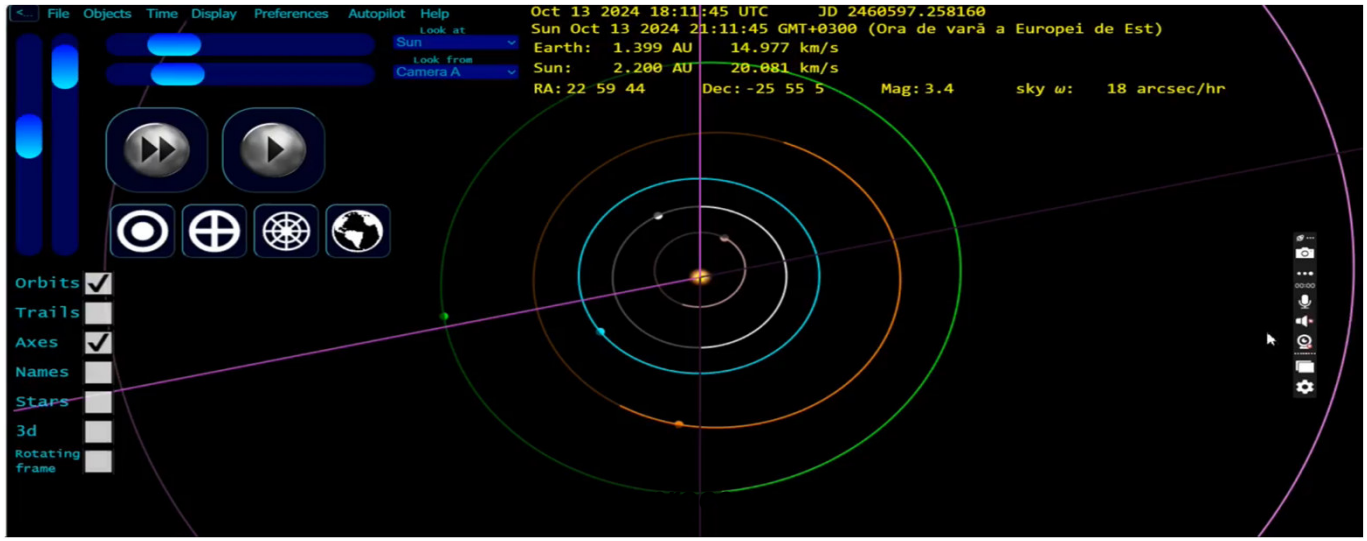
According to the orbital characteristics both asteroids belong inside the Main Asteroid Belt

	Observation 1	Observation 2
Semimajor Axis	2.2 AU	2.2 AU
Eccentricity	0	0
Inclitation (deg)	8.42559°	11.32044°

3. Presentation of Results



Recording 2: Orbit Trajectory for 1st observation



Recording 3: Orbit Trajectory for 2nd observation

Inside the Main Asteroid Belt

4. Encountered problems

- Errors in defining reference stars while Blinking;
- While finding the orbit, many moving objects can appear as duplicates (NOT real asteroids!)

```
Astrometry:
     x-3     ! CK240930:213109   346.81361   -26.63393   Duplicat!17.82GV     XXX
     X-2     ! CK240930:213109   346.89645   -26.76012   Duplicat!17.67GV     XXX
     x1      ! CK240930:213109   347.00479   -26.71367   Duplicat!17.56GV     XXX
     x-3     ! CK240930:213614   346.81183   -26.63160   Duplicat!16.13GV     XXX
     X-2     ! CK240930:213614   346.89460   -26.75793   Duplicat!16.92GV     XXX
     x1      ! CK240930:213614   347.00253   -26.71238   Duplicat!17.87GV     XXX
     x-3     ! CK240930:214121   346.81010   -26.62965   Duplicat!18.62GV     XXX
     X-2     ! CK240930:214121   346.89276   -26.75588   Duplicat!18.77GV     XXX
     x1      ! CK240930:214121   347.00048   -26.71038   Duplicat!18.91GV     XXX
     x-3     ! CK240930:214630   346.80874   -26.62726   Duplicat!17.79GV     XXX
     X-2     ! CK240930:214630   346.89126   -26.75347   Duplicat!17.82GV     XXX
     x1      ! CK240930:214630   346.99855   -26.70908   Duplicat!17.75GV     XXX
```

Fig.6: Duplictes

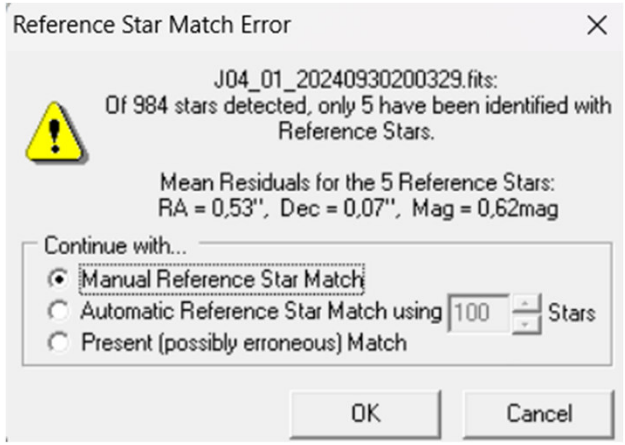


Fig.7: Errors in defining reference stars

5. Conclusions

- Successfully applied asteroid orbit determination techniques using real observational data;
- Demonstrated the use of astrometry to calculate precise asteroid positions from images;
- Emphasized the value of continuous observations to improve orbital accuracy, crucial for collision risk assessment and future predictions;
- Future work:
  - Highlighted the importance of tracking ***Near-Earth Asteroids*** for assessing potential threats;
  - A potential candidate of a galaxy was observed in one of the observations, sky maps can be used together with ***Astrometrica*** to identify it.

Thank you!