Lab Report

Page limit: 12 +1

Times New Roman’ font

* The **minimum** font size for the body of text is **10 pt (**9 pt for captions, tables, references, and abstract);
* The minimum total margin width is **37 mm.**
* “floats” (the tables and figures) either at the **top or bottom** of a page
* All figures and tables should have a figure or table number (**but not title**!) and caption explaining what they represent. Figure captions usually go under the figure, while table captions are usually placed above the table. **All figures and tables should be referred to in the main text of the report**.

Introduction

* History of main belt, main belt asteroids, what uses asteroids had in the past
* Evolution over time The distribution and size of asteroids in the Main Belt have evolved over time. The Yarkovsky effect, a force caused by the way asteroids absorb sunlight and re-emit it as heat, can slowly change their orbits. Additionally, collisions and gravitational interactions with planets have further shaped the belt's structure.
* Families, spectral types
* EMPHASIZE YOU CAN TELL SOMETHING ABOUT THIS FAMILY OF ASTEOIRDS FROM ITS LOOKS, SHAPE AND SIZE, OPTICAL SPECTRUM
* Why MBasteroids are different, compare to other type of asteroids (eg:trojan,NEO
* Importance of asteroids as resources
* Motivations of looking at asteroids
* Link to Meteorites: Many meteorites found on Earth are believed to have originated from the Main Belt, knocked out of their orbit by collisions or gravitational interactions and eventually finding their way to Earth. Studying these meteorites has provided direct insights into the composition and history of the Main Belt asteroids.
* Introduce asteroids, include their shape and size
* Scientific Research and Exploration: The Main Belt has been a focus of scientific interest, leading to various explorations and studies. Missions like NASA's Dawn spacecraft, which visited Vesta and Ceres, have provided invaluable data, shedding light on the belt's history and the conditions in the early solar system.
* Talk about parallax, uses in the past back to the greeks
* History of parallax

Asteroid information https://asteroid.lowell.edu/astinfo/

<https://link.springer.com/article/10.1007/s10569-022-10094-4> (C.Marcos,R. Marcos,2022)

<https://hal.science/hal-03419396/document> ( Raymond, Nesvorný 2020)

https://www.sciencedirect.com/science/article/abs/pii/S0019103523002270

(Liu, Wu 2023)

https://iopscience.iop.org/article/10.3847/2041-8213/ac511c/pdf (Martin, Livio 2020)

<https://www.elementsmagazine.org/wp-content/uploads/archivearticles/e10_1/2michel.pdf> (Michel 2014)

<https://www.researchgate.net/publication/297691226_On_the_oldest_asteroid_families_in_the_main_belt> (Carruba 2016)

https://www.sciencedirect.com/topics/physics-and-astronomy/orbital-element#:~:text=The%20six%20classical%20orbital%20elements,and%20shape%20of%20an%20orbit (Catling, Leovy 2007)

parallax

<https://www.researchgate.net/publication/314447532_Measuring_Distances_in_Space> (Thabet 2013)

<https://vanderbei.princeton.edu/tex/MeasureAU/ms.pdf> (Vanderbei, Belikov 2007)

<https://www.researchgate.net/publication/234294551_The_Early_Search_for_Stellar_Parallax_Galileo_Castelli_and_Ramponi> (Siebert 2005)

<https://www.researchgate.net/publication/266497326_VERA_Project_Measuring_Our_Milky_Way_Galaxy> (Omodaka 2009)

<https://adsabs.harvard.edu/full/1982JHA....13...77A> (Atkinson 1982)

<https://www.sciencedirect.com/science/article/abs/pii/S0019103519305329> (Eggl et al 2020)

<https://ui.adsabs.harvard.edu/abs/2018A%26A...616A...1G/abstract> (Gaia Collaboration et al. , 2018)

<https://www.sciencedirect.com/topics/medicine-and-dentistry/jackknife-test#:~:text=The%20jackknife%20method%20is%20a,subsamples%20of%20the%20available%20sample>. (Sinharay 2010)

<https://www.researchgate.net/figure/Fig-A1-Error-in-parallax-reduction-due-to-uncertainties-in-the-position-of-observer_fig4_282413046> (**[Thuillot](https://www.researchgate.net/profile/William-Thuillot?_tp=eyJjb250ZXh0Ijp7ImZpcnN0UGFnZSI6Il9kaXJlY3QiLCJwYWdlIjoicHVibGljYXRpb24iLCJwcmV2aW91c1BhZ2UiOiJfZGlyZWN0In19)** et al 2015)

<http://www.astrometrica.at/Papers/PointSources.pdf> (Raab 2003)

<https://www.researchgate.net/publication/237636797_Classical_and_modern_orbit_determination_for_asteroids> (Gronchi 2004)

(Farae et al 2021) https://www.researchgate.net/publication/354626767\_An\_Improved\_Approach\_to\_Orbital\_Determination\_and\_Prediction\_of\_Near-Earth\_Asteroids\_Computer\_Simulation\_Modeling\_and\_Test\_Measurements

<https://doi.org/10.1051/0004-6361:20020149> (Pourbaix 2002)

(Farnocchia, 2015) https://www.sciencedirect.com/science/article/abs/pii/S0019103519305329

Method

* + How you determine orbits <https://www.researchgate.net/publication/237636797_Classical_and_modern_orbit_determination_for_asteroids> (Gronchi 2004)
* How observations were done- telescope, observation strategy

### How xyz was used- Positioning in Space https://www.sciencedirect.com/topics/physics-and-astronomy/orbital-element#:~:text=The%20six%20classical%20orbital%20elements,and%20shape%20of%20an%20orbit

\section{Results}

\section{Discussion

* Trace evolution of asteroids over few hundred years
* - Or visit them
* - Or track whether they wills smash into smthn
* - Find smthn that allows you to phrase what youre trying to get at
* - parallax images not taken during opposition
* - using 2mass instead of gaia catalogue https://www.sciencedirect.com/science/article/abs/pii/S0019103519305329

- astrolab project details page

-pertubations: yarkovsky effect - <https://iopscience.iop.org/article/10.3847/PSJ/ad0226>

https://www.sciencedirect.com/science/article/abs/pii/S0019103521004863

-improvements

* An asteroid in resonance experiences enhanced gravitational perturbations from Jupiter, which can cause regular variations in its orbital elements. The extent of these variations depends on the asteroid's location within the resonance, which is, in turn, is determined by the starting conditions. <https://www.sciencedirect.com/topics/physics-and-astronomy/orbital-element#:~:text=The%20six%20classical%20orbital%20elements,and%20shape%20of%20an%20orbit>
* Planning a trip to an aserroid

The difference between the observed position and the predicted position is the residual. If the model is perfect and the observations are flawless, the residuals should be zero or close to zero. However, several factors can cause the residuals to be larger:

* **Weather Conditions**: Ground-based telescopes, unlike Gaia, which operates in space, are subject to weather conditions. Poor weather can obscure some stars, making them invisible or less bright in the images, and thus they cannot be used as reference points.
* **Atmospheric Disturbances**: Even with clear skies, atmospheric turbulence can distort the light from stars, leading to less accurate position measurements.
* **Instrumental Factors**: Limitations in the telescope's optics or detectors, as well as calibration errors, can lead to inaccuracies in the observed positions.
* **Limitations in the Catalog**: The reference catalog itself might have small errors in the positions of stars, which can introduce errors when used to determine the position of the asteroid.

When residuals are consistently non-zero, they can indicate systematic errors in the observations or the models used to predict positions. By analyzing these residuals, astronomers can identify and correct for such errors, leading to more accurate measurements and a better understanding of the celestial mechanics governing the movements of asteroids and other objects in our solar system.

\section{Conclusion}

\discussion

Look at their implications

Compare them to accepted values

Examine and compare your method and results to those of other scientists, and discuss possible improvements (these need to be practical).

Discuss any errors your may have omitted and how this would affect your results

- improvements:

- on parallax: Refinement with Kepler's Laws: To refine this calculation, one might also consider the exact position of Earth and the asteroid in their orbits at the time of the parallax measurement. This can be done by taking into account the Earth's and asteroid's true anomaly, which is their actual position in orbit relative to their closest approach to the Sun (perihelion). By adjusting the distance to the asteroid for these orbital positions, a more accurate determination of the AU can be achieved.With the absolute distance from Earth to Marion known, one can then use Kepler's third law to find the distance from Marion to the Sun in astronomical units. Since the law correlates the square of the orbital period to the cube of the semi-major axis of the orbit, this relationship gives the distance from the Sun to Marion in terms of AU.

This method of calculating the AU relies on a combination of direct parallax measurement and the known orbital characteristics of the asteroid

- planning a mission to an asteroid

- mcm method

-how we can expand on the project, what else can we use op for?

- number of observations which is better: Gauss's method of orbital determination is a classical technique used to calculate the orbital elements of a celestial body, like an asteroid or comet, from a minimum of three precise positional observations (usually right ascension and declination) taken from Earth. The method involves solving a series of equations to determine six orbital elements that describe the size, shape, and orientation of the orbit, as well as the position of the body within the orbit at a given time.

Whether 10 observations or 3 are better for calculating the orbital elements can depend on several factors:

1. \*\*Accuracy of Observations\*\*: If the observations are very precise and there is high confidence in their accuracy, then three well-timed observations could be sufficient to determine an accurate orbit.

2. \*\*Distribution of Observations\*\*: Gauss's method requires observations to be spread out over a span of time. If three observations are closely clustered, they may not provide as much information about the orbit as more widely spaced observations. In such cases, having more observations (like 10) can lead to a more accurate determination of the orbit.

3. \*\*Redundancy and Error Reduction\*\*: More observations provide redundancy, which can help in identifying and reducing random errors. With 10 observations, it is possible to use statistical methods to refine the orbital elements and get a more reliable result.

4. \*\*Orbit Type and Complexity\*\*: For simple orbits that are nearly circular or elliptical, fewer observations may be sufficient. However, for more complex orbits, such as those with high eccentricity or influenced by non-gravitational forces, having more observations can be beneficial.

5. \*\*Computational Resources\*\*: With Gauss's method, increasing the number of observations leads to more complex calculations. While three observations might be simpler to handle computationally, modern computing resources typically make handling larger numbers of observations feasible.

6. \*\*Outlier Rejection\*\*: With more observations, it is easier to identify and reject outliers that may skew the orbital elements. This can be particularly useful when observational errors are suspected.

In summary, while Gauss's method can provide a solution with just three observations, using more observations can generally improve the robustness and accuracy of the orbital determination. This is because more data points allow for a better assessment of observational errors and uncertainties, as well as providing more information about the orbit over time. In practice, astronomers often use as many observations as possible to determine the most accurate orbits.

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- plot of orbital p from jpl and ours w error bars

-mcm x2

-dp/p x2

- residuals x2

- errors