Parallax in the "Pi of the Sky" project

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4 Summary
- The most direct method to determine a distance from the observer to the object,
- There is no need for any assumptions to measure it.
What is needed:

- Directions of the lines of sight from two places,
- Angle between them,
- Distance between these places (called the base).
Limitations:

- The parallax angle gets smaller with the distance, quickly,
- Can be used only for relatively close objects,
- To improve parallax observation more powerful telescope or larger base is needed.
Parallax in the "Pi of the Sky" project

Pi of the Sky North Observatory in Southern Spain

- In use since October 2010,
- Located in southern Spain, at 37° 6' 14''N, 6° 44' 3''W,
- New design of equatorial mount carrying 4 cameras (designed by Space Research Center, PAS),
- Single camera has 20° x 20° field of view,
- Half of a FOV's diagonal is equal over 14°, half of a pixel's diagonal is equal 25".
"Pi of the Sky" North Observatory in Southern Spain

- Two observation modes: WIDE (cameras observing adjacent fields) and DEEP (all cameras observing the same part of the sky)
- The field of view is $40^\circ \times 40^\circ$ (in WIDE mode) or $20^\circ \times 20^\circ$ (in DEEP),
- Usually we observe in WIDE mode.
Pi of the Sky South Observatory in Northern Chile

- In use since March 2011,
- Located in northern Chile at 22° 57’ 12”S, 68° 10’ 48”W (740 km North from LCO),
- The chilean prototype was relocated from LCO to SPdA,
- Two cameras in coincidence,
- The field of view covers 20°x20°.

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- Since March 2011 we are able to observe a parallax of objects close to the Earth,
- It is very important, because it allow us to reject false triggers, mostly due to artificial satellites, other kinds of rockets and space debris elements.
- The base is huge, almost 8500 km along the Earth’s chord,

- We are able to observe parallax angle from 25” to over 14°,

- Combination with camera’s diagonal results in an observable parallax angle for objects more than 20600 km from the Earth centre,

- For closer objects the parallax angle exceeds the image size.
- Combination with diagonal of the pixel results in an observable parallax angle for objects almost 38.2 million km from the Earth centre,
- For further objects the parallax angle is smaller than the pixel size.
Between 20600 km and 38.2 million km one can find:

- geostationary and GPS satellites,
- space debris,
- the Moon,
- near Earth comets, planetoids, etc.
In the near future we plan to establish another observatory in Southern Spain:

- most probably located near Malaga,
- more or less 240 km from INTA,
- it will allow us to observe a parallax of objects between 6800 and 870 thousand km from the Earth centre,
- Low Earth Orbit objects’ (like ISS, HST) parallax will be available.
Determination of a parallax in "Pi of the Sky"

If observations were performed at the same time, it is possible to determine a straight line connecting the observatories with the object, which are parametrized as:

\[ d_{SPdA} = r_{SPdA} + pr_{SAT_{SPdA}} \]
\[ d_{INTA} = r_{INTA} + qr_{SAT_{INTA}} \]

\( p, q - \) parameters \( > 0 \)
Determination of a parallax in "Pi of the Sky"

then the position of the center of vector connecting positions of their smallest distance can be determined as:

\[ R = \frac{d_{SPdA}(p_0) + d_{INTA}(q_0)}{2}, \]

where \((p_0, q_0)\) - a position of the smallest distance between the two straight lines.
Observation’s strategy

- Due to huge base we observe the parallax of geostationary satellites,
- Observations are executed once or twice a night, about 0 UT and 3 UT.
- Each observation lasts nearly 90 minutes,
- Before beginning of observations computer checks if both observatories are working,
- The algorithm searches for flashes with maximal angular distance 180’,
- Every flash candidate is verified in TLE NORAD satellites database,
- A list of candidates is published on the website.
Results

- During nearly 90 minutes of observations we record almost 3000 different satellites,
- It is possible to determine the distribution of difference between satellites distances known from the TLE database and the distance $R$ determined by our algorithm,
Since March 2011 we have two observatories working: one in Chile and one in Spain,

For now we are able to observe a parallax of geostationary satellites,

In the future we will able to observe a parallax of LEO objects,

Each cloudless night in both observatories we record almost 3000 different satellites with known orbit,

And many others, which are not in NORAD TLE satellites database,

It allow us to reject from databases all object between the Earth and the Moon or even further,

Distant satellites shine too weak to our cameras and are beyond our reach.