Astroraga: Mission Space Lab Report

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Chosen theme: Life on Earth
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Introduction

Can astronauts orient themselves in space with the compass? The compass has been used since ancient times for human exploration, but is it useful when we are in orbit around the Earth? Can we measure the Earth's magnetic field at 400 km in height? Are there variations in magnetic field when the latitude and longitude varies?
We will try to answer these questions through the data collected by the Raspberry on ISS and then we will analyze data on Earth and compare them with the data from the World Magnetic Model (WMM) at 400 km (the altitude of ISS orbit).
If the data of the model will coincide with those collected we could say that it is possible to correctly measure the Earth's magnetic field from the ISS.
If the result will be positive we will compare the intensity of the magnetic field on the ISS with that on the Earth's surface.

Method

To answer our questions we wrote a program in Python that reads the magnetometer every 15 seconds and saves data in a text file. To check whether ISS had changed its orbit or height, we also collected data from accelerometer and gyroscope, the coordinates of the ISS (using the ephem library and TLE files) and photos of Earth's surface.
Waiting for the data we studied the Earth's magnetic field by answering questions such as "how is it generated?", "What is its shape?", "How can we measure it?", "Does it change in space and in time? "
After we received the data we loaded and analyzed them using Python and spreadsheets https://github.com/CoderDojoTrento/AstroPi_2018-19.
Using coordinates and data we have created an online map using the umap service https://umap.openstreetmap.fr/it/map/astropi-2019-astroraga_326628#3/16.30/28.83 which shows the points on the planisphere. By clicking them we can see the data collected and the photos. Using Python Basemap module, we displayed ISS trajectory with circles 400 km in diameter in red when it was in light and blue when in shadow.

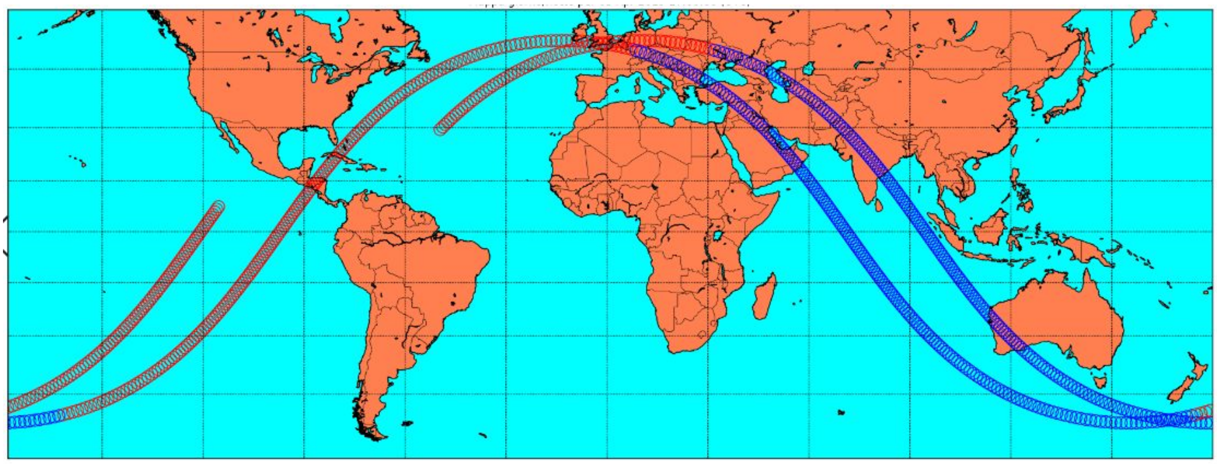

Figure 1: ISS orbit during the experiment

We have downloaded the World Magnetic Model data https://www.ngdc.noaa.gov/geomag/calculators/magcalc.shtml?#igrfgrid at 400km for comparison.

Using the x, y and z components of the magnetometer we calculated the horizontal component H ($\sqrt{x*x+y*y}$), total intensity F ($\sqrt{x*x+y*y+z*z}$) and to determine the orientation the Incidence I *(arctan (z / H))* and Declination D *(arctan (y / x))*

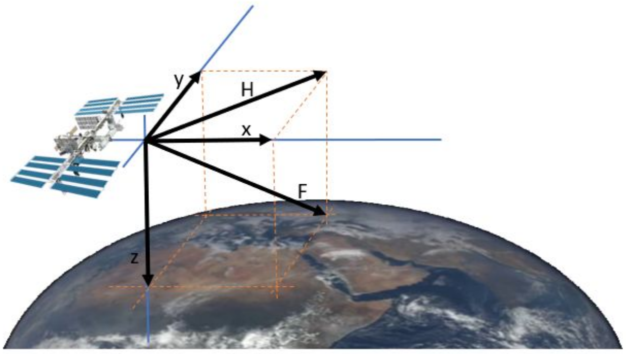

Figure 2 : Earth magnetic field component

Finally, we compared the total intensity of the magnetic field on the ISS with that at sea level in all points of the orbit.

Results

Analyzing the photographs and the trajectory we noticed that in the daylight hours we flew over oceans. Despite this we were able to recognize some places like Cuba, Bahamas, French Polynesia atolls, Dnieper river.

We noticed that the ISS has maintained the orientation with the camera always facing the Earth: gyroscope and accelerometer data confirm this too.

Comparing the horizontal component H we found a good correspondence with the WMM data at 400 km (excluding some values completely out of scale) (Fig.3).

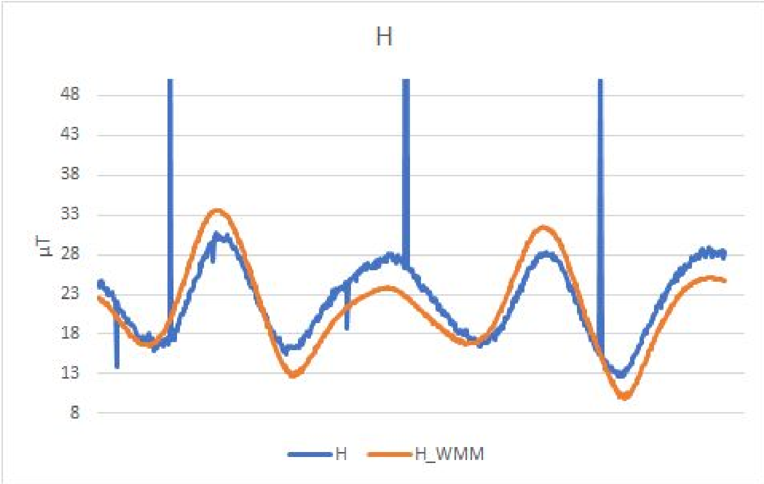

Figure 3 : Horizontal component comparison (ISS Vs WMM)

Comparing the values of the total intensity F we found some differences with respect to the model. Since the only new element introduced by F is z we focused on this. Comparing experimental z with the model we noticed that that it was constantly higher of about 24 microtesla (fig. 4). We believe that this is not due to the real value of the magnetic field (both because it is constant and because of its magnitude) but rather to an incorrect calibration of the magnetometer or to the presence near the raspberry of a magnetic field caused by the power supply or by ISS itself.
So we applied a -24 µT correction factor to z, obtaining a good correspondence with the model. (fig. 5)

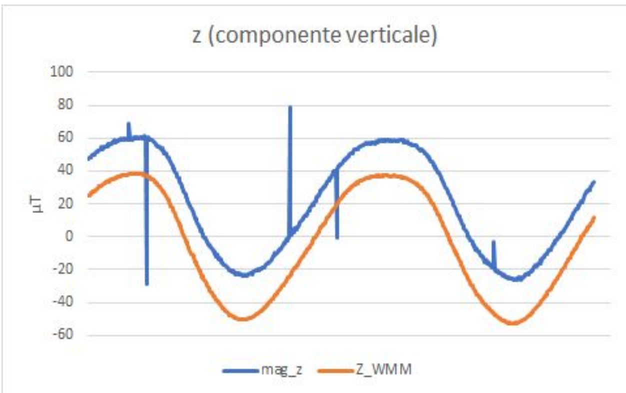

Figure 4 : z comparison (ISS Vs WMM)

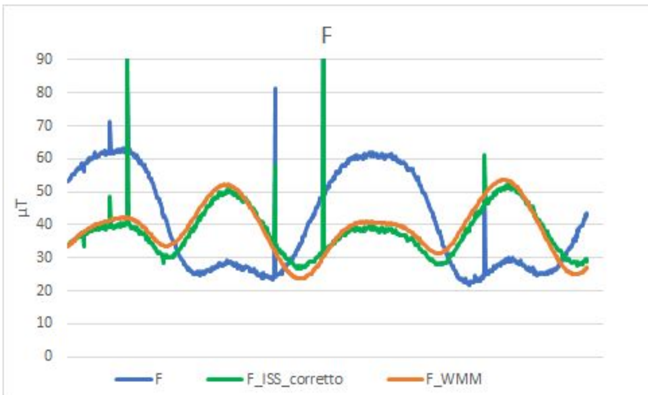

Figure 5:Intesity F

Using corrected z the values of the incidence I (inclination of the magnetic field with respect to the horizontal plane) correspond with the model since the z-axis of the model coincides with that of the ISS (directed towards Earth) as well as the horizontal plane.
In WMM the declination D measures the angle between the horizontal component H and x axis which in the model coincides with the geographical North. In our experiment the x axis of the magnetometer is not oriented towards the geographic North so we cannot make a comparison; however, in the same way, we can calculate the inclination of H with respect to the x axis of the ISS (fig. 6).
As we expected at the points of maximum latitude, the inclination is approximately equal to zero since the North coincides with the x axis (the IIS is parallel to the equator) while at the equator the inclination reaches the maximum value.

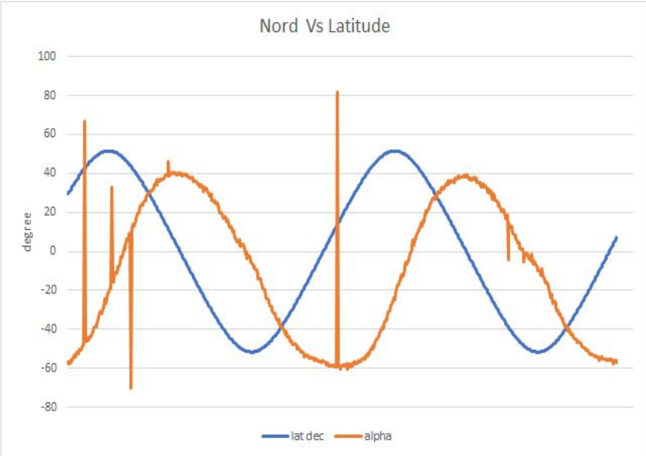

Figure 6 : Nord inclination Vs Latitude

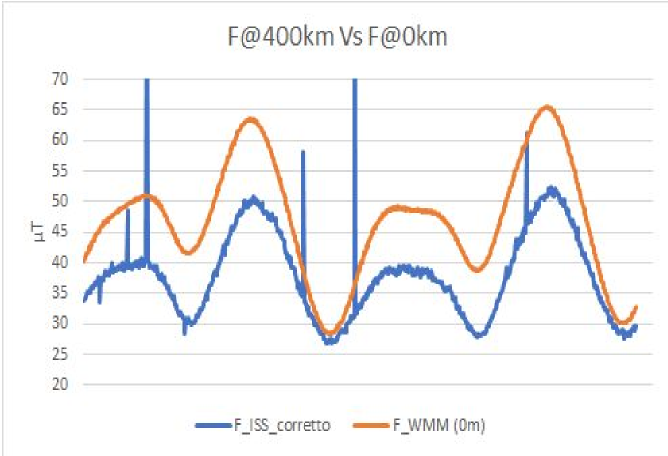

Figure 7 : Intensity at 400km Vs 0 km

Looking at fig. 7 we noted that the intensity on the ISS is lower than at sea level, but around lat. -5 and long. -110 the values are the same. Those points are the closest to the South Atlantic Anomaly in our experiment, so an hypothesis is that the anomaly reduces the magnetic field intensity reducing the difference related to the altitude.

Conclusion

The Earth's magnetic field is measurable by the magnetometer on the IIS even if at 400km it appears to have a **lower intensity** than at sea level.
The Earth's magnetic field extending beyond the orbit of the ISS protects it from radiation, but the reduction in the intensity and absence of the atmosphere could cause **astronauts to be subjected to larger doses of radiation** than on Earth.
In the experiments conducted in orbit it will therefore be necessary to take into account the influence of the magnetic field (also for the biology experiments where the organisms even in microgravity could find an orientation thanks to the magnetic field or can be influenced by radiation).
The **ISS could be used to conduct experiments on the Earth magnetic field** by detecting differences with respect to ground measurements to evaluate the effects at different altitudes of phenomena that alter the magnetic field (solar wind, electric currents on the surface, earthquakes (?),..) or to collect long series of data to analyze changes in the magnetic field.
Now we can answer our question: **Astronauts can use a compass as reference on ISS**.

Despite the magnetic field, however, we have lost the orientation due to the emotion of taking photos from space and having been able to analyze data coming from the ISS and collected by the Raspberry a programs written by us!!!!
Thanks ESA and thanks Izzy Astro Pi!!!