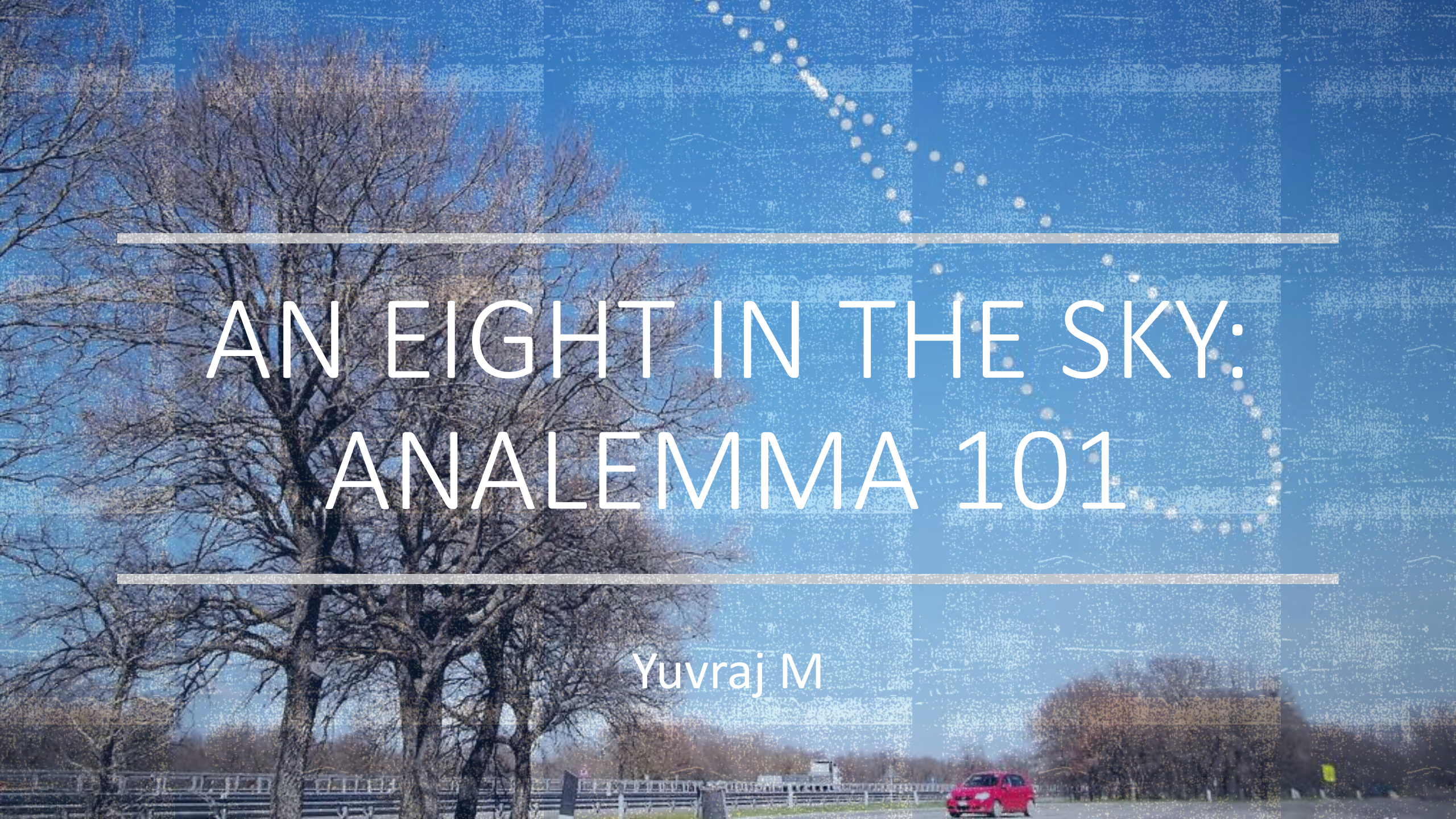
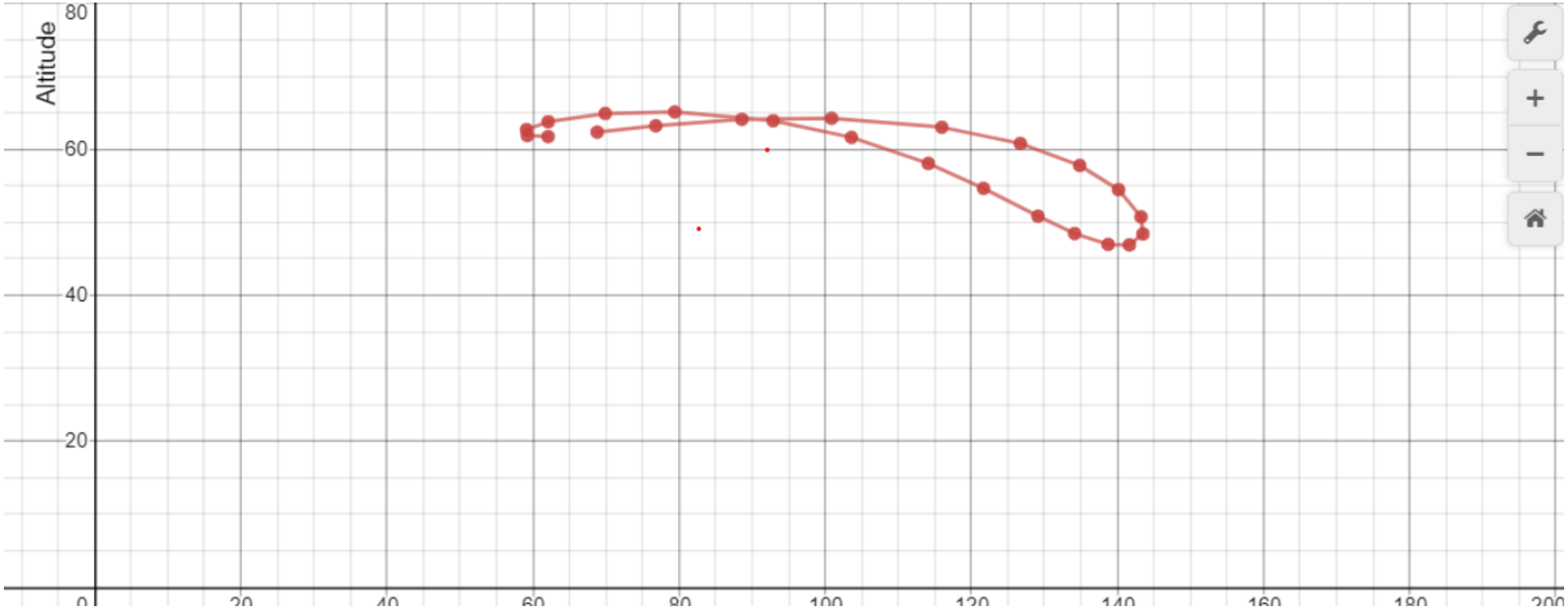


AN EIGHT IN THE SKY: ANALEMMA 101

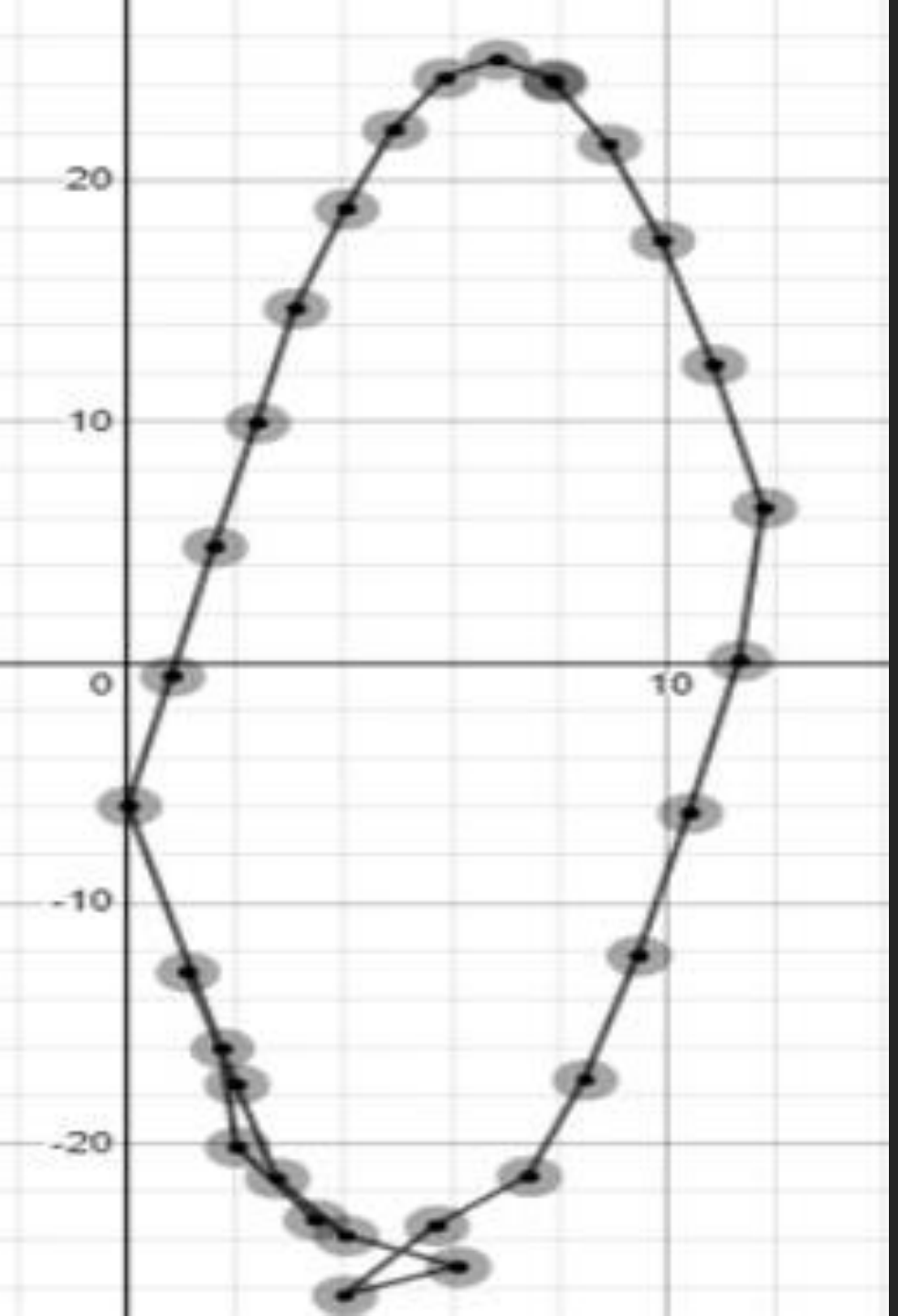
Yuvraj M

Analemma

A figure of eight transit that the Sun seems to undergo across the sky, when seen at a particular period of the day for a course of a year.



Analemma of Sun

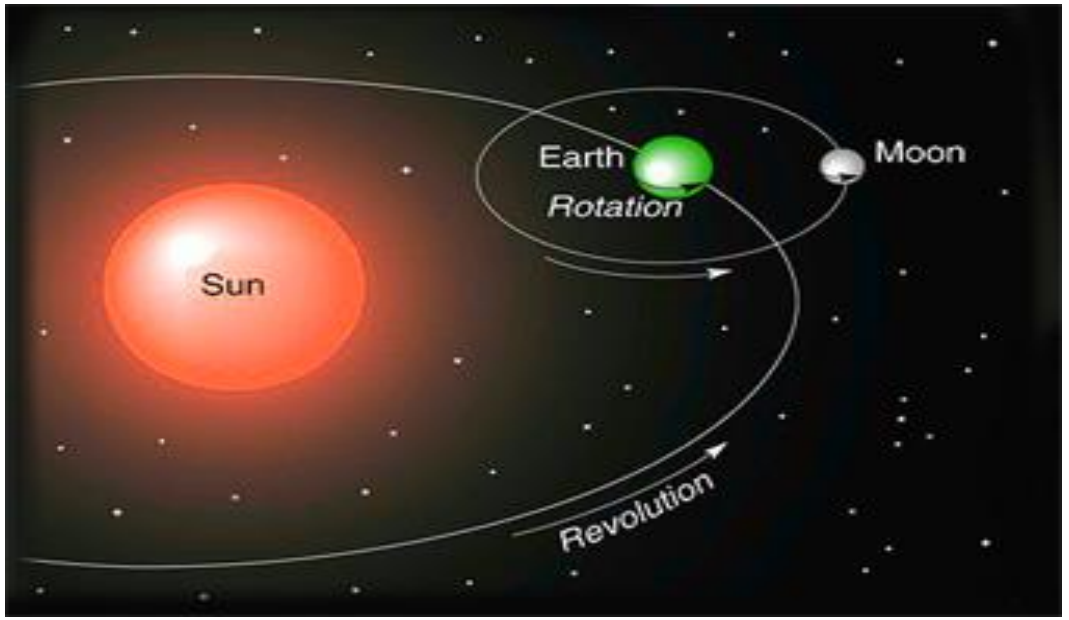


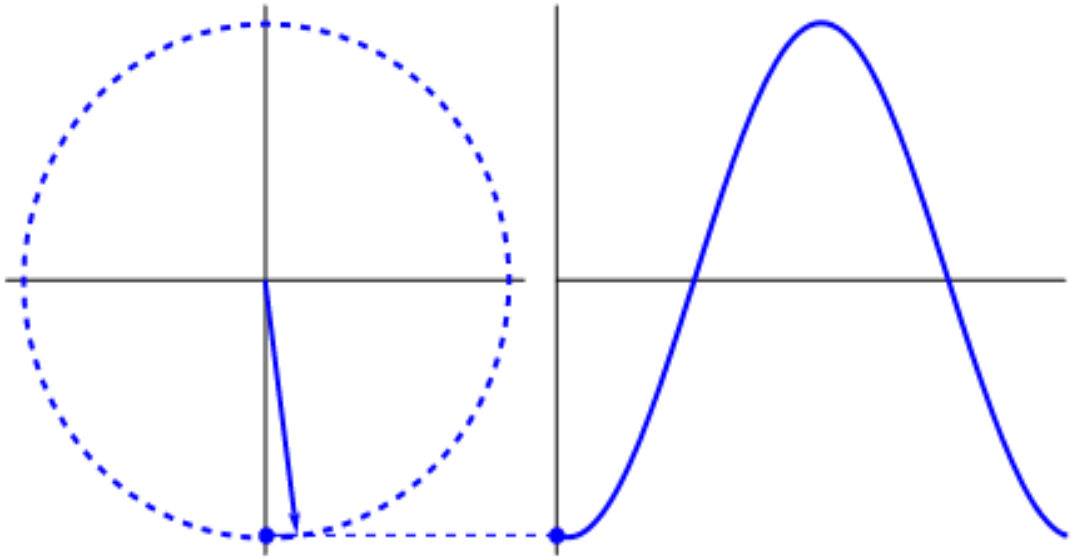
Analemma of Moon

What causes this Analemma?

- Rotation of Earth and Revolution of Earth around the Sun

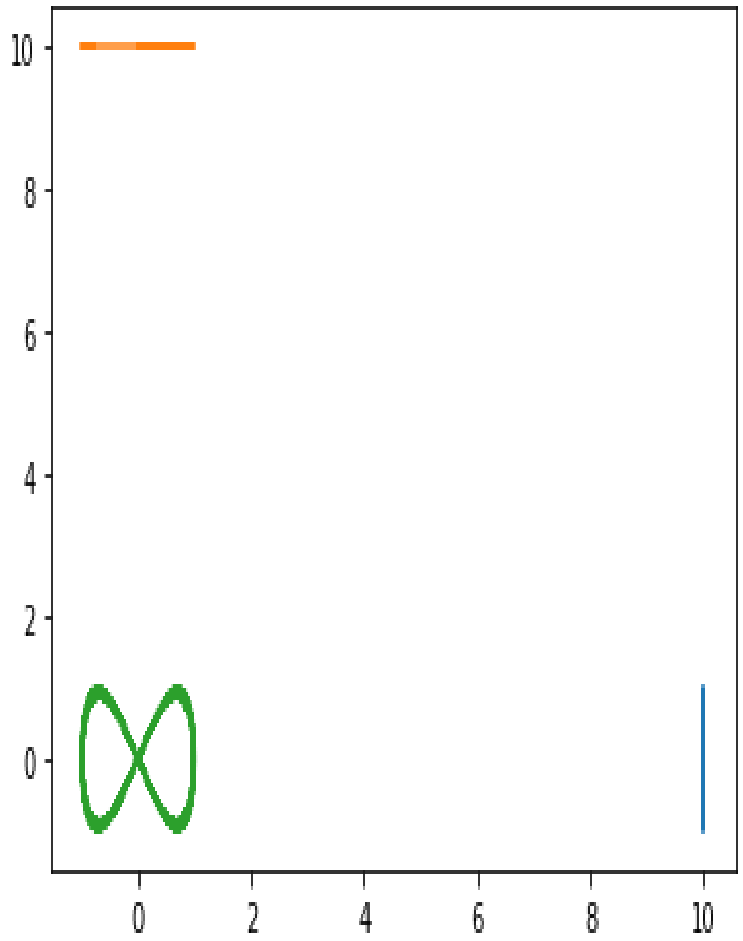
- But, when simplified further, it is caused by the influence of two harmonic oscillators



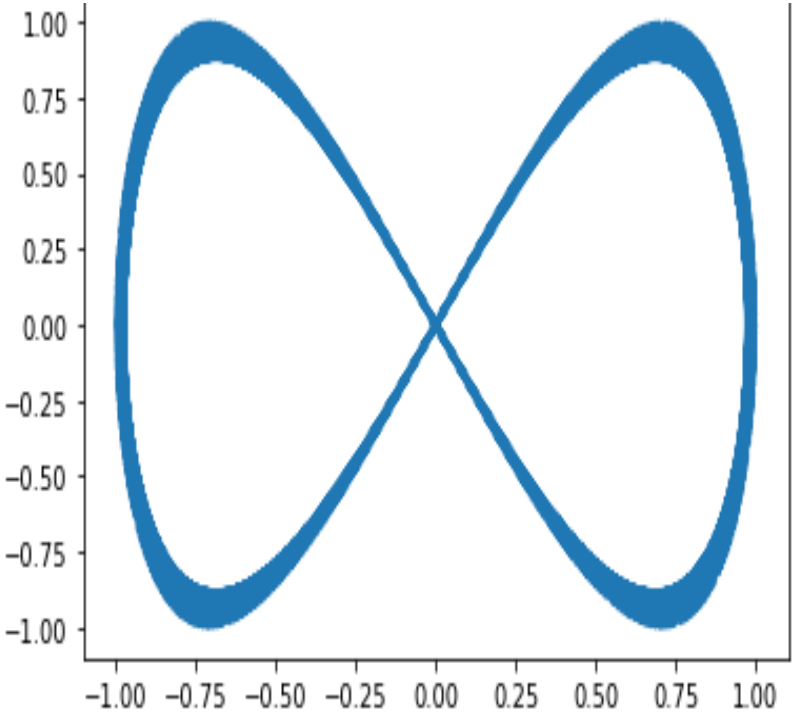


```python
import matplotlib.pyplot as plt
import math
dummy_list = []
dummy_list2 =[]
dummy_list3 =[]
dummy_list4 =[]
a = 10
b = 10
for y in range (0,361):
    dummy_list.append(math.sin(y))
    dummy_list3.append(a)
for x in range (0,361):
    dummy_list2.append(math.sin(x/2))
    dummy_list4.append(b)
plt.plot(dummy_list3, dummy_list)
plt.plot(dummy_list2, dummy_list4)
plt.plot(dummy_list2, dummy_list)
```

```
In [1]: runfile('C:/Users/Murali/.spyder-py3/temp.py', wdir='C:
py3')
```



```
import matplotlib.pyplot as plt
import math
dummy_list = []
dummy_list2 =[]
for y in range (0,361):
    dummy_list.append(math.sin(y))
for x in range (0,361):
    dummy_list2.append(math.cos(x/2))
plt.plot(dummy_list2, dummy_list)
```



So, it is possible with other planets, like Jupiter, Mars when seen from Earth?

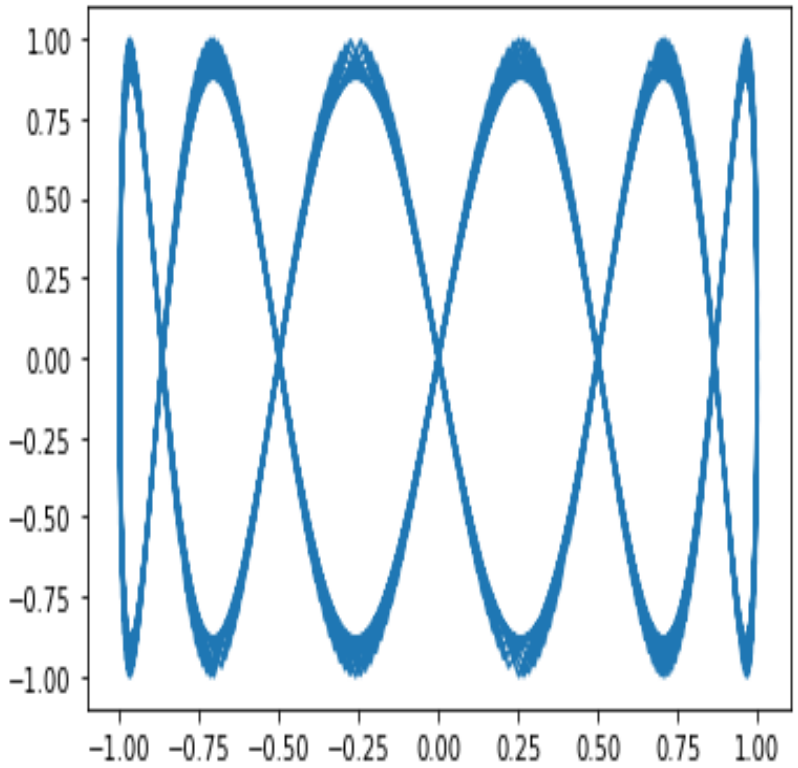

Well yes, but actually no

The SHMs should be just right to result an Analemma

The Sun and our natural satellite just rightly fulfill the criterions to trace the Analemma Path, like the Goldilocks' Porridge

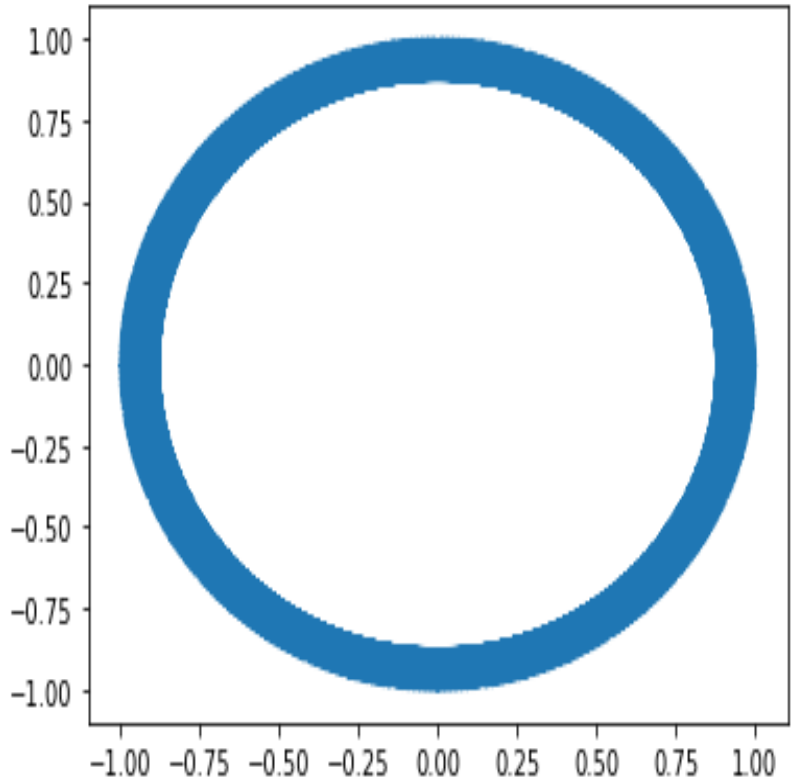
Let's play with the data, to understand what I mean

```python
import matplotlib.pyplot as plt
import math
dummy_list = []
dummy_list2 =[]
for y in range (0,361):
    dummy_list.append(math.sin(y))
for x in range (0,361):
    dummy_list2.append(math.cos(x/6))
plt.plot(dummy_list2, dummy_list)
```

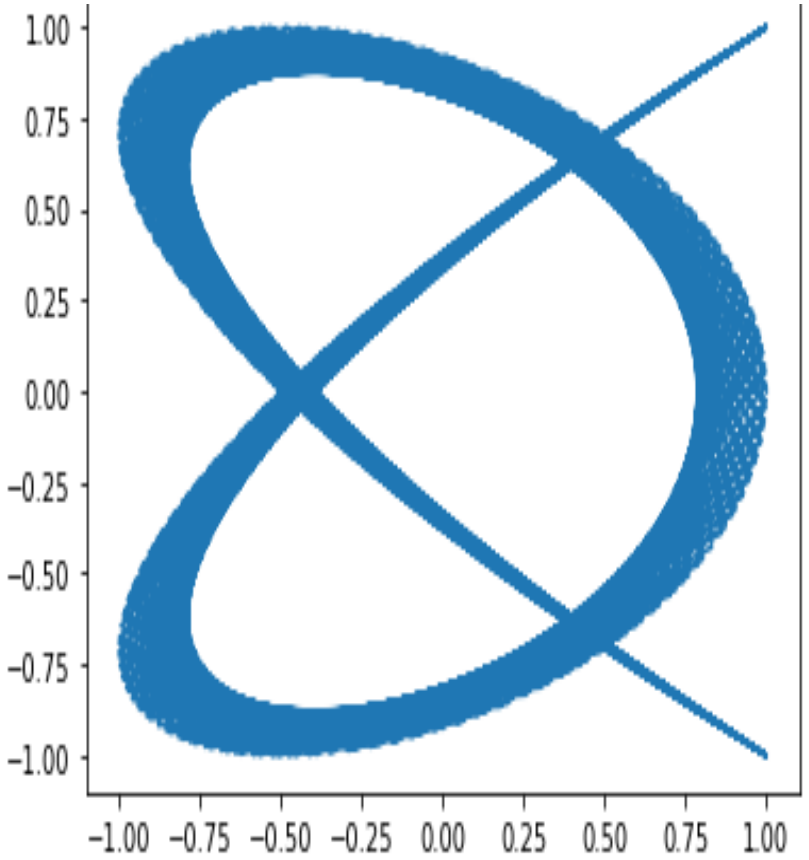


```
clc()

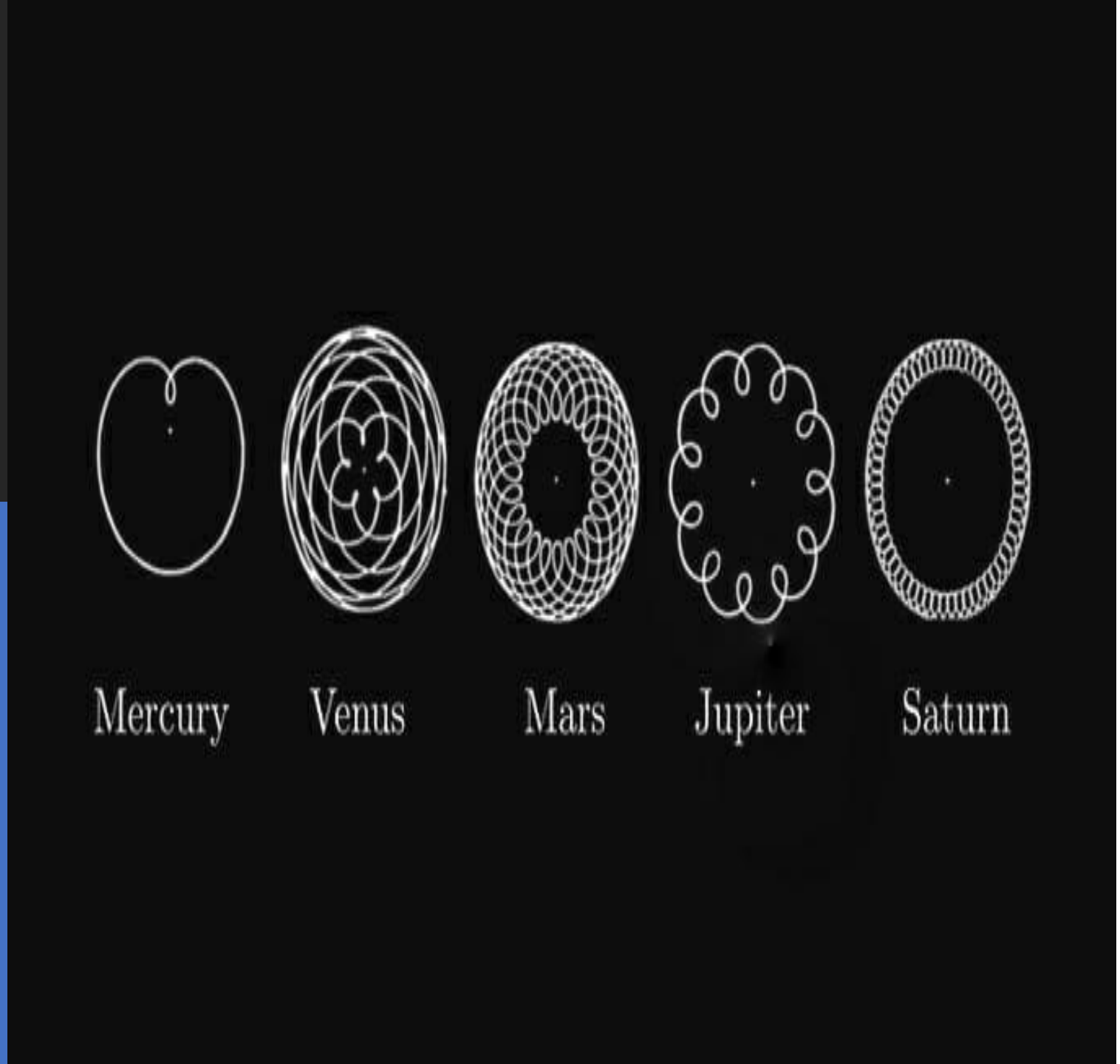

import matplotlib.pyplot as plt
import math
dummy_list = []
dummy_list2 =[]
for y in range (0,361):
    dummy_list.append(math.sin(y))
for x in range (0,361):
    dummy_list2.append(math.cos(x))
plt.plot(dummy_list2, dummy_list)
```



```
import matplotlib.pyplot as plt
import math
dummy_list = []
dummy_list2 =[]
for y in range (0,361):
    dummy_list.append(math.sin(y))
for x in range (0,361):
    dummy_list2.append(math.cos(x/0.75))
plt.plot(dummy_list2, dummy_list)
```



Also, other celestial bodies retrograde for a small period in their transit when seen from Earth, which doesn't contribute to the Analemma Formation



These Observations had a major impact in our Tradition in the forms of Kolam a.k.a Rangoli.

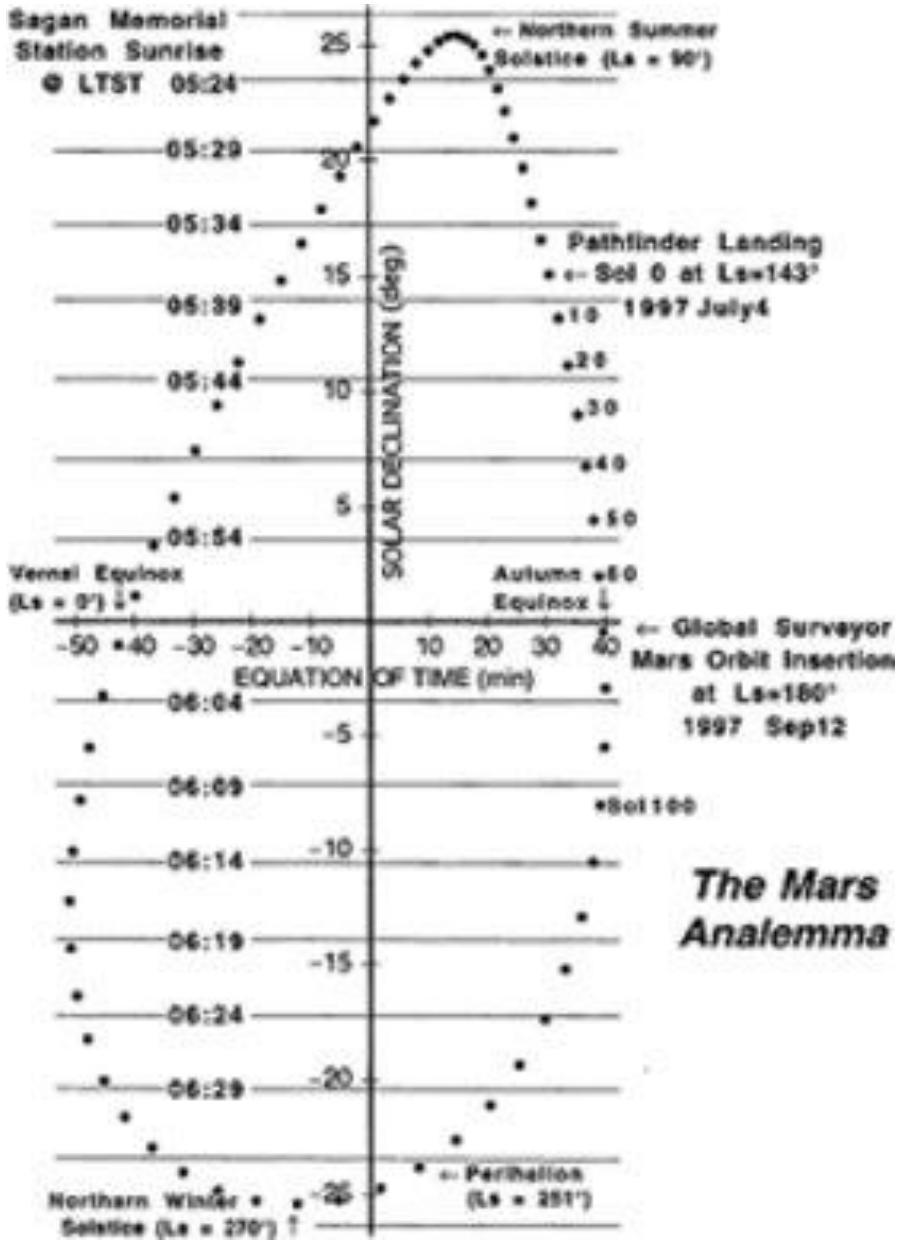
The elders believed that mimicking those transits of Celestial Bodies in the sky, shall shower them, their blessings

Fine, then is Analemma of Sun seen from the other planets?


Well yes, but actually no

Analemma of Sun from Mars

(Tear-Dropped Shaped)



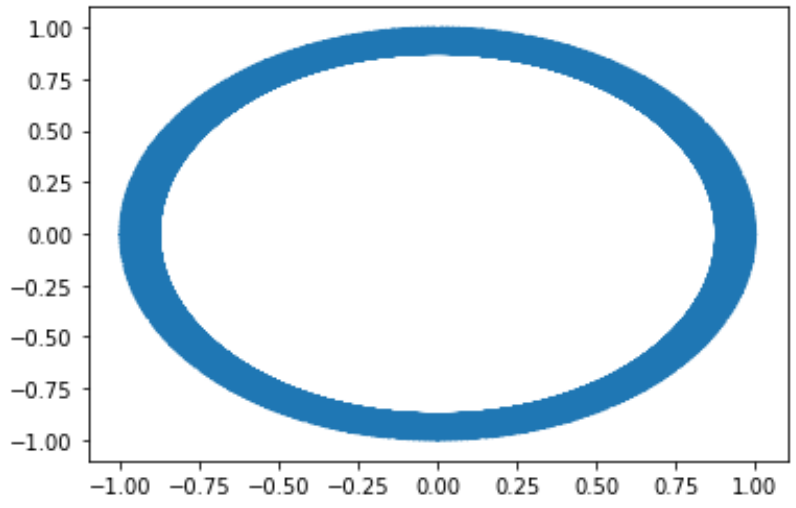
So, what went south here?

Well, the analemma of the Sun seen from the Mars, is not in the figure of Eight due to a combination of many factors

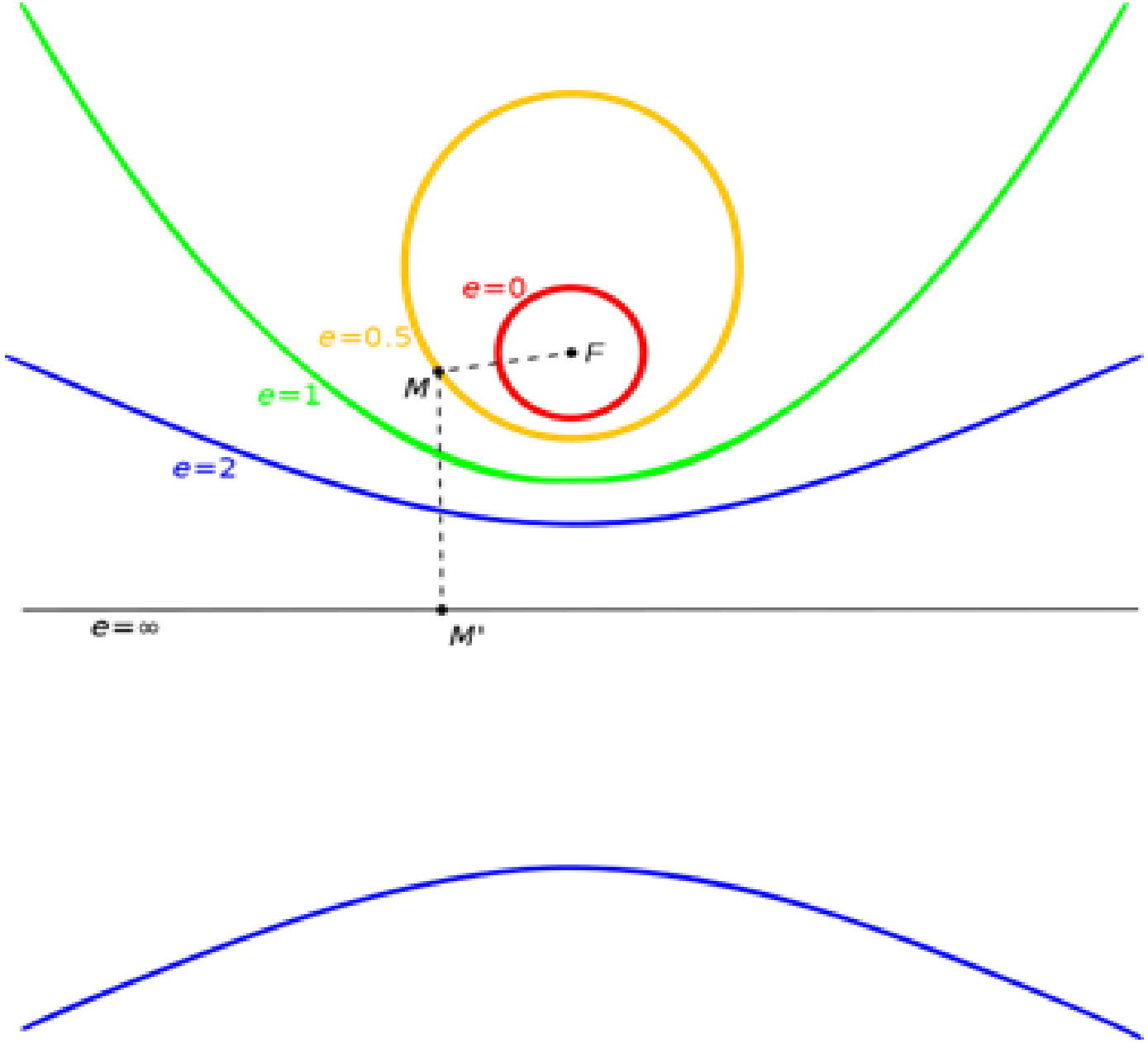
- The Ratio of the frequency of the SHMs governing the position of the Sun in the Martian Sky is nearly equal to one. This explains the seemly circular nature of the Sun's Transit in the Martian Sky, within a Martian Year
- Apart from the ratios of the SHMs, the Eccentricity of the orbit of the planet around the Sun, and the Tilt of Axis of Rotation of the Planet from which the observation is done also affects the Analemma Transit of the Sun or other Celestial body. The elongated nature of the Analemma is attributed to the Eccentricity of the orbit.
- Higher the eccentricity of the orbit is, more elongated the Lobs of the Analemma appear. Lesser the Tilt of the Axis of Rotation is, more perfect the Lobs of Analemma will be

```
clc()


import matplotlib.pyplot as plt
import math
dummy_list = []
dummy_list2 =[]
for y in range (0,361):
    dummy_list.append(math.sin(y))
for x in range (0,361):
    dummy_list2.append(math.cos(x))
plt.plot(dummy_list2, dummy_list)
```



Eccentricity



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import matplotlib.pyplot as plt
import math
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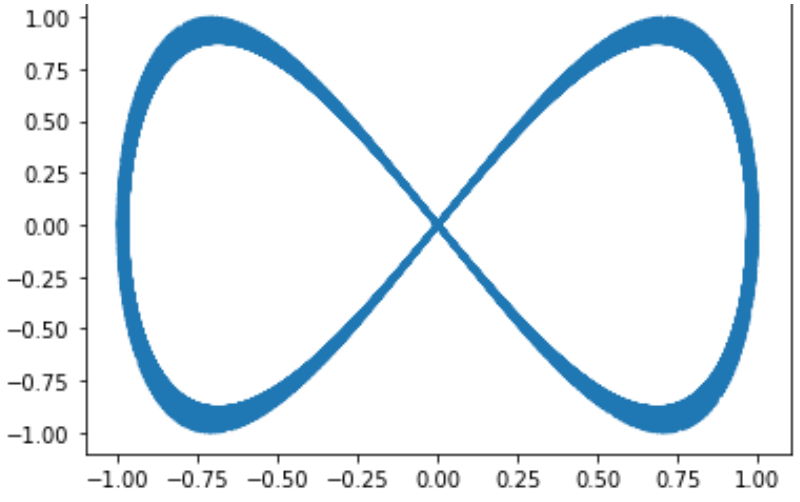
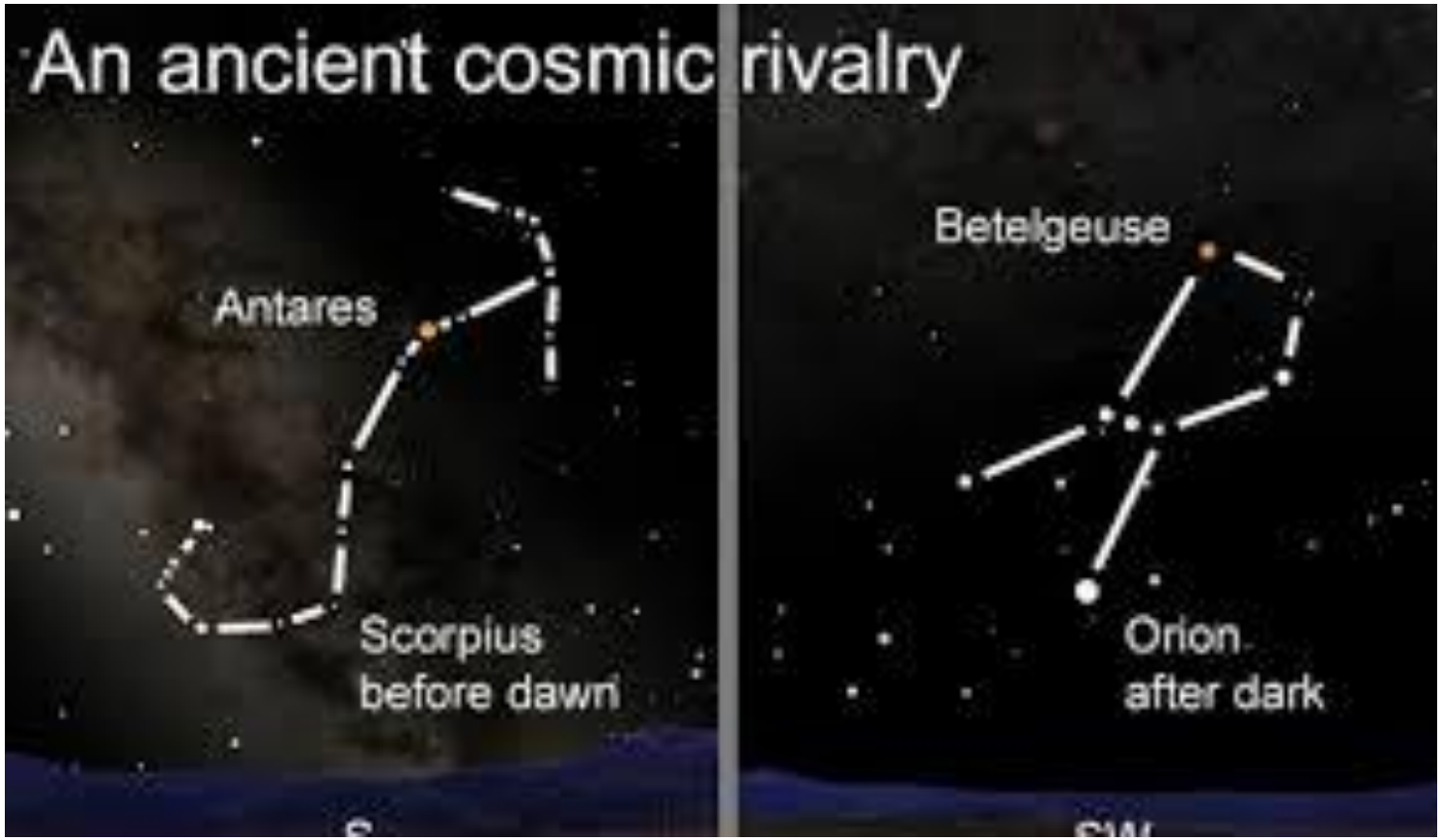
dummy_list2 =[]
for y in range (0,361):
    dummy_list.append(math.sin(y))
for x in range (0,361):
    dummy_list2.append(math.cos(x/2))
plt.plot(dummy_list2, dummy_list)
```



Inferences that can be made from Analemma

The Analemma is also used to measure time anomalies, identify the which part of the Year, a period of Time is, which was essential in those days to sustain a livelihood

- Observation of these Celestial Bodies helped in the conclusion of the Helio-Centric Model of the Solar System in India by 5th Century, way before it's acceptance in the Western Civilizations
- E.g.: Aryabhatiya by Aryabhata: 5th Century



An Interesting Myth: Orion and Scorpius

- Orion and Scorpius are 180 degree apart in the Celestial Sky, i.e. opposite of each and other
- So, when Orion rises in the sky at East, the Scorpio sets at West and vice versa

- If you rotate 360 degree now, you complete a full rotation and come back to stare at your PC, similarily if things are normal, then one should look at the same constellations at night. But that is not the case.

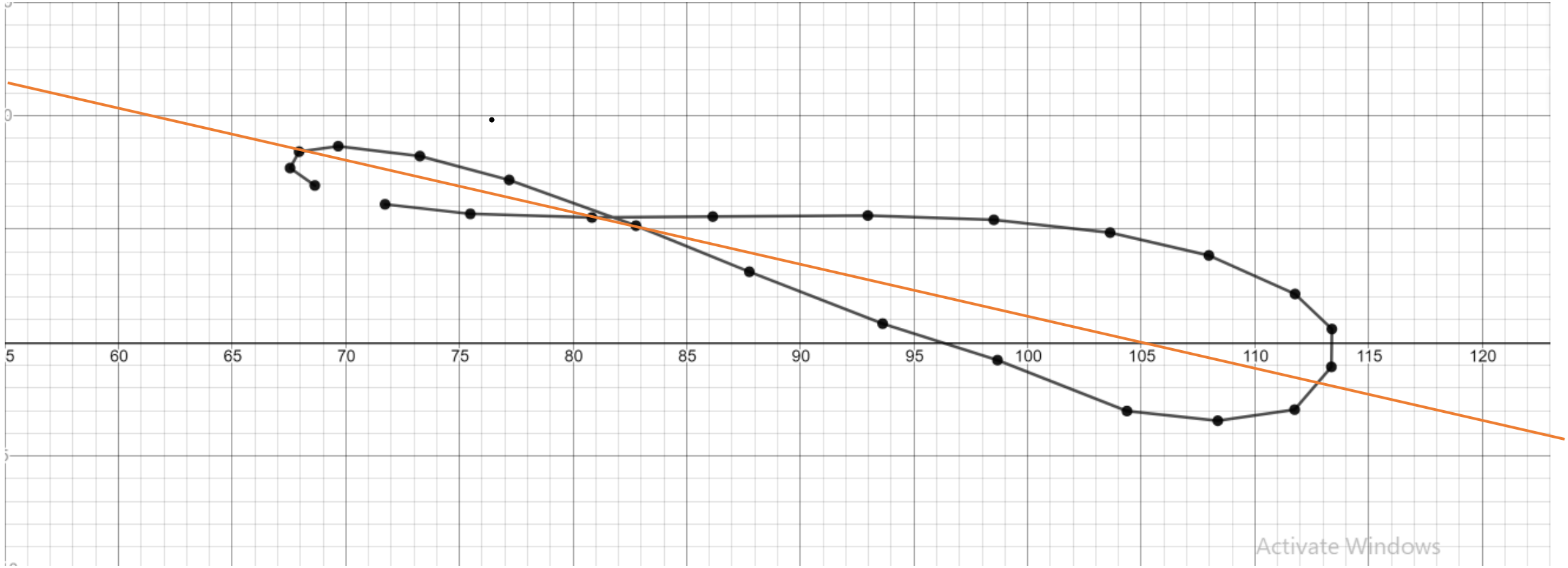
- So, if one asks what causes this, then the Answer would be Rotation and Revolution of the Earth

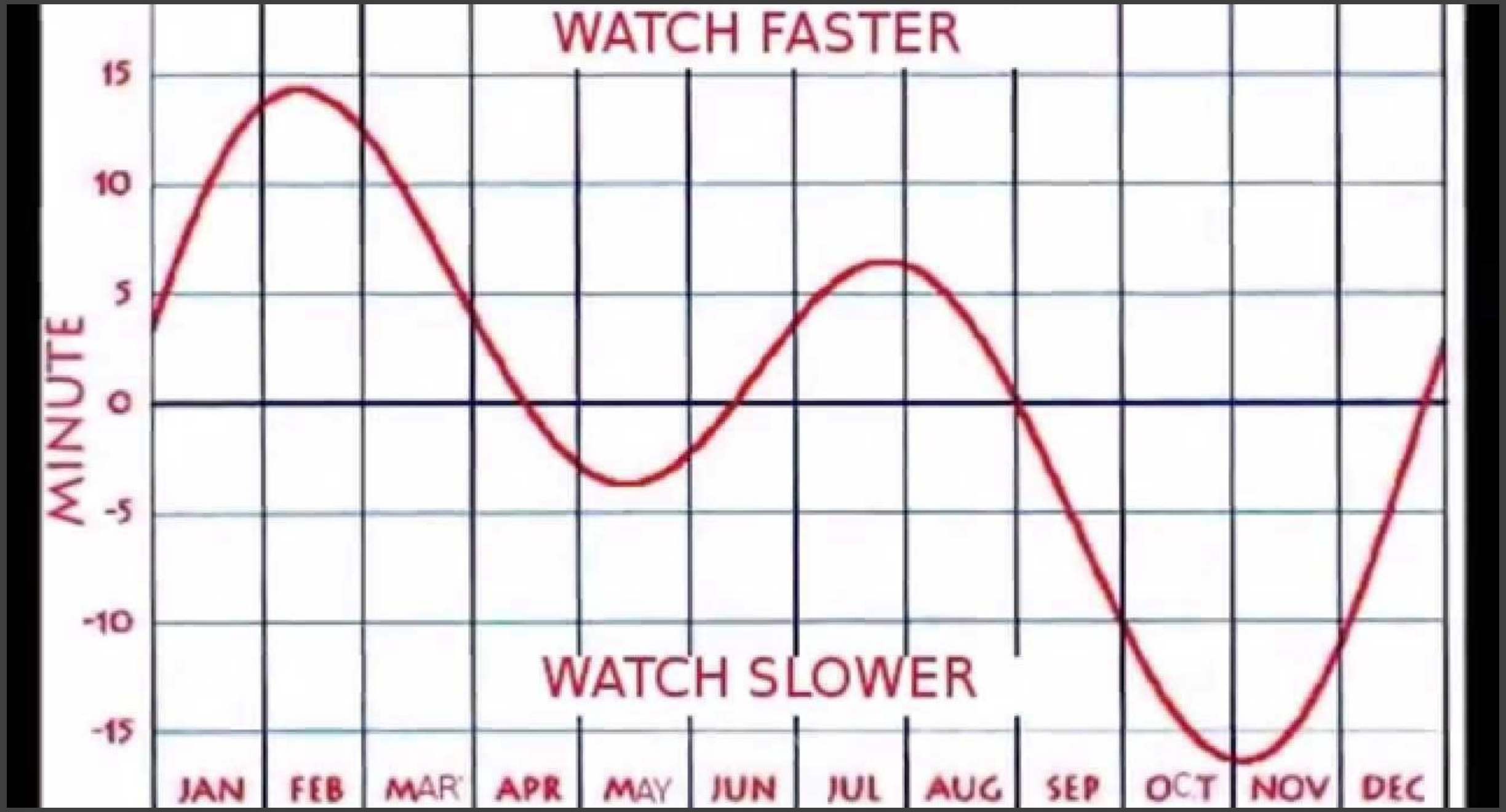
But, what is lesser known is the effect this phenomenon causes: This causes discrepancy between the apparent time and the actual time calculated with the Sun's Transit

Discrepancy in the Time:

- Apparent Time is the duration taken by the Earth to complete its rotation. It is roughly estimated to be 24 hours (The average time that we are used to by the Clocks)
- But due to Rotation and Revolution of Earth, the time calculated with the diurnal motion of the Sun differs with the apparent time
- The Analemma can be used to study these time differences, because it is caused by the same effects that causes these Time Discrepancy
- One interesting thing to note is that the Average Time Deviation between the Apparent Time and the Time measured by the Diurnal Motion of Sun in nearly zero.
- This means that there period in Year where the Time calculated by the Diurnal Motion of the Sun is ahead (faster) than the Apparent Time and there are similarily period of a year where the Diurnal Time is behind (slow) than the Apparent Time

Analemma of the Sun at Six AM:




WATCH FASTER
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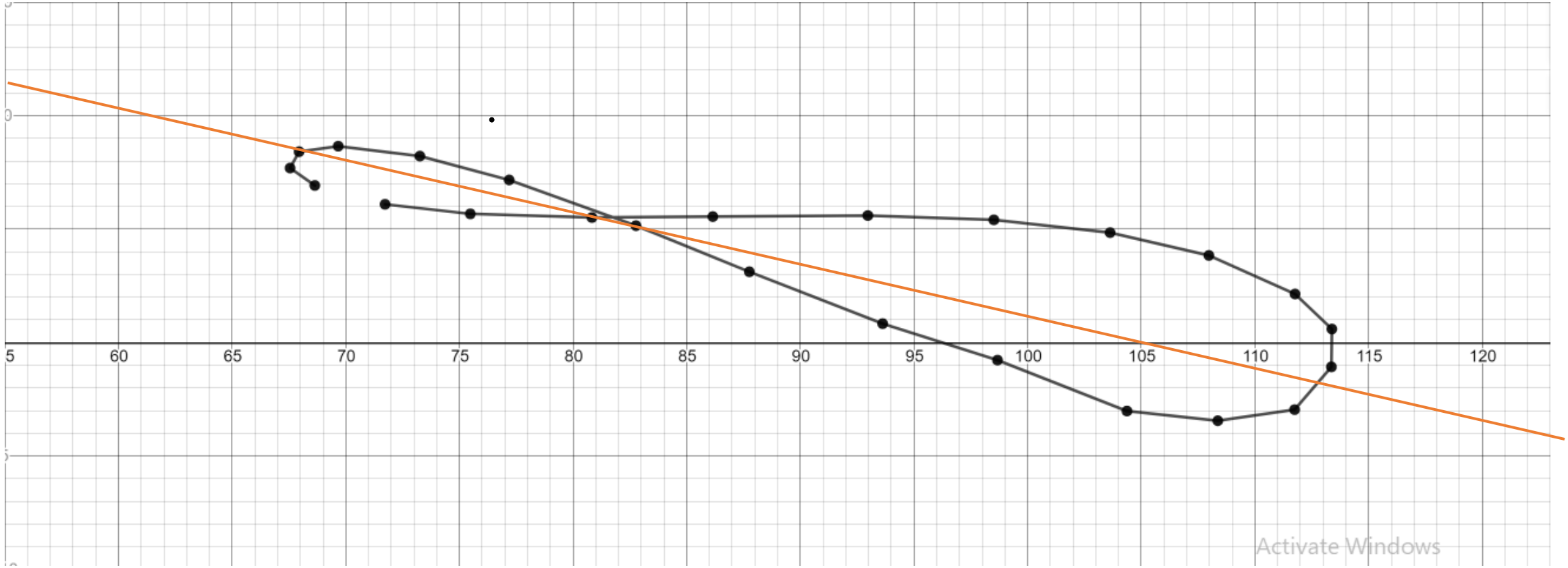
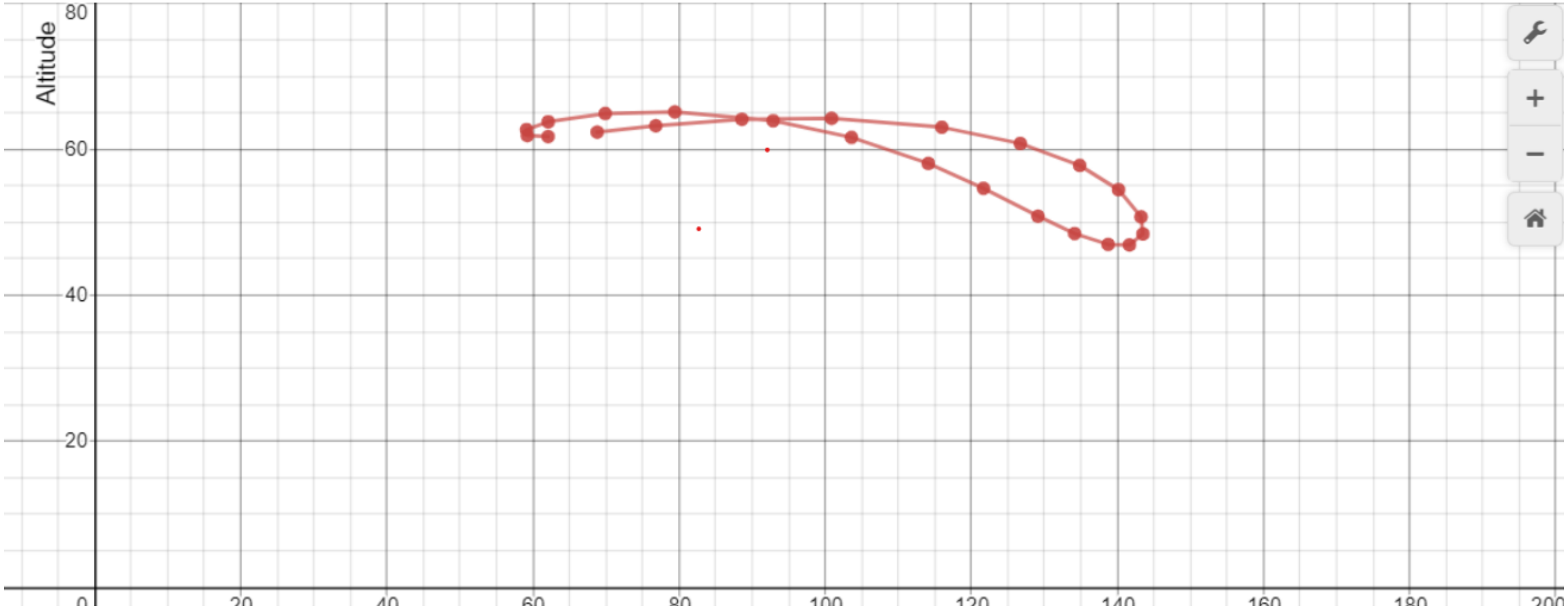
Analemma of the Sun at Six AM:



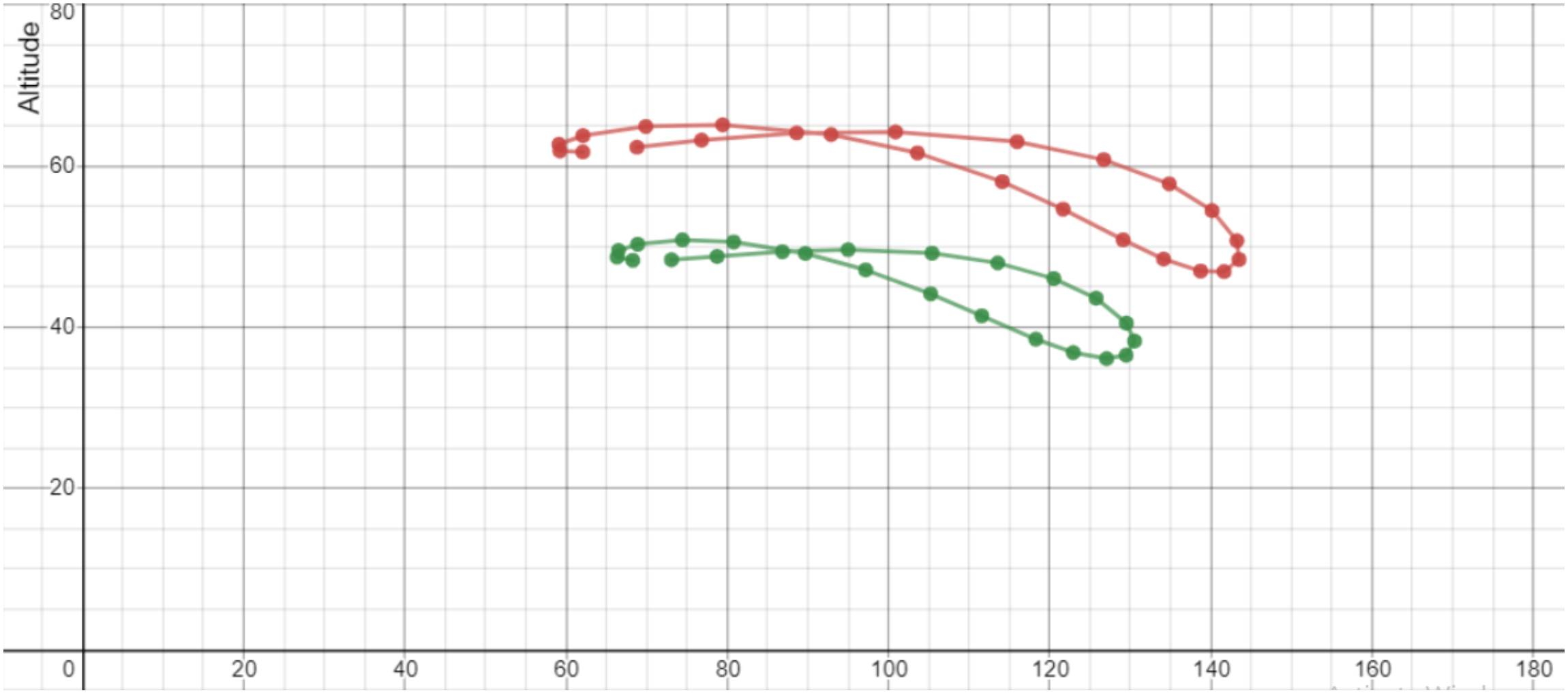
Analemma from Real – Time Data

Just few things to add on about the Data collected

- The Data collected were the Azimuthal-Altitude of the Sun
- They are expressed in Degree-Arc Minute-Arc Second
- So, to fit into the cartesian co-ordinates, the data is converted and expressed as a decimal value
- Also, if a data point is beyond 180, then it is subtract from 360, and the new data point is used in the plotting. Why? To accommodate the 360-nature of the actual data points



Analemma of Sun, at Two P.M


Altitude
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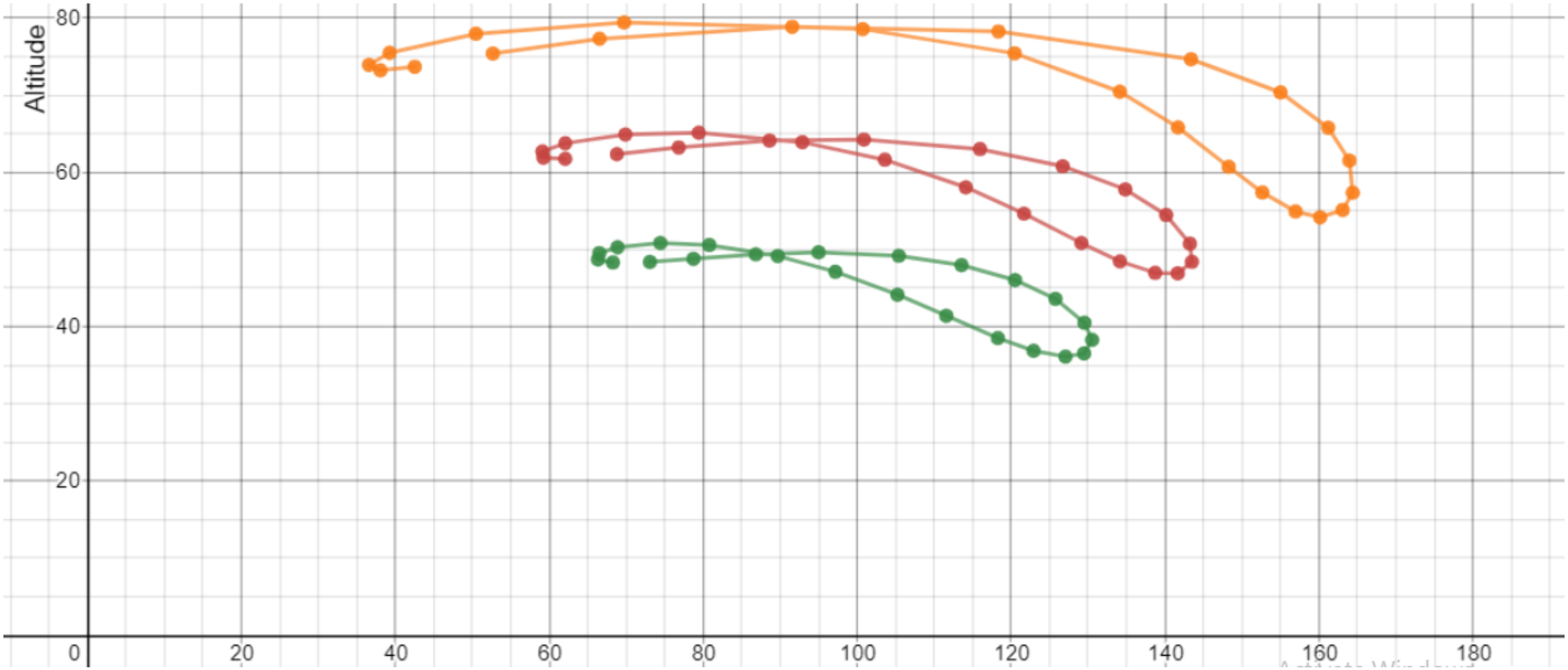
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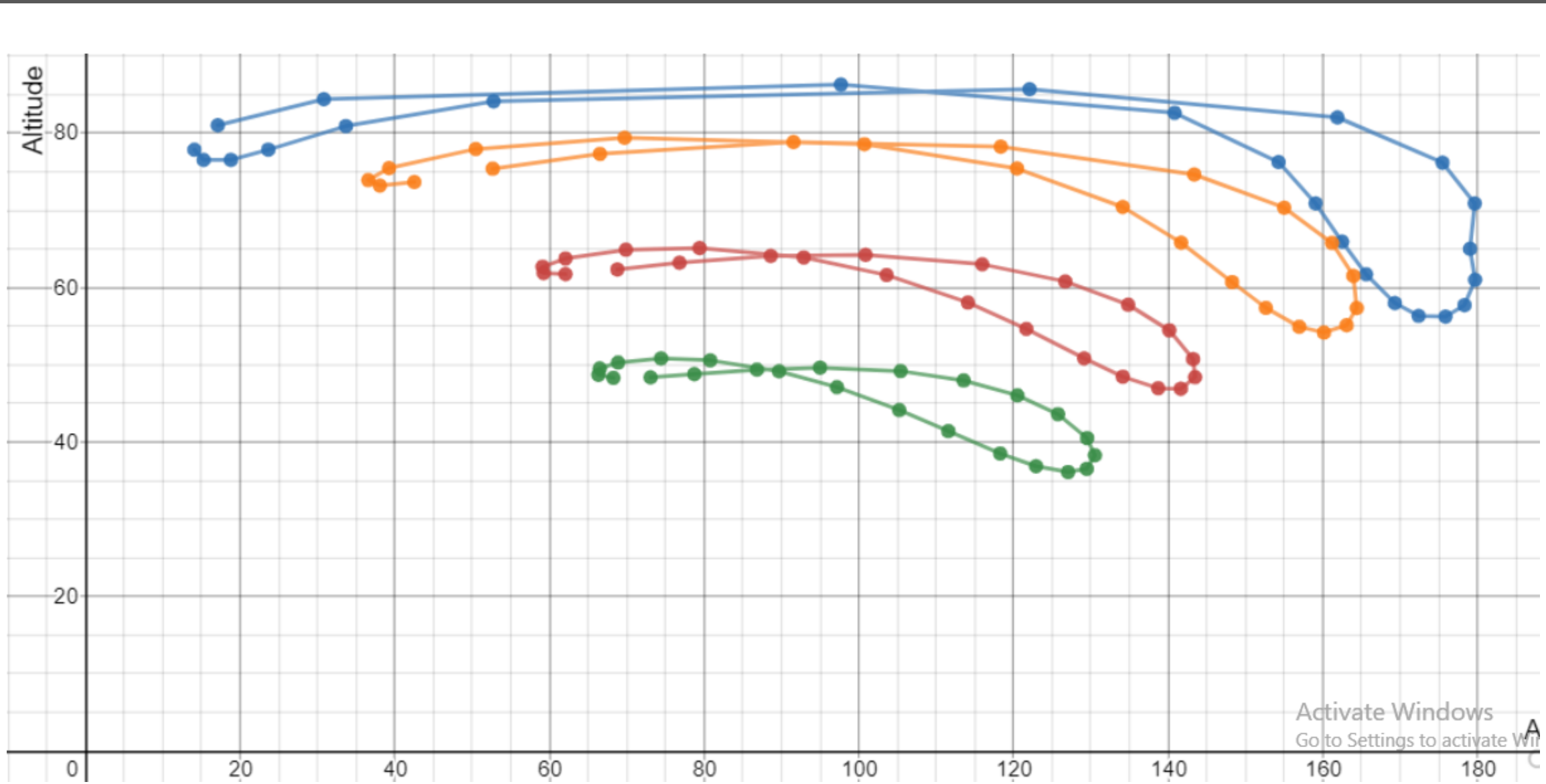
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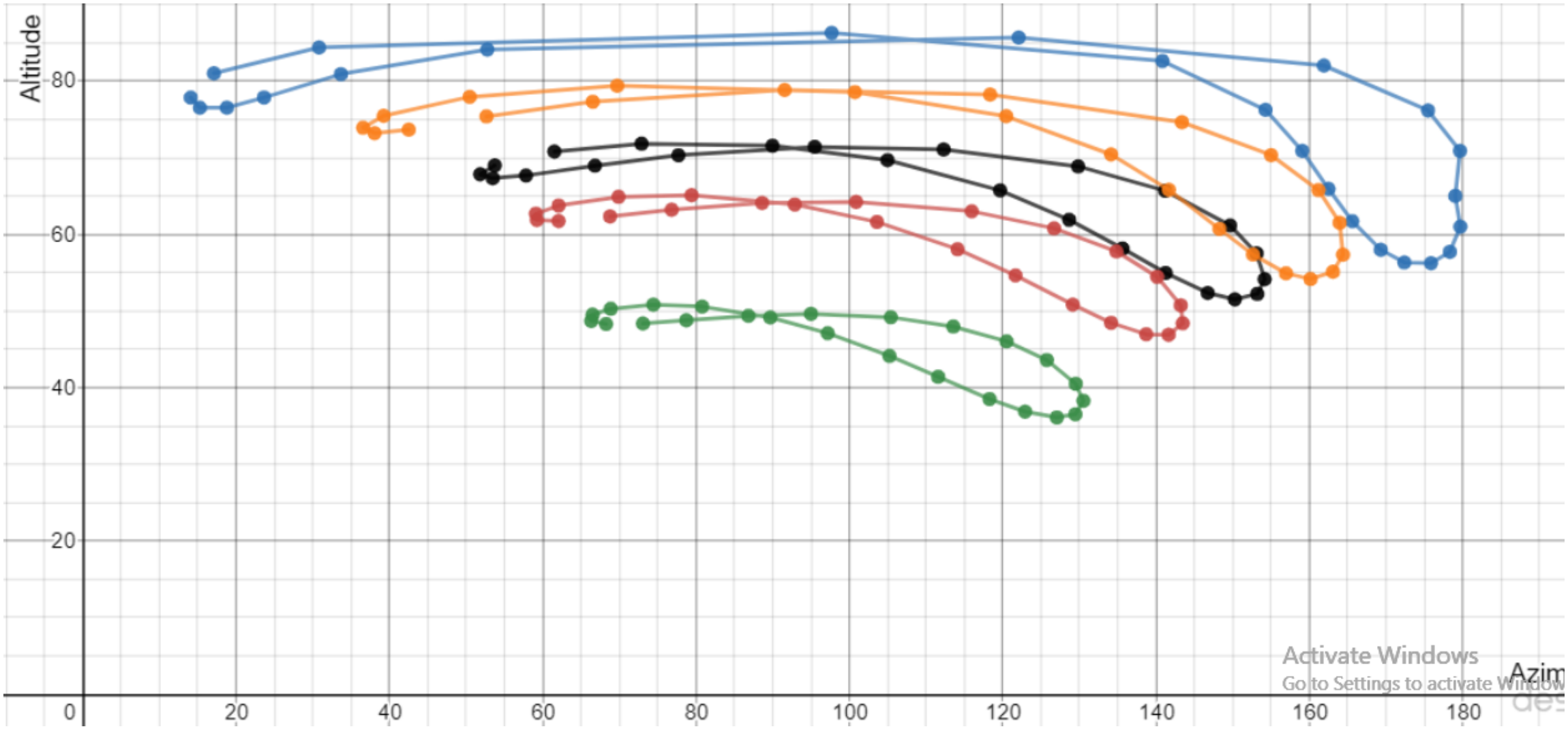
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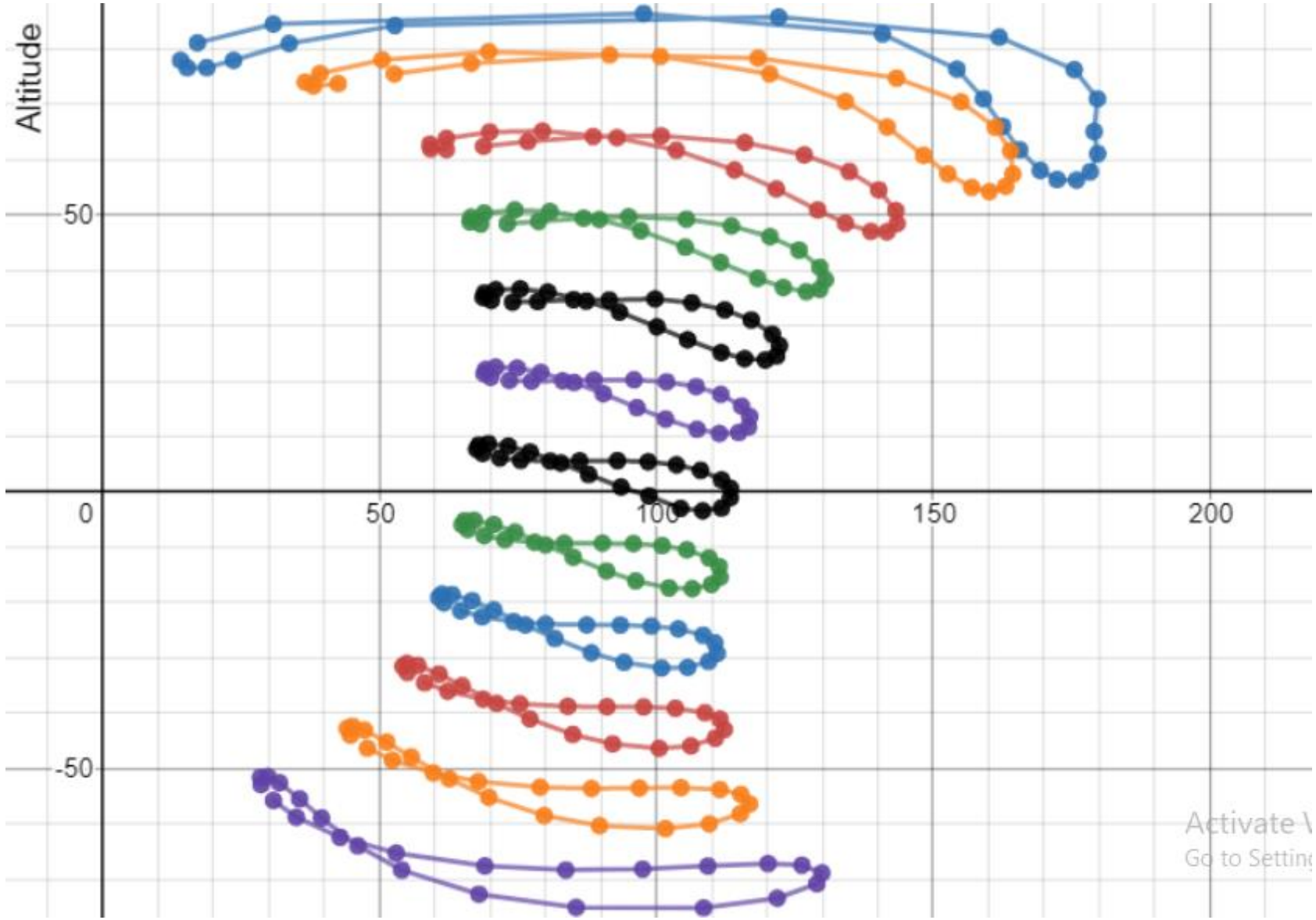
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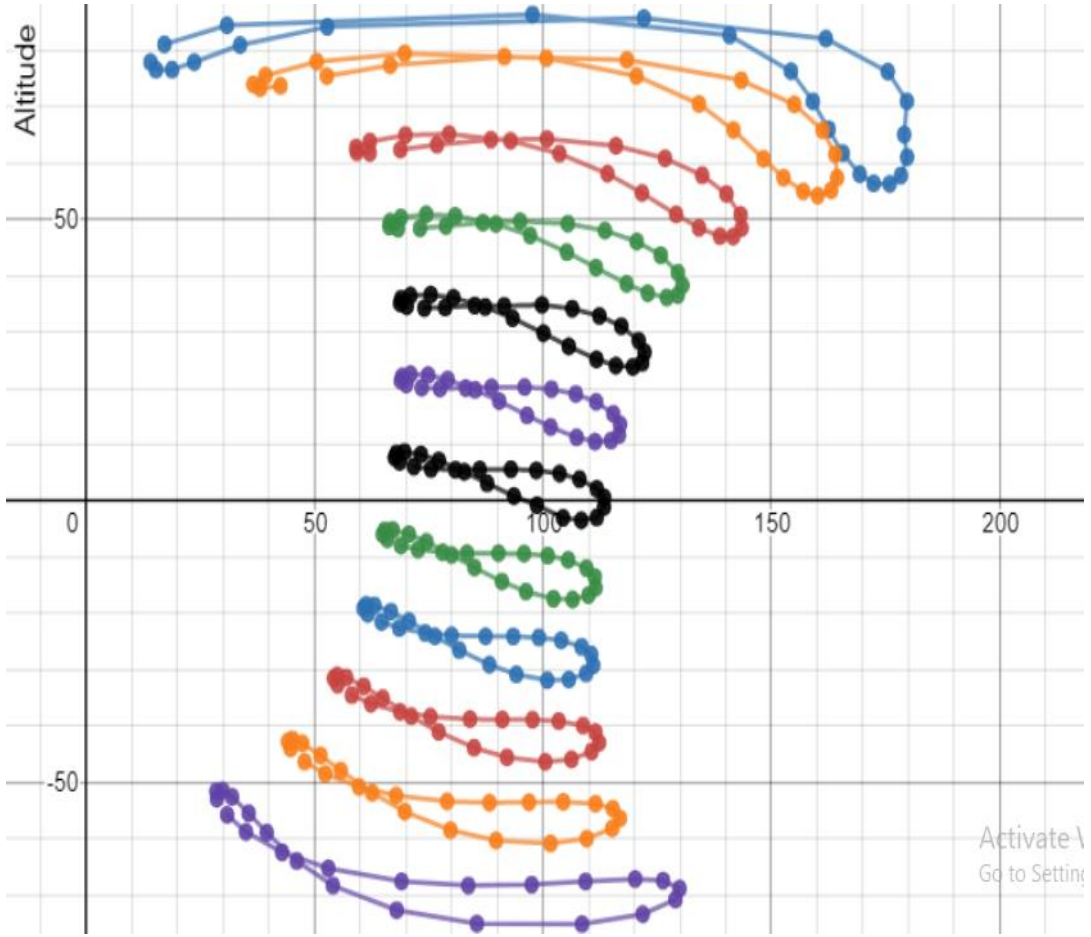
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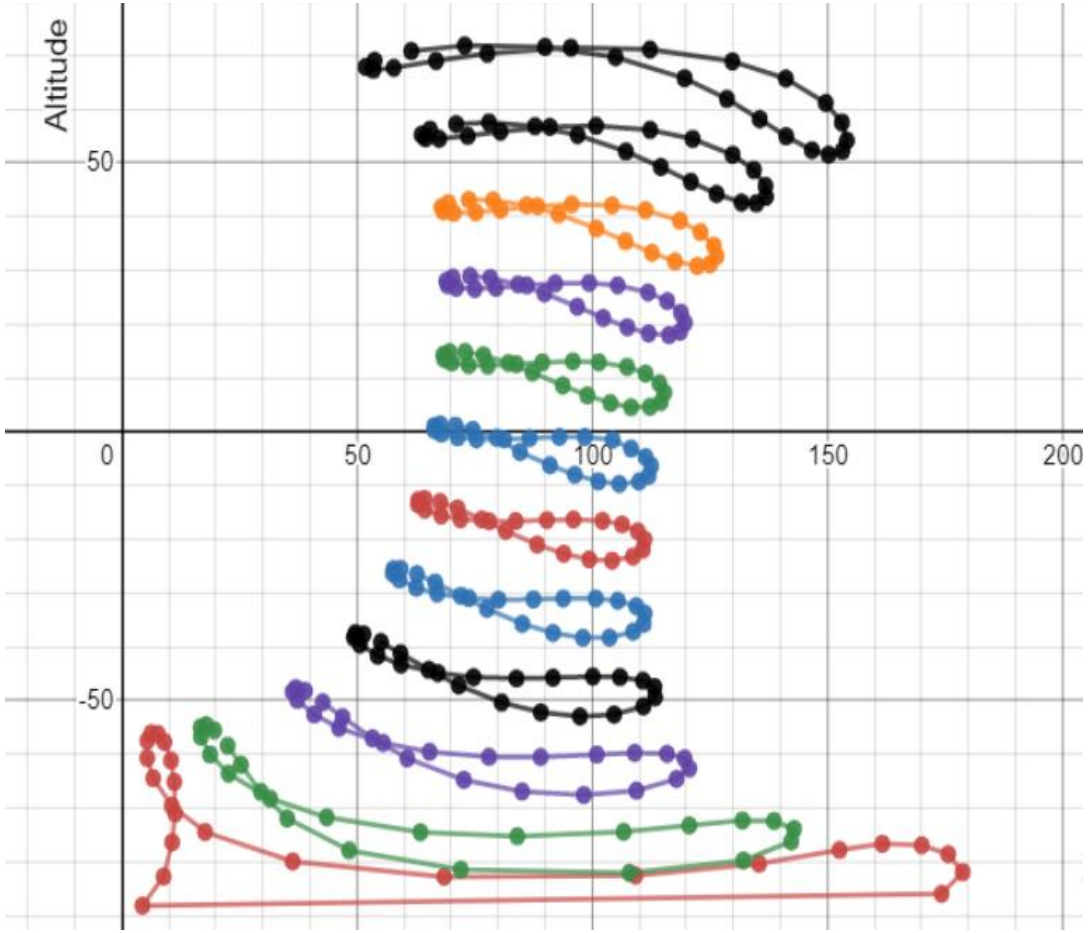
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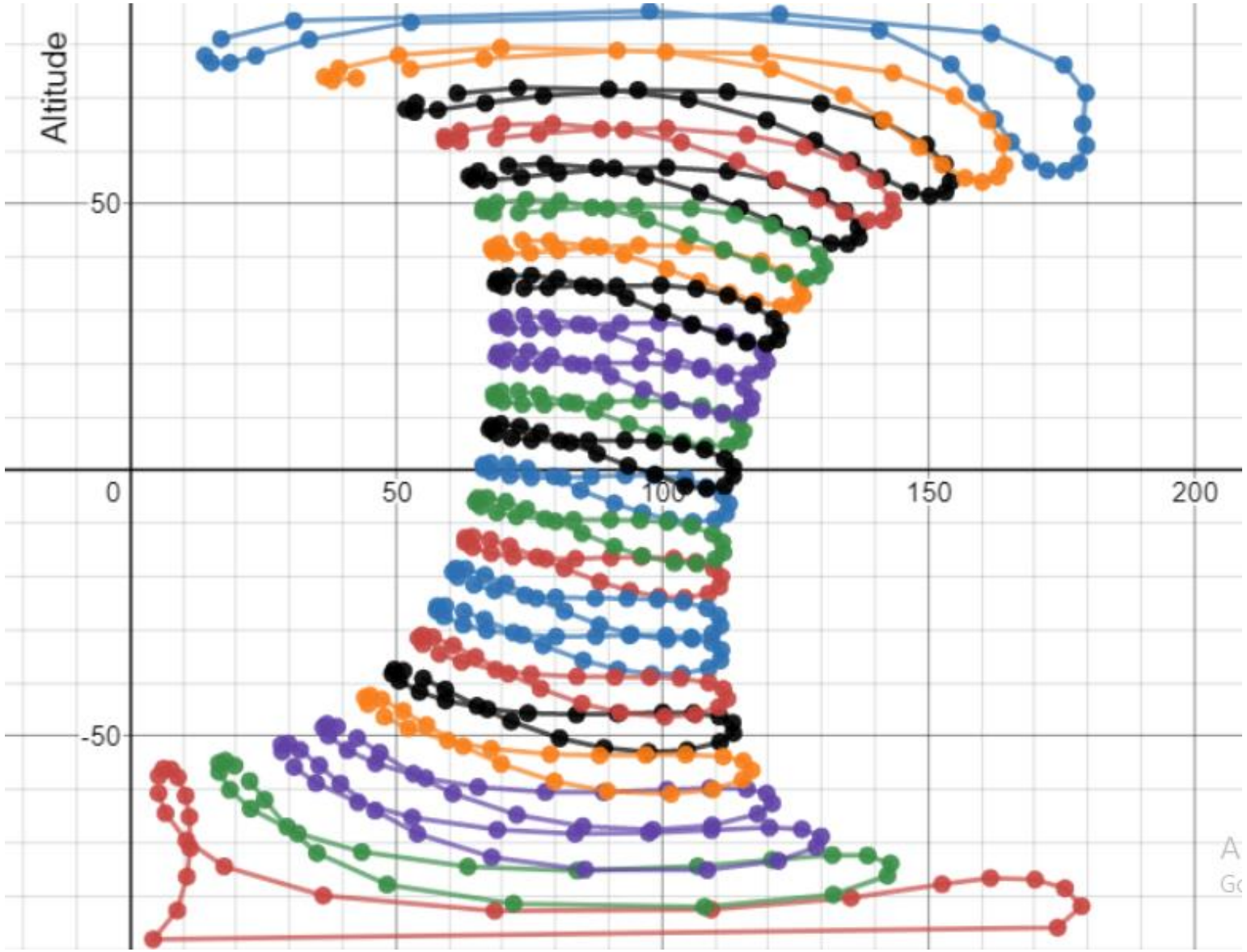
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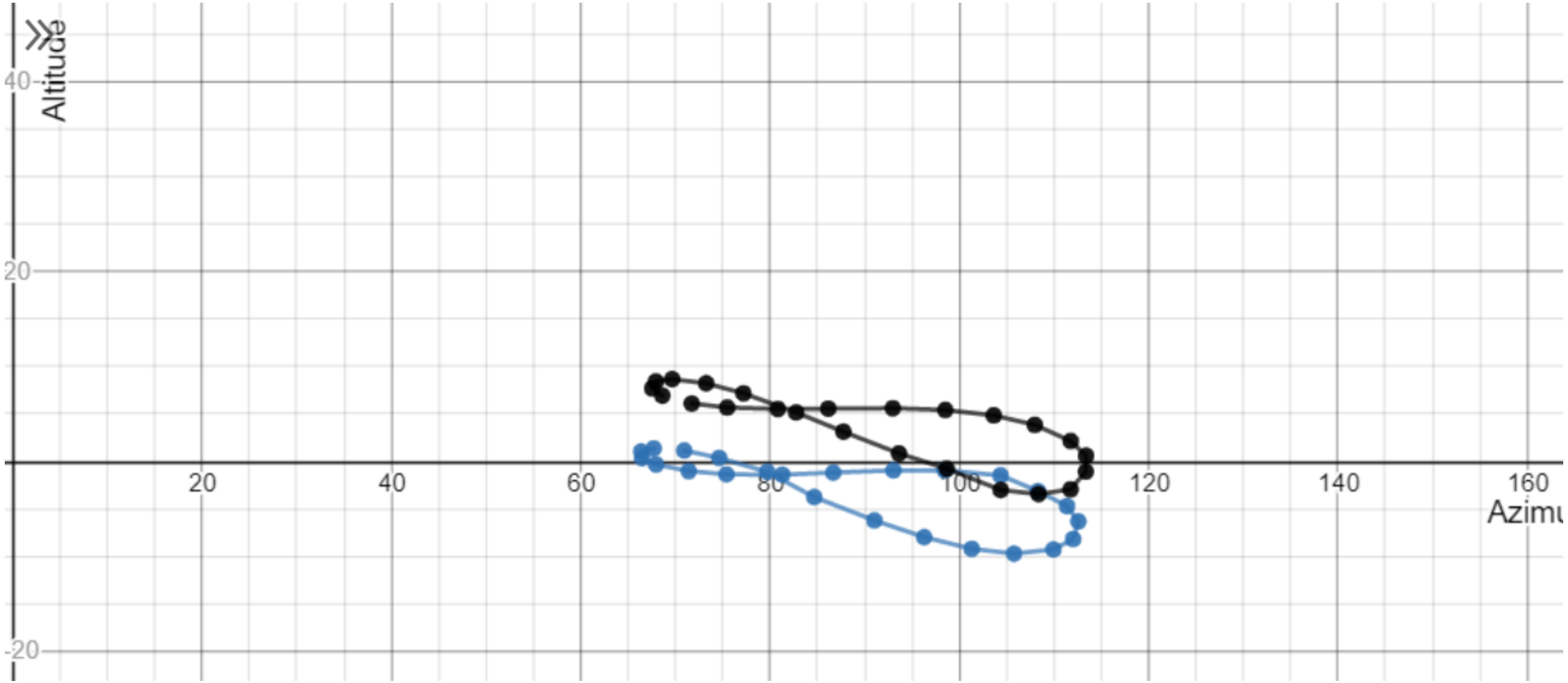
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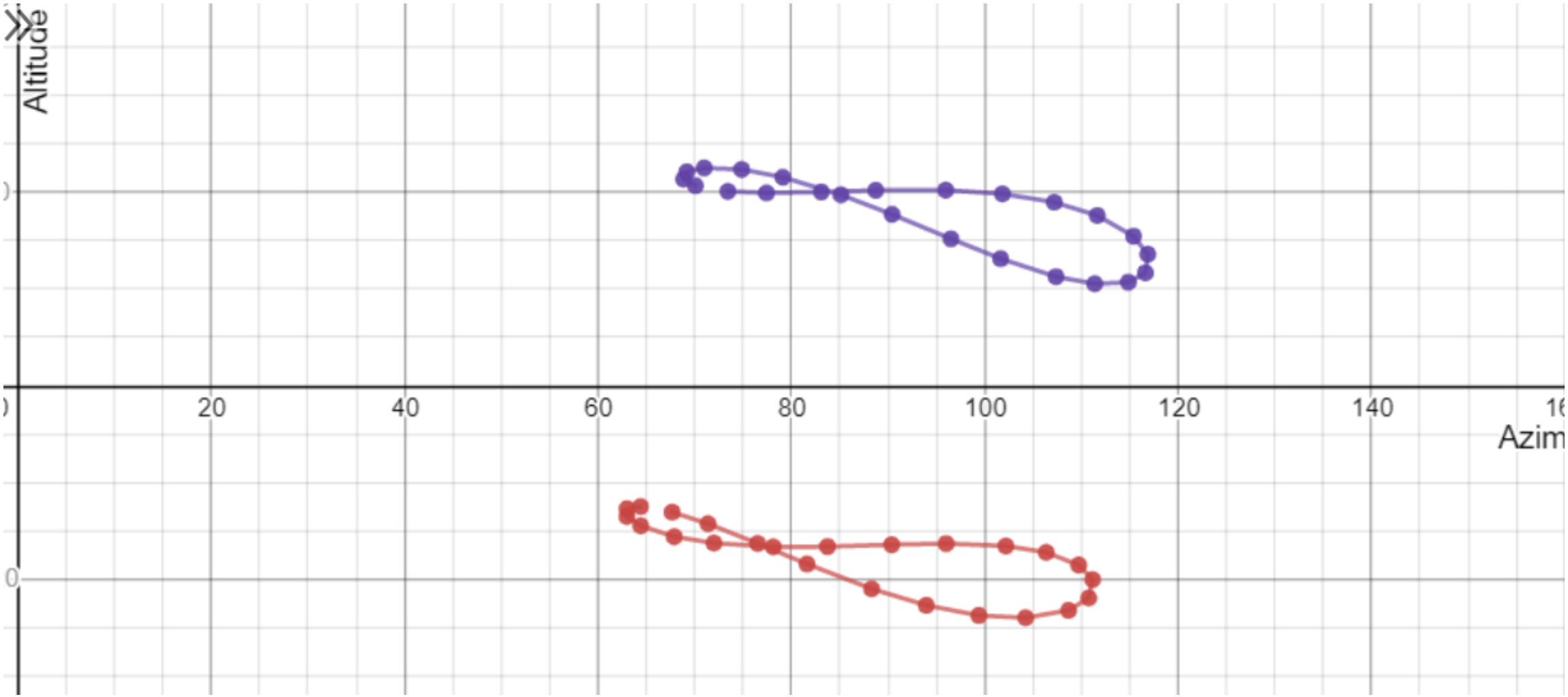
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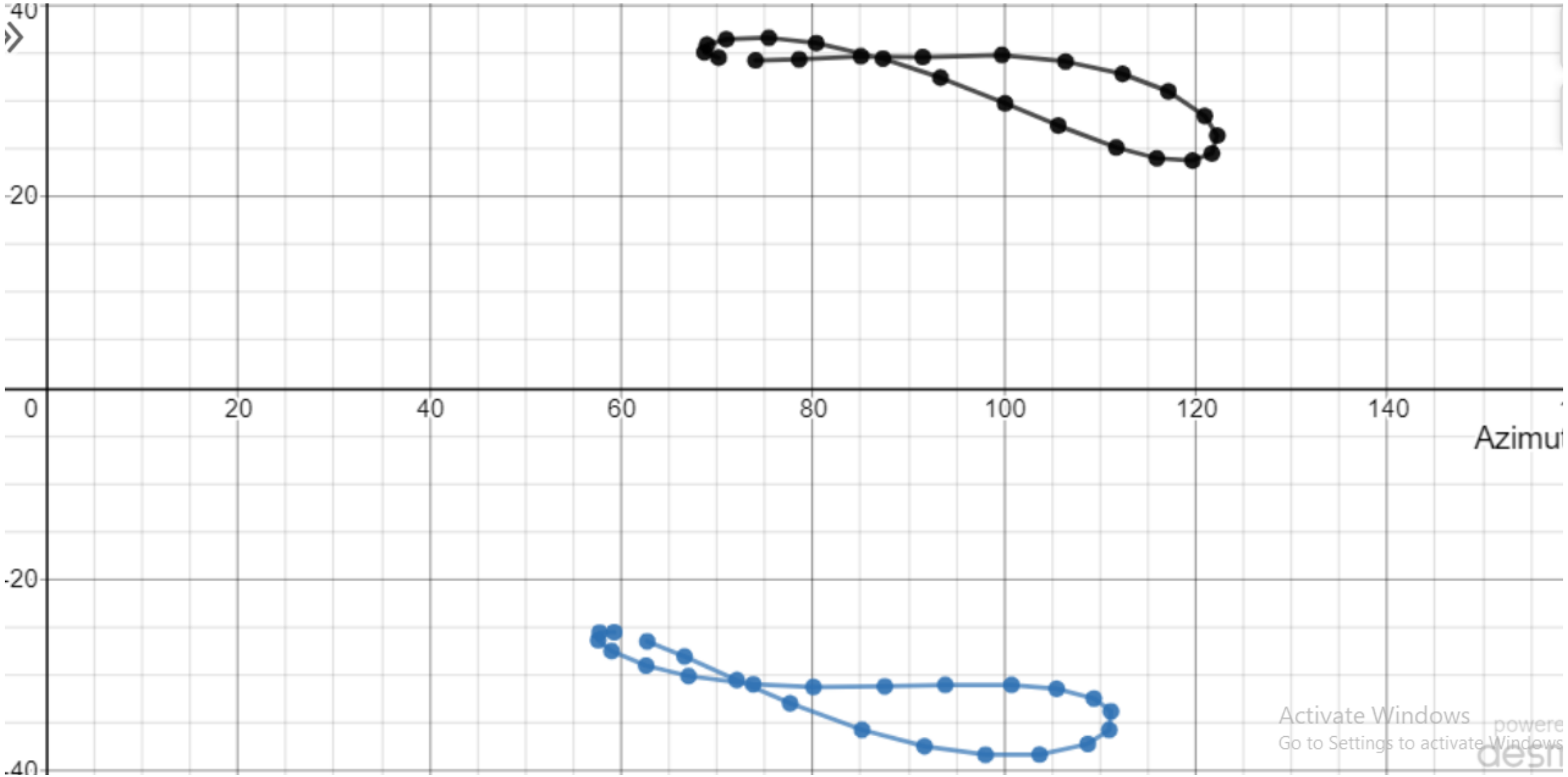

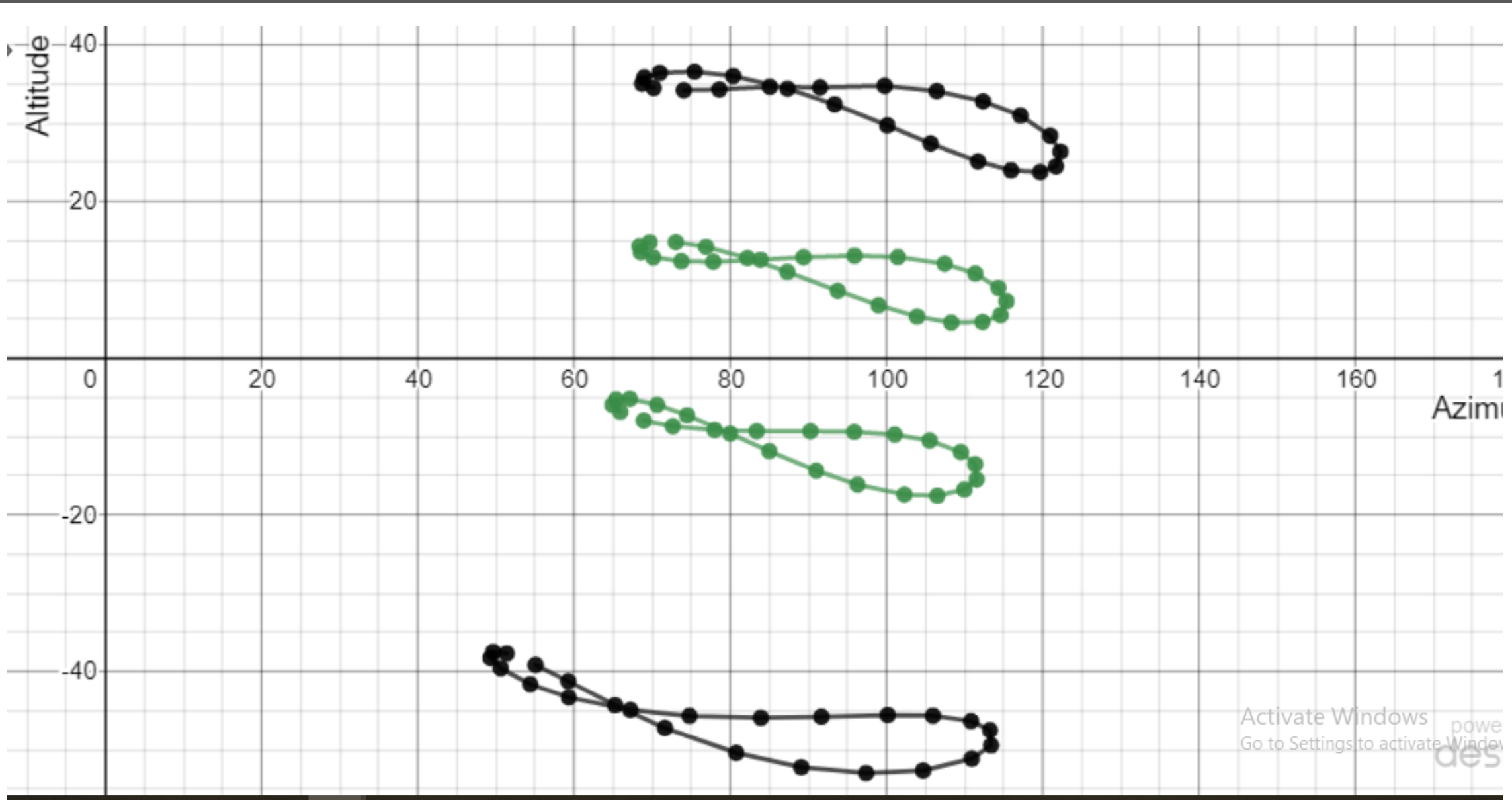
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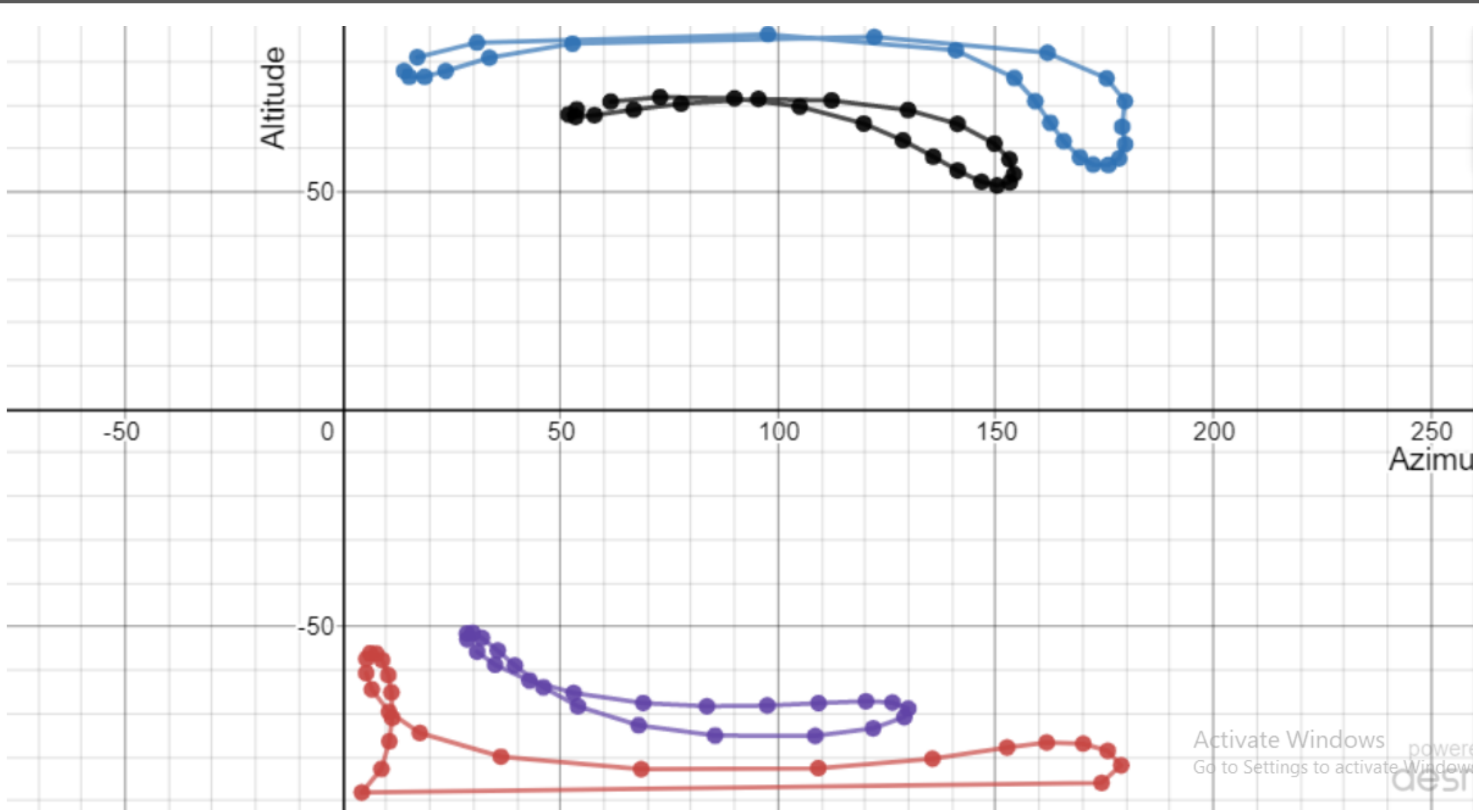

Thanks for Listening!