Construction and accuracy of a 3D Astrolabe

Science in 3D - Competition STEM4youth

INTRODUCTION

Universe: inspirational source

We see a universe marvellously arranged and obeying certain laws, but only dimly understand these laws. Our limited minds cannot grasp the mysterious force that moves the constellations.

- Albert Einstein

The problem

Is it possible to build a model of the universe?

For instance…, an astrolabe using a 3D printer?

Will it be precise? How much?

Hypothesis

It is **possible**, although the plate and the calendar is made of cardboard, the rete will be a 3D piece!

The accuracy is going to be ***good enough***… which means that we don’t want to send a satellite to the outer space...

Stages

1st Stage

Mercedes

Jeremi

Lucía

2nd Stage

Stages

1st Stage → Theory Astrolabe → 2D Plans → 3D 1st model

Mercedes

Jeremi

Lucía

2nd Stage

Stages

1st Stage → Theory Astrolabe → 2D Plans → 3D 1st model

Mercedes

Jeremi

Lucía

2nd Stage

→ Calendar other location → Report

→ Study of the accuracy → Report

→ 2nd Model Improved → Report

Conclusions

Considering that an astrolabe is a **medieval instrument**…. It is a device with **great accuracy**

Mean of 3 observations

MAXIMUM ERROR < 22’ 30”

92% GUARANTEED

3 KEY IDEAS

(that we learnt from each other)

1. Stereographic projection

Greeks tried to find out a method to express a 3D object in 2D; the way that it is made mathematically is called projection. The stereographic projection shows that.

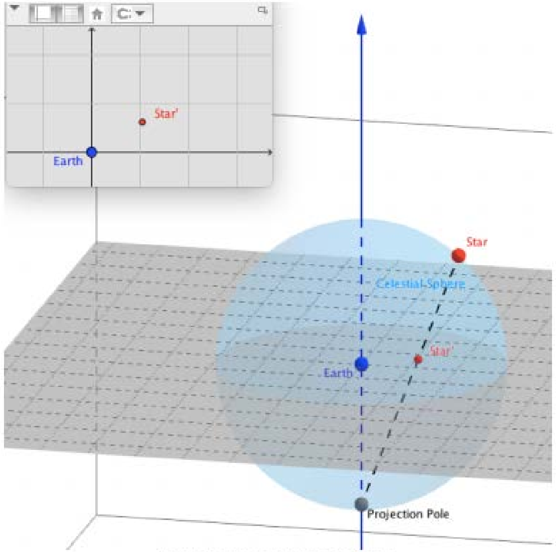


Figure 5. Stereographic projection

The mathematics involved in that geometric operation is quite simple. Considering properties, we can obtain importants results like the *Fundamental equation of the Astrolabe (Theorem 1).*

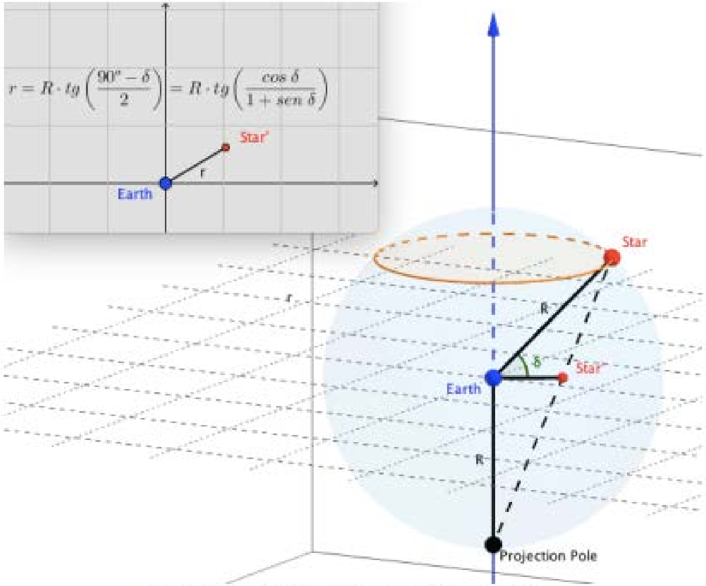


Figure 6. Fundamental equation of the Astrolabe.

1.1. Circumferences and angles preservation. Distortions.

Theorem 2 (preservation of circumferences)

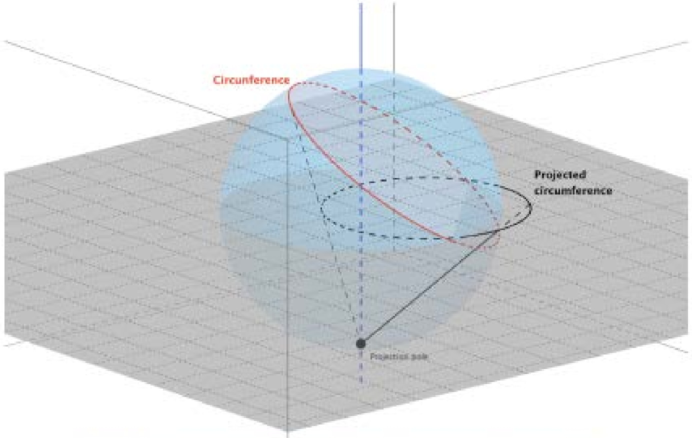


Figure 7. Stereographic projection and circumference preservation.

Theorem 3 (preservation of angles)

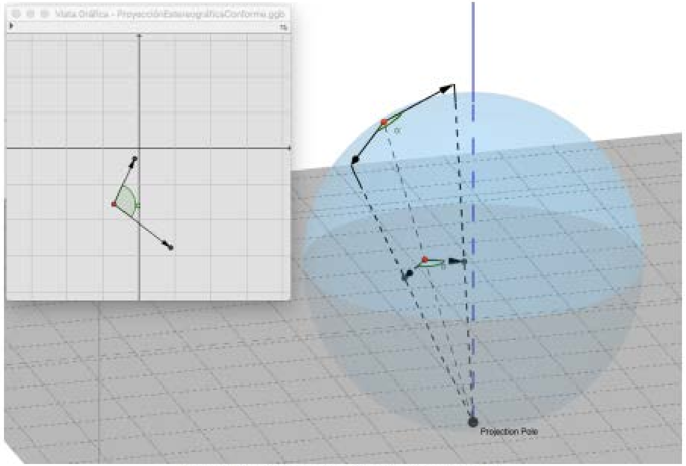
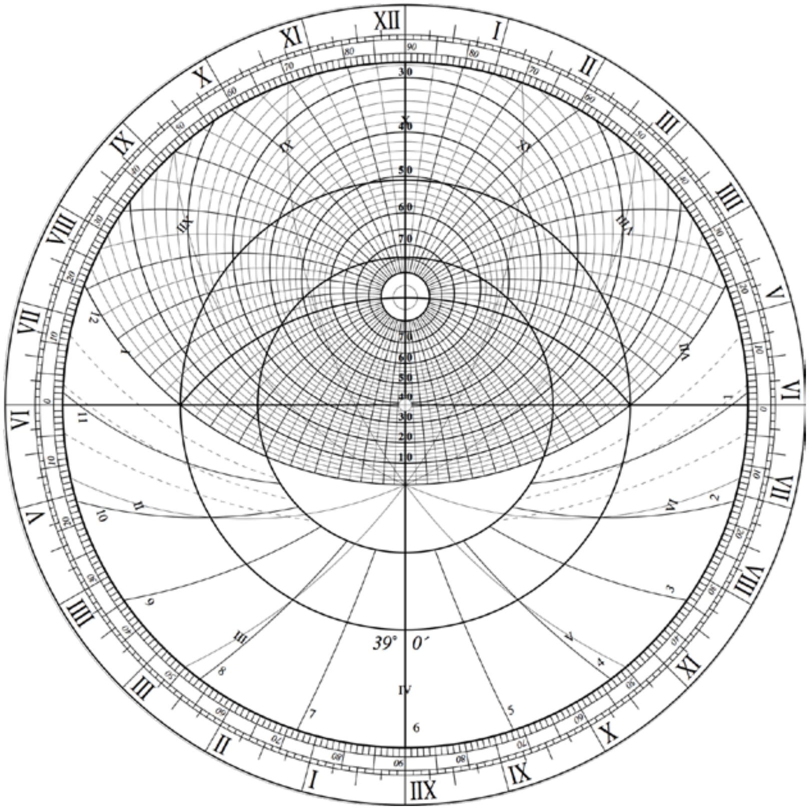
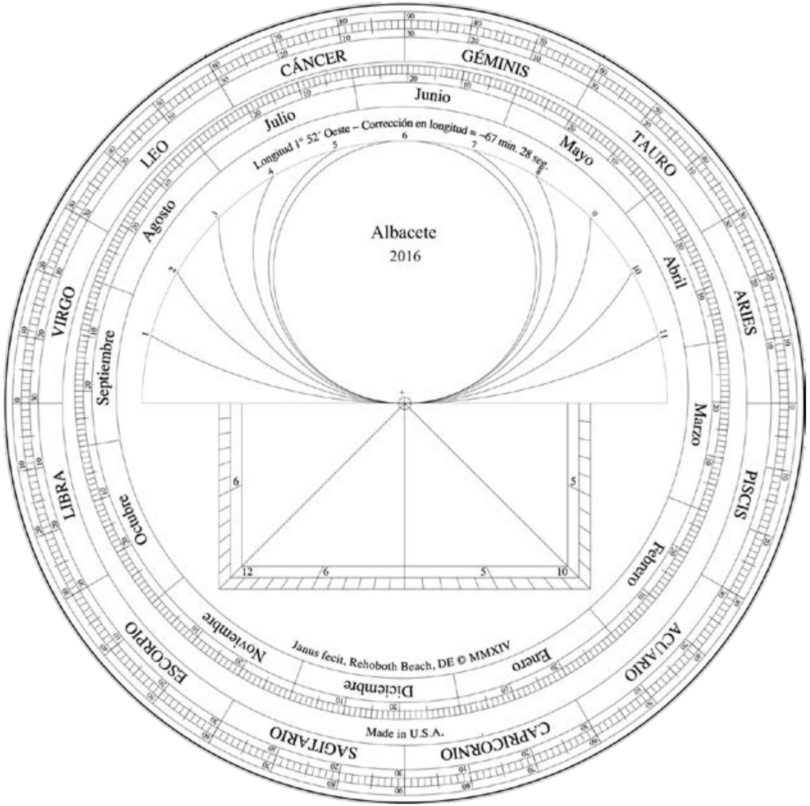


Figure 8. Preservation of angles by the s. p.

1.2. James Morrison plans of the astrolabe





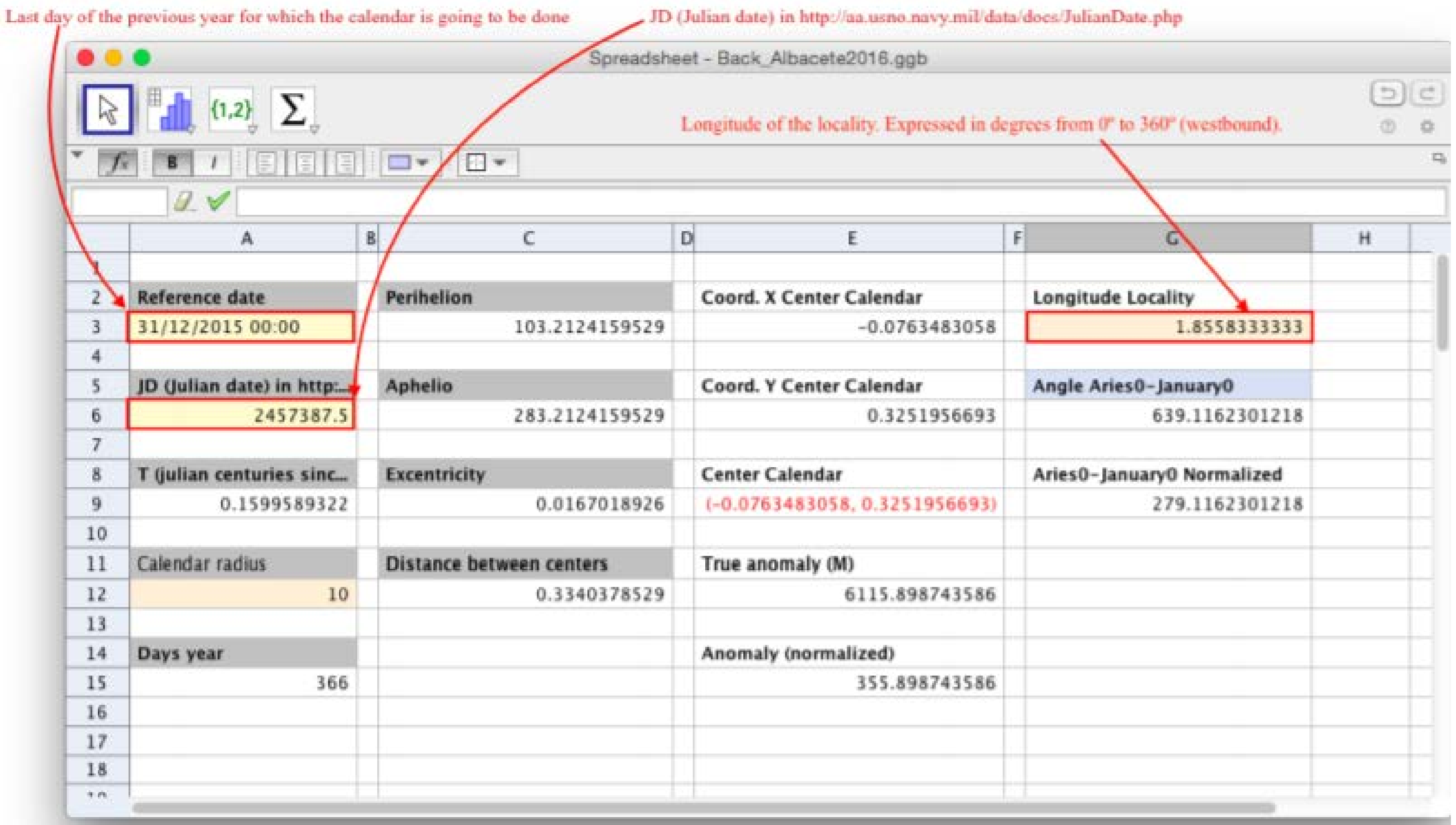
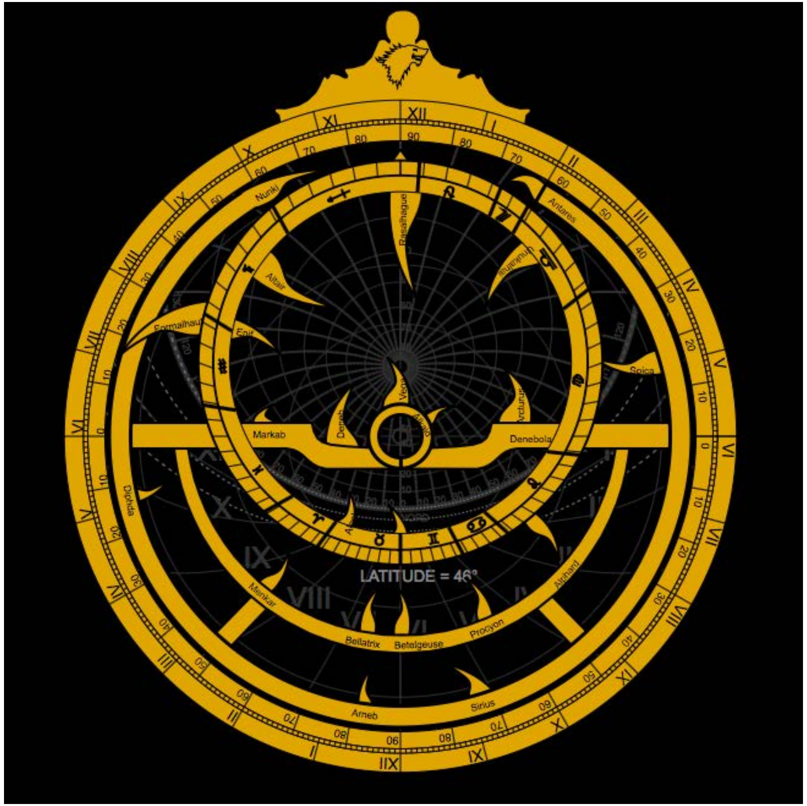


Figure 24. Calendar values for 2016 in Albacete (Spain). Included in folder GUABack.

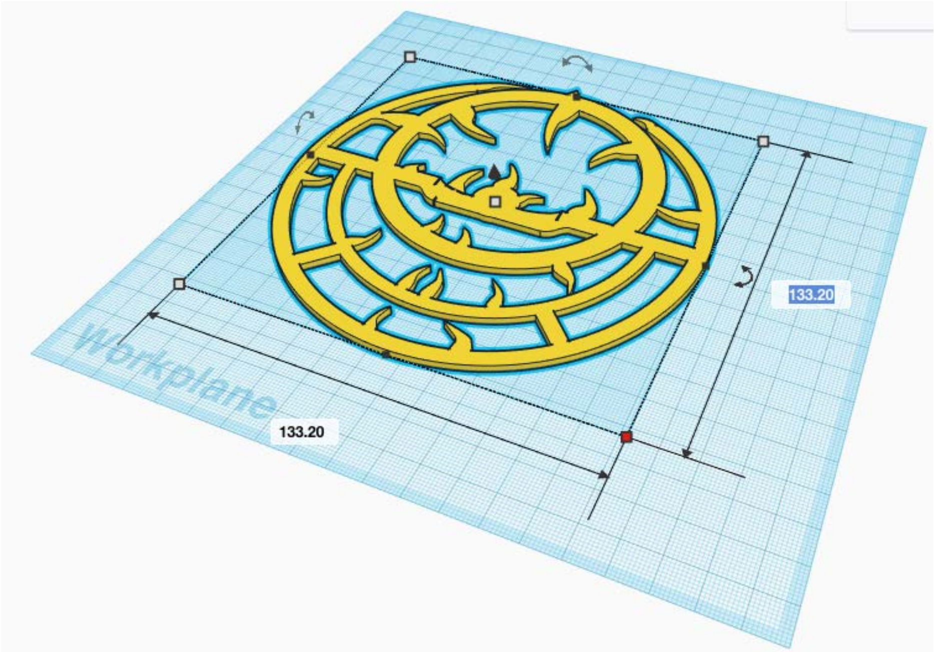
1.2. Liechti rete



1.2. Plans of the STEM4Youth Astrolabe

2. 3D Designing and Printing

2D plans were moved to 3D models.



2. 3D Designing and Printing

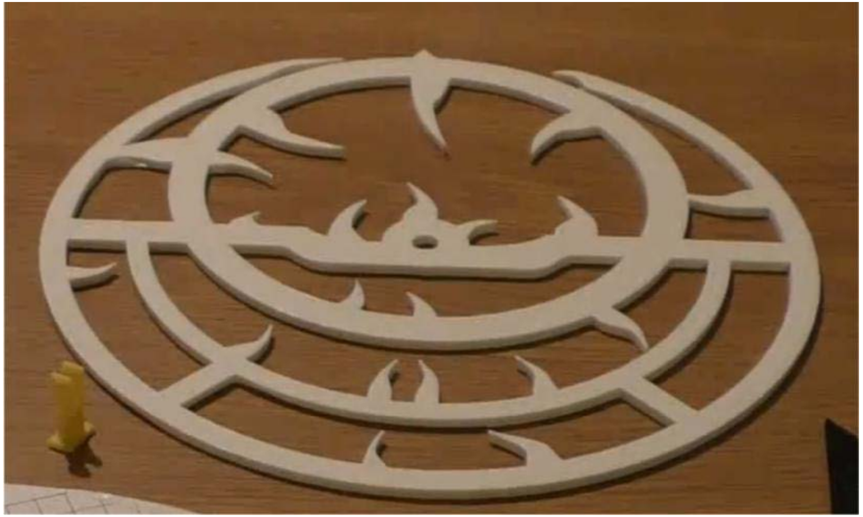
The 3D printing of the prototype of the astrolabe was done using the Prusa i3 printer. The final astrolabe has been printed mostly on a Creality printer, with an exception of a connector piece, that was printed using a Zortrax M200.

2.1 The Mater

The Mater is the biggest part, and is the main plate of the astrolabe. Both printed graded plates are located directly on both sides of it. Unfortunately, in the printed version, it is only possible to have an indentation on one side, unless one is ready to cope with tremendous printing difficulties.

2.2 The Rete

The rete is the part of the astrolabe that is used to point the location of the star on the graduated paper plate, with a representation of the sky. It is the most complicated piece, and many printing issues were met, mainly concerning its final precision.



2.3 The Rule

The rule is used to check which grade on one set of grades corresponds to which on another grade. The holes can also be aligned with a star, to measure its angle relative to the ground. Its desing was relatively simple, however, the optimal way to secure the holes to the main part so that they hold sturdy had to be found.

2.4 The Alidade

This part serves the exact same role as the Rule, but it does not have the part used to measure the hight of a star in the sky, as that can already be done with the Rule.

2.5 The Connector

The Connector is a small, very carefully designed part, used to connect and hold together all other pieces of the astrolabe. It is used here instead of a screw and nut, due to the difficulty of printing small on a 3D printer, and because the rotating parts could loosen the nut. This is the only part of the final design that was printed on the Zortrax M200, because the plastic it uses is more flexible than PLA plastic used by the Creality printer.

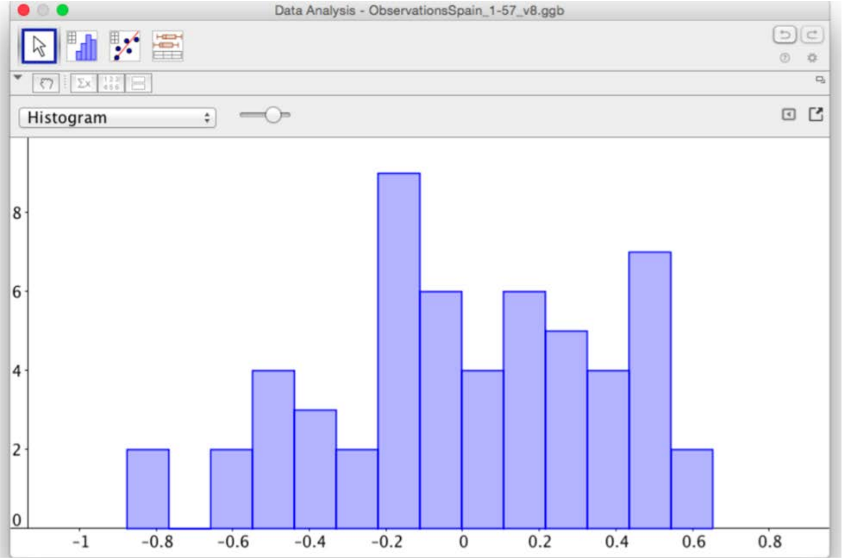
The connector piece, sticking out of the hole in the Mater

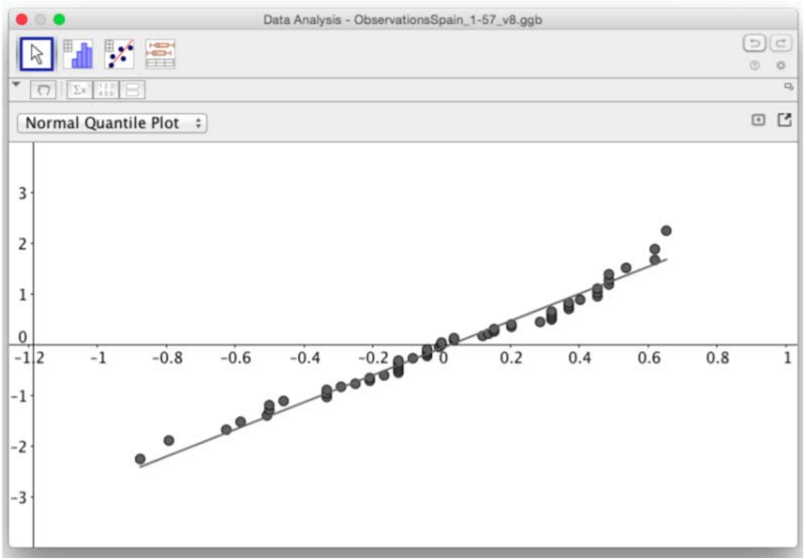
3. Normal distribution

We generated 60 true observations using Stellarium.

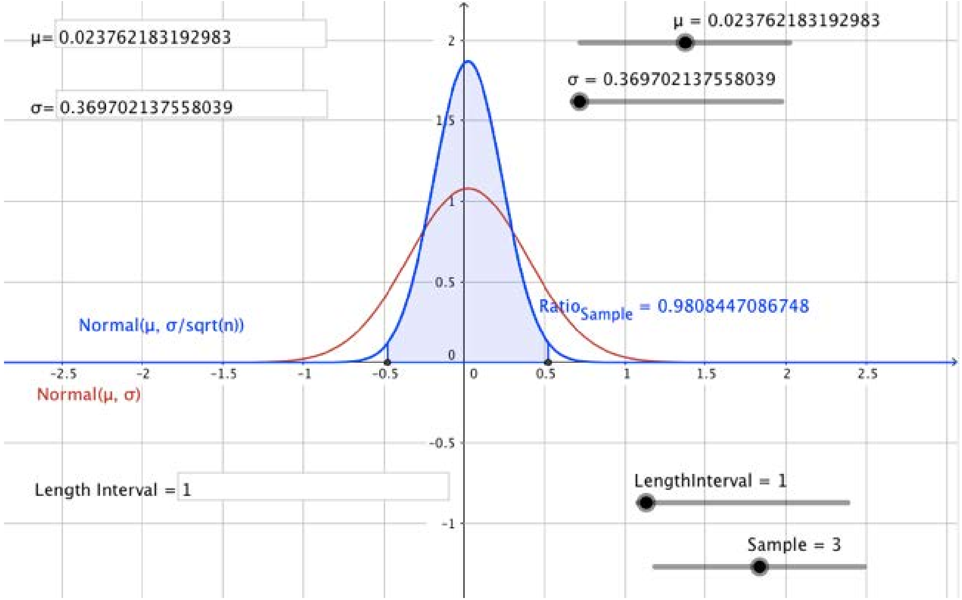
30	Albacete (Spain)	2018	June	22	14:00	Vega	-12° 05′ 47″		-12,1
31	Albacete (Spain)	2018	July	4	13:00	Deneb	-1° 28′ 27.2″		-1,47
32	Albacete (Spain)	2018	July	18	4:00	Deneb	68° 04′ 21″		68,07
33	Albacete (Spain)	2018	July	7	1:00	Vega	28° 03′ 21.8″		28,06
34	Albacete (Spain)	2018	July	19	19:00	Capella	34° 19′ 44″		34,33
35	Albacete (Spain)	2018	July	24	11:00	Sirius	33° 17′ 47.9″		33,3
36	Albacete (Spain)	2018	August	24	20:00	Vega	83° 36′ 52.2″		83,61
37	Albacete (Spain)	2018	August	23	17:00	Arcturus	69° 47′ 00.9″		69,78
38	Albacete (Spain)	2018	August	4	7:00	Vega	4° 38′ 05.7″		4,63
39	Albacete (Spain)	2018	August	3	17:00	Capella	15° 11′ 30.7″		15,19
40	Albacete (Spain)	2018	August	2	20:00	Vega	66° 51′ 11.2″		66,83
41	Albacete (Spain)	2018	September	27	19:00	Arcturus	47° 27′ 45.5″		47,46
42	Albacete (Spain)	2018	September	7	11:00	Capella	62° 19′ 29.5″		62,32
43	Albacete (Spain)	2018	September	11	8:00	Capella	83° 59′ 27.4″		83,99
44	Albacete (Spain)	2018	September	22	12:00	Vega	0° 29′ 36.4″		35,14
45	Albacete (Spain)	2018	September	2	19:00	Deneb	35° 03′ 06.2″		35,05
46	Albacete (Spain)	2018	October	23	12:00	Sirius	-0° 42′ 23.6″		-0,71
47	Albacete (Spain)	2018	October	9	8:00	Vega	-10° 31′ 34.3″		-10,53
48	Albacete (Spain)	2018	October	29	13:00	Arcturus	68° 30′ 03.3″		68,5
49	Albacete (Spain)	2018	October	11	19:00	Capella	-2° 48′ 04.3″		-2,08
50	Albacete (Spain)	2018	October	26	11:00	Capella	30° 20′ 41.7″		30,34
51	Albacete (Spain)	2018	November	6	12:00	Vega	35° 30′ 14″		35,5
52	Albacete (Spain)	2018	November	23	1:00	Capella	73° 16′ 39.7″		73,28
53	Albacete (Spain)	2018	November	10	15:00	Sirius	-57° 14′ 35.2″		-57,24
54	Albacete (Spain)	2018	November	11	15:00	Deneb	50° 53′ 45.6″		50,9
55	Albacete (Spain)	2018	November	20	1:00	Vega	-0° 46′ 25.4″		-0,77
56	Albacete (Spain)	2018	December	6	12:00	Sirius	-44° 11′ 06.9″		-44,19
57	Albacete (Spain)	2018	December	3	20:00	Vega	34° 50′ 21.7″		34,84
58	Albacete (Spain)	2018	December	8	2:00	Capella	82° 02′ 16.1″		82,04
59	Albacete (Spain)	2018	December	23	16:00	Sirius	-33° 55′ 31″		-53,93
60	Albacete (Spain)	2018	December	17	21:00	Arcturus	-29° 18′ 47.9″		-29,31

3.1. Histogram and Normal Quantile Plot





3.2. Study of the accuracy



The distribution for the mean (∑x)/n is N$(\mu, \frac{\sigma}{\sqrt{n}})$

	$Int.length = 60'$	$Int.length = 45'$	$Int.length = 30'$
$n = 2$	94.42%	84.86%	66.11%
$n = 3$	98.08%	92.11%	75.85%
$n = 4$	99.32%	95.75%	82.37%

2 QUESTIONS

1. Will it be the same for other latitudes?

We study the precision of the astrolabe for Albacete, but it will be necessary to study other locations and compare them.

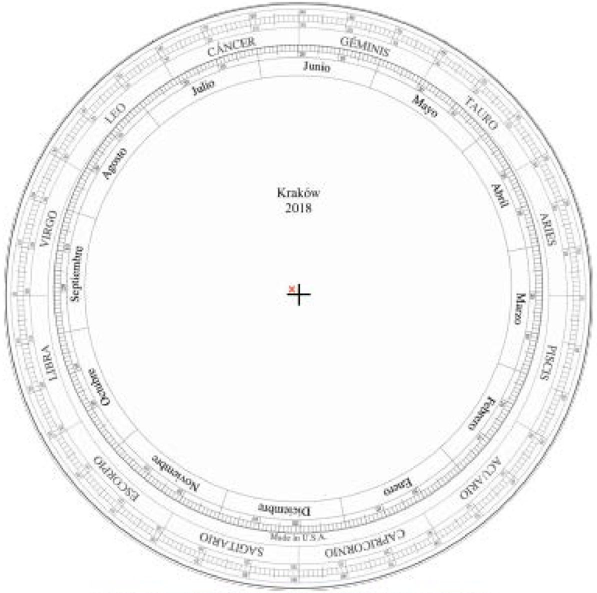


Figure 40. Back of the Astrolabe for 2018 in Kraków.

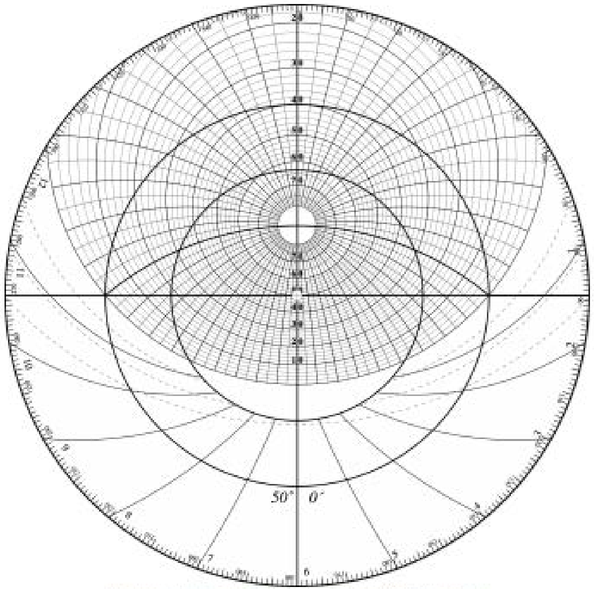


Figure 41. Front of the Astrolabe for Kraków.

2. For a given error E and confidence C%, how many n observations do we need?

Maybe, we should generalize Table 2 of the report.

	$Int.length = 60'$	$Int.length = 45'$	$Int.length = 30'$
$n = 2$	94.42%	84.86%	66.11%
$n = 3$	98.08%	92.11%	75.85%
$n = 4$	99.32%	95.75%	82.37%

Table 2. Percentage of confidence for mean value $\overline{X}$ of size n and interval length expressed in minutes.

1 IMAGE


CAPRICORNVS

Thanks everybody!