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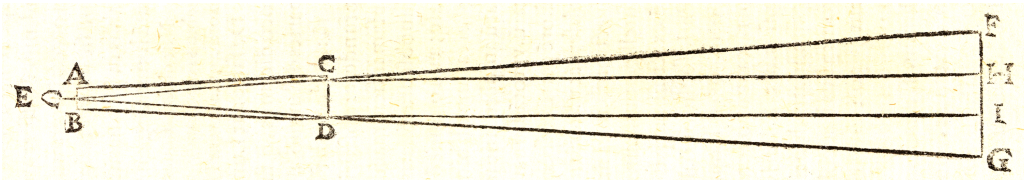
How to build a Galilean Telescope

A Galilean telescope is defined as having one convex lens and one concave lens. The concave lens serves as the ocular lens, or the eyepiece, while the convex lens serves as the objective. The lens are situated on either side of a tube such that the focal point of the ocular lens is the same as the focal point for the objective lens.
The Galilean telescope was innovative in that it was the first to expand the range of magnification of the new spyglasses beyond 3X, using its particular set of lenses.
In Sidereus Nuncius, Galileo described how these two lenses served to magnify an object.

Radii, dum nulla in tubo adessent Perspicilla, ad obiectum FG secundum lineas rectas ECF, EDG ferrentur; sed, appositis Perspicillis, ferantur secundum lineas refractas ECH, EDI: coarctantur enim, et qui prius liberi ad FG obiectum dirigebantur, partem tantummodo HI compraehendent. [1]



Actually, Galileo could not explain how his telescope magnified precisely. He did not understand, as we now know, that the magnification of his telescope can be computed by $|F/f|$, where F is the positive lens focal length while f is the focal length of the negative one, we used the absolute value because negative lenses have a negative focal length. Increasing the magnification requires lengthening the telescope. Our 10X telescope is about one meter long.
From the above picture, you can see that an image, HI, will be viewed upright, making the Galilean telescope useful for terrestrial purposes as well as astronomical. Keplerian telescopes, in contrast, invert the image.

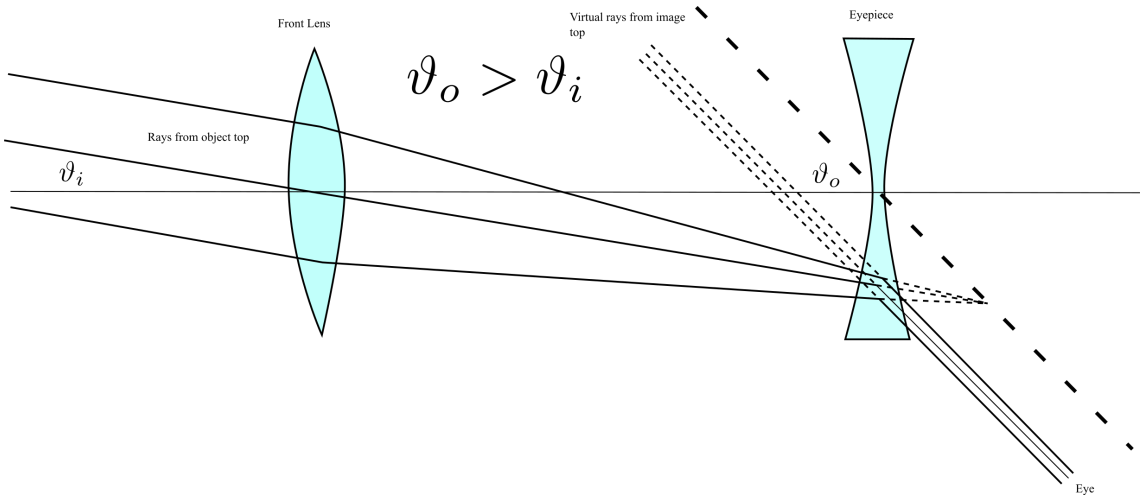


Figura 1: Modern ray diagram of a Galilean telescope

[1] When there are no glasses in the tube, the rays proceed to the object FG along the straight lines ECF and EDG, but with the glasses put in they proceed along the refracted lines ECH and EDI. They are indeed squeezed together and where before, free, they were directed to the object FG, now they only grasp the part HI" Galileo, Sidereus Nuncius

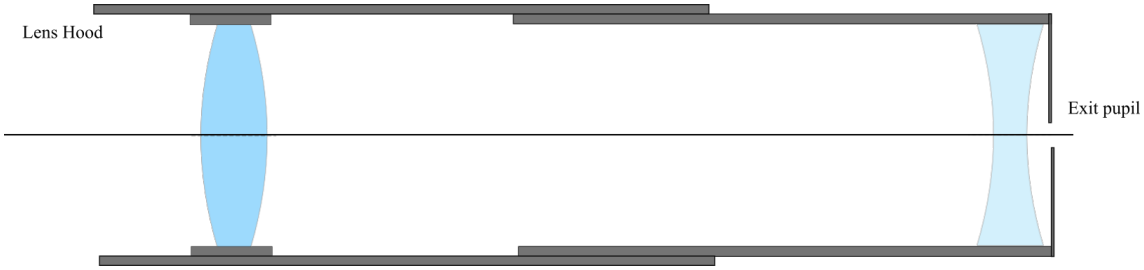
The Galilean telescope's biggest disadvantage is its small field of view. A Galilean telescope typically has a field of view of about 15-18 arc minutes[2]. The moon has a diameter of about 30 arc minutes, so the Galilean telescope only reveals approximately one-fourth of the moon's surface at one time. In a typical north Italian sky, a typical field of view has only one star or no stars at all. This makes it very difficult to map a constellation.[3]
Increasing the magnification on the Galilean telescope, like all telescopes, reduces the field of view. Perhaps Galileo built a 30X telescope, but it is doubtful that he used much in his observations. The field of view must have been very tiny.

Telescope building

To build our telescope we need the following materials:

- Two cardboard telescopic tubes, the external diameter of one must be equal to the inner diameter of the other, one meter length.
- A positive lens, plano convex or bi-convex, or a positive meniscus. For our implementation we will be using a biconcave lens with a 1000mm focal length.
- A negative lens, a biconcave or plano concave one. For our implementation we will be using a -100m focal length one.
- Cardboard spacers to fix lenses in place
- Two sheets of black cardboard

Lenses are the only difficult items to find, we bought ours online at `www.amazingcameraobscura.co.uk`. The basic premise of the telescope tube is to align two lenses at the appropriate distance from each other. For this telescope, the lenses are a bi-convex and bi-concave . The bi-concave lens is used as the "eyepiece". The bi-convex is used as the "objective lens" that is aligned with the eyepiece. Notice that this lens is actually different than the plano convex lens used in the original Galilean telescope, but still gives the same results.
The following design uses pieces of the inner tube to hold the lenses in place inside the outer tube. This is best illustrated in the following diagram, which shows the cross section of the telescope tube:



Cut a section of approximately 5cm from the outer tube, this will be used as an eyepiece holder. The inner tube must have three pieces (about 3 cm each) cut off of it that will be used as spacers to hold the objective lens and eyepiece lens in place. Make these cuts as straight and clean as possible, which will be difficult since the tube is made out of cardboard. A coping saw works pretty well for this.
Take the short piece of the outer tube and cut or drill a hole (from 5 mm to 8 mm should be fine[4]) directly in the center of the plastic cap at its end[5]. This will be the eyehole. An electrician's hole

[2] An arc minute is a 60th of a degree)
[3] During Galileo's times skies were much darker at night though.
[4] Maximum human pupil diameter is between 5 mm and 9 mm
[5] If your tube comes without a plastic or metal cap build it out of black cardboard paper

punch works well for this task. If a drill is used, drill with a light pressure, then smooth out the inside surface as much as possible.
Place the eyepiece lens flush against the inside of this eyehole. The large piece of the inner cardboard tube left will be used to hold this in place. To do this, drill small holes around the outside of the eyepiece tube. Then, with the eyepiece properly in place, slide the inner tube into it, put glue into the holes, and turn the tube a little bit to spread the glue inside. Hold the tube snugly against the lens inside the cap until the glue dries.
Now, put this aside and take the large outer tube and the two spacers cut from the inner tube. Cut the closed end off of the outer tube, then use the other end to mount the objective lens (since that end already has a clean cut). Again, the "drill holes - put in glue" technique will be used to hold the spacers in place. First, check how far the inner spacer needs to be placed inside the tube so that the lens and other spacer will be able to sit inside the tube comfortably. Then drill holes in the outer tube around this area and glue in the spacer as before.
After the first spacer is in place and dry, place the concave side of the objective lens flush against it, and put the other spacer snugly against the lens to hold it in place (again using the drill - glue method).
Now there are two pieces, each containing one of the lenses. Slide the tubes together as shown in the drawing above, and the telescope is done. By leaving these two pieces unglued, the telescope may be focused simply by sliding the eyepiece part inside the objective part. After a desired magnification/focus is found, the two pieces may be permanently attached (or some tape will give a semi-permanent attachment).