

# Newtonian Telescope Collimation with the Astrosystems LightPipe/SightTube and Autocollimator

## Contents

|  |              |
|--|--------------|
| <b>Introduction</b>                                      | <b>i</b>     |
| <b>Preparation</b>                                       | <b>1 - 2</b> |
| <b>Mechanical Alignment with the Crosshair SightTube</b> | <b>2 - 3</b> |
| <b>Optical Collimation with the LightPipe collimator</b> | <b>4 - 5</b> |
| <b>Fine Optical Collimation with the Autocollimator</b>  | <b>5 - 6</b> |
| <b>Checking Optical Collimation - Star Test</b>          | <b>7</b>     |
| <b>Secondary Offset</b>                                  | <b>8-9</b>   |
| <b>References / Further Reading</b>                      | <b>9</b>     |

**i**

## Introduction

The first two steps, preparation and mechanical alignment, need only be performed the first time the telescope is assembled. Thereafter, only the optical alignment and star testing are needed to collimate your telescope. Don't underestimate the importance of mechanical alignment. Most troublesome collimating jobs can be traced back to mistakes or assumptions regarding the placement of components.

**Quick Tour:** If you are familiar with your telescope's collimation and only want an abbreviated guide to using the *AstroSystems* collimating tools, just read through the lines in bold type at the beginning of each paragraph.

## **Position the telescope**

Place the telescope on a horizontal surface or move it to the horizontal. Position the focuser so it is easily accessible. You will be moving back and forth from the rear to the front of the tube assembly to check progress and it helps to have things positioned for convenience.

## **Assemble the proper tools**

Gather the necessary tools required to adjust the primary mirror holder, secondary mirror holder, and spider and focuser base.

## **Center spot the primary mirror**

It is necessary to "spot" the center of the primary and secondary mirrors. To facilitate collimation at night, a white mark on the primary is most visible. The ideal spot can be made from any type of adhesive backed white paper or label. Cut a square 1/2" on a side or a triangle 5/8" on a side and use a paper hole punch to make a smooth 1/4" hole in its center. An adhesive backed paper reinforcing ring such as the type used on notebook paper also works. The spot is placed at the center of the primary mirror.

**NOTE:** To avoid possible damage to your optics, remove rings, watches, bracelets, pens, pencils and any other loose articles from your person or around your work area that could fall on or scratch your mirror. It is also advisable to use a plastic or wooden ruler when measuring your optics.

The center of the primary mirror can be determined by first finding its diameter and dividing by two. Use this radius to measure in from the edge at six or eight positions around the mirror. After several measurements, you will begin to zero-in on the exact center. Use a fine tipped permanent marker to mark the center and then accurately position and attach your paper "spot." Use acetone or alcohol on a cotton swab to remove the permanent marker in the center of the spot.

**NOTE:** Don't worry about placing a spot on the mirror, the center of the primary is shadowed by the secondary mirror. The reflection from the primary back towards the secondary mirror has a "hole" in its center from the secondary mirror shadow, leaving a small central portion of the secondary mirror shadowed.

## **Mark the secondary mirror**

There are two ways to position the secondary mirror, on axis or offset. On axis is recommended since the advantages of offset are not visually perceptible and it makes collimation more difficult. Offset should be incorporated if the telescope is going to be used photographically, here the unequal illumination at the edge of the field will occur, or if the telescope is f/4 or less, requiring a large offset.

**Mark and position the secondary mirror on-axis**

Measure the center of the secondary and place a small dot with a permanent marker at that location. If you prefer there is a technique to align the secondary under the focuser without a center spot. The spider is also positioned in the center of the tube.

**Mark the tube opposite the focuser**

Mark a spot on the side of the tube opposite the focuser by carefully measuring from the front of the tube down an equal distance (on the outside of the tube) as the center of the focuser drawtube. A piece of adding machine paper works well to find the dimension around the tube (or upper cage). Wrap this paper around the outside, measure its center, rewrap the paper and drill or punch a tiny hole through to the inside. Place a mark or spot on the inside to complete preparations.

**Mechanical Alignment with the Crosshair SightTube**

Mechanical alignment is the accurate positioning of components in the tube assembly. The importance of mechanical alignment lies in the fact that all the collimation steps that follow are either easy or difficult, depending on how well the telescope components are mechanically positioned.

**NOTE:** Truss tube owners are proceeding on the assumption that when the telescope is assembled the upper cage is centered over and square to the mirror box. Measuring to verify this will save time and frustration later.

**Center the primary mirror in the mirror box**

With open end mirror boxes, it is a simple task to measure in from the mirror box sides to the side of the mirror. With closed tubes, centering the mirror relative to the mirror mount and then centering the mirror mount relative to the tube works well. Mirror cells supplied with a sling can be adjusted in combination with cams or locating pads to center the primary mirror. It's a help to first turn the collimating screws so they all have the same amount of travel in both directions.

**Square the focuser to the upper cage (or tube)**

With the secondary mirror and holder removed, insert the Crosshair SightTube into the focuser. The focuser mounting screws are loosened and the adjusting feet, if the focuser is so equipped, are used to tilt the focuser until the crosshairs are centered on the mark opposite the focuser. On focusers not provided with tilt, adjustment shims made of cardboard or other suitable material can be placed under the focuser base until the crosshairs are centered on the opposite spot.

**Square the spider**

The spider is next squared to the optical axis. This is checked by sighting through the spider bore towards the primary. The spider bore should look directly at the mirror center spot. Adjustment can be made by drilling the mounting holes slightly oversize and shifting the spider vanes to square. Also be sure the spider screws are well tensioned to hold collimation.

### Position the secondary mirror laterally under focuser

**Without offset / center spot on secondary mirror** - Replace the secondary mirror and holder and position it under the focuser so the crosshairs are centered on the center spot. Washers or the adjustment nuts can be used to position the secondary (see **Figure 3**).

**Without offset / no center spot on secondary mirror** - Replace the secondary mirror and holder and position it under the focuser. Move the LightPipe/Sighttube up and down in the focuser until the outer edge of the secondary mirror is just visible in the bottom of the LightPipe/Sighttube. It is usually necessary to adjust the secondary mirror laterally under the focuser to get the secondary centered.

**With offset / secondary center spot is necessary** - Replace the secondary mirror and holder and position it under the focuser. Using the LightPipe/Sighttube, center the offset spot on the crosshairs of the Sighttube. This laterally positions the secondary mirror under the focuser with the desired offset.

### Position the secondary mirror rotationally under the focuser

Remove the LightPipe/SightTube and look through the focuser drawtube. Rotate the secondary holder and mirror until the reflection of the primary mirror is centered all around. Move towards or away from the focuser until the edge of the primary is just seen in the secondary. Insert the LightPipe/SightTube, adjusting its height in the focuser until only the edge of the secondary can be seen. When the primary mirror reflection is centered, lock the secondary in place. This completes the mechanical alignment.

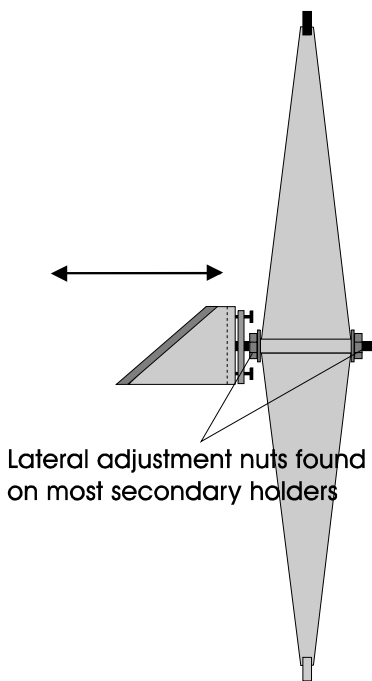


Figure 3. Lateral adjustment

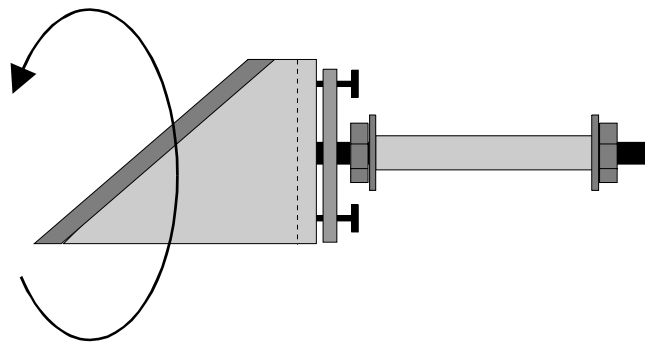
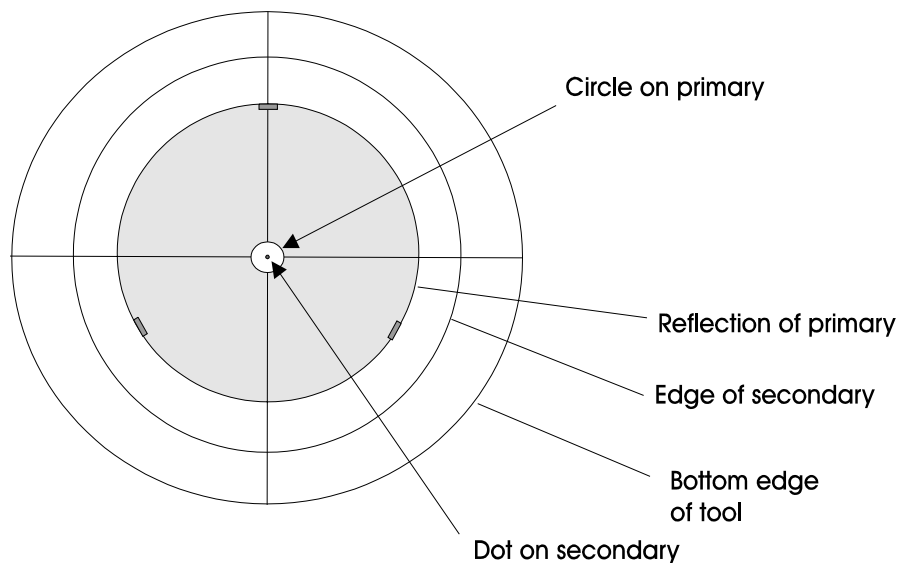


Figure 4. Rotational adjustment

## Optical Collimation with the LightPipe



**Figure 5.** View through LightPipe/SightTube of collimated system.

### **Adjust tilt of secondary mirror**

Insert the LightPipe/SightTube into the focuser. Adjust the secondary tilt so that the primary mirror's reflection appears centered front to back and side to side in the secondary. After this step is done, insure that the secondary spot is centered under the crosshair of the collimation tool. If not, adjust the secondary lateral or rotational position and then readjust tilt. Aligning the secondary becomes an iterative process, with each successive pass generating smaller changes to the placement of the secondary. When it is set up correctly, the reflection of the primary in the secondary should appear centered in the focuser. The spot on the secondary should be centered under the crosshair of the collimation tool.

### **Adjust tilt of primary mirror**

Now that the secondary mirror is positioned, it's time to adjust the primary to point in the correct direction so that the optical system becomes closed. By closed, we mean that the image at the focuser (your eye) reflects off the secondary to the primary and then the primary reflects light back to the secondary, which in turn reflects the light 90 degrees back to the focuser. You will then be able to see the reflection of your own eye when you look into the focuser. The open sky or a white wall work well to evenly illuminate the view. The primary collimation screws are now used to adjust the tilt of the primary so the LightPipe reflection is centered on the primary mirror spot. At this point, it becomes obvious why the center spot was cut square or triangular. It is much easier to see the corners of the "square spot" extend equally around the illuminated LightPipe reflection when the two become superimposed.

When you get through, the crosshairs on the collimation tool should aim at the dot on the secondary and be exactly centered in the circle on the primary. Simultaneously, the primary must still appear centered in the secondary, front to back and side to side.

By introducing a circle of light at the focuser, the reflection of that light will appear centered on both the primary and secondary marks. This is precisely what a LightPipe eyepiece does. It has a clear diffuse upper section that introduces light into the closed system while allowing you to look through a tiny hole to see the reflection of that light in the system.

If you have aligned your secondary correctly, you will only need to tweak the primary at this time. The dot on the secondary should be centered in the dark center of the light circle generated by the LightPipe. The mark on the primary should be centered in the circle of light as well. Figure 5 illustrates the collimated view. A large offset will appear to make the reflection of the focuser slightly off center in the reflection of the secondary. An offset reflection will be centered side to side, but skewed front to back (along the axis of the telescope).

After using the crosshair and LightPipe eyepieces, your Newtonian is very close to being collimated. The next step in fine tuning requires an autocollimator or you can use the star test on Page 7.

## **Fine Optical Collimation with the Autocollimator**

### **Theory**

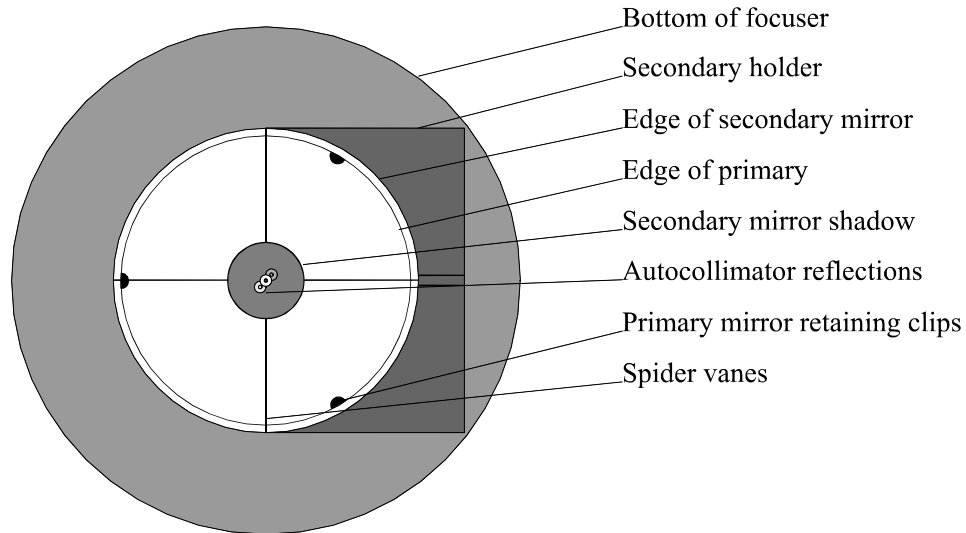
To understand how an autocollimator is used, consider the following analogy: a fun house has two mirrors facing each other in a room. One of the mirrors can be moved by using a lever in the center of the room. If you stand in the center of the room and look in one mirror, you will see your reflection. If the two mirrors are not exactly parallel, you will also see a reflection of your reflection in the other mirror. These reflections will go on for what seems forever, creating a line of ever smaller images of yourself. When the mirrors are parallel, you will only see your reflection in the mirror because your body is blocking the reflection from the other mirror. Suppose another person is looking through a small hole in the fixed mirror. This hole is centered on the position where you are standing. When the mirrors are slightly out of parallel, he sees you and a series of reflections of you in the mirror behind you from his perspective. When both mirrors are parallel, he sees only you and no reflections.

If a flat mirror is placed in the focuser of a Newtonian telescope and it has a small hole placed in it to look through, the center of the primary along with the secondary and the mirror in the autocollimator act like the two mirrors in the example. When a Newtonian is properly collimated all the multiple reflections will appear as one.

### **Using the Autocollimator**

First, it is necessary to collimate the optics with a LightPipe or Laser collimator sufficiently close to give a "closed" light path. Insert the autocollimator in the focuser without using a setscrew, if possible. Even better is to use an adapter or drawtube that has a compression ring. This gives a repeatable and accurate orientation of the autocollimator in the focuser. A very loose fit or an irregular setscrew will tend to tip or shift the autocollimator.

If the initial collimation was close, you will see a dark or partially dark view on initially looking into the autocollimator. If part or all the view is bright, indicating the introduction of external light and an open optical system you will need to return to the optical alignment of the primary and secondary, Page 4.



Once you see a mostly dark view, you will see one or more reflections of the center spot, the brightest being the first reflection and subsequent dimmer reflections being the second or third reflection of the center spot. Reaching around and applying a light twist or tilt to the secondary will usually bring multiple reflections into view. Make small adjustments to the secondary to get all the reflections to converge together. If you can see multiple images that are in a line perpendicular to the tube axis a slight rotation of the secondary will bring them together. If the images are parallel to the tube axis (left to right) then tilt adjustment to the secondary will bring them together.

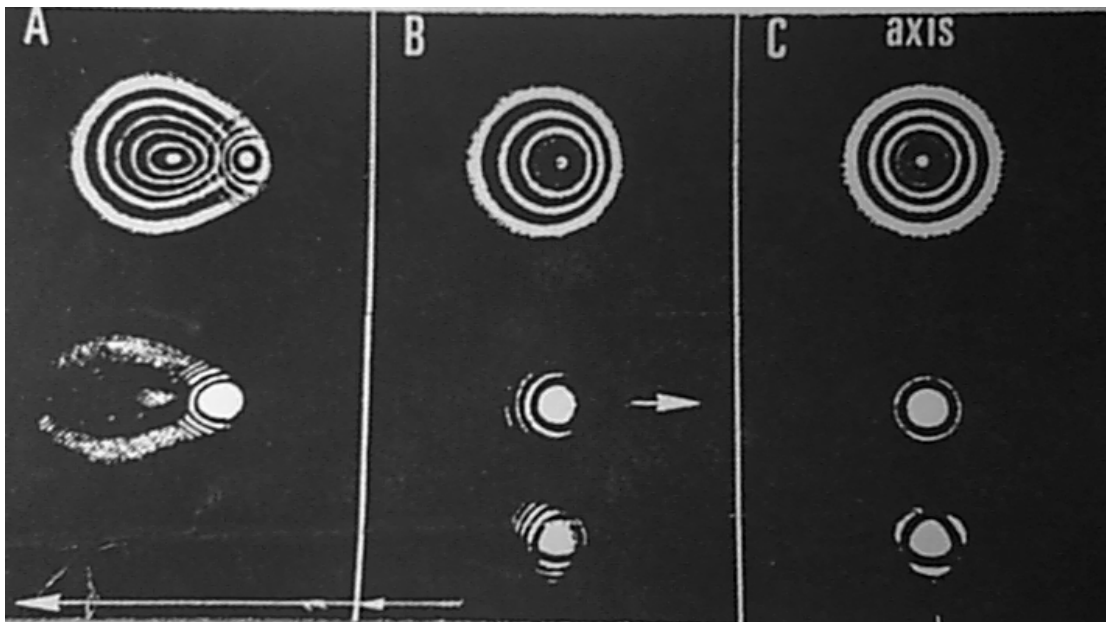
At this point, you will see very small adjustments having a great affect. Each reflection is two times the focal length, so a third or fourth reflection is 6 to 8 times the focal length! This is very sensitive and may need to be touched up as the night progresses due to thermal expansion/contraction.

**You have now reached perfect collimation.**

The advantage an autocollimator has is that it can be done in daylight or under cloudy conditions. On fast systems (low f-ratio), it is the only way proper collimation can be obtained because the large amount of secondary offset (if present) will make a properly collimated system appear poorly collimated when viewed with the LightPipe.

## Checking Optical Collimation - Star Test

Optical collimation can be checked and fine tuned by sighting on a star, however this is only possible if the skies are not overly turbulent and the optics are thermally equilibrated. This is a very sensitive test, if we tilt a f/6 mirror to shift the image in the focal plane by 1/100 inch, visually perceptible coma results. For example, if the collimation screws have 16 threads per inch, this will correspond to as little as 1/8 turn. Interpreting the images seen in this test will take some experience. Locate a star of third or fourth magnitude fairly high in the sky. This improves the chances of a good image and insures the primary mirror makes positive contact on its flotation pads. Using a medium-power eyepiece defocus the image. **Figure 8** below shows stars outside of focus in the top row and inside of focus in the bottom row. Should your image appear like **8A.**, exhibiting gross coma, astigmatism and diffraction, something is severely misaligned or has shifted and returning to mechanical alignment may be necessary. Usually the star's appearance will look much like **8B.**, showing a small amount of decentering. For more detail, shift to a high-power eyepiece. Work by trial and error, rather than trying to figure out which primary mirror collimation screw to adjust. The lower arrow shows direction in which to displace the image in the field to return the beam on axis. Once this is accomplished and checks out with high power, the telescope is accurately collimated.



**A. Large centering error    B. Small centering error    C. Perfect centering**

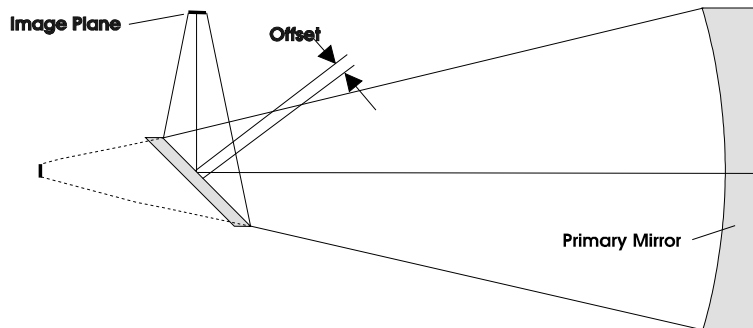
**Figure 8.** Adjusting the primary mirror with a star.



## Secondary Mirror Offset

Offset (repositioning) the secondary in a Newtonian reflector will even the illumination at the edges of the field. This is not perceptible in a visual telescope over  $f/4$ . For that reason it is not recommended for a visual telescope of  $f/4.5$ . For shorter focal lengths, especially in larger telescopes (20"+) or photography it can provide a small benefit. To offset the secondary mirror, it is repositioned (offset) in the light cone coming from the primary mirror (see Figure 1.). To make better use of the full light gathering ability of the primary mirror and more evenly illuminate the edge of the eyepiece field.

The secondary mirror is positioned a small distance away from the focuser and an equal distance towards the primary. To realize why this offset is necessary we see that the light returning from the primary mirror is shaped like a *cone*. When this cone is intercepted at a 45 degree angle, the shape is larger in area on the side towards the primary and smaller on the side towards the open end of the telescope. The diagonal is shaped like a 45 degree cut through a *cylinder* and so it is uniform in area front to back and side to side. Obviously these two shapes are not the same, so shifting the secondary mirror towards the "fat" side of the light cone will help equalize the illumination at the image plane.



**Figure 1.** The center of the secondary mirror is offset away from the focuser and towards the primary.

**Note:** The following example is given for incorporating offset into the position of the secondary, but is *not recommended* for a visual telescope. To calculate the amount of offset to maximize illumination of the field use the following formula that yields a very close approximation:

$$s' = \frac{N(D - N)}{4(F - L)}$$

$s'$  = The secondary mirror offset     $N$  = Secondary mirror minor axis  
 $D$  = Diameter of primary mirror     $F$  = Focal length  
 $L$  = Intercept distance measured from the secondary mirror to focal plane.

## Secondary Mirror Offset

### An example using the above formula:

A 20" telescope has a focal length of 100 inches. The tube outside diameter is 22", the secondary minor axis is 3.1" and the focuser height is 1.5". The focal plane is 0.25" above the fully racked in focuser; this distance is known as "in-travel."

$$\begin{array}{ll} \mathbf{N} = 3.1" & \mathbf{D} = 20" \\ \mathbf{F} = 100" & \mathbf{L} = 11" + 1.5" + 0.25" = 12.75" \end{array}$$

By inserting the values in the formula for offset we have:

$$s' = \frac{3.1(20 - 3.1)}{4(100 - 12.75)} = \frac{3.1(16.9)}{4(87.25)} = \frac{52.39}{349} = \mathbf{0.15"}$$

The offset for this telescope would be 0.15", or just over 1/8". This calculated offset is the horizontal or vertical offset, the offset along the face of the secondary is 1.414 ( $\sqrt{2}$ ) times s'. In this case 0.15" times 1.414 gives us 0.21".

The easiest way to introduce offset is to position a spot, using a pointed permanent marker, on the center of the secondary mirror. Then mark a second spot, shifted by the amount of the offset, along the centerline towards the end of the secondary mirror in the direction of the tube front as seen above. This spot is centered under the focuser to move the secondary mirror the correct horizontal component of offset, while the spider is repositioned away from the focuser by the vertical component. This has the net effect of offsetting the secondary mirror along its face by the prescribed amount. The spot can be removed with alcohol and a swab when finished. Offset will cause the reflections to be non-concentric when viewed visually through the focuser or with a LightPipe.

## References / Further Reading

- |  |                           |
|--|---------------------------|
| <i>Astronomy</i><br>Collimating Your Telescope                     | January 1981<br>.         |
| <i>Sky and Telescope</i><br>Backyard Astronomy                     | March 1988                |
| <b>Newtonian Collimation</b><br>Sky Publishing                     | Vic Menard, Tippy D'Auria |
| <b>How to Make a Telescope</b><br>Willmann-Bell, Inc               | Jean Texereau             |
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