Chapter Ten
Horseshoes and Split Rings

At A Glance

Advantages:
- Well supported at both ends of both axes.
- High resonant frequencies.
- Low profile, portable.

Disadvantages:
- Difficult to make for a wide latitude range.
- Low profile makes polar alignment tedious, painful or messy.

We saw that the English Yoke mount has excellent stability and a higher resonant frequency than other mounts in its family. Unfortunately, it has a region of sky that it can't see. What if you could have the stability of the yoke and no blind spots? The concept is simple; since the thing that stops the yoke-mounted scope from seeing this area is the mechanical interference of the telescope body bumping into the top of the mount, cut a slot in the north end so that the telescope can observe along the line of the polar axis. The north end has to be re-shaped to allow it to rotate; a large disk with a slot cut for the tube is ideal. This concept, of course, is not new. It is the concept behind the mount used for the Hale telescope on Mt. Palomar.

The Horseshoe mount, as it is known, is a large mount and the position of the OTA in the polar yoke is the same as the yoke mount. The yoke is simply supported at both ends, so the vibration and deflection relationships for a center-loaded, simply-supported beam are appropriate here. These were defined in the section on the English Yoke mount.

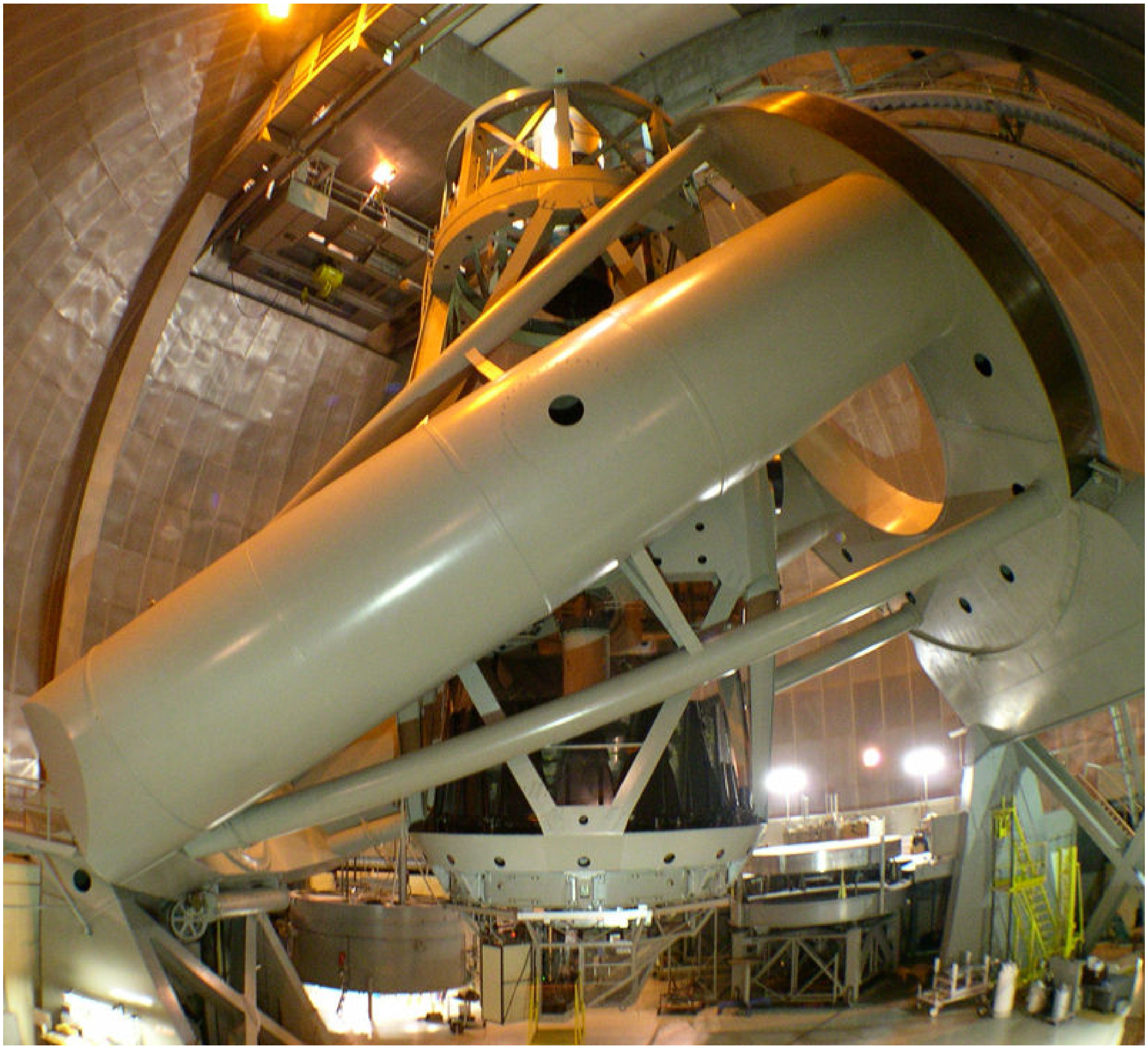

Figure 1 - The 200" Hale Telescope - Caltech Astronomy Photograph

Figure 1 the Hale telescope as seen looking from the east to the west, north on the right – taken with a very wide angle camera lens. While it is hard to convey the scale of this instrument, you can observe the ladders at lower right, which are typical step ladders.

The strength to weight ratio of this mount, while quite good, can be improved. Consider the yoke itself; what does it contribute to the stability of the mount? If we could slide the telescope forward along the yoke, we could reduce the deflection and raise the resonant frequency. When we think about this, we find that we can move the telescope all the way forward until it is mounted on the polar disk itself! This has several advantages: first, the mount can be shorter front to back, reducing size and weight; second, the polar disk is loaded in a stable manner, that is, a component of the weight puts it compression while the component acting to bend the disk can be countered with a brace between the polar disk and the polar shaft bearing; third, the polar disk becomes one end of an enormous tapered bearing, so that the system feels very smooth in rotation; and fourth, the mount can be made quite short top to bottom, further reducing size and weight.

The resulting mount is the split ring equatorial, and the mount is credited to Porter in the first ATM book. The split ring design has been adopted by several of the world's largest telescopes, including the 4 meter Mayall telescope on Kitt Peak and its twin on Cerro Tololo. While not extremely popular among amateurs, it has somewhat of a following among ATMs; they are in evidence at Stellafane and other ATM gatherings. There is only one commercial instrument that I have seen which uses this style of mount; the NGT-12.5 from JMI is mounted on a derivative of this style mount.

Figure 2 - A big split ring seen at Stellafane, by Al Francis (copyright Al Francis photo).

Figure 2 is an example of an ATM-built split ring equatorial. The polar disk is often made of plywood with a metal band around the edge, as done by Al Francis here, but a fiberglass and foam disk would work well here at a small fraction of the weight. The polar yoke is cut out so that the bottom of the telescope will clear it at all viewing angles, and the points where the yoke meet the disk are reinforced with vertical plates, shown here as semicircular in section. The polar axis shaft is not under bending load, so the diameter is not critical, however, the rule of large bearings feeling smoother is true here as well, and they tend to be 2 or 3 inch pipes. The disk is shown riding on two wheels which is another of the advantages of this mount. Ball bearing roller skate or skateboard wheels are excellent here, smooth and cheap. One wheel can be driven with a motor to allow motorized tracking easily. As a bonus, it is very easy to calculate the drive wheel size this for sort of drive.

If two rotating objects are in contact and not slipping, their edges must be rotating at the same linear speed. We'll use the subscripts R and P for the roller wheel and the Polar disk, respectively. Saying their linear speeds are equal says:

$$V_R = V_P \tag{1}$$

Further, we said in chapter two that the linear velocity of rotating body is its angular velocity ω times its radius r. This says:

$$\omega_R r_R = \omega_P r_P \tag{2}$$

The required radius for the roller skate wheel is just:

$$r_R = \frac{\omega_P}{\omega_R} x\, r_P \tag{3}$$

So if the roller skate wheel is rotating at one rev per hour (24 per day), and we want one rev in 24 hours (one per day), we need to solve the following:

$$r_R = \frac{1 rev/day}{24 rev/day} x\, r_P \tag{4}$$

So if the radius of the polar disk is 18 inches, the radius of the roller skate wheel should be 18/24 or 3/4 inch. For a true sidereal rate we want one rev in 23.9344 hours or .0417809 rph. Then:

$$r_R = \frac{.0417809 rev/hr}{1 rev/hr} x\, r_P \tag{5}$$

or r_p = .752 inch.

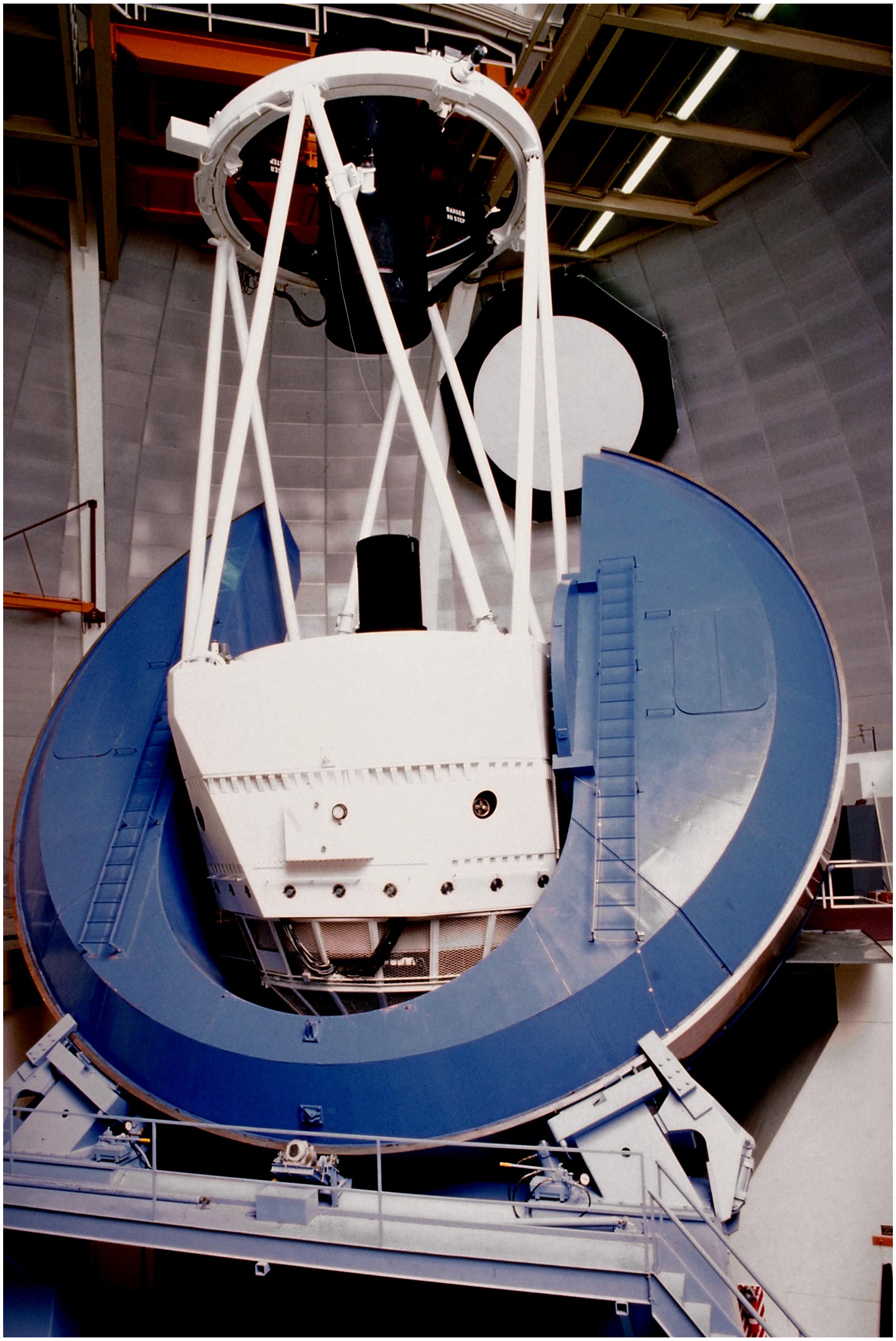

Figure 3 - The 4 meter Mayall reflector. Image copyright NOAO/AURA/NSF

Figure 3 shows the 4 meter Mayall telescope on Kitt Peak. The massive split ring is prominent with the circular declination bearings midway up the sides of the ring.

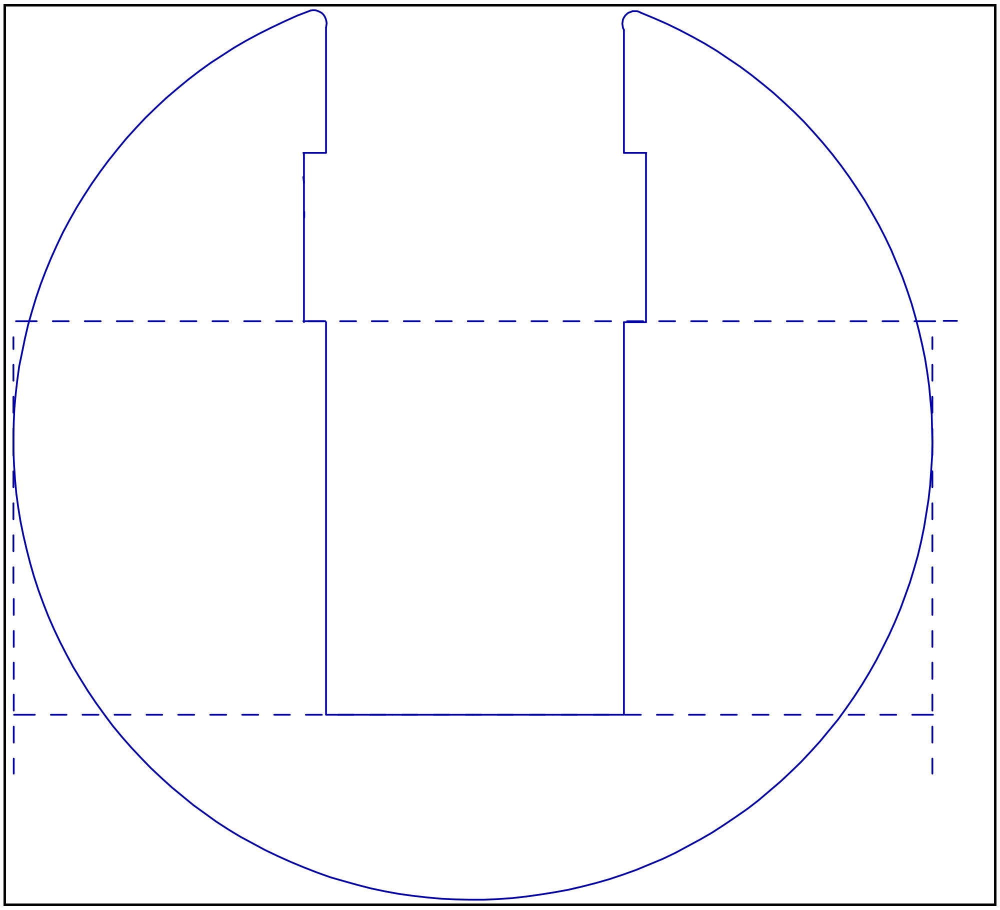

Figure 4

The scale of the picture is apparent when the ladders that are on the polar disk are noticed.

Look closely at **Figure 4**. The dashed lines show that the portions of the ring supporting the telescope are very much like a rectangle in cross section as seen from the front. The approximation breaks down as you get closer to the bottom of the tube cutout, but it is rather good higher up. Because of this, we will model the mount as the two rectangles on the sides. The OTA will sit in the declination axis cutouts shown, where it will be assumed to be clamped.

Starting with vibration, we have a load acting down the plane of the polar disk of Wt sin(90 - lat), where Wt is the weight of the tube and tube clamp. Notice that this is not the latitude angle, as it is in every other mount we've looked at.

Since sin(90-lat)=cos(lat), you may choose to use cosines here.

I am sticking with sines because I have used them throughout the book for the downhill component of weight, and don't want to introduce any more confusion for those new to using this math.

This is modeled as weight pressing down on a spring, and the resonant frequency of this geometry is:

$$f = \frac{1}{2\pi}\sqrt{\frac{385.4\ EA}{(Wt + Wb/3)l}} \tag{6}$$

where Wb is the weight of the rectangular arm, and l is the length of the arm. A is the cross-sectional area as seen from the bearing's location; the thickness of the disk times the length to its edge. The 385.4 factor, as before, is used to correct weight in the US system to mass, and is omitted for mass in kg.

Our standard OTA weighs 34.3 pounds, and we'll assume a 3/4 inch plywood disk. The arms are roughly 11.25 by 3/4 thick. The arms then weigh 4.39 pounds, and their component along the arm is 4.39 sin(90-35) or 3.6 pounds. Each holds one half of the weight of the OTA; 34.3(sin(90-35))/2 or 14.0 pounds. Substituting into equation 6 yields:

$$f = \frac{1}{2\pi}\sqrt{\frac{385.4\,(1.4x\,10^{6})(8.44)}{(14.0 + 3.6/3)20}} \tag{7}$$

which tells us f=616 Hz.

We can calculate the deflection in these rectangles by the simplest model we have:

$$\Delta l = \frac{\vec{F}l}{EA} \tag{8}$$

Then:

$$\Delta l = \frac{(14.0)(20)}{(1.4x\,10^{6})(8.44)} = 23.7x\,10^{-6}\ inch \tag{9}$$

Both of these numbers are the best in their class, but this is a simple example. If we were to have a lighter telescope, one balanced closer to its bottom, and make the mount out of lighter, stiffer, material such as fiberglass or kevlar over foam, the resonant frequency would climb out of sight, while deflection would get smaller.

As I've said many times before, there is no magic. The mount is very well supported, with both axes being supported at both ends. This eliminates the tendency of singly supported structures to become overgrown tuning forks. The polar disk is loaded in compression by one component, which is strongest way to load anything, and the component tending to bend the mount is counteracted by compressing the brace at the declination bearing cutouts.

Looking at the effect of wind, we see that any wind trying to rotate the telescope about the polar axis is pushing against a very large moment of inertia. It doesn't get any better than this. Rotating the telescope about the declination axis pushes against the moment of inertia of these bearings, and these should be as large as practical.

Figure 5 - A commercial split ring, the JMI NGT 12.5

Figure 6 - A small split ring mount, lightened by drilling holes in the truss tubes.

References

1. Berry, Richard, Build Your Own Telescope, 1985, Charles Scribner's Sons, New York, NY

2. Ingalls, Albert G., Editor, Amateur Telescope Making, 1933, 1928, 1926, Scientific American Publishing Co.

3. Avallone, Eugene A., and Baumeister, Theodore, editors, Mark's Standard Handbook for Mechanical Engineers 9th ed., 1987, McGraw-Hill, New York, NY.

4. Albrecht, Richard E., "The Design of Telescope Structures, Part II.", Sky and Telescope Magazine, February, 1989. Sky Publishing Corporation, MA.

5. Porter, R.W., Dr., Giants of Palomar, 1983, 11th printing, California Institute of Technology, CA.

6. Francis, Al, "Al's 12½" Split-Ring Telescope", online at http://www.focuser.com/atm/spltring/spltring.html

7. Another excellent split ring mount, for a 10" mirror online at: http://www.geocities.com/ejjbee/ under the "split ring" frame (select on the left).