Improving Dobsonian Motion

A remarkable new material and a basic understanding of friction can enhance your viewing experience. | **By Martin Lewis**

Among the joys of a good Dobsonian telescope are rock-solid rigidity and ease of use. These traits are so compelling that many visual observers are willing to forgo the advantages of an equatorial mount — particularly for telescopes larger than 8-inch aperture. Regrettably, many Dobsonians do not move as smoothly as they should. Often they are impossible to use at high magnifications because they move in jerky fits and starts. So prevalent is this shortcoming that Dobsonians have begun to acquire the undeserved reputation as instruments unsuited for high-power viewing. This problem, however, is not inherent in the design.

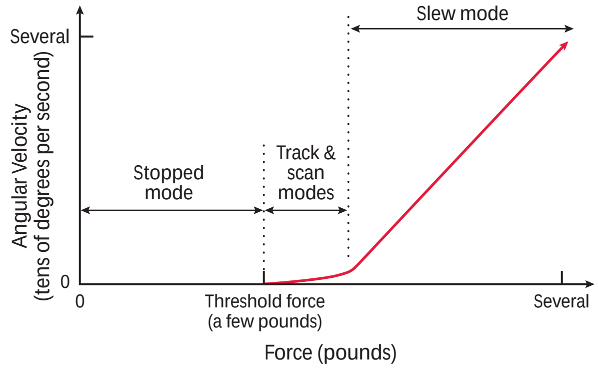
Getting Your Bearings

Dobsonian mounts use simple friction bearings. Pads of a low-friction material support a rotating base in azimuth and two large side rings that rotate in altitude. The bearings hold the telescope in place until you push hard enough to make it move. But this seemingly simple fact involves a number of subtle design issues. The wrong combination of bearing materials can make a telescope move so poorly that it is next to useless.

When a Dobsonian is used to view the sky, four distinct modes of movement can be recognized:

• ***Slewing.*** To aim at an object you swing the telescope through large angles. This motion should be easy and controlled without need for excessive force.

The author and his 18-inch truss-tube Dobsonian reflector, which he has dubbed Fossil Light. The telescope is designed not only for optimum smooth motion but also to break down and fit into the back of his car for travel to dark skies. All photographs courtesy Martin Lewis.



A Dobsonian telescope with ideal bearings would change speed smoothly and predictably as you push it. Below a certain threshold force the telescope would not move at all. Just beyond this threshold force the scope would begin to move very slowly (track and scan modes) and would speed up smoothly (to slew mode) as greater force is applied.

In addition, there should be a strong correlation between the force applied (how hard you push) and the speed the telescope moves.

• ***Scanning.*** You use slower motions to survey extended objects and to center objects in the field of view. For this the telescope should move smoothly at slow speeds. As with slew mode, there should be a predictable relationship between force and velocity. Ideally the movement should have a viscous feel, like moving a spoon through thick syrup. Similar force should provide similar movement in both altitude and azimuth.

• ***Tracking.*** This is the mode you use most of the time. To keep an object centered in view, the telescope must be capable of small and precise movements in altitude and azimuth.

• ***Stopped.*** When the force applied to the tube falls below a certain threshold, the telescope should not move at all. This threshold force should be large enough to prevent the telescope from moving due to breezes or minor imbalance but small enough that neither the tube nor the mount flexes before motion begins.

How well the telescope performs in each mode depends on the friction characteristics of the materials used in the bearings. Many telescope makers concentrate unduly on ease of movement in the slew mode. However, performance in track and scan modes is what really determines how much of a joy or pain the telescope will be.

A problem often encountered when using a Dobsonian telescope with poorly designed bearings is that when you push just hard enough to start motion, the instrument suddenly jumps forward and overshoots. You then try to move the scope back but overshoot in the other direction. Soon the exercise begins to resemble a frustrating game of high-magnification Ping-Pong. Does this sound familiar? Let's find out what is going on.

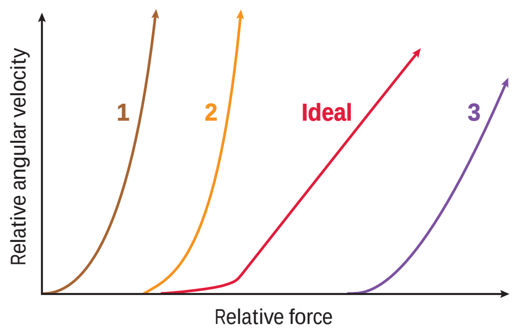
Science Friction

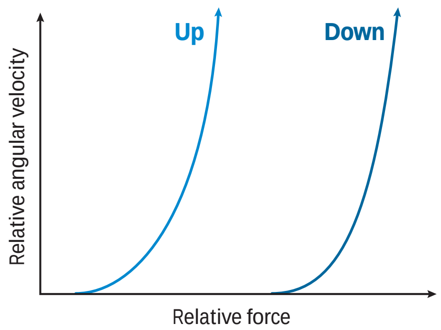
To understand proper Dobsonian movement, it helps to know a few basic terms. Consider a block of weight *W* being pulled across a flat surface from a standstill. Experiments show that the force required to *just start the block moving* (F_s) divided by *W* is a fixed ratio. This ratio is called the *coefficient of static friction*, or f_s. It generally depends on the nature of the two surfaces in contact.

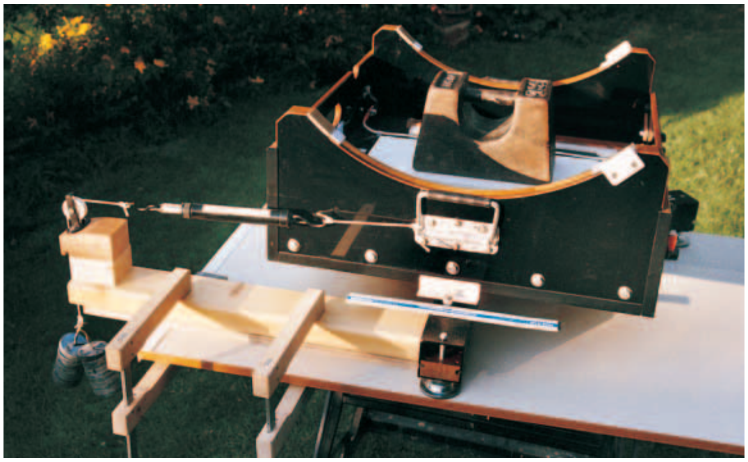
Another fixed ratio is found by dividing the force required to *keep the block moving* (F_D)by *W*. This ratio is called the *coefficient of dynamic friction*, or f_d.

For most common materials, both f_s and f_d are unaffected by the pressure of contact. For these materials, f_d is also independent of the velocity between the surfaces. Most important, however, f_s is always greater than f_d. This simply means that it is easier to keep the block moving than to get it started. *How much* easier is at the root of our problem with jerky motions.

Dobsonian bearings made of common materials will perform poorly even if the materials feel slippery, because the force required to move the scope will be significantly greater than the force necessary to keep it going (f_s is greater than f_d). With f_d being independent of velocity, it will also be hard to control the scope's speed by adjusting the force on the tube. As a result, slow, controlled sweeps will be difficult, and there will also be a sticky







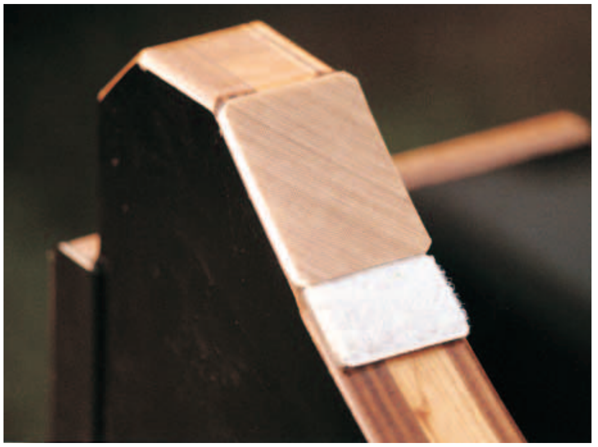
Above left: **Compare the velocity curve for an ideal bearing with: 1, a bearing that moves too easily; 2, a bearing with too much static friction and not enough dynamic friction; and 3, a bearing requiring a great deal of force to move at all.**

Above right: **A common error in Dobsonians is side bearings that are too small. As a rule of thumb, they should be the same diameter as the telescope's primary mirror. Scopes with small bearings are likely to be too sensitive to slight changes in the tube's balance point — resulting in different forces being required to move the scope up or down.**

Left: **With this setup the author was able to precisely measure the frictional characteristics of several bearing materials and verify that Teflon Sheet was superior to ordinary Teflon.**

feel to the scope's movement in fast slew mode.

Ideally, Dobsonian bearing surfaces should have identical values for the coefficients of static and dynamic friction — zero "stiction." Second, at slow speeds the coefficient of friction would ideally increase with speed. A scope with these characteristics would move smoothly off the mark and allow fine adjustments while you track an object. Scanning would also be easy, with speed readily controlled by how hard you push.



One of the altitude bearing pads using Teflon Sheet. Lewis discovered that this low-cost material performs much better than ordinary Teflon. The strip of fuzzy Velcro below acts as a dust wiper to keep the bearing surfaces clean.

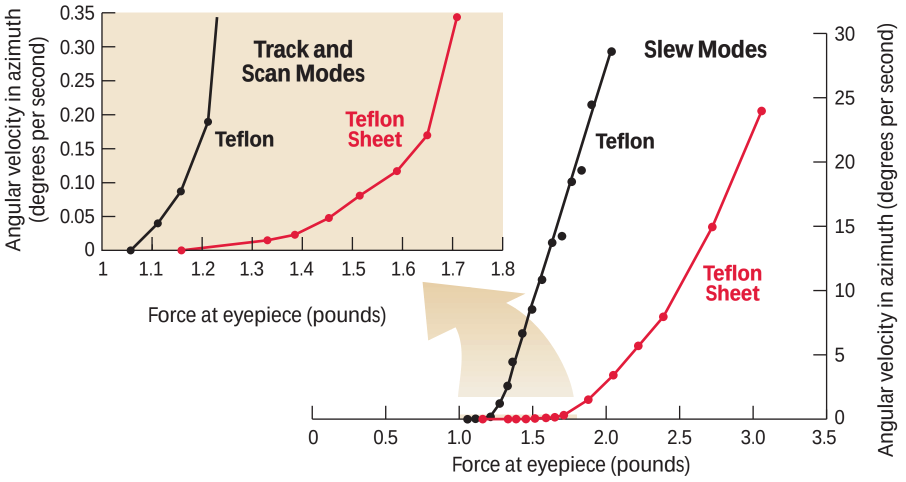
Most Dobsonian telescopes use pads of Teflon (du Pont's trade name for polytetrafluoroethylene plastic) rubbing against some other surface. Teflon has one of the lowest coefficients of friction of any solid, allowing large bearing surfaces to be used (with important gains in scope stability). It is commonly thought that Teflon's low coefficient of friction is its main advantage, but two other properties are just as important. First, Teflon used in contact with a number of other materials has a value of f_s only slightly higher than f_d. Second, the coefficient of friction increases significantly with speed. Thus Teflon comes close to the characteristics of our ideal bearing material.

Better Than Teflon!

I have devoted much time in the last few years to perfecting my 18-inch Dobsonian telescope. I started off by using the recommended combination of Teflon pads running against textured plastic laminate with a finely pebbled gloss (similar to the much-favored Ebony Star Formica). Textured laminates prevent the formation of vacuum pockets that can cause the bearing surfaces to stick.

The completed scope had reasonably good motion with the right threshold force and a good feel in slew. But I still felt there was room for improvement. In the track and scan modes it was somewhat difficult to move the telescope precisely at very slow speeds. In addition, the force required to get the scope moving seemed to depend on how long it had been sitting in one place. This effect was evident even when the scope had been motionless for just a few minutes and was obvious when I moved the instrument for the first time in several days. Apparently the little peaks in the pebbled laminate were sinking slowly into the Teflon.

I decided to experiment with other low-



The author's measurements of the force required to move his scope at various angular speeds for normal Teflon and Teflon Sheet. Note the crucial low-speed region of the curves *(inset)*, which clearly illustrates the superiority of the new material.

friction materials for the bearing pads. First I measured the frictional properties of the original bearings. Next I made similar measurements for other materials to draw comparisons.

After testing several candidates with the apparatus shown on page 129, I found a low-cost bearing material with superior frictional properties. It is also easy to obtain. This new material consists of a thin woven sheet of fiberglass coated with Teflon and has a finely dimpled surface. It is designed as a high-temperature release film for hot presses used for printing on T-shirts and is available in 15-by-15-inch and 16-by-20-inch sheets from several venders, including HIX Corporation (316-231-8568), at $10.50 and $15 a sheet, respectively. In the U.K. it is available from Active Supply (01634 719400). Ask for "Teflon Sheet" when you phone.

The material is quite thin. To keep it from wearing through at high points, I stuck the pieces in place with double-sided foam tape, 0.02 inch thick. I applied this right onto the original Teflon pads. Before doing so, however, I prepared the existing solid Teflon pads so that they accurately matched the curve of the side bearings. This is to ensure that the weight of the telescope is evenly distributed over the entire surface area of the pads and not simply resting on a couple of high spots. I accomplished this by taping sand paper to the faces of the big curved altitude bearings and rocking the scope back and forth to wear the soft Teflon into shape. Once this was done, I affixed the Teflon Sheet pads directly to the shaped pads. The telescope acquired considerably better handling characteristics, particularly in scan and track modes. Testing verified what I could feel!

This improved performance is due mainly to Teflon Sheet's much slower increase in speed with force at low speeds (notice how flat the bottom of the curve is in the graph above). This allows much more precise control over the speed of movement and results in less jerkiness at the eyepiece. With the new bearings it is possible, with care, to move the scope so slowly that a planet can be kept almost stationary in the center of the eyepiece. To do this the scope has to be moved smoothly at a speed of about 0.005° per

The lightweight ground board of the author's Dobsonian features adjustable feet and, of course, bearings using Teflon Sheet. These three pads bear against the bottom of the rocker box, which is faced with a textured Formica.

second — a feat that would have been impossible with plain Teflon bearings.

Both regular Teflon and Teflon Sheet have a similar relationship between the getting-started force and the time that the scope has been motionless. Despite this similarity, however, the difference in the shape of the two curves means that, in normal use, the performance of the Teflon bearings is badly affected by this time dependency, whereas it hardly matters for Teflon Sheet. Why? Imagine observing an object near the celestial equator with an eyepiece having a true field of about 0.5° and a magnification of 100×. In this example, telescope movements of about 0.1° are required every 20 seconds or so to keep the object centered in the field. My experiments showed that after a 20-second wait, the force required to get the scope moving increased to about 1.25 pounds for the Teflon bearings and 1.30 pounds for the Teflon Sheet bearings. However, as the graph on the previous page illustrates, once the scope is moving, these two forces will lead to dramatically different velocities. For the Teflon bearings the speed jumps to about 0.35° per second — way too much — while for the new bearings the value is about 0.015° per second — some 30 times lower!

This dramatic reduction has a huge impact on your ability to track objects at high magnifications. Once the scope moves, the Teflon bearings give you only about 0.3 second to react and stop, but the new bearings allow 6½ seconds, all the time you could want.

The understanding I have gained from studying Dobsonian movement and the frictional characteristics of various bearing materials has enabled me to make significant improvements to my Dobsonian. The Teflon Sheet bearings are almost as simple as the previous plain Teflon ones but have dramatically improved the ease with which I can find and follow objects in the telescope — even at powers as high as 650×. If you have a Dobsonian that doesn't move as well as it should, or if you're planning to build one in the future, give this substance a try.

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