PLANETARY TUNER

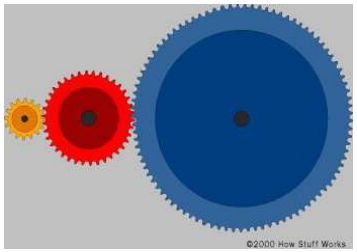
For some time now, I've been wanting to do a short article on "planet" or "planetary" tuners. Generally, they look like this:

			
Here is a 5-Star brand sold by Stew-Mac.	A "Planet" brand tuner.	Gotoh tuner from Japan	Inexpensive Saga brand.

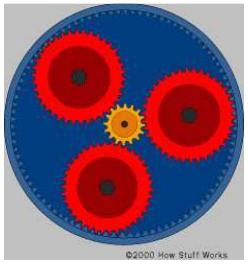
Gee, they look alike! Well, they **are** pretty similar. Many are made in China but to different specifications of material, fit, finish, and quality control. Good tuners are also made in Japan, Germany, and the US.

A planetary gearset refers to small gears that rotate around a central or "sun" gear like the planets. Planetary gearing or Epicyclic gearing is a gear system that consists of one or more outer gears, or planet gears, rotating about a central, or sun gear. Typically, the planet gears are mounted on a movable arm or carrier which itself may rotate relative to the sun gear. Epicyclic gearing systems may also incorporate the use of an outer ring gear or annulus, which meshes with the planet gears (from the Wikipedia), like in banjo tuners.

One specialized gear train is called a planetary gear train. Planetary gears solve the following problem. Let's say you want a gear ratio of 6:1 with the input turning in the same direction as the output. One way to create that ratio is with the following three-gear train:



In this train, the blue gear has six times the diameter of the yellow gear (giving a 6:1 ratio). The size of the red gear is not important because it is just there to reverse the direction of rotation so that the blue and yellow gears turn the same way. However, imagine that you want the axis of the output gear to be the same as that of the input gear. A common place where this same-axis capability is needed is in an electric screwdriver [or banjo tuner]. In that case, you can use a planetary gear system, as shown here:



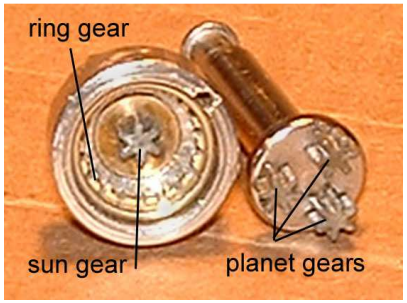
In this gear system, the yellow gear (the sun) engages all three red gears (the planets) simultaneously. All three are attached to a plate (the planet carrier), and they engage the inside of the blue gear (the ring, sometimes called the annulus) instead of the outside. Because there are three red gears instead of one, this gear train is extremely rugged. The output shaft is attached to the blue ring gear, and the planet carrier is held stationary -- this gives the same 6:1 gear ratio.

Another interesting thing about planetary gearsets is that they can produce different gear ratios depending on which gear you use as the input, which gear you use as the output, and which one you hold still. For instance, if the input is the sun gear, and we hold the annular ring gear stationary and attach the output shaft to the planet carrier, we get a different gear ratio. In this case, the planet carrier and planets orbit the sun gear, so instead of the sun gear having to spin six times for the planet carrier

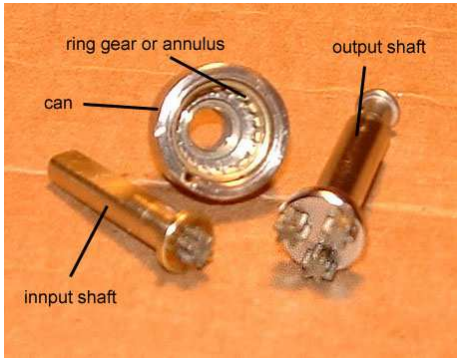
to make it around once, it has to spin seven times. This is because the planet carrier circled the sun gear once in the same direction as it was spinning, subtracting one revolution from the sun gear. So in this case, we get a 7:1 reduction. [From How Stuff Works (http://auto.howstuffworks.com/gear-ratio4.htm)]

OK, lets tear a banjo tuner apart.

Sorry this photo is so crappy. Anyway, on the left is the input shaft (that the plastic button screws on to) and the sun gear, in the center is the stationary ring gear or annulus, and to the right are the 3 planet gears sitting on the planet carrier (which is also the output shaft to the string). A different view:



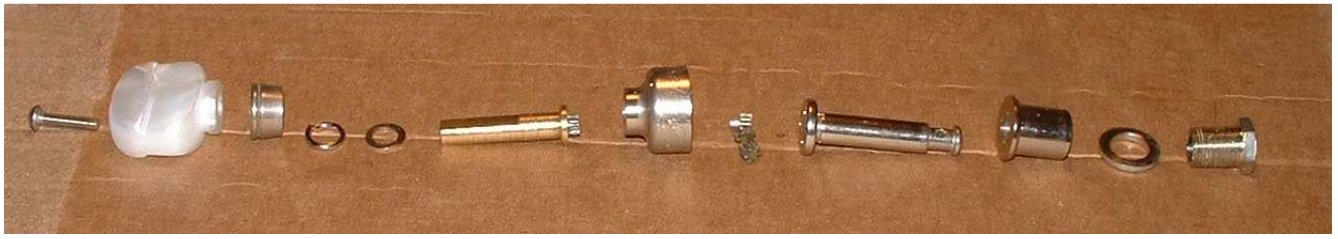
This view shows the input shaft and sun gear in the "can" (I don't know what else to call it). Note also the annular gear with its 20 teeth on the inside of the can. The sun gear, with 6 teeth, is in the center. On the right is the output shaft with the 3 6-tooth planetary gears.



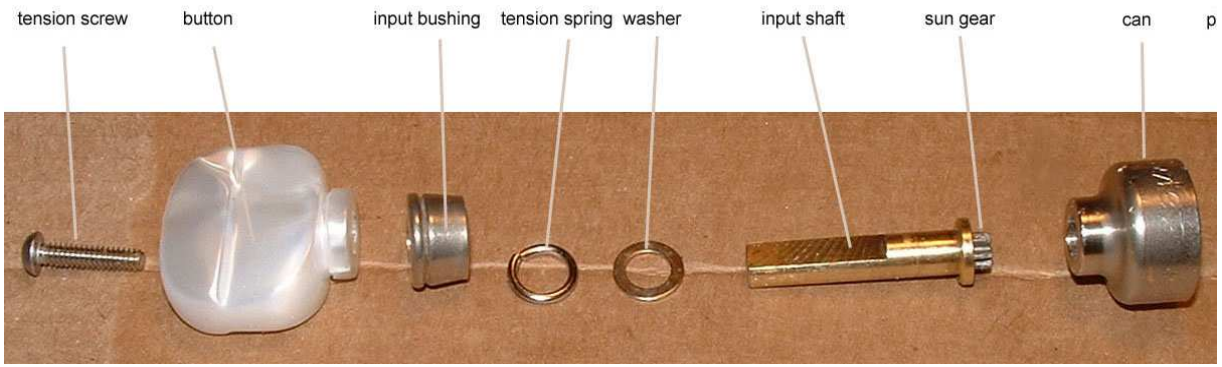
Maybe it isn't clear how the sun and planet gears interact:

OK, here you see the planet gears in place on the carrier/output shaft. The sun gear is inside the triangle formed by the 3 planet gears.

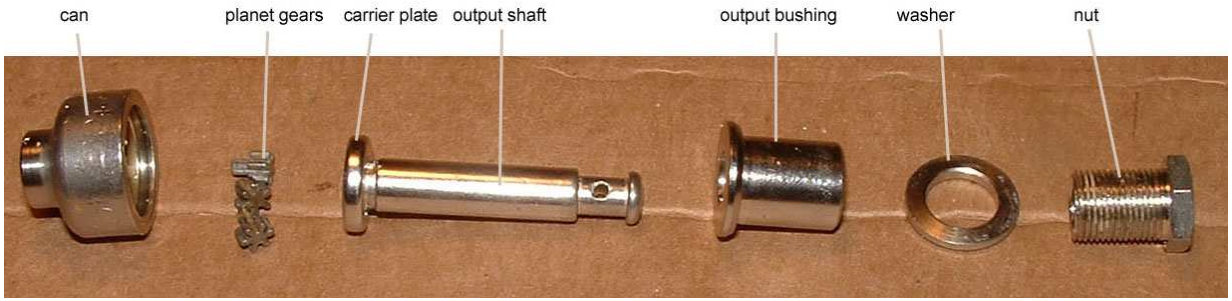
Now, taking everything apart:



In more detail, from the button screw to the planet gears:



And from the planet gears to the output shaft, bushing, washer, and nut:



OK, you get the idea. By the way, the annular ring gear in the can has 20 teeth. If the annulus is held stationary and the sun gear is used as the input, the planet carrier will be the output. The gear ratio in this case will be 1/(1+A/S), or 1/(1+20/6), or 1/4.33.

This example has been cleaned with ethanol and again in an ultrasonic cleaner. The lubricant in the inexpensive Chinese tuners looks to me like ear wax and tends to dry out and harden over time. This is the primary reason that these tuners can freeze or operate stiffly. Usually, a thorough cleaning and repacking with lithium grease will fix them right up. Other failure modes are possible. One one occasion, the sun gear had come loose from the input shaft and could be repaired by soldering it back in place. In another case, the ring gear was rotating in the can. That, too, was repaired by soldering. There isn't much else that can break on these things.

In many cases, the most difficult part is actually getting the tuner apart. There are three types that I have encountered. The most common type has the output bushing press-fitted into the can. Some screw into the can - the little sharpened wire that keeps the can from turning on the peghead also keeps the output bushing from screwing out. In the third type (rare), the output bushing is held in place with a snap ring. The press fit type can be opened by putting the can in a padded vise, placing a snug-fitting mechanic's deep socket over the output bushing, and pulling sideways sharply. It will pop apart. Alternatively, you can put the can vertically in a padded vise and hammer on the input shaft - the force is transmitted from the sun gear platform through the planet gears to the carrier plate and finally to the output bushing. Chances are you will damage the button end of the input shaft so use caution.