**Joseph Fraunhofer: The Father of Modern Astronomy**

When we think of astronomy, we think of this: a person studying the position of the stars with a telescope, but in the mid-1800s until the mid-1900s most astronomy was more like this: studying the image of the different frequencies of stars from a photograph made with a telescope and a diffraction grating or prism. And then in the 1960s to now of course it is mostly done with computers not photographs, but the basic idea of studying the stars by the intensity of the different frequencies of visible and invisible light called spectroscopy remain a staple of modern astronomy. But how what does that have to do with Joseph Fraunhofer who was a glassmaker not an astronomer? Why would a glassmaker invent spectroscopy AND diffraction gratings and become the father of modern astronomy? Let me explain. Ready? Let’s go! [May 1876, Margaret Huggins]

I would like to start in Munich, Bavaria on a Tuesday of July 21, 1801.[[1]](#endnote-1) I picked that momentous day because that was when Joseph Fraunhofer was only 14-years-old and he and his boss’s wife were buried in a collapsed building for several hours. Now you might think this was a terrible event for young Joseph, and I am sure it was traumatic, but it also turned out to be the day that changed his life for the better. Admittedly, his life up to that point had been pretty horrific. He was the youngest of 11 children born to a poor overworked glass maker in a small town of Straubing, Bavaria. Seven of his older brothers and sisters died in childhood from poverty, sickness, and dangerous work conditions. On top of that, his mother died when he was 10 from malnutrition, and his father the following year from the toxic fumes of his work. Orphaned and nearly alone, young Fraunhofer was indentured for 6 years to a decorative glassmaker named Philipp Weichelsberger in far-away Munich. Before his parents died, Fraunhofer wasn’t allowed to go to school much as his father needed his help in a glass workshop and after his parent’s death it was even harder. There was a “holiday school” that would teach young workers to read and write on Sundays and late at night but Weichelsberger wouldn’t let Fraunhofer go and, even at 14, he could barely read. Then, as I said before, in 1801, the building that Joseph Fraunhofer was in collapsed and he and his master’s wife were buried alive. Soon, a large group of volunteers tried to rescue them, and the prince Maximillian Joseph came by regularly to encourage the diggers (mind you at the time, Munich was a pretty sleepy and small town, population around 40,000). After digging for over four hours, they found young Fraunhofer saved by a cross-beam whereas his master’s wife, whose name has been lost to time and sexism, was crushed to death. Fraunhofer’s escape from near death was the talk of the town, and the prince decided that the child was a gift of providence and personally gave the young boy money and made his privy councilor, Joseph Utzschneider, to look out for him from then on.

Fraunhofer used the money to buy his way out of his contract[[2]](#endnote-2) and start an engraving business that went bust in less than six months. Soon, poor Fraunhofer found himself back working for Weichelsberger and miserable. Meanwhile, in 1804, the privy councilor Utzschneider left politics and started a “Mechanical Institute” with a friend, and in 1806, Utzschneider took pity on Fraunhofer and hired him as an assistant at the Institute. At around the same time Utzschneider hired a Swiss glassmaker named Pierre Guinand to make quality lenses for their telescopes at an abandoned Benedictine Monastery[[3]](#endnote-3). Within a year, Guinand asked for a large raise and Utzschneider agreed but with the stipulation that Guinand had to teach all of his secrets to 20-year-old Fraunhofer[[4]](#endnote-4). This partnership did not last long as Fraunhofer and Guinand did not get along. In fact, by 1809, Utzschneider decided that his young protegee was the superior glassmaker and actually paid Guinand a “pension” to go away and not work on glass anymore. He then made Fraunhofer (at just 22 years old) the director of the glassworks and a junior partner of the: “Optical Institute of Utzschneider, Reichenbach and Fraunhofer.[[5]](#endnote-5)” By 1811, Fraunhofer had 48 employees and by 1820, he was made the director of the institute[[6]](#endnote-6).

Meanwhile, Fraunhofer was constantly searching for ways to improve the quality and the precision of his glass. That is why in 1814 or so 27 year old Fraunhofer started to look for light of one color so that he could more accurately measure the refraction (or bending power) of his glass or as he put it “it would be most advantageous if one could measure for every kind of glass the dispersion for every color; but the different colors in the spectrum have no definite limits[[7]](#endnote-7)”. Fraunhofer had noticed a bright yellow-red spot from a lamp when he viewed it through a prism and decided to see if sunlight had the same bright mark that was diffracted in the same way. He therefore shined sunlight through a small opening to get a beam and then through one of his prisms and examined the light with an eyepiece. However, instead of a bright spot at the yellow he saw various dark lines. Shocked, he looked at the light through a telescope and as he put it: “I saw with the telescope an almost countless number of strong and weak vertical lines, which are, however, darker than the rest of the color-image.[[8]](#endnote-8)” Fraunhofer was not the first person to notice shadows in the sunlight. Twelve years before Fraunhofer, in 1802, an English scientist named William Hyde Wollaston spent a long time determining the refractive index of different materials by using a prism. In this paper Wollaston noted 5 dark lines and 2 faint lines in sunlight but only thought they were bands distinguishing four colors “red, yellowish green, blue and violet[[9]](#endnote-9)”. Unlike Wollaston, however, Fraunhofer realized with the addition of the telescope that the lines actually have no relationship to the colors remarking, “the strongest lines do not in any way mark the limits of the various colors; there is almost always the same color on both sides of a line, and the passage from one color into another cannot be noted.[[10]](#endnote-10)” Fraunhofer labeled the thicker lines with letters and counted over 540 lines on a ridiculously detailed colored chart and his labels are still used today!

Fraunhofer wondered if the dark bands were inherent in the sunlight itself or if it was from a trick of the experiment, like from the shape and size of the opening. After various experiments, Fraunhofer thought of studying the light from Venus instead of the sun as he could examine it, “without making the light pass through a small opening[[11]](#endnote-11)” and found, “the same lines as those which appear in sunlight,” with the caveat that some lines were hard to see in the weak light. He then decided to study the even weaker light from some stars and found, to his surprise, that the star Sirius has, “three broad bands which appear to have no connection with those of sunlight” and that various stars seemed to “differ among themselves.” Thus, it seemed pretty conclusive that these bands were in the sunlight or starlight itself and might tell you something about the star. Or as he put it, he was “convinced…that these lines and bands are due to the nature of sunlight.[[12]](#endnote-12)” Fraunhofer then went back to his lamplight and studied it even more carefully with both a prism and a telescope. He found that, “the reddish-yellow bright line of this spectrum consists of two very fine bright lines which in intensity and distance apart are like the two dark lines D. [[13]](#endnote-13)” Fraunhofer didn’t know that the bright lights from his lamp were from burning sodium and the dark lines were from the sodium on the sun absorbing those same frequencies!

Fraunhofer didn’t have much time for study with his very busy business and it was seven years later in 1823, when he managed to publish something significant again. This time, it came from a surprising observation stemming from his previous studies of sunlight. See, Fraunhofer had been experimenting with thin beams of light and noticed that before he added his prism, the image of his beam of light on a screen had colored edges. Fraunhofer was intrigued by the colored edges as it reminded him of the rainbows from light going through a prism and decided to investigate further. He therefore started with light going through a small opening that he could change with a screw and observed the result on a screen with a telescope. He found that there were many dim “rainbows” on the side of the central beam of diminishing intensity. He also found that the position of the “mini-rainbows” was a constant divided by the width of the opening. This, by the way, is why single slit diffraction is often called Fraunhofer diffraction.

Fraunhofer then became irritated with how dark his image through a tiny slit was and had the idea of having multiple slits in a row or a grating to increase how bright his image would be. He came up with an ingenious design for the grating: he wound thick wire between two screws that were only slightly wider than the wire, so that he ended up with 260 parallel wires that were 20 mili-inches thick and only 3.8 mili-inches inches apart[[14]](#endnote-14)! When he conducted the experiment, instead of making the same pattern as a single slit only brighter, he found a whole new system, writing, “I was most surprised to observe the phenomena seen through the telescope when the grating was used were entirely different from those observed by diffraction through a single opening.[[15]](#endnote-15)” He found that the central peak looked “exactly like those seen through a good prism[[16]](#endnote-16)” and even recreated his Fraunhofer lines with his grating! This was a major advance as at the time it was incredibly difficult to make the truly high-quality prism required to see “his” lines. However, it didn’t take the world’s premier glassmaker to make a good grating, and many astronomers used gratings instead of prisms for this very reason.

Joseph Fraunhofer was then appointed a Royal Professor and knighted in 1824. Tragically, less than three years after publishing this paper on gratings, Fraunhofer fell ill from all of his work with lead-and heavy metal based glass (same thing that killed his father) and died when he was just 39 years old. At his funeral, his former mentor Joseph Utzschnieder added an epitath: “Approximavit Sidera” which loosely translates to “He Brought the Stars Closer.” Now Utzchnieder meant that Fraunhofer brought the stars closer with his fantastic telescopes (which you can still buy if you have the cash), but it turned out that his work with the shadows in the sunlight and the bright lines from his lamp would bring the stars closer still. For they were the clues to solving an ancient mystery: what are the stars made of? The story of how we know the composition of the stars is next time on the lightning tamers.

1. The date of the accident and the death of his family members is from “Memoir of the life of Joseph Fraunhofer” found in The Franklin Institute *Journal of the Franklin Institute* **Vol. 8** (1829) Elsevier p. 97 [↑](#endnote-ref-1)
2. Jackson, Myles *Spectrum of Belief* (2000) p. 1-5 [↑](#endnote-ref-2)
3. According to King, H *The History of the Telescope* (2003) p. 177-8 [↑](#endnote-ref-3)
4. The actions of Utzschneider, Guidand and Fraunhofer were found in King, H *The History of the Telescope* (2003) p. 177-9 [↑](#endnote-ref-4)
5. According to Band, J. C. D. *Lines of Light* (2017) [↑](#endnote-ref-5)
6. According to King, H *The History of the Telescope* (2003) p. 186 [↑](#endnote-ref-6)
7. Fraunhofer, J “Determination of the Refractive and the Dispersive power of different kinds of glass, with reference to the perfecting of achromatic telescopes” (1817) found translated in *Prismatic and Diffraction Spectra, Memoirs* (1899) p. 3 [↑](#endnote-ref-7)
8. Fraunhofer, J “Determination of the Refractive and the Dispersive power of different kinds of glass, with reference to the perfecting of achromatic telescopes” (1817) found translated in *Prismatic and Diffraction Spectra, Memoirs* (1899) p. 4 [↑](#endnote-ref-8)
9. Wollaston, W “A Method of examining refractive and dispersive Powers, by prismatic Reflection” (June 24, 1802) *Phil. Trans. R. Soc.* **Vol. 92** p. 378 [↑](#endnote-ref-9)
10. Fraunhofer, J “Determination of the Refractive and the Dispersive power of different kinds of glass, with reference to the perfecting of achromatic telescopes” (1817) found translated in *Prismatic and Diffraction Spectra, Memoirs* (1899) p. 5 [↑](#endnote-ref-10)
11. Fraunhofer, J “Determination of the Refractive and the Dispersive power of different kinds of glass, with reference to the perfecting of achromatic telescopes” (1817) found translated in *Prismatic and Diffraction Spectra, Memoirs* (1899) p. 8 [↑](#endnote-ref-11)
12. Fraunhofer, J “Determination of the Refractive and the Dispersive power of different kinds of glass, with reference to the perfecting of achromatic telescopes” (1817) found translated in *Prismatic and Diffraction Spectra, Memoirs* (1899) p. 8 [↑](#endnote-ref-12)
13. Fraunhofer, J “Determination of the Refractive and the Dispersive power of different kinds of glass, with reference to the perfecting of achromatic telescopes” (1817) found translated in *Prismatic and Diffraction Spectra, Memoirs* (1899) p. 10 [↑](#endnote-ref-13)
14. According to Fraunhofer, J “New Modification of Light” (1823) found translated in *Prismatic and Diffraction Spectra, Memoirs* (1899) p. 22 [↑](#endnote-ref-14)
15. According to Fraunhofer, J “New Modification of Light” (1823) found translated in *Prismatic and Diffraction Spectra, Memoirs* (1899) p. 22 [↑](#endnote-ref-15)
16. According to Fraunhofer, J “New Modification of Light” (1823) found translated in *Prismatic and Diffraction Spectra, Memoirs* (1899) p. 22 [↑](#endnote-ref-16)