WTF Star H-alpha Monitoring and Binary Status Confirmation
An Exercise in Futility and Unexplained Diffuse Phenomena in Data
Diary Entry, Week 2

I have embarked on a quest to confirm whether WTF Star has a faint M-type dwarf companion on its orbit which would help to refine our hypotheses on the nature of this enigmatic object. I assume everybody heard about the WTF star already. My secondary aim is to monitor it in H-alpha and V bands every night throughout one or two months in order to see if there are any previously undetected ionized hydrogen emission outbursts.

The more I set up for this project, the more I realize how Mel was right, and that if Boyajian et al. (2016) said that the companion is "faint" in their AO-enabled mas-grade resolution data from a telescope as advanced as *Keck*, I have rather slim chances of success. I've persuaded Mel to grant this project to me, that "I will get it," but now I begin to doubt my powers.

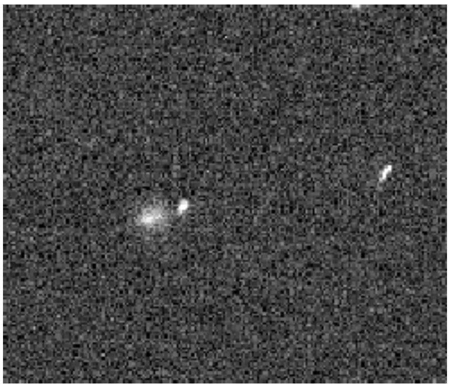
The WTF Star itself is V=11.02 mag star in Cygnus. Boyajian et al. (2016), the authors of the primary review paper on it, estimate its companion to be 3.8 magnitudes fainter in *Keck*'s H-band. If WTF star is H=10.551 mag, the companion is, hence, 14.351 mag, separated 2". Seems to be doable even with an average amateur telescope and CCD equipment, isn't it? I've reached V~21.5 mag via modest exposures here with a 0.25 m telescope in the center of Prague. I've resolved ~0.5" Zeta Boo and globular clusters in a galaxy far away. I can do it!

Not so fast… My main instrument was a 0.8 m Cassegrain in southern Alps in France. The strategy was to make lots of short exposures and do the lucky imaging approach. Well, Light Buckets cancalled my observing plans each night for about a week. It appears they are no longer operating, but they continue to take people's money, so beware! Tech support is silent, and the best I could get is a money refund, without even an excuse. (Don't trust the French!) So I had to use iTelescope's flagship 0.6 m Planewave CDK in Sierra Nevada mountains. In the images coming from it, though, I couldn't even get even a hint of companion's flux, although I've collected about 1 hour of data in 4 nights—it takes much, much more of telescope time to do lots of short exposures than fewer long ones. Another setback is that it appears the Johnsons I filter is not focusing correctly on the 0.6 m. So I am imaging in R while we're trying to understand the problem with Aron.

So why I don't see it? I can see ~17.5 m stars in the images. So I began investigations. I've created a monochromatic stellar flux calculator based on the formula from the Big Orange Book (BOB; Carroll & Ostline 2017). We assume mass-radius power law for MS stars in order to get the radius of the dwarf. Now, the flux of the companion is indeed ~ 2%, as stated, however in R-band, it is ~ 0.5%. I need an infrared telescope! (Yet, Boyajian's team weren't able to clearly image it even through the 3.8 m *UKIRT*.) I've constructed a "double star generator"—a spreadsheet that shows two Gaussian PSFs superimposed. With 0.5% flux ratio, and even with 2%, at FWHMs I get in Sierra Nevada, there's not even a glimpse of PSF asymmetricity. Another problem is that at 2" separation, the peak of the companion is right at the edge of the Gaussian profile of the primary, so it is drowning in starlight.

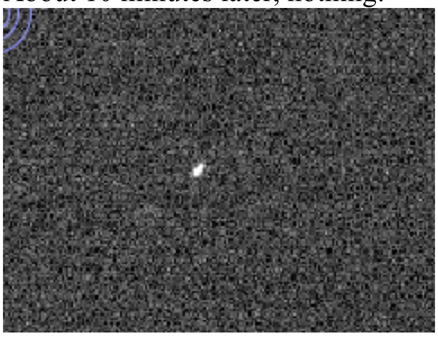
Have I given up? Not yet. I've bought ZWO ASI1600MM-C for my 0.21 m Dall-Kirkham n Prague and Astronomik IR-Pro 642 filter that gives me a widebandpass from about 642 nm and towards the IR end. The flux ratio through this filter should be 1%. If I get enough data, I can fit do some PSF fitting and analyze residuals. My double star generator says that residuals should be about 10% of the sky background on SNR~20-40, and that should be doable with a few hours worth of data. (I've attempted subtracting PSF of a nearby star from the WTF Star itself on the 0.6 m data, however residuals are on the order of the sky background noise—nothing there.) I also continue to gather photons via 0.6 m in R. Eventually, even with 0.5% flux ratio, residuals should appear, if I get SNR good enough.

Meanwhile, I'm doing H-alpha/V ratio monitoring every night on a 0.32 m in Spain via iTelescopes. The data is good, except of very strange diffuse "clouds" that appear in the vicinity of the WTF star. At first I was convinced it was a cosmic ray or a particle shower producing soft imprint, see fully calibrated single frame exposures below.



August 28 02:16:28. My first exposure of the WTF star which is near the center, diffuse object is to the left of it, near the right edge is a cosmic ray.

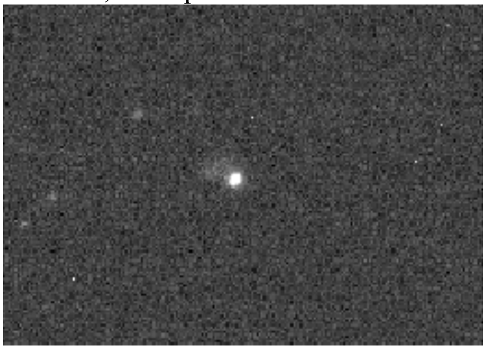
About 10 minutes later, nothing:



August 28 02:25:10.

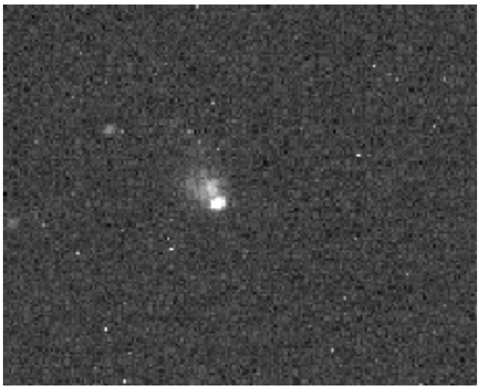
August 29 02:06:24. This is 3 sec exposures, better SNR. This is how WTF star normally appears in H-alpha.

But then, on September 3:



September 3 00:05:03. Diffuse object to the left of the star.

So I began to do 3x H-alpha exposures per night to confirm whether it's an artifact:



September 4 23:11:13.

September 4 23:17:19. Still a glimpse of diffuse emission above sky background level can be seen to the left of the star.

September 4 23:22:57. Back to quiescence.

These are calibrated single stack exposures. I still think I'm dealing with cosmic rays, however, what a coincidence it must be that they continue to appear in a diffuse form and at the same sky coordinate. Perhaps, a speck of dust on the H-alpha filter? But then, star position varies throughout exposures, especially on different nights. A cloud of hydrogen? But if WTF star is the ionization source, at this scale it must be ~ 5,000 AU in diameter, and, thus, couldn't flicker so fast.

Max