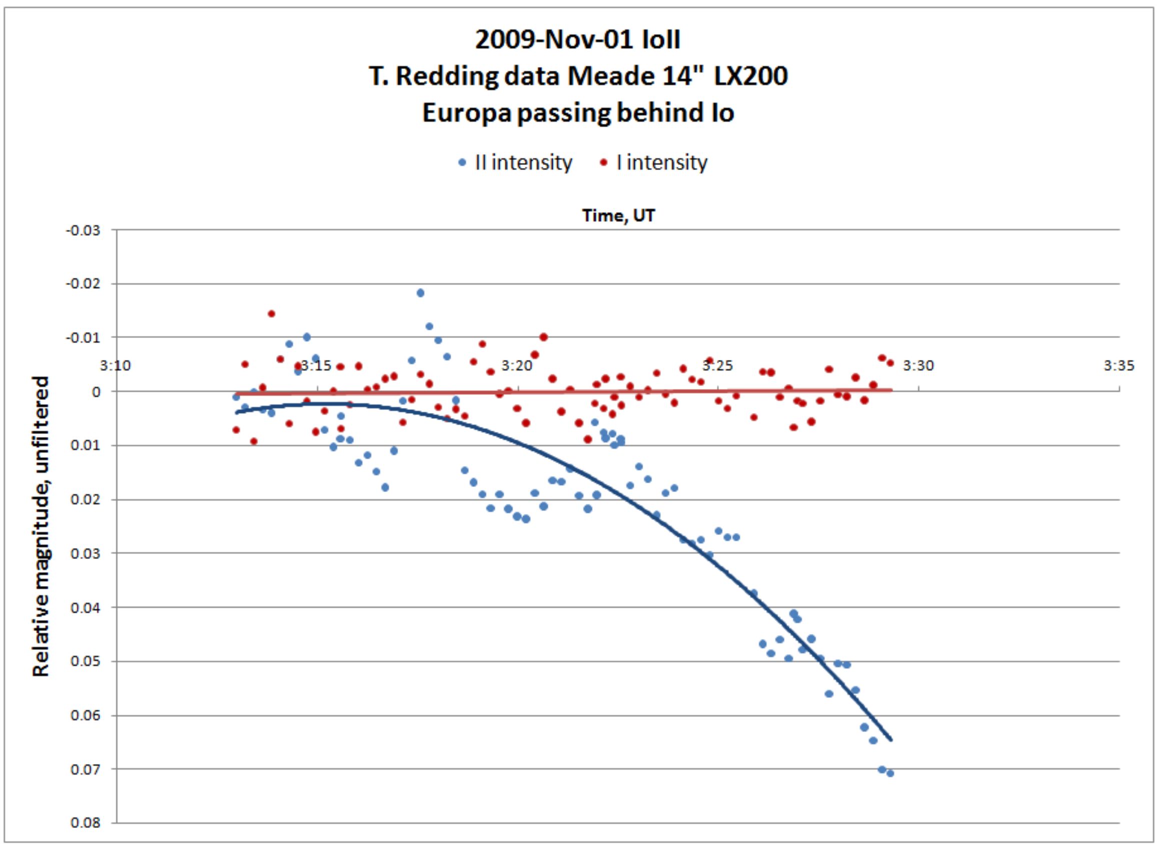
Io Torus JEE Discussion 2014-Mar-08

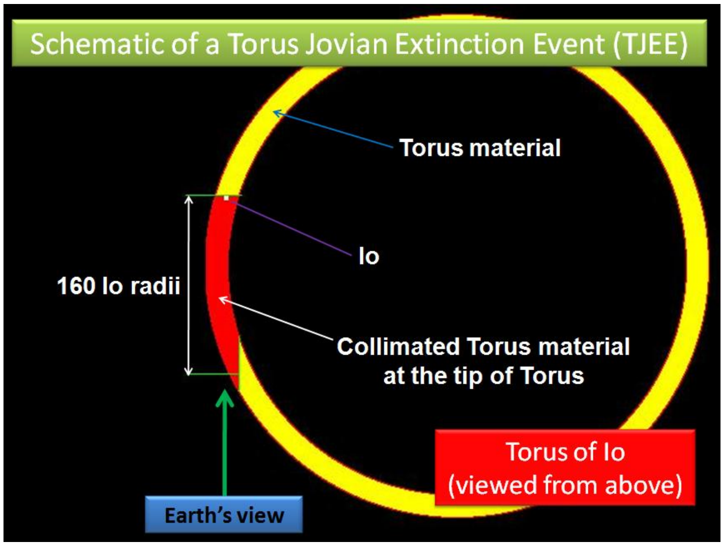
This informal discussion highlights some major breakthroughs in Jovian Extinction Event (JEE) research regarding self extinction of Io via Io Torus Tip Transits as well as confirmation data towards a photon scattering model as the source of JEE in photometric lightcurves involving certain geometrical alignments of the Jovian System.

First a little history background behind Io Torus JEE. By the end of Jovian Mutual Event (JME) season of PHEMU2009 (which ended January of 2010) the observing group I had assembled of about a dozen observers from 5 countries had successfully documented two dozen lightcurves depicting JEE dimming surrounding occultations during JME, mainly involving Io being the body in front causing the dimming (and we had a few Europa in front JEE data). So many doubters insisted that the dimming found in our lightcurves in the wing data outside the occultations were merely an artifact induced in the CCD imaging device caused by two merging intensity sources during the occultation. We easily dismissed that by doing a number of experiments, but separate photometry on the two merging moons showed that only the moon that was behind a known debris was the source of the dimming in that lightcurve (here is one of several such examples of 2009-Nov-01).

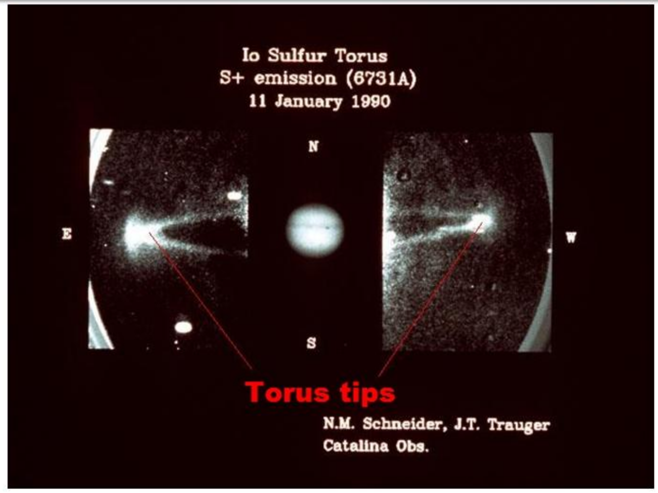


No one seemed to pay attention to the many examples of reductions we did to demonstrate that the dimming in our JEE lightcurves were consistently found to be the moon in back suffering extinction of its reflected sunlight whenever the geometry was such that a moon in front provided material to scatter the light of the moon behind it line of sight. It occurred to me that since the material that surrounds Io as a tenuous atmosphere remains bound to Io for only a short period of time after which it migrates away, only to have some of it bound in the Io Torus Ring, this Torus should be extinctive. Furthermore, after digging up one of Nick Schneider's paper on Io and the Torus I saw an actual image of the Torus Ring taken in sulfur light and I instantly noticed a fortuitous scenario that I predicted might provide additional JEE measurements of the Io debris. I began telling everyone that out at the tips of the Torus ring the material there is collimated line of sight to an observer on earth. If that material was indeed extinctive to light passing through

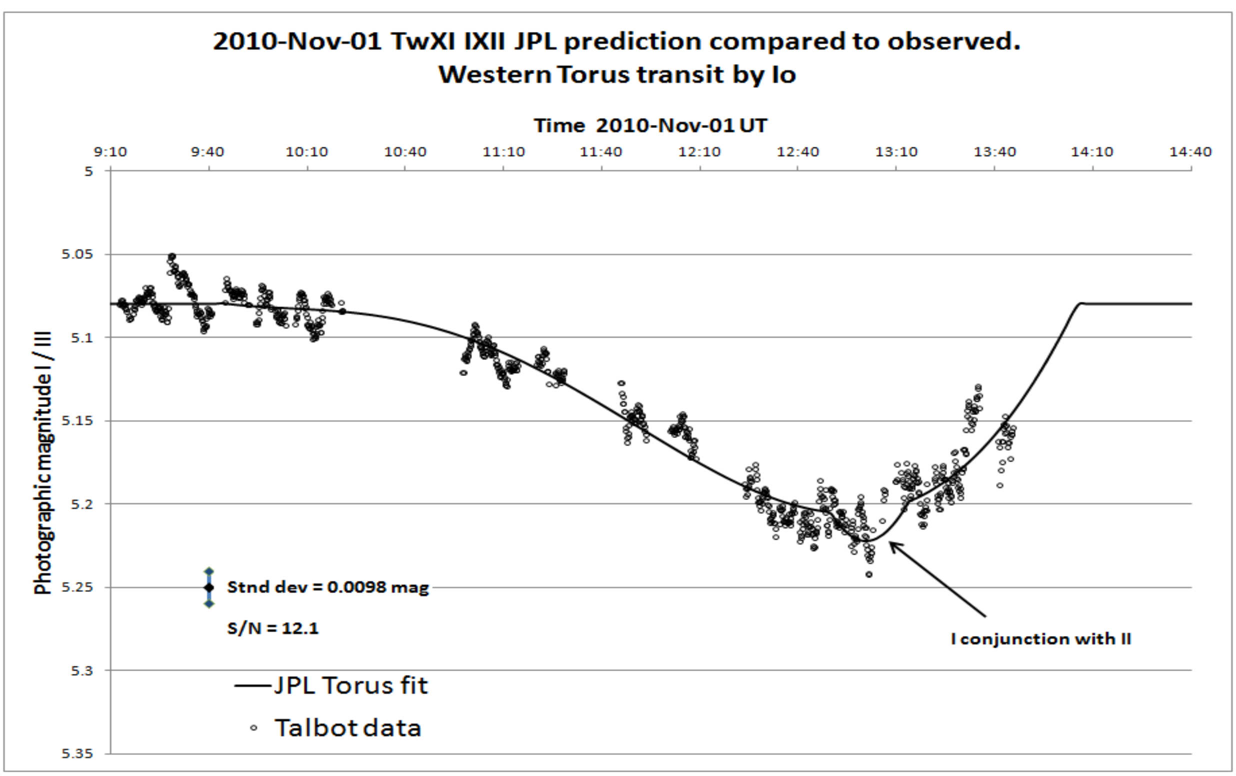
Io's atmosphere then it should also cause Io to dim through self extinction via its Torus debris as Io transited the eastern and western Torus Tips behind this collimated debris.



Io's eastern and western Torus tips appear more dense due to an optical geometry where the Torus material is collimated to our line of sight.



In April of 2010 I began painfully manually measuring this Schneider et. Al 1990 Torus image to create a crude model of debris distribution and then using Guide 8 and Orion's Starry Night planetarium software I generated best guestimates of when the onset of dimming, minima, and end of dimming might potentially occur for a Torus Tip transit of Io. The only real problem in acquiring data was that Io takes more than 5 hours to transit the tip. Throughout 2010 we got only snippets of Io Torus JEE data. It wasn't until Nov 1, 2010 before John Talbot would take the time to record as much of one of my predicted windows of opportunity before we would see validation of my theory that the debris from Io trapped in the Torus was extinctive just like it was surrounding Io providing an independent Io atmopshere JEE validation. Also, the beauty of the Torus Tip JEE is you remove one of the two light sources that everyone claimed was causing the artifact represented in a JEE lightcurve. There are no merging intensities, just pure dimming of Io as it travels deeper behind its own debris, and brightening as it emerges from behind this debris.



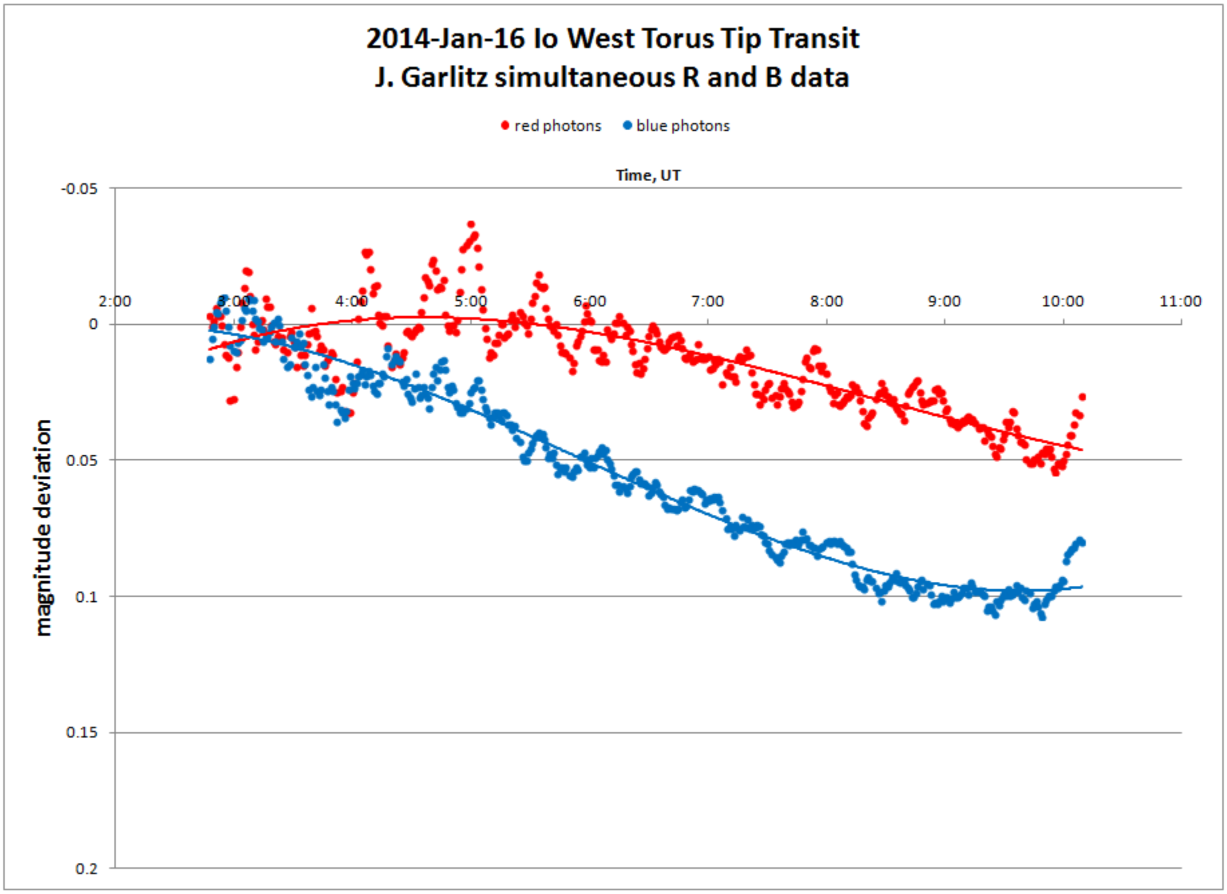
Fast forward to the October 2013 Io Workshop where I would try to discuss the Torus measurements with Dr. Schneider himself. I would soon learn a new concept that I never knew about the Torus…. It wobbles! Nick brought this to my attention and even gave reference to a movie created by the Cassini data that demonstrates this (Torus wobble video: http://lasp.colorado.edu/cassini/images/316mov1.mov). This made me realize how fortuitous Talbot had that night that he got such good data. He just happened to observe on one of those nights when the Torus was in sync with Io so that Io was inside the debris field. This would actually explain some past observations where an observer complained that they did not get anything close to what Talbot's data suggested as a model, and in some cases an observer got flat nothing.

After the 2013 Io Workshop I decided to more aggressively go after data that might finally reveal the mechanism that causes our JEE data. While always being curious as to the cause, my prime initiative had always simply been to get extinction data to further develop models of the extinctive portion of the atmosphere's of Io and Europa as well as the Torus of Io. I learned at the Workshop sources of information that could clue me in on the measured particle sizes and distributions as detected by passing probes. These particles range from 10nm to 1000nm. Around Europa the average size detected was 600nm. What this meant to me was some longer visible wavelength photons may be large enough to not even interact with these particles, while UV and blue photons would be smaller than the average particle sizes detected and would have more frequent interactions that if even slightly redirected would cause the photon to scatter enough to not reach an observer on earth.

Having this basic scattering model in hand on Dec 4, 2013 I put out a call to JEE observers for anyone with color filter capability to observe all future JEE in R and B simultaneously if they were capable of that. Joe Garlitz had submitted a few data sets of Europa JEE events from November 2013 he took in only an R filter, and they curiously showed no extinction even though they should have. I looked back at a few other past filtered JEE events and those that observed in R or Methane, all long wavelengths, had very poor if any dimming detected. This further strengthened my scatter theory that longer wavelength light is simply not bothered by the smaller particles. After the Dec 4th call for R and B photometry Joe Garlitz responded saying he was quite capable of recording in both simultaneously. In January 2014 Joe automated his equipment to take many hours of data surrounding Torus Tip Transit JEE windows of opportunity. This data unequivocally goes great lengths to validate:

- Blue photons suffer greater scattering than red photons by virtue of the known particle sizes become larger than blue wavelengths.
- Past PHEMU JME Campaigns were strongly recommended to be observed with R or even I filters, and since R and I filters exclude B and UV photons from detection, and since B and UV are where the scatter in JEE is likely occurring, JEE has gone unnoticed for decades due to non-sampling of light shorter than R.
- Garltiz's January 16 (deep extinction), 17 (no extinction), and 23 (moderate extinction), 2014 Io Torus Tip Transit lightcurves (you will get to see these below) correlate well to Schneider's assertion that Io is not always in the Torus debris. So one would expect different transits to show varying degrees of extinction while others would show none at all.
- Using the Jan 2014 data sets from Garlitz and the known orbital periods of Jupiter and Io one could potentially create a prediction algorithm that would tell you future geometries favorable for Torus JEE measurements.
- One side note of an emerging observation is zebra patterns tend to abound in R data but not in B data. More on that in future papers…

Here is the 2014-Jan-16 R and B lightcurve from J. Garlitz which clearly demonstrates the R photons do not suffer the same extinction or scatter effects as the B:



Working with the Jan 16th event as an optimal alignment of the Torus and Io I set out to predict future Io Torus JEE events. I started by using very basic first order assumptions. Io orbits Jupiter every 1.769138 days. Using a basic formula for a sine wave predicting future Io-Jupiter-elongations:

I = A sin(wt)

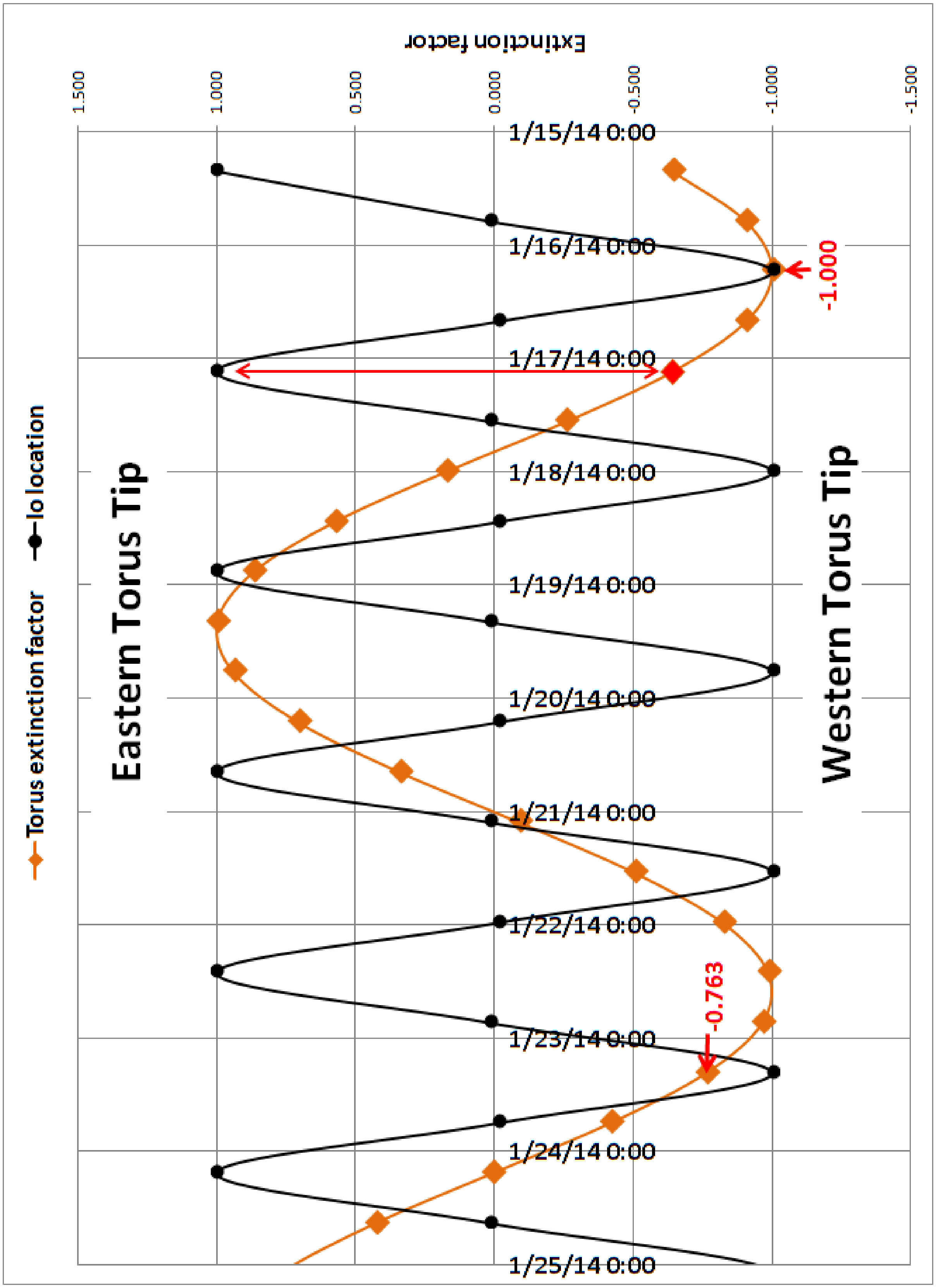
Where:

- I = the phase of Io's east-west position relative to Jupiter at a given time. -1 = West elongation, +1 = East elongation.
- A = maximum intensity = 1 (actually representing phase more than intensity for this purpose)
- W = frequency in days for Io's orbit = 1.769138 days
- T = time UT, which I used decimal calendar days of elapsed time

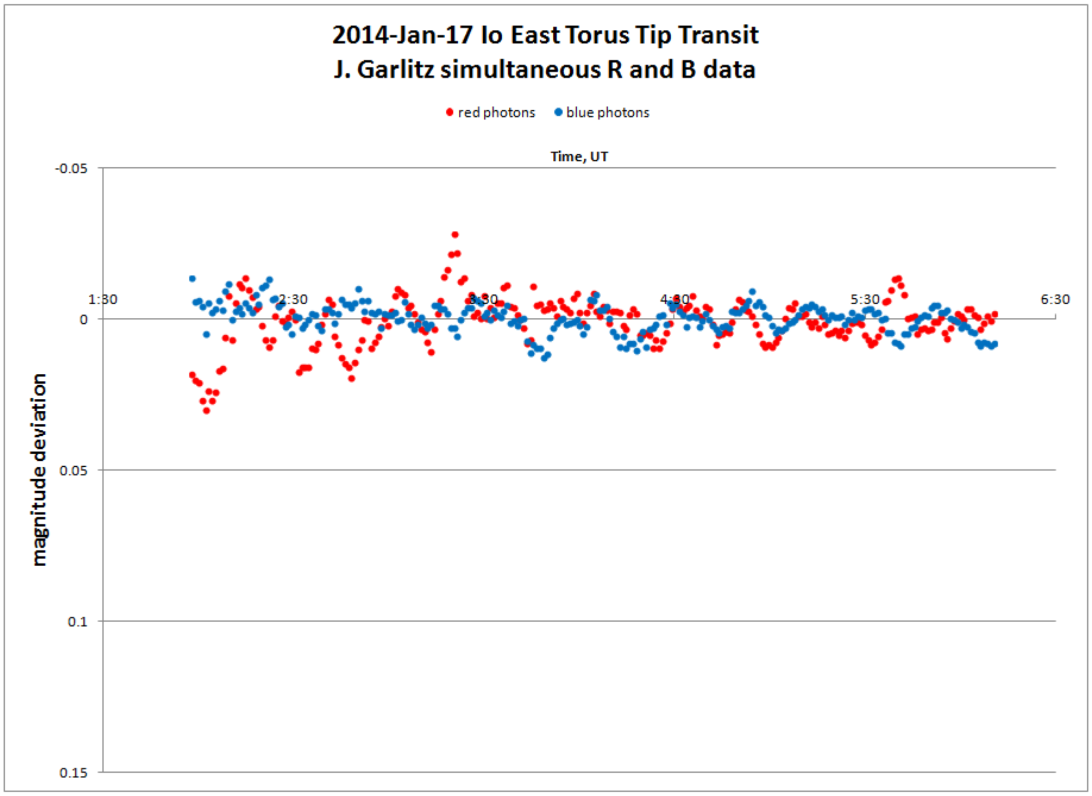
According to a thesis I read by Andrew Joseph Steffi ("***The Io Plasma Torus During the Cassini Encounter with Jupiter: Temporal, Radial and Azimuthal Variations***", 2002) the Torus is sort of "pinned" to a specific longitude of Jupiter's magnetosphere. Since Jupiter rotates every 9.925 hours I then created a second sine wave representing the Torus material where:

- I = first order scaled intensity factor of the peak intensity extinction caused by Torus debris.
- A = 1 for peak intensity scaling factor
- W = 0.41354 days (9.925 hours) period of Jupiter's rotation.
- T = same time UT for a given phase position of Io.

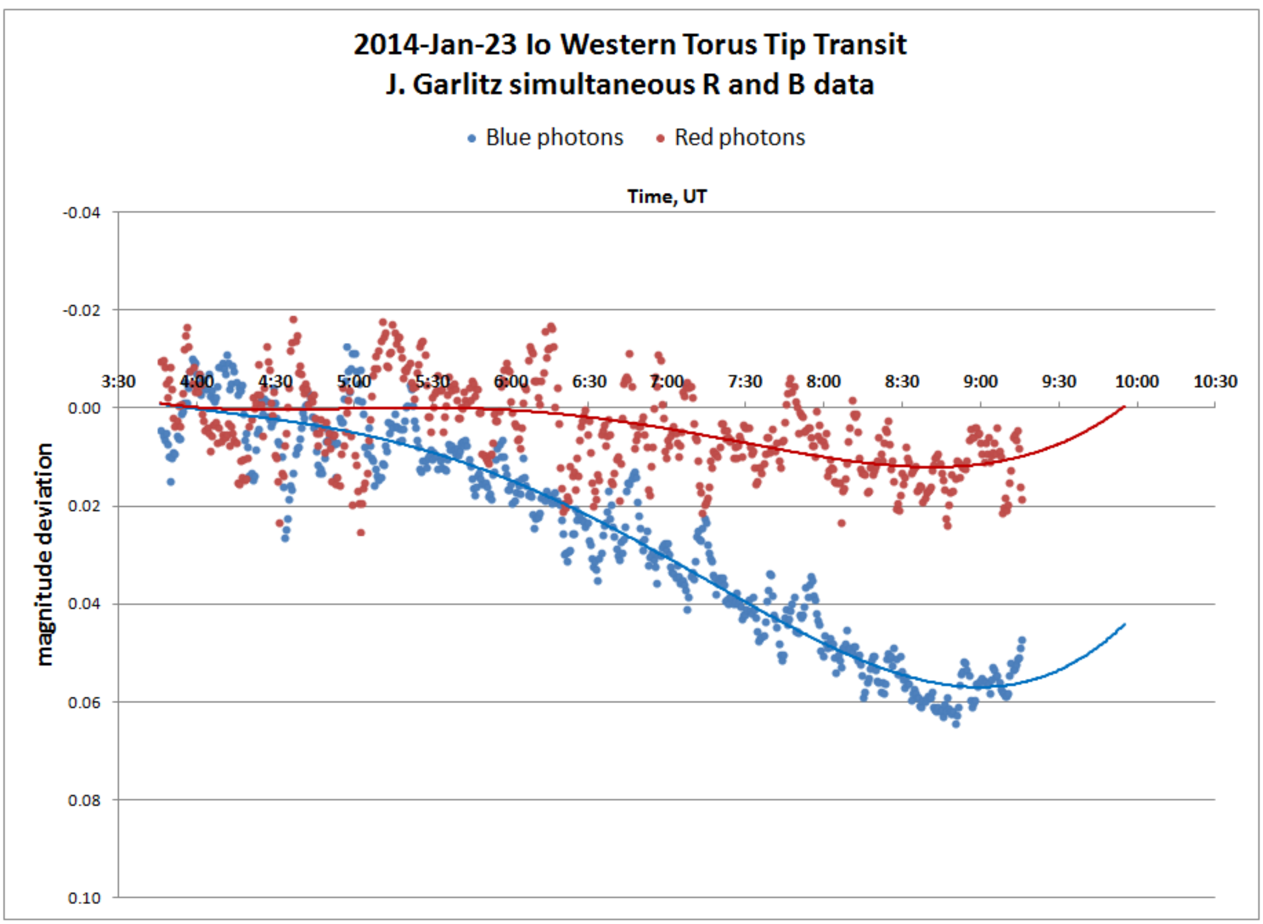
I plotted Io's phase position relative to Jupiter and then tweaked the Torus maximum optimal extinction factor of 1 to correlate with Jan 16, 2014 5:37 UT when Io was at greatest Western elongation to match the Garlitz data from that day. The resulting plot looks like this which I then used to predict future Torus JEE data:



According to this first order Torus debris prediction plot of the very next day's Jan 17, 2014 East Torus Tip transit JEE Io was "out of phase" so to speak with the dense part of the Torus debris and Io would not be inside the Torus material to create any detectable JEE dimming. Looking at Joe Garlitz data from that period I find my prediction was spot on displaying a flat line for R and B photons:



Going further into the future of the Torus debris prediction tool I find that the Jan 23rd 2014 8 hour UT West Torus Tip Transit is back "in phase" with the Torus debris, but not 100% in phase. So according to that plot above it predicts the Jan 23rd JEE extinction would not be as deep as the Jan 16th 2014 Torus Tip JEE. And indeed we see the Jan 23rd 2014 Garlitz data to display just that:



Conclusions:

1. We now demonstrate a potential scattering model showing that particle sizes in the Jovian System are small enough to interact with short wavelength visible light but not scattering as efficiently longer wavelength photons. It is my contention that the reason JEE has gone unnoticed for decades of Jovian photometry is due to historical observations predominantly in R and I wavelengths and the occasional V, excluding B and UV photons.
2. By the end of 2014 we will have multicolor data that should completely wrap up validation of all our model theories. Future instructions for JEE observing are:
   a. If you have the capability to image in two different wavelengths please do so in a long one such as R or I, and your second color be a short one such as B or UV.
   b. If you can only image in a single wavelength please do so in a short wavelength such as B or UV so that you are assured an extinction measurement to go towards our models.
   c. If you do not have filter capability there is no problem with doing unfiltered observations as these will still sample the shorter wavelengths.
3. We show that the debris in the Torus of Io is extinctive under the right geometries to Io as it transits the Torus Tip while being inside the Torus debris. This extinction independently validates this debris is extinctive and one would expect the same scattering mechanics to occur to light passing through the atmosphere of Io.
4. We present a first order predictions tool that once refined could predict when Io is in phase with the Torus of Io to predict extinction events. This could further enhance our knowledge of the Torus of Io without having to park a probe around Jupiter as these Torus Tip transits occur every single day.
5. Given the validity the above data lends to the JEE phenomenon it would behoove the professional community to enter into a observational collaboration for 2014 and 2015 as the JEE season is deep in JME PHEMU2015 because the orbits of the moons of Jupiter goes edge on giving rise to multiple fortuitous geometries enabling many measurements of all four major moon potential atmospheres and Torus debris through JEE.

Best of regards!

Scotty

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