Solar Eclipse Spectroscopy Specifications

Robert B Slobins

Revision 1.1   3 November 2020

1.0. Introduction and Summary.

This document presents my procedures for imaging the chromospheric ("flash") and coronal spectra during a total solar eclipse. The reader is referred to other books, papers and articles for background information.

The cover image of the December 1970 issue of Applied Optics tells the story of a total solar eclipse. The image's creator used a Hasselblad 6cm X 6cm film camera with a suitable telephoto lens in front of which a diffraction grating was mounted. He made exposures of the eclipse and the spectra on either side of the eclipse at the moments of second and third contacts and during totality, each exposure to its own frame. After viewing the flash spectrum visually in 1972 and then later reading the magazine, I made attempts in 1973 and 1979.

My first success at imaging the changing spectrum was at the 4-second annular eclipse of 1984 in South Carolina, when I imaged the red hydrogen-alpha (Hα) line at 6563 Angstroms (656.3 nm). My first successful spectrum images occurred with the 1988 total solar eclipse from Penyak, Bangka Island, Indonesia. Since then, I have acquired spectra at all of the following 14 total solar eclipses I have attended except for the one in Chongqing, China in 2009, when air pollution greatly attenuated the sunlight by an approximate factor of 8, although I may work on the scanned film images to tease out some results.

In 2010, I worked with Dr Miloslav Druckmüller and he made spectra with a donated diffraction grating filter. The effort produced excellent details of the photospheric absorption spectrum with chromospheric emission lines because he used a 300mm lens whose field of view excluded the eclipse.

The purpose of this paper is to describe my procedures on how to tell the total solar eclipse physics story showing the eclipse and the spectrum together. If one wants better detail and is not interested in imaging the solar corona, he can use a longer lens as was done in 2010, but that will require much better tracking. However, the procedures here can provide a guide on how to accomplish that. To view the film scans of spectra from 1984-2006, please go to www.flashspectrum.com.

The 2019 eclipse turned out to be especially important. The sun is still in a prolonged and deep minimum, although sunspots from new cycle 25 have started to appear. My images show the strong red coronal line at 6376 A and a much weaker green coronal line at 5304 A. The red line at 6376 A is weaker than the green line at 5303 because we are at the minimum of the sunspot cycle, with a somewhat cooler corona; it is the opposite with the green line (circle) more prominent than the red one nearer the maximum of the sunspot cycle.

The green line is the result of stripping 13 of iron's 26 electrons in the inner corona. This ion is designated Fe XIV for 13-times ionized iron (the ground state is Fe I). These iron atoms need to be accelerated to energies (temperatures) of 2.2 million kelvins. As electrons return to the iron atoms, they emit this particular green light. The red line indicates the loss of 9 electrons from iron atoms; the ion is designated Fe X. Ionizing iron 9 times requires temperatures of only 1 million kelvins.

Usually, the sun is active enough to create more Fe XIV ions and we say that the solar corona's temperature is 2.2 million degrees. Actually, the spectra show where such energy exists to ionize iron that much. There are cooler regions where one can observe Fe X ions. In 2019, the Fe X line was much more prominent than the Fe XIV line, indicating very low solar activity.

There are a few other coronal spectral lines of in the visible spectrum, but they are rather inconspicuous.

Therefore, these 'pretty pictures' now take on some importance. It would be interesting to compare the relative intensities between these two lines over time (and the sunspot cycle) and the purpose of this paper is to ensure that this time series indefinitely continue.

2.0. Equipment

Generally, one needs to have the best equipment available within budget. Fortunately, there is plenty of used gear. It is not really necessary to use the latest versions.

2.1. Camera body

Either an FX or DX format camera body is acceptable, provided that the resolution is sufficient. It would be best to use the highest resolution CMOS or CCD sensors because the exposures required are going to be short, unlike what is needed for imaging deep-sky objects.

One needs to look at the burst rate: the higher, the better. One has to choose between burst rate and sensor resolution: cameras needed for action tend to be low resolution. Also, consider buffer space and the read rate of the CF or SD card.

Fred Bruenjes and Xavier Jubier have written software to control camera equipment for the Windows and Mac OS X operating systems respectively. It is strongly recommended that one uses those camera bodies the software supports: generally Canon and Nikon. If one is using the Nikon DX bodies, the D7100 and D7200 are recommended, especially for video work.

The memory card is also important. The highest possible write rate is the best. I use SanDisk Extreme Pro CF cards for the Nikon D800 bodies and comparable SD cards for the DX bodies.

It is also necessary to have a remote cable release attached to the body. Even if one is using computer controller software, this cable release will be available in case of failure of the more complex controller system, including connections.

Ensure that the camera body is set to manual exposure mode, never automatic. The camera controller can vary the lens opening, shutter speed and ISO. Also, make sure that there is no exposure bias; that setting must be zero and that the images produced will be RAW. (Nikon 14-bit lossless compressed is acceptable.)

One may use an Hα modified camera body. Using a full-spectrum body is not recommended because the differing orders of spectra will overlap each other. One needs to test prior to the eclipse, especially when using finer-ruled diffraction grating.

2.2. Camera lens

This is a daylight subject. Even a kit zoom lens can work. Diffraction grating filters degrade the zero-order image (the primary subject which is the eclipse. The spectrum and the emission lines most important. The zoom lens allows for flexibility in composition.

One must consider the field of view for the format used. If one is using an FX format camera, then he can use up to 180 mm to include the eclipse and the spectrum. The DX format would need a lens 1.5 times shorter: in this case 120 mm. A shorter focal length will better allow for positioning errors. In my experience, a 135 mm lens for the FX format would suffice. This assumes placement of the sun and spectrum across the frame's diagonal.

If one does not care to include the eclipse in the frame, he can use a longer focal length. Miloslav Druckmüller did well with a 300 mm and the FX format. However, he had the camera and lens mounted on a motor drive.

Most current lenses can be set by controls on the camera body. If one uses a fully manual lens from the days of film, then the lens diaphragm must be pre-set to the chosen f-stop and taped at that setting. The only controls available in this case will be the shutter speed and ISO.

2.3. Diffraction grating.

A diffraction grating produces the spectrum. It is used as a filter in front of the lens.

The moon creates the equivalent of a spectroscope's slit and this is what enables us to observe and record the solar spectrum. With a 300 mm lens in the FX format, we can even record the solar absorption spectrum in the continuum before second and after third contact.

Diffraction-grating special effects filters can be found in camera stores' used equipment. An example is the Cokin 040 filter in 'A' size. These filters are ruled at about 250 lines/mm by my calculation and although low dispersion, they will present an adequate eclipse and spectrum image with 135-180 mm focal lengths with the FX format.

Commonly available plastic gratings are ruled between 500-600 lines/mm and although great for distinguishing lines, it will require shorter focal lengths to accommodate. I advise using a polar-aligned motor drive in this case, allowing plenty of time for set-up and foregoing including the solar eclipse unless one wants to sacrifice detail for an artistic image.

It is acceptable to use a diffraction grating that produces multiple spectra around the eclipse. It may produce an interesting image, but one will have to test the exposure well before the eclipse.

2.4. Solar filter and safety.

Direct sunlight focused on your unprotected eye's retina is damaging enough. If the sunlight is amplified by a magnifier like a telephoto lens or telescope, the damage to your eye will happen much quicker.

Therefore, to avoid blindness, it is absolutely necessary to use a metallized Mylar film filter that is designed to reduce the sunlight intensity by 100,000 times. It must protect against infrared and ultraviolet light as well as visible light. There are suppliers of this solar filter material. This filter must be attached to the front of the attached diffraction grating which is attached to the lens.

You meet safety requirements your way. This is what I do:

Solar filters that screw securely onto camera lenses–Use an old lens UV protection filter and remove the glass and the retaining ring. Make cardboard rings to fit the filter. The rings can be 1 cm wide with the outer diameter the same as the filter's, which will be enough for attaching the filter material. Then lay the filter material on the table.

Cover one side of the cardboard ring with double-stick tape and drop the adhesive side onto the filter material. Cut away the ring and trim the excess. Repeat the procedure unless you know that only one layer of filter material suffices. You now have two filter pieces.

Then use double-stick tape on one of these pieces and affix the other piece on the taped one. Apply the tape to the filter side and affix the other piece's filter side so that the cardboard ring faces out. Then trim the filter as needed so that it snugly fits into the filter ring from the outside, then if feasible, replace the filter's retaining ring. Otherwise, tape the filter securely with duct or electrical tape and trim the excess. Place the filter into a protective case. Make several copies of this filter so that you have enough backups.

This way, a screw-in solar filter enables one to view, focus and compose safely the image. The other safety component is a heavy dark fabric from ½ to 1 meter square. See the procedure below for use.

2.5. Tripod and mount.

The quality of tripod and mount is critical.

One has a choice of either fixed or driven mount in this case. The driven mount for telescopes is harder to carry and set up and there is the task of polar alignment. The fixed mount can be more stable because if not using a drive and heavy enough, one can make images by hand.

It is possible to image the spectrum hand-held and I did that from a plane at 39000 feet in 2015. However, the ISO had to be increased from a normal 200-400 to 1600 and higher to accommodate that focal length. The longest shutter speed needs to be < 1/400 second in order to minimize effects from shaking and 1/1000 and less would have the best chance of a somewhat sharp image at the cost of excessive noise. Clearly, a solid mount on the ground is optimal.

I advise using a solid well-made mount of the Gitzo or Manfrotto class. For fixed mounts, I use Bogen heads, and there are used Bogen 3047 and 3057 3-way pan heads available. Ball and gimbal heads are not accurate enough in altitude or azimuth. It is best to use quick-release heads and plates.

In any case, I would calculate the weight of camera and lens and use a mount rated for at least twice that weight and a tripod rated for at least twice the weight for camera, lens, and head or mount.

Having a portable mount like a Star Adventurer and can limit the camera weight to about 5 pounds or 2.3 kilograms would work. If properly aligned, one has the convenience of not needing to position the camera in anticipation of the sun and moon's location during totality.

The tripod should have a bubble level installed or bring several bubble levels along to ensure polar alignment and tracking or having the frame in position so that the eclipse will be in the correct location, a corner, during totality.

2.6. Computer controls.

I recommend using a computer to control the equipment. Xavier Jubier's Solar Eclipse Maestro is a great choice. However, it runs only on the Mac OS X operating system. Apple has modified later versions of OS X that cause malfunctioning, so Sierra and Mojave are the only versions to use, though Jubier is updating his software. Solar Eclipse Maestro is compatible with Garmin 18-X GPS pucks that one can plug into the computer and SEM will set up the timetable for the eclipse based on the data from this GPS receiver and run the script (an example is in the appendix). See http://xjubier.free.fr/en/site_pages/solar_eclipses/Solar_Eclipse_Maestro_Photography_Software.html

A backup to the GPS is a handheld unit. One can enter the coordinates and altitude and set the time manually. There will be human error introduced, but the sequence for the flash spectrum would still start in time to catch the event.

Windows 10 users will need to use Fred Bruenjes' Eclipse Orchestrator. I have no experience with this software, but it appears to function similarly to SEM.

I recommend attaching an electronic cable release to the camera and holding it or making sure it is within reach in the event this automated system fails. In the event the cable release fails, then it will be necessary to trigger the shutter manually and hope the assembly does not vibrate too much. I have found it better to use a pen or pencil instead of a finger.

Controlling the camera with either program requires a script. Appendix has an example of the 2012 eclipse script, which would be suitable because the duration of totality over South America compares to what was observed in northeast Australia.

2.7. Manual controls.

If a computer is or becomes unavailable, one must operate the camera manually. Have a hand-held GPS and two countdown electric timers with fresh batteries. Have the time of second and third contacts ready. Attach a cable or remote release on the camera body.

3.0. Procedure

I recommend creating a parts inventory or packing list with details on the items' locations, especially after rehearsals are completed. This will also function as an inventory for customs officials for international trips.

I strongly recommend testing all assemblies independently and together set up as a system, then rehearsing your particular procedure many times, anticipating problems and learning to respond automatically to different situations. As soon as you have defined your workflow, create a checklist to follow during rehearsals and especially at the eclipse site.

3.1. Camera and lens assembly.

Attach the lens to the camera. Before doing this, I set the shutter to a long exposure of at least 15 seconds or bulb, hold the camera without the lens attached and release button down and use a manual blower like a Giotto (never canned air!) to blow dust off the sensor and the surrounding area. Then lay the camera body face down and blow the dust off the lens' rear element. Then quickly attach the lens to the camera body with the lens mount facing down.

Do not remove the lens from the camera body after that. It is best to do this task inside especially if it is windy.

Remove any UV or haze filters protecting the lens' front element. Screw or mount the clean diffraction grating to the front of the lens.

Screw or otherwise secure the metallized solar filter in front of the diffraction grating. This filter will protect the camera and your eyes.

Have the heavy dark cloths available and, if necessary on a windy day, enough electrical or duct tape to secure the cloths on the assembly as a shroud.

3.2. Mounting.

If one has a motorized equatorial mount head, attach it to the leveled tripod, check the leveling and polar align the head. Then attach the camera and lens assembly to the head.

If one is using a fixed tripod, first secure the quick release plate to the bottom of the camera (or lens ring mount in the case of a longer or heavier zoom or prime lens). That can be done before eclipse day, preferably 24 hours before.

I would use a square to ensure that the lens is aligned with the mount. The less error, the better.

The next step is attaching USB cables and the electronic cable release. Then secure the camera and lens on the head.

3.3. Connecting.

The camera body is then connected to the computer. The computer is then turned on and the program is run.

3.4. Location.

The location should be on centerline or, at least on the line of maximum totality. The line of maximum totality is not necessarily the centerline because of the irregularities on the lunar limb. However, that all depends on the track's width.

If the track is narrow, like that of the eclipse of 1995, locate on centerline.

Locating on centerline is where the points of second and third contact are diametrically opposite each other. This lets one orient the grating parallel to the second and third contact crescents.

3.5. Composition.

The spectrum, with or without the eclipsed sun, should be oriented across the frame's diagonal. If possible, print out a star chart from a planetarium program that projects the frame for your format and focal length on the sky. With that information, determine the altitude and azimuth of the center and the tilt required to place the spectrum and if desired, the sun in the corner at mid eclipse. Allow for enough space to keep the target or targets in the frame in the event a fixed tripod is used.

The earth rotates through 1 degree every four minutes. Assume that the sun's and moon's diameter is ½ degree. A driven mount will not require this additional work, but one should be able to orient the spectrum or eclipse and spectrum across a diagonal if possible for the largest possible image scale.

The grating must be oriented on the lens so that the lines are parallel to the second and third contact crescents. This will create the best presentation of the flash spectrum. Orientation is not critical to viewing the coronal spectrum. As soon as an acceptable presentation is acquired, tape the grating to the lens to secure the orientation.

Xavier Jubier's eclipse website http://xjubier.free.fr/en/index_en.html and interactive maps provide the orientation of the contacts in clock format, for a particular location on the eclipse track. In the case of the 2020 December 14 eclipse, http://xjubier.free.fr/en/site_pages/solar_eclipses/TSE_20201214_pg01.html these points are at 3:00 and 9:00 for South America, so the grating lines would be perpendicular to the horizon. The bottom long side of the frame would be tilted 33.7 degrees clockwise to place the eclipse in the upper right corner or bottom left corner.

The preferred orientation would have the eclipse in the upper right corner. This would allow one to time the checkpoints of the eclipse moving across the fixed frame: tangent to the left side, mid frame and the vertical distance from the bottom of the frame.

Use printed star maps to determine the checkpoints and make several copies to be used on-site. I use SkyMap Pro for this purpose—it allows one to plot checkpoints of the eclipse across the frame. One can select the frame and include an altitude-azimuth grid. This works well for fixed-mount setups. See Appendix D for examples from the 2019 eclipse.

Within, say 6 minutes of totality (second contact), make the final composition adjustment allowing for Earth's rotation so that the spectrum and/or eclipse and spectrum remain comfortably in the frame especially if one is using a fixed mount. When satisfied, remove the filter and immediately place a heavy black cloth in front of the lens. That cloth is removed at about 30 seconds before second contact and replaced within 30 seconds of third contact.

Alternatively and better, move the camera off the eclipse immediately after the moon starts to uncover the sun—best at or after 10 seconds after third contact.

3.6. Exposures.

The guideline is that the first-order spectrum is about 6 to 7 stops fainter than the zero-order image, the target.

A good basic guideline for eclipse imaging is on Fred Espenak's website www.mreclipse.com. We are exposing for prominences. The lens is set to f/4, ISO set to 200. The exposure in his table for the prominences is extrapolated to 1/8000 second.

The shutter speed for 6 stops fainter objects is 1/125 second, for 7 stops fainter, 1/60 second. My images in nice, clear skies at elevations of 5 000 – 6 000 feet are at 1/50 second.

The solar corona has two layers. The first is the K-corona, formed by light scattered by free electrons: those stripped off those iron and other atoms. This K-corona is most of what we see during totality. Solar magnetic fields determine the shape of the K-corona as streamers and plumes.

The F-corona is dust. We can see it on clear nights before dawn and after sunset; it is the zodiacal light. At midnight, we can see sunlight reflecting off this dust beyond Earth, this is gegenschein. It is reddish in color but extremely faint.

Both the K and F coronas emit a continuous spectrum. However, the region within 1/10-1/5 solar radius is where atoms are heated to millions of kelvins and thus multiple-times ionized. As these ions lose energy by quantum steps, their electrons emit light in particular wavelengths. This is what interests us.

In my experience, the best exposures are f/4, ISO 200 and 1/15 to 1/8 second. My better exposures from 2017 and 2019 are 1/8 second.

These times will vary because of clouds, haze, other aerosols and pollution. Altitude helps with transparency. In Chongqing, China, my exposures were about three times underexposed because of the haze and especially the pollution that made the daylight sunlight intensity about 12.5 to 25% of that on Mars.

I strongly advise testing exposures. The first test is shooting the moon, preferably the crescent moon at exposures ranging from 1/4000 to 1 second in one-stop steps. This can even be done in half or third stop steps. Find where the sunlit lunar surface is best exposed and note the shutter time. Then find the best rendering of the spectrum: all colors are distinct and the spectrum, continuous. Then calculate the stops or full steps between the best lunar image and the best spectrum.

In this and all tests, make sure that the spectrum is widest. That is when the lines in the grating are parallel to the crescent. This will help get you in the habit of proper orientation.

Now test an emission spectrum. The most convenient examples are found in mercury and sodium vapor lamps. Make the same series of exposures as for the moon. Pick the best rendition of the bulb and/or filament (light source) and then pick the best rendition of the emission lines which are monochromatic or pure color reproductions of the light source. Other test targets are neon or other colored signs on businesses (not LED's), but try to use single color light sources and isolate a single letter or feature. Otherwise one may get very confused with a mess of colorful lines.

In any case, this practice will create familiarity with spectra.

If one wants to do a video of the spectrum, he has to understand that each exposure can be no longer than 1/30 second. My initial flash spectrum exposure is f/5.6, 1/50 second at ISO 400. This is one stop darker than for the stills. You could use the same exposure as for the stills above.

For the corona, the same exposure time and f-stop apply. The ISO has to vary. From five seconds after second contact to five seconds before third, set the exposure time from 1/50 to 1/30 second and increase (decrease) ISO from 400 to 640 and 800, varying the ISO by 1/3 stop to ISO 1600 and back to 800 as many times as totality time allows. Make sure that the ISO goes to 400 and the exposure time goes back to 1/50 second for third contact.

Appendix A is an example of the script I used with Solar Eclipse Maestro. Please note that one needs to use Nikon D7100, D7200, D7500 and D800-class bodies. D3000- and D5000- class bodies are not supported for movies. I do not use other brands and cannot make any statements about them for video.

3.7. Manual Operation.

Set the image exposure for the flash spectrum as determined in Section 3.6. Knowing the exact moment of contact, set one the countdown timers to something like 45 minutes to an hour before second contact and watch the time pass. Turn on the timer as quickly as possible at that moment. Do likewise with the other timer at third contact.

Position yourself behind the viewfinder or screen with the shroud still over at least the lens. At 30 seconds before second contact, get behind the screen and watch the spectrum diminish. At 9 to 10 seconds before second contact, press the electronic release with the camera set to a sequence or cadence of 2 per second or alternatively manually press the shutter at about 2 shots/second. Continue until 10 seconds after second contact.

Then increase the exposure to capture the solar corona. This should be nothing more than increasing shutter speed. I would use an exposure of 1/8 second at ISO 200 or even 1/30 second at ISO 800. Meanwhile, the second timer, counting down to third contact is running. Just space the coronal spectra images about 2 to 3 seconds apart.

When the timer comes to 20-30 seconds to third contact, stop imaging the coronal spectrum and reduce the exposure to the flash spectrum value. At ten seconds to third contact, press the electronic release just as you did for second contact and at 10-20 seconds after third contact, move the camera and lens off the eclipse for safety.

3.8. Checklists and preparations.

A solar-eclipse is a one-shot event. We cannot reverse the moon’s motion.

Therefore, I strongly recommend writing and following a checklist. Appendix C is the checklist I created for the 2019 total solar eclipse. At that eclipse I set up five workstations, one for each specific experiment or activity. Also include any preliminary tasks like fully charging batteries and a packing list to follow, so that nothing is left behind.

Writing the checklist will help you focus on organizing your own work. Please feel free to modify the material in Appendix C to suit your purposes.

Also, make sure that you carry backup material: tools, tape, batteries and chargers, memory cards, extra filters, cables, timers and even an extra camera body and lens as the case may be. In case of loss, damage or failure, this will better assure success.   Budget for any additional baggage fees if air travel is involved.

Appendix A
2012 SEM script

This Solar Eclipse Maestro (SEM) script is from the 2012 total solar eclipse. This provides a sequence for a 126-second (2 minutes, 6 seconds) totality that closely matches the maximum duration of this eclipse in South America and includes solar corona imaging. This can be adjusted for currently supported cameras. Some newer models and memory cards may allow for more images in a given unit of time. Please refer to Xavier Jubier's documentation.

It is important to rehearse the script you design. Rehearsal needs to be done with the lens uncovered and the grating on. Make sure the recording mode is RAW. Audit each actual image against the script to make sure each image is taken as specified and that no image is lost.

```
# Solar Eclipse Maestro #  SEM Script EAST  Signed off for 3 cameras 5/11/2012 06:55
#########################
#Action,Date/Ref,Offset Sign,Time Offset,Camera,Exposure,Aperture,ISO,MLU/Burst
Number,Quality,Size,Incremental,Comment
#signed off 0557 4/11/2012

PLAY,C2,-,00:10:00.1,10_Minutes.wav, , , , , , , ,'10 minutes' voice prompt
PLAY,C2,-,00:05:00.1,5_Minutes.wav, , , , , , , ,'5 minutes' voice prompt
PLAY,C2,-,00:02:00.1,2_Minutes.wav, , , , , , , ,'2 minutes' voice prompt
PLAY,C2,-,00:01:00.1,60_Seconds.wav, , , , , , , ,'1 minute' voice prompt
PLAY,C2,-,00:00:30.1,30_Seconds.wav, , , , , , , ,'30 seconds' voice prompt
PLAY,C2,-,00:00:20.1,Filters_Off.wav, , , , , , , ,'Filters off' voice prompt
PLAY,C2,-,00:00:10.1,10_Seconds.wav, , , , , , , ,'10 seconds' voice prompt
PLAY,MAX,-,00:00:00.1,Max_Eclipse.wav, , , , , , , ,'Maximum eclipse' voice prompt

PLAY,C3,-,00:01:00.1,60_Seconds.wav, , , , , , , ,'1 minute' voice prompt
PLAY,C3,-,00:00:30.1,30_Seconds.wav, , , , , , , ,'30 seconds' voice prompt
PLAY,C3,-,00:00:10.1,10_Seconds.wav, , , , , , , ,'10 seconds' voice prompt
PLAY,C3,+,00:00:19.9,Filters_On.wav, , , , , , , ,'Filters on' voice prompt

CHGCROP,C2,-,00:03:00.0,D700, , ,0, , , , ,FX Crop
CHGBIT,C2,-,00:02:59.0,D700, , ,14, , , , ,Switch to 14-bit

TAKEPIC,C2,-,00:03.2,D700,1/2000,5.6,200,0.000,RAW,None,Y,C2-2 seconds
TAKEPIC,C2,-,00:00.0,D700,1/2000,5.6,200,0.000,RAW,None,Y,C2
TAKEPIC,C2,+,00:03.2,D700,1/2000,5.6,200,0.000,RAW,None,Y,C2+2 seconds
TAKEPIC,C2,+,00:07.3,D700,1/1000,5.6,200,0.000,RAW,None,Y,C2+5 seconds
TAKEPIC,C2,+,00:09.3,D700,1/500,5.6,200,0.000,RAW,None,Y,C2+6 seconds
TAKEPIC,C2,+,00:11.3,D700,1/250,5.6,200,0.000,RAW,None,Y,C2+7 seconds
TAKEPIC,C2,+,00:13.3,D700,1/125,5.6,200,0.000,RAW,None,Y,C2+11 seconds
TAKEPIC,C2,+,00:16.3,D700,1/60,5.6,200,0.000,RAW,None,N,C2+14 seconds
TAKEPIC,C2,+,00:20.3,D700,1/30,5.6,200,1.000,RAW,None,Y,C2+20 seconds
TAKEPIC,C2,+,00:24.3,D700,1/15,5.6,200,1.000,RAW,None,Y,C2+26 seconds
TAKEPIC,C2,+,00:28.3,D700,1/15,5.6,200,1.000,RAW,None,Y,C2+29 seconds
TAKEPIC,C2,+,00:32.3,D700,1/8,5.6,200,1.000,RAW,None,Y,C2+32 seconds
TAKEPIC,C2,+,00:36.3,D700,1/8,5.6,200,1.000,RAW,None,Y,C2+36 seconds
TAKEPIC,C2,+,00:40.3,D700,1/4,5.6,200,1.000,RAW,None,Y,C2+40 seconds
TAKEPIC,C2,+,00:44.3,D700,1/4,5.6,200,1.000,RAW,None,Y,C2+44 seconds
TAKEPIC,C2,+,00:48.3,D700,1/2,5.6,200,1.000,RAW,None,Y,C2+48 seconds
TAKEPIC,C2,+,00:52.3,D700,1/2,5.6,200,1.000,RAW,None,Y,C2+52 seconds
TAKEPIC,C2,+,00:56.3,D700,1,5.6,200,1.000,RAW,None,Y,C2+56 seconds

TAKEPIC,MAX,-,00:00.0,D700,1/1000,5.6,200,0.000,RAW,None,N,MAX reference
```

```
TAKEPIC,C3,-,00:54.3,D700,1/2,5.6,1600,1.000,RAW,None,N,earthshine
TAKEPIC,C3,-,00:50.3,D700,1/2,5.6,1600,1.000,RAW,None,Y,earthshine
TAKEPIC,C3,-,00:46.3,D700,1,5.6,200,1.000,RAW,None,N,C3-56 seconds
TAKEPIC,C3,-,00:42.3,D700,1,5.6,200,1.000,RAW,None,Y,C3-52 seconds
TAKEPIC,C3,-,00:38.3,D700,1/2,5.6,200,1.000,RAW,None,Y,C3-48 seconds
TAKEPIC,C3,-,00:34.3,D700,1/4,5.6,200,1.000,RAW,None,Y,C3-40 seconds
TAKEPIC,C3,-,00:30.3,D700,1/8,5.6,200,1.000,RAW,None,Y,C3-36 seconds
TAKEPIC,C3,-,00:26.3,D700,1/15,5.6,200,1.000,RAW,None,Y,C3-32 seconds
TAKEPIC,C3,-,00:22.3,D700,1/30,5.6,200,1.000,RAW,None,Y,C3-28 seconds
TAKEPIC,C3,-,00:18.3,D700,1/60,5.6,200,1.000,RAW,None,Y,C3-24 seconds
TAKEPIC,C3,-,00:14.3,D700,1/125,5.6,200,0.000,RAW,None,Y,C3-20 seconds
TAKEPIC,C3,-,00:12.3,D700,1/250,5.6,200,0.000,RAW,None,Y,C3-17 seconds
TAKEPIC,C3,-,00:09.3,D700,1/500,5.6,200,0.000,RAW,None,Y,C3-15 seconds
TAKEPIC,C3,-,00:06.3,D700,1/1000,5.6,200,0.000,RAW,None,Y,C3-13 seconds
TAKEPIC,C3,-,00:02.5,D700,1/2000,5.6,200,0.000,RAW,None,Y,C3-4 seconds
TAKEPIC,C3,-,00:00.0,D700,1/2000,5.6,200,0.000,RAW,None,Y,C3
TAKEPIC,C3,+,00:02.5,D700,1/2000,5.6,200,0.000,RAW,None,Y,C3+4 seconds
```

```
# Canon 5D 300/2.8  Coronal Script EAST
# Signed off 4/11/2012  06:21

TAKEPIC,C2,-,00:03.0,5D,1/2000,4.0,200,0.000,RAW,None,N,C2-2 seconds
TAKEPIC,C2,-,00:00.0,5D,1/2000,4.0,200,0.000,RAW,None,Y,C2
TAKEPIC,C2,+,00:03.0,5D,1/2000,4.0,200,0.000,RAW,None,Y,C2+2 seconds
TAKEPIC,C2,+,00:07.2,5D,1/1000,4.0,200,0.000,RAW,None,Y,C2+5 seconds
TAKEPIC,C2,+,00:09.2,5D,1/500,4.0,200,0.000,RAW,None,Y,C2+6 seconds
TAKEPIC,C2,+,00:11.2,5D,1/250,4.0,200,0.000,RAW,None,Y,C2+7 seconds
TAKEPIC,C2,+,00:13.2,5D,1/125,4.0,200,0.000,RAW,None,Y,C2+9 seconds
TAKEPIC,C2,+,00:16.2,5D,1/60,4.0,200,0.000,RAW,None,Y,C2+14 seconds
TAKEPIC,C2,+,00:19.6,5D,1/30,4.0,200,0.000,RAW,None,Y,C2+20 seconds
TAKEPIC,C2,+,00:23.6,5D,1/15,4.0,200,0.000,RAW,None,Y,C2+26 seconds
TAKEPIC,C2,+,00:27.6,5D,1/15,4.0,200,0.000,RAW,None,Y,C2+29 seconds
TAKEPIC,C2,+,00:31.6,5D,1/8,4.0,200,0.000,RAW,None,Y,C2+32 seconds
TAKEPIC,C2,+,00:35.6,5D,1/8,4.0,200,0.000,RAW,None,Y,C2+36 seconds
TAKEPIC,C2,+,00:39.6,5D,1/4,4.0,200,0.000,RAW,None,Y,C2+40 seconds
TAKEPIC,C2,+,00:43.6,5D,1/4,4.0,200,0.000,RAW,None,Y,C2+44 seconds
TAKEPIC,C2,+,00:47.6,5D,1/2,4.0,200,0.000,RAW,None,Y,C2+48 seconds
TAKEPIC,C2,+,00:51.6,5D,1/2,4.0,200,0.000,RAW,None,Y,C2+52 seconds
TAKEPIC,C2,+,00:55.6,5D,1,4.0,200,0.000,RAW,None,Y,C2+56 seconds

TAKEPIC,MAX,-,00:00.0,5D,1/1000,4.0,200,0.000,RAW,None,N,MAX reference
TAKEPIC,C3,-,00:54.6,5D,1/2,4.0,1600,0.000,RAW,None,N,earthshine
TAKEPIC,C3,-,00:50.6,5D,1/2,4.0,1600,0.000,RAW,None,Y,earthshine
TAKEPIC,C3,-,00:46.6,5D,1,4.0,200,0.000,RAW,None,N,C3-56 seconds
TAKEPIC,C3,-,00:42.6,5D,1,4.0,200,0.000,RAW,None,Y,C3-52 seconds
TAKEPIC,C3,-,00:38.6,5D,1/2,4.0,200,0.000,RAW,None,Y,C3-48 seconds
TAKEPIC,C3,-,00:34.6,5D,1/4,4.0,200,0.000,RAW,None,Y,C3-40 seconds
TAKEPIC,C3,-,00:30.6,5D,1/8,4.0,200,0.000,RAW,None,Y,C3-36 seconds
TAKEPIC,C3,-,00:26.6,5D,1/15,4.0,200,0.000,RAW,None,Y,C3-32 seconds
TAKEPIC,C3,-,00:22.6,5D,1/30,4.0,200,0.000,RAW,None,Y,C3-28 seconds
TAKEPIC,C3,-,00:18.6,5D,1/60,4.0,200,0.000,RAW,None,Y,C3-24 seconds
TAKEPIC,C3,-,00:14.6,5D,1/125,4.0,200,0.000,RAW,None,Y,C3-20 seconds
TAKEPIC,C3,-,00:12.1,5D,1/250,4.0,200,0.000,RAW,None,Y,C3-17 seconds
TAKEPIC,C3,-,00:09.3,5D,1/500,4.0,200,0.000,RAW,None,Y,C3-15 seconds
TAKEPIC,C3,-,00:06.6,5D,1/1000,4.0,200,0.000,RAW,None,Y,C3-13 seconds
TAKEPIC,C3,-,00:03.0,5D,1/2000,4.0,200,0.000,RAW,None,Y,C3-4 seconds
TAKEPIC,C3,-,00:00.0,5D,1/2000,4.0,200,0.000,RAW,None,Y,C3
TAKEPIC,C3,+,00:03.0,5D,1/2000,4.0,200,0.000,RAW,None,Y,C3+4 seconds
```

```
# Spectra 1  D7000 EAST  Signed off 2/11/2012  03:47


CHGBIT,C2,-,01:09.0,D7000, , ,14, , , , ,Switch to 14-bit
CHGCSSL,C2,-,01:07.0,D7000, , ,1, , , , ,Change continuous shooting speed to 1 fps
TAKEBST,C2,-,00:07.0,D7000,1/50,4.0,200,15,RAW,None,Y,Burst of 15 at 1 fps

TAKEPIC,C2,+,00:09.5,D7000,1/50,4.0,200,0.000,RAW,None,Y,
TAKEPIC,C2,+,00:17.4,D7000,1/8,4.0,200,0.000,RAW,None,Y,
TAKEPIC,C2,+,00:21.4,D7000,1/4,4.0,200,0.000,RAW,None,Y,
TAKEPIC,C2,+,00:24.4,D7000,1/2,4.0,200,0.000,RAW,None,Y,
TAKEPIC,C2,+,00:28.4,D7000,1,4.0,200,0.000,RAW,None,Y,

TAKEPIC,C2,+,00:35.4,D7000,1/8,4.0,200,0.000,RAW,None,Y,
TAKEPIC,C2,+,00:39.4,D7000,1/4,4.0,200,0.000,RAW,None,Y,
TAKEPIC,C2,+,00:43.4,D7000,1/2,4.0,200,0.000,RAW,None,Y,
TAKEPIC,C2,+,00:47.4,D7000,1,4.0,200,0.000,RAW,None,Y,

TAKEPIC,C2,+,00:55.4,D7000,1/8,4.0,200,0.000,RAW,None,Y,
TAKEPIC,C2,+,00:59.4,D7000,1/4,4.0,200,0.000,RAW,None,Y,
TAKEPIC,C2,+,01:03.4,D7000,1/2,4.0,200,0.000,RAW,None,Y,
TAKEPIC,C3,-,00:57.4,D7000,1,4.0,200,0.000,RAW,None,Y,

TAKEPIC,C3,-,00:49.4,D7000,1/8,4.0,200,0.000,RAW,None,Y,
TAKEPIC,C3,-,00:45.4,D7000,1/4,4.0,200,0.000,RAW,None,Y,
TAKEPIC,C3,-,00:41.4,D7000,1/2,4.0,200,0.000,RAW,None,Y,
TAKEPIC,C3,-,00:37.4,D7000,1,4.0,200,0.000,RAW,None,Y,

TAKEPIC,C3,-,00:29.4,D7000,1/8,4.0,200,0.000,RAW,None,N,
TAKEPIC,C3,-,00:25.4,D7000,1/4,4.0,200,0.000,RAW,None,Y,
TAKEPIC,C3,-,00:21.4,D7000,1/2,4.0,200,0.000,RAW,None,Y,
TAKEPIC,C3,-,00:17.4,D7000,1,4.0,200,0.000,RAW,None,Y,

TAKEBST,C3,-,00:07.0,D7000,1/50,4.0,200,15,RAW,None,Y,Burst of 15 at 1 fps
```

Appendix B
2019 SEM script for spectra

This script is for more recent Nikon equipment. Please refer to SEM and your camera's documentation and make appropriate changes.

Totality in this eclipse was 2 minutes 24 seconds. This is likely to require adjusting the timetable and eliminating steps and images.

```
# Solar Eclipse Maestro #  1.8.6.v2 (200) 145 Seconds Bella Vista, Argentina  D800 2:24 = 144
seconds 2.7 second cadence Signed off  7 June 2019. 00:19
# Action,Date/Ref,Offset Sign,Time Offset,Camera,Exposure,Aperture,ISO,MLU/Burst
Number,Quality,Size,Incremental,Comment
# signed off  7 June 2019  00:19 FOR 29 EXPOSURES FLASH SPECTRUM

# spectra


PLAY,C2,-,00:10:00.1,10_Minutes.wav, , , , , , , ,'10 minutes' voice prompt
PLAY,C2,-,00:05:00.1,5_Minutes.wav, , , , , , , ,'5 minutes' voice prompt
PLAY,C2,-,00:02:00.1,2_Minutes.wav, , , , , , , ,'2 minutes' voice prompt
PLAY,C2,-,00:01:00.1,60_Seconds.wav, , , , , , , ,'1 minute' voice prompt
PLAY,C2,-,00:00:30.1,30_Seconds.wav, , , , , , , ,'30 seconds' voice prompt
PLAY,C2,-,00:00:20.1,Filters_Off.wav, , , , , , , ,'Filters off' voice prompt
PLAY,C2,-,00:00:10.1,10_Seconds.wav, , , , , , , ,'10 seconds' voice prompt
PLAY,MAX,-,00:00:00.1,Max_Eclipse.wav, , , , , , , ,'Maximum eclipse' voice prompt

PLAY,C3,-,00:01:00.1,60_Seconds.wav, , , , , , , ,'1 minute' voice prompt
PLAY,C3,-,00:00:30.1,30_Seconds.wav, , , , , , , ,'30 seconds' voice prompt
PLAY,C3,-,00:00:10.1,10_Seconds.wav, , , , , , , ,'10 seconds' voice prompt
PLAY,C3,+,00:00:19.9,Filters_On.wav, , , , , , , ,'Filters on' voice prompt


CHGCROP,C2,-,00:03:09.0,D800S, , ,0, , , , ,FX Crop
CHGBIT,C2,-,03:07.0,D800S, , ,14, , , , ,Switch to 14-bit
CHGCSSL,C2,-,03:05.0,D800S, , ,3, , , , ,Change continuous shooting speed to 3 fps
EXPMODM,C2,-,03:03.0,D800S, , , , , , , ,Manual (M)
CHGCMP,C2,-,03:01.0,D800S, , , ,0, , , ,No exposure compensation

LVPSTART,C2,-,01:35.0,D800S, , , , , , , ,Start Lv

CHGEXP,C2,-,01:10.0,D800S,1/50,4.0,200,0.000,RAW,None,N,Set aperture and shutter speed before
spectra.

TAKEBST,C2,-,00:04.7,D800S,1/50,4.0,200,29,RAW,None,Y,Burst of 29 at 3 fps  C2 -4.7 to +4.7
seconds  Flash spectrum 1-29

TAKEPIC,C2,+,00:15.0,D800S,1/15,4.0,200,0.000,RAW,None,N, Coronal spectrum 30
TAKEPIC,C2,+,00:18.0,D800S,1/15,4.0,200,0.000,RAW,None,Y, Coronal spectrum 31
TAKEPIC,C2,+,00:21.0,D800S,1/8,4.0,200,0.000,RAW,None,Y, Coronal spectrum 32

TAKEPIC,C2,+,00:24.0,D800S,1/15,4.0,200,0.000,RAW,None,Y, Coronal spectrum 33
TAKEPIC,C2,+,00:27.0,D800S,1/8,4.0,200,0.000,RAW,None,Y, Coronal spectrum 34

TAKEPIC,C2,+,00:30.0,D800S,1/15,4.0,200,0.000,RAW,None,Y, Coronal spectrum 35
TAKEPIC,C2,+,00:33.0,D800S,1/8,4.0,200,0.000,RAW,None,Y, Coronal spectrum 36

TAKEPIC,C2,+,00:36.0,D800S,1/15,4.0,200,0.000,RAW,None,Y, Coronal spectrum 37
TAKEPIC,C2,+,00:39.0,D800S,1/8,4.0,200,0.000,RAW,None,Y, Coronal spectrum 38
```

```
TAKEPIC,C2,+,00:42.0,D800S,1/15,4.0,200,0.000,RAW,None,Y, Coronal spectrum 39
TAKEPIC,C2,+,00:45.0,D800S,1/8,4.0,200,0.000,RAW,None,Y, Coronal spectrum 40

TAKEPIC,C2,+,00:48.0,D800S,1/15,4.0,200,0.000,RAW,None,Y, Coronal spectrum 41
TAKEPIC,C2,+,00:51.0,D800S,1/8,4.0,200,0.000,RAW,None,Y, Coronal spectrum 42

TAKEPIC,C2,+,00:54.0,D800S,1/15,4.0,200,0.000,RAW,None,Y, Coronal spectrum 43
TAKEPIC,C2,+,00:57.0,D800S,1/8,4.0,200,0.000,RAW,None,Y, Coronal spectrum 44

TAKEPIC,C2,+,01:00.0,D800S,1/15,4.0,200,0.000,RAW,None,Y, Coronal spectrum 45
TAKEPIC,C2,+,01:03.0,D800S,1/8,4.0,200,0.000,RAW,None,Y, Coronal spectrum 46

TAKEPIC,C2,+,01:06.0,D800S,1/15,4.0,200,0.000,RAW,None,Y, Coronal spectrum 47
TAKEPIC,C2,+,01:09.0,D800S,1/8,4.0,200,0.000,RAW,None,Y, Coronal spectrum 48

TAKEPIC,MAX,-,00:00.0,D800S,1/15,4.0,200,0.000,RAW,None,N, 72 / 73.5 seconds  Coronal spectrum 49

TAKEPIC,C3,-,01:09.0,D800S,1/15,4.0,200,0.000,RAW,None,Y, Coronal spectrum 50
TAKEPIC,C3,-,01:06.0,D800S,1/8,4.0,200,0.000,RAW,None,Y, Coronal spectrum 51

TAKEPIC,C3,-,01:03.0,D800S,1/15,4.0,200,0.000,RAW,None,Y, Coronal spectrum 52
TAKEPIC,C3,-,01:00.0,D800S,1/8,4.0,200,0.000,RAW,None,Y, Coronal spectrum 53

TAKEPIC,C3,-,00:57.0,D800S,1/15,4.0,200,0.000,RAW,None,Y, Coronal spectrum 54
TAKEPIC,C3,-,00:54.0,D800S,1/8,4.0,200,0.000,RAW,None,Y, Coronal spectrum 55

TAKEPIC,C3,-,00:51.0,D800S,1/15,4.0,200,0.000,RAW,None,Y, Coronal spectrum 56
TAKEPIC,C3,-,00:48.0,D800S,1/8,4.0,200,0.000,RAW,None,Y, Coronal spectrum 57

TAKEPIC,C3,-,00:45.0,D800S,1/15,4.0,200,0.000,RAW,None,Y, Coronal spectrum 58
TAKEPIC,C3,-,00:42.0,D800S,1/8,4.0,200,0.000,RAW,None,Y, Coronal spectrum 59

TAKEPIC,C3,-,00:39.0,D800S,1/15,4.0,200,0.000,RAW,None,Y, Coronal spectrum 60
TAKEPIC,C3,-,00:36.0,D800S,1/8,4.0,200,0.000,RAW,None,Y, Coronal spectrum 61

TAKEPIC,C3,-,00:33.0,D800S,1/15,4.0,200,0.000,RAW,None,Y, Coronal spectrum 62
TAKEPIC,C3,-,00:30.0,D800S,1/8,4.0,200,0.000,RAW,None,Y, Coronal spectrum 63

TAKEPIC,C3,-,00:27.0,D800S,1/15,4.0,200,0.000,RAW,None,Y, Coronal spectrum 64
TAKEPIC,C3,-,00:24.0,D800S,1/8,4.0,200,0.000,RAW,None,Y, Coronal spectrum 65

TAKEPIC,C3,-,00:21.0,D800S,1/15,4.0,200,0.000,RAW,None,Y, Coronal spectrum 66
TAKEPIC,C3,-,00:18.0,D800S,1/8,4.0,200,0.000,RAW,None,Y, Coronal spectrum 67

TAKEPIC,C3,-,00:15.0,D800S,1/15,4.0,200,0.000,RAW,None,Y, Coronal spectrum 68

TAKEBST,C3,-,00:04.7,D800S,1/50,4.0,200,29,RAW,None,Y,Burst of 29 at 3 fps  C2 -4.7 to +4.7
seconds  Flash spectrum 69-97

LVPSTOP,C3,+,00:15.0,D800S, , , , , , , ,Stop Lv
```

```
#######################

# Solar Eclipse Maestro #  1.8.6.v2 (200) 145 Seconds Bella Vista, Argentina  D800 2:24 = 144
seconds 2.7 second cadence Signed off  7 June 2019. 00:19
# Action,Date/Ref,Offset Sign,Time Offset,Camera,Exposure,Aperture,ISO,MLU/Burst
Number,Quality,Size,Incremental,Comment
# signed off  7 June 2019  00:19 FOR SPECTRUM Movie D7100

# SET CAMERA TO MOVIE--MANUAL RECORDING FROM MENU

CHGBIT,C2,-,02:07.0,D7100, , ,14, , , , ,Switch to 14-bit
EXPMODM,C2,-,02:05.0,D7100, , , , , , , ,Manual (M)
CHGCMP,C2,-,02:03.0,D7100, , , ,0, , , ,No exposure compensation

CHGEXP,C2,-,01:10.0,D7100,1/50,5.6,400,0.000,RAW,None,N,Set aperture and shutter speed before
movie.
MREC,C2,-,01:00.0,D7100, , , , , , , ,Start flash spectrum movie
CHGEXP,C2,-,00:20.0,D7100,1/50,5.6,400,0.000,RAW,None,N,
CHGEXP,C2,+,00:05.0,D7100,1/30,5.6,640,0.000,RAW,None,Y,
CHGEXP,C2,+,00:06.0,D7100,1/30,5.6,800,0.000,RAW,None,Y,
CHGEXP,C2,+,00:09.0,D7100,1/30,5.6,1000,0.000,RAW,None,Y,
CHGEXP,C2,+,00:12.0,D7100,1/30,5.6,1200,0.000,RAW,None,Y,
CHGEXP,C2,+,00:15.0,D7100,1/30,5.6,1600,0.000,RAW,None,Y,
CHGEXP,C2,+,00:25.0,D7100,1/30,5.6,1200,0.000,RAW,None,Y,
CHGEXP,C2,+,00:30.0,D7100,1/30,5.6,1000,0.000,RAW,None,Y,
CHGEXP,C2,+,00:35.0,D7100,1/30,5.6,800,0.000,RAW,None,Y,
CHGEXP,C2,+,00:40.0,D7100,1/30,5.6,1000,0.000,RAW,None,Y,
CHGEXP,C2,+,00:45.0,D7100,1/30,5.6,1200,0.000,RAW,None,Y,
CHGEXP,C2,+,00:50.0,D7100,1/30,5.6,1600,0.000,RAW,None,Y,
CHGEXP,C2,+,00:55.0,D7100,1/30,5.6,1200,0.000,RAW,None,Y,
CHGEXP,C2,+,01:00.0,D7100,1/30,5.6,1000,0.000,RAW,None,Y,
CHGEXP,C2,+,01:05.0,D7100,1/30,5.6,800,0.000,RAW,None,Y,
CHGEXP,C3,-,01:05.0,D7100,1/30,5.6,1000,0.000,RAW,None,Y,
CHGEXP,C3,-,01:00.0,D7100,1/30,5.6,1200,0.000,RAW,None,Y,
CHGEXP,C3,-,00:55.0,D7100,1/30,5.6,1600,0.000,RAW,None,Y,
CHGEXP,C3,-,00:50.0,D7100,1/30,5.6,1200,0.000,RAW,None,Y,
CHGEXP,C3,-,00:45.0,D7100,1/30,5.6,1000,0.000,RAW,None,Y,
CHGEXP,C3,-,00:40.0,D7100,1/30,5.6,800,0.000,RAW,None,Y,
CHGEXP,C3,-,00:35.0,D7100,1/30,5.6,1000,0.000,RAW,None,Y,
CHGEXP,C3,-,00:30.0,D7100,1/30,5.6,1200,0.000,RAW,None,Y,
CHGEXP,C3,-,00:25.0,D7100,1/30,5.6,1600,0.000,RAW,None,Y,
CHGEXP,C3,-,00:20.0,D7100,1/30,5.6,1200,0.000,RAW,None,Y,
CHGEXP,C3,-,00:15.0,D7100,1/30,5.6,1000,0.000,RAW,None,Y,
CHGEXP,C3,-,00:10.0,D7100,1/30,5.6,800,0.000,RAW,None,Y,
CHGEXP,C3,-,00:06.0,D7100,1/30,5.6,640,0.000,RAW,None,Y,
CHGEXP,C3,-,00:05.0,D7100,1/30,5.6,400,0.000,RAW,None,Y,
MSTOP,C3,+,01:00.0,D7100, , , , , , , ,Stop flash spectrum movie
```

Appendix C
2019 Checklists

1. VIDEO SPECTRA

TRIPOD:	Gitzo G1228 MK2
HEAD:	Bogen 3047
CAMERA:	Nikon D7100 #2753145 D7100
Lens;	Nikon 80-200/2.8
TRIGGERS:	SEM on 2011 Air, 2019 Spectra script with GPS

Checklist:

- CAMERA OFF
- INSERT FULLY CHARGED BATTERY AND CLEAN 95 SD CARD
- MOUNT SQUARELY AND HORIZONTALLY ON HEAD.
- MOUNT B+W GRATING ON LENS
- MOUNT SOLAR SCREEN ON LENS
- CAMERA ON AND VERIFY CAMERA OPERATION
- CONNECT CORD TO CAMERA
- LENS AT 135mm AND TAPE
- FOCUS ON MOUNTAINS USING MAX MAG ON LIVE VIEW
- CAMERA OFF
- MOUNT CAMERA 17.3° UP; 309.6° AZIMUTH; TURNED VERTICAL
- ALIGN GRATING LINES PARALLEL TO CRESCENT ALONG DIAGONAL (7.1)
- GO TO SEM GENERAL SCRIPT →

19:48Z (16:48)
- CRESCENT FULLY IN FRAME AND TANGENT TO EDGE JUST BELOW CORNER
- VERIFY GRATING ORIENTATION BELOW.

20:17Z (17:17)
- VERIFY POSITION MID UPPER RIGHT QUADRANT.
- VERIFY GRATING ORIENTATION.

20:25Z (17:25)
- VERIFY POSITION OF SUN
- VERIFY GRATING ORIENTATION AND TAPE.
- REMOVE SOLAR SKREEN AND COVER CAMERA.

40 seconds before Second Contact:
- UNCOVER LENS

After Third Contact:
- CAMERA OFF SUN

2. FLASH SPECTRA

TRIPOD:	Gitzo GT3531
HEAD:	Bogen 3057
CAMERA	Modified D800 (Spencer's sticker) #3069384 D800S
Lens;	Nikon 80-200/2.8
TRIGGERS:	SEM on 2011 Air, 2019 Spectra script with GPS

Checklist:

- CAMERA OFF
- INSERT FULLY CHARGED BATTERY AND CLEAN 160 CF CARD
- MOUNT SQUARELY AND HORIZONTALLY ON HEAD.
- MOUNT B+W GRATING ON LENS
- MOUNT SOLAR SCREEN ON LENS
- CAMERA ON AND VERIFY CAMERA OPERATION
- CONNECT CORD TO CAMERA
- FOCUS ON MOUNTAINS USING MAX MAG ON LIVE VIEW
- CAMERA OFF
- MOUNT CAMERA 15.5° UP; 308° AZIMUTH; TURNED VERTICAL
- ALIGN GRATING LINES PARALLEL TO CRESCENT ALONG DIAGONAL (7.1)
- GO TO SEM GENERAL SCRIPT →

20:02Z (17:02)
- CRESCENT FULLY IN FRAME AND TANGENT TO EDGE JUST BELOW CORNER
- VERIFY GRATING ORIENTATION BELOW.

20:18Z (17:18)
- VERIFY POSITION MID UPPER RIGHT QUADRANT.
- VERIFY GRATING ORIENTATION.

20:27Z (17:27)
- VERIFY POSITION OF SUN
- VERIFY GRATING ORIENTATION AND TAPE.
- REMOVE SOLAR SKREEN AND COVER CAMERA.

35 seconds before Second Contact:
- UNCOVER LENS

After Third Contact:
- CAMERA OFF SUN

3. 400 mm CORONA PHOTOGRAPHS

TRIPOD:	Gitzo G1548 MK2
HEAD:	Manfrotto/Bogen 3039 with large plate 3/8
CAMERA:	NIKON D800E #3014567 D800E
LENS:	TAMRON 400/4
TRIGGERS:	SEM on 2017 Air, 2019 Coronal script with GPS

Checklist:

- CAMERA OFF
- INSERT FULLY CHARGED BATTERY AND CLEAN 160 CF CARD.
- MOUNT SQUARELY AND HORIZONTALLY ON HEAD.
- REMOVE BLACK FILTER.
- PUT SOLAR SCREEN ON HOOD SECURELY!
- MOUNT CAMERA 11.6° UP; 305.6° AZIMUTH; TILT 21° LEFT
- LENS TILTED ZERO
- FOCUS ON MOUNTAINS USING MAX MAG ON LIVE VIEW
- CAMERA ON AND VERIFY CAMERA OPERATION
- CONNECT CORD TO CAMERA
- MOUNT SOLAR SCREEN ON LENS
- CAMERA OFF
- SET LENS to F/5.6
- GO TO SEM GENERAL SCRIPT →

20:30Z (17:30)
- SUN TANGENT TO UPPER RIGHT CORNER AND TOP OF SUN ON CORNER

20:35Z (17:35)
- CRESCENT HALFWAY TO CENTER IN UPPER RIGHT QUADRANT.
- SOLAR SKREEN OFF
- COVER LENS WITH CLOTH

40 Seconds before Second Contact:
- UNCOVER LENS

After Third Contact:
- CAMERA DROPPED OFF SUN OR COVERED

4. 300 mm CORONA PHOTOGRAPHS

TRIPOD:	Gitzo G1548
HEAD:	Manfrotto/Bogen 3057 with hex plate 3/8
CAMERA:	NIKON D800 #3044059
LENS:	TAMRON 300/2.8
TRIGGERS:	SEM on 2017 Air, 2019 Coronal script with GPS

Checklist:

- CAMERA OFF
- INSERT FULLY CHARGED BATTERY AND CLEAN 160 CF CARD.
- MOUNT SQUARELY AND HORIZONTALLY ON HEAD.
- REMOVE BLACK FILTER.
- PUT SOLAR SCREEN ON HOOD SECURELY!
- MOUNT CAMERA 11.6° UP; 305.6° AZIMUTH; TILT 21° LEFT
- LENS TILTED ZERO
- FOCUS ON MOUNTAINS USING MAX MAG ON LIVE VIEW
- CAMERA ON AND VERIFY CAMERA OPERATION
- CONNECT CORD TO CAMERA
- MOUNT SOLAR SCREEN ON LENS
- CAMERA OFF
- SET LENS to F/5.6
- GO TO SEM GENERAL SCRIPT →

20:26Z (17:26)

- SUN TANGENT TO UPPER RIGHT SIDE AND ½ SOLAR DIAMETER BELOW UPPER RIGHT CORNER

20:33Z (17:33)

- CRESCENT HALFWAY TO CENTER IN UPPER RIGHT QUADRANT.
- SOLAR SKREEN OFF
- COVER LENS WITH CLOTH

40 Seconds before Second Contact:

- UNCOVER LENS

After Third Contact:

- CAMERA DROPPED OFF SUN OR COVERED

5. 35 mm LANDSCAPE

TRIPOD:	Gitzo G1325/1321
HEAD:	Manfrotto/Bogen 3047 with hex plate
CAMERA:	NIKON D800 #3090871 D800W
LENS:	ROKINON 35/1.4
TRIGGERS:	SEM on 2017 Air, 2019 Coronal script with GPS

Checklist:

- CAMERA OFF
- INSERT FULLY CHARGED BATTERY AND CLEAN 160 CF CARD.
- MOUNT SQUARELY AND HORIZONTALLY ON HEAD.
- REMOVE BLACK FILTER.
- PUT SOLAR SCREEN ON HOOD SECURELY!
- MOUNT CAMERA 17° UP; 305.6° AZIMUTH; HORIZONTAL
- FOCUS ON MOUNTAINS USING MAX MAG ON LIVE VIEW
- CAMERA ON AND VERIFY CAMERA OPERATION
- CONNECT CORD TO CAMERA
- MOUNT SOLAR SCREEN ON LENS
- CAMERA OFF
- SET LENS to F/5.6
- GO TO SEM GENERAL SCRIPT →

18:15Z (15:15)

- CONFIRM ENTRANCE OF SUN TOP OF FRAME, 2 DIAMETERS LEFT OF TOP RIGHT CORNER

19:20Z (16:20)

- CRESCENT HALFWAY TO VERTICAL CENTER IN UPPER RIGHT QUADRANT.

20:25Z (17:25)

- VERIFY SUN POSITION.
- SOLAR SKREEN OFF
- COVER LENS WITH CLOTH

40 Seconds before Second Contact:

- UNCOVER LENS

After Third Contact:

- CAMERA DROPPED OFF SUN OR COVERED

GENERAL SEM CHECKLIST

Checklist:

- AIRS FULLY CHARGED AND OFF!
- ALL CAMERAS OFF
- MICE IN EACH COMPUTER
- INSERT USB HUBS IN EACH USB PORT
- 2017 AIR RUNS 3 CORONAL IMAGERS TO RIGHT.
- 2011 AIR RUNS 2 SPECTRA IMAGERS TO LEFT.
- CONNECT CAMERAS TO USB HUBS
- CONNECT GPS PUCKS TO HUBS
- TAPE ALL CONNECTIONS

19:10Z (16:10)

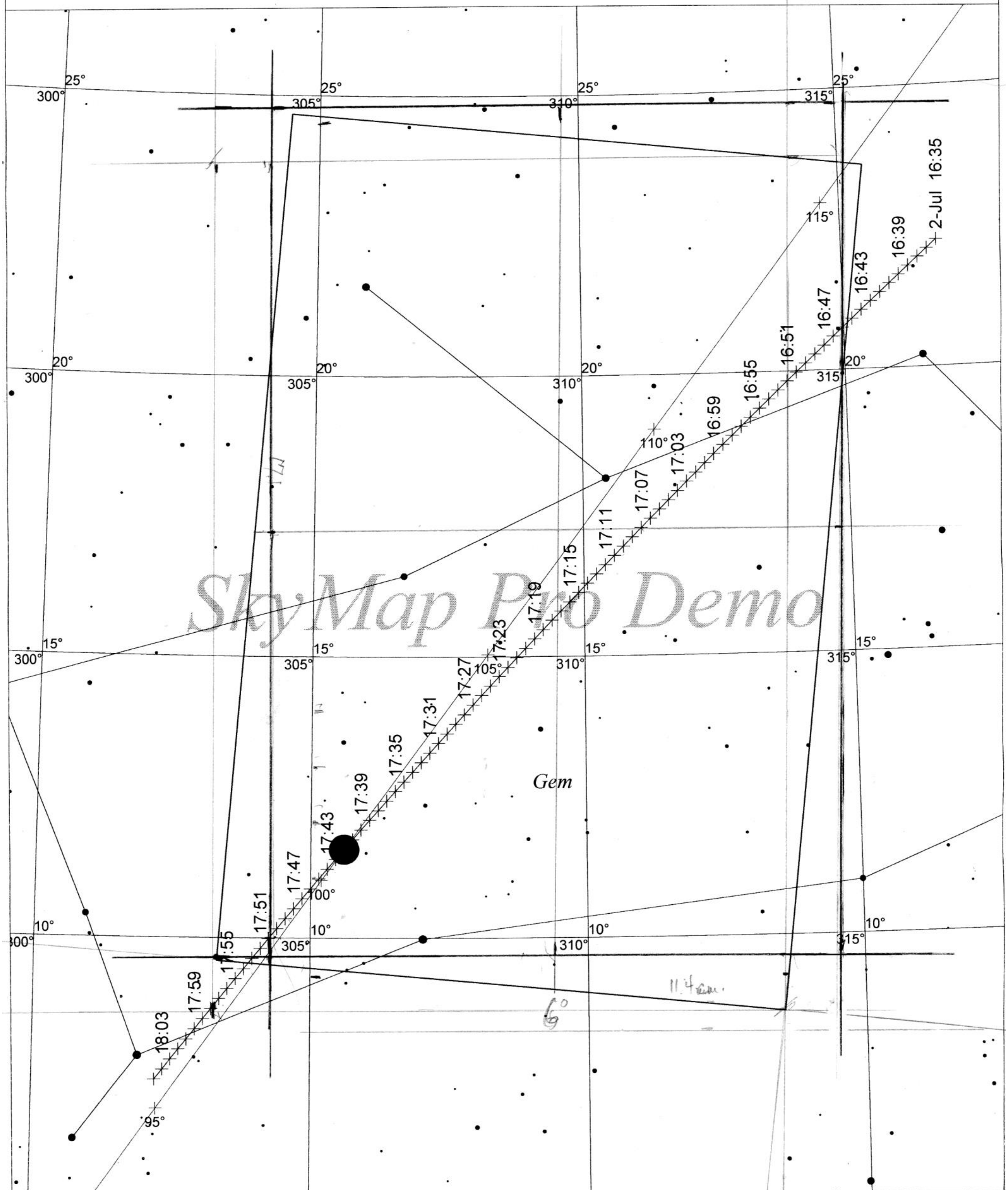
- TURN ON CORONAL MACHINE
- PASSWORD: rags7247
- CALL UP SEM
- VERIFY CAMERA REFERENCES
- VERIFY 2019 JULY 02 ECLIPSE
- VERIFY 959.98 SOLAR RADIUS
- VERIFY GPS POSITION TRACKING
- VERIFY GPS TIME CHECKED AND WORKING
- VERIFY SATELLITES IN WINDOW.
- VERIFY TIME WITH PHONE, IPAD.
- TURN CAMERA 1 ON; VERIFY RECOGNITION.
- TURN CAMERA 2 ON; VERIFY RECOGNITION.
- TURN CAMERA 3 ON; VERIFY RECOGNITION.
- TEST FIRE EACH CAMERA, VERIFY CLICK.
- TEST FIRE ALL CAMERAS, VERIFY CLICK.
- LOAD **2019 CORONA** SCRIPT.

19:40Z (16:40)

- TURN ON SPECTRA MACHINE
- CALL UP SEM
- VERIFY CAMERA REFERENCES
- VERIFY 2019 JULY 02 ECLIPSE
- VERIFY 959.98 SOLAR RADIUS
- VERIFY GPS POSITION TRACKING
- VERIFY GPS TIME CHECKED AND WORKING
- VERIFY SATELLITES IN WINDOW.
- VERIFY TIME WITH PHONE, IPAD.
- TURN CAMERA 1 ON; VERIFY RECOGNITION.
- TURN CAMERA 2 ON; VERIFY RECOGNITION.
- TEST FIRE EACH CAMERA, VERIFY CLICK.
- TEST FIRE ALL CAMERAS, VERIFY CLICK.
- LOAD **2019 SPECTRA** SCRIPT.

Appendix D
2019 Checklists

135 mm max totality

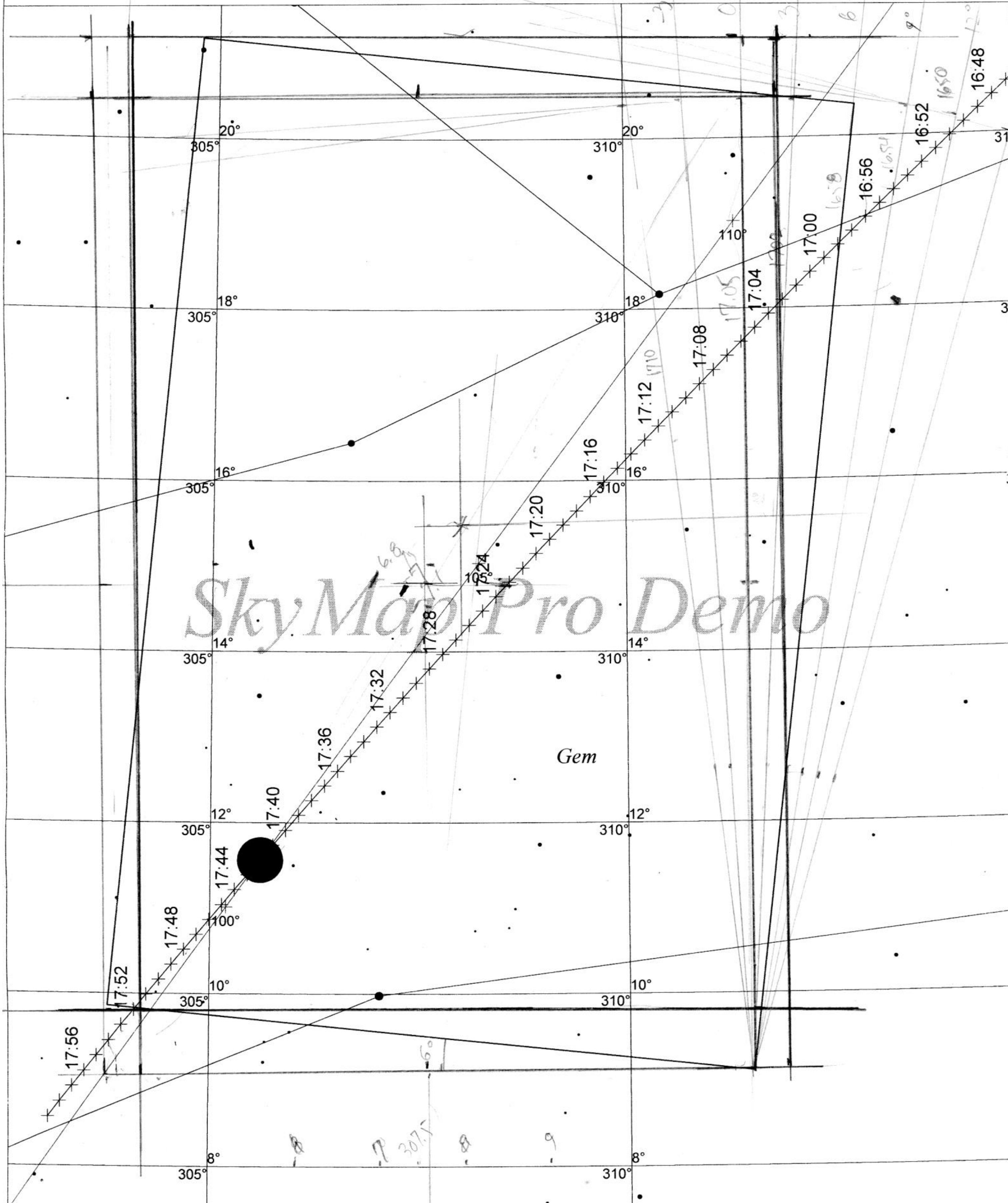


Local Time: 17:41:00 2-Jul-2019
Location: 30° 27' 1" S 69° 15' 55" W

UTC: 20:41:00 2-Jul-2019
RA: 7h09m13s Dec: +22° 10' Field: 17.8°

Sidereal Time: 10:46:18
Julian Day: 2458667.3618

180 mm max totality



Local Time: 17:41:00 2-Jul-2019 UTC: 20:41:00 2-Jul-2019 Sidereal Time: 10:46:18

Location: 30° 27' 1" S 69° 15' 55" W RA: 7h04m32s Dec: +23° 10' Field: 11.9° Julian Day: 2458667.3618

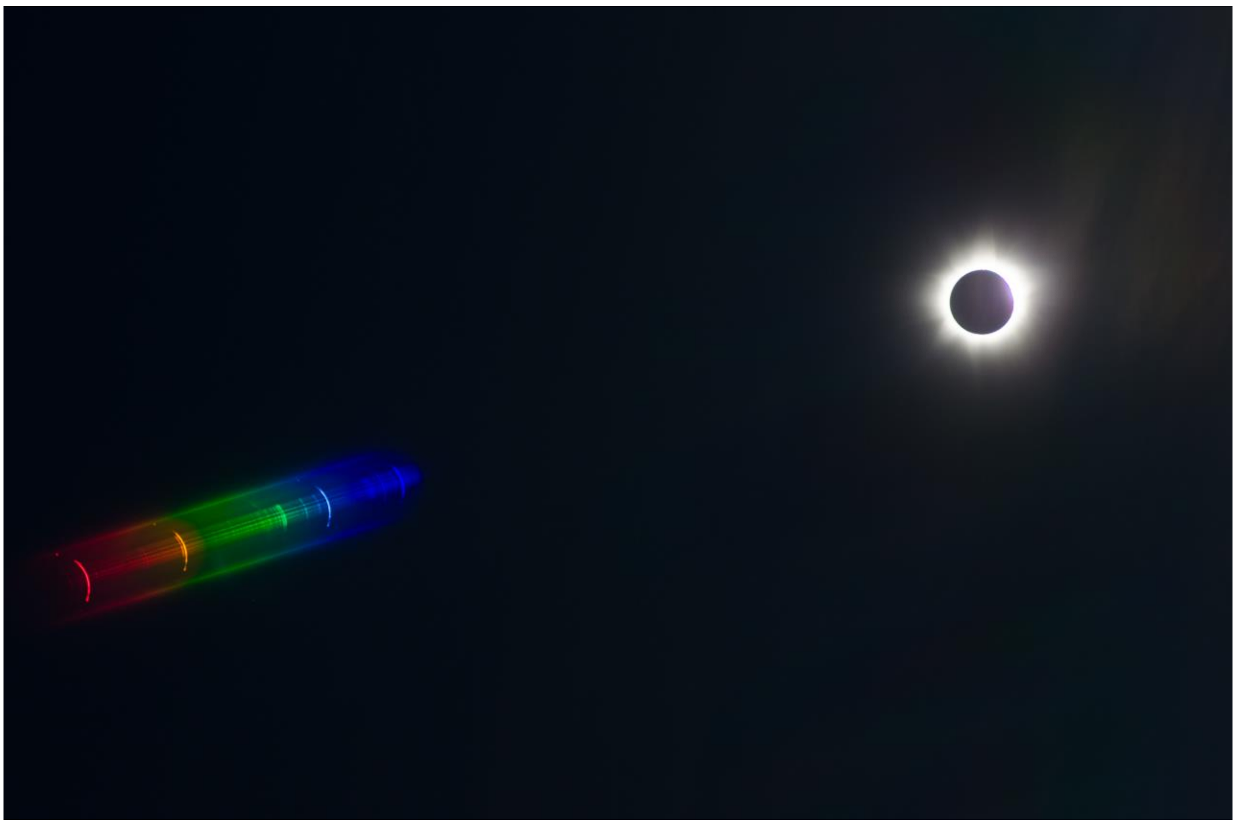
Appendix E
Spectra 2012

These are the images my wife Elisabeth and I obtained at the 14-13 November 2012 total solar eclipse in Maitland Downs, Queensland, Australia.   I used a Nikon D-7000 and a Tamron 80-200/2.8 lens.

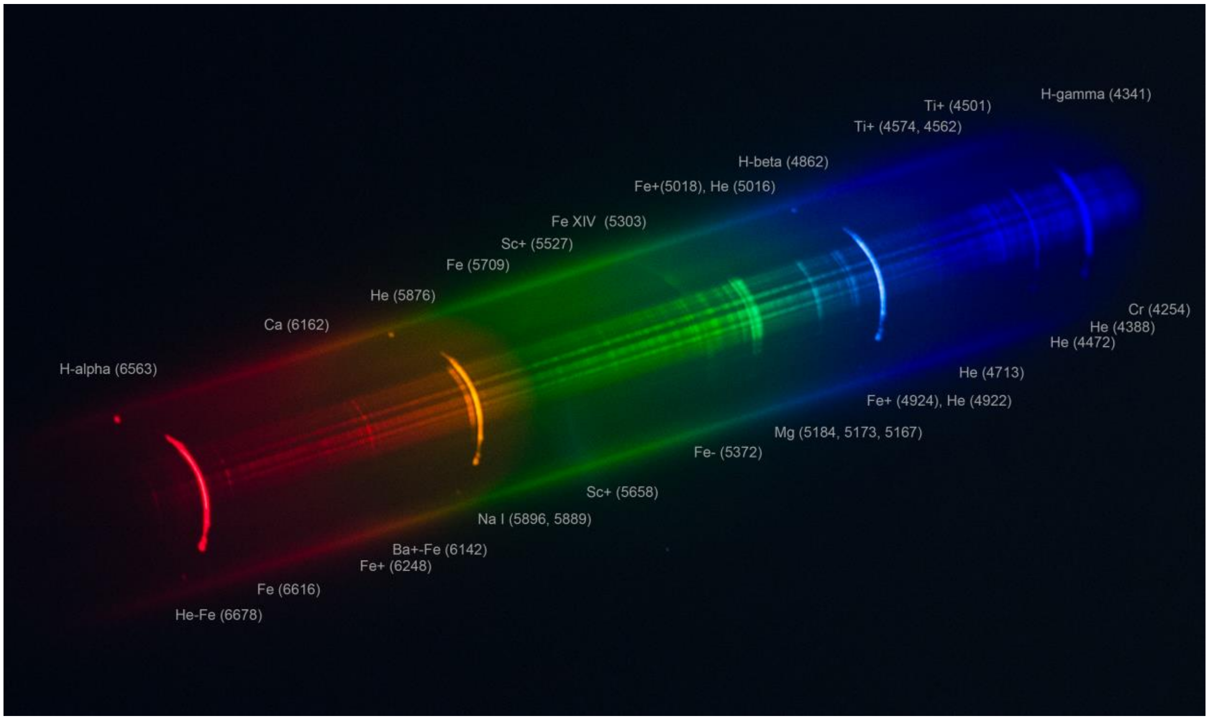
The second contact flash spectrum was part of a burst sequence of 13 at a rate of 2/second beginning at 6 seconds before the contact. Settings: f/4, 1/50, ISO 200.

The coronal spectra were part of a bracketing sequence of 1/8, 1/4, 1/2, and 1 second during totality at f/4, ISO 200.

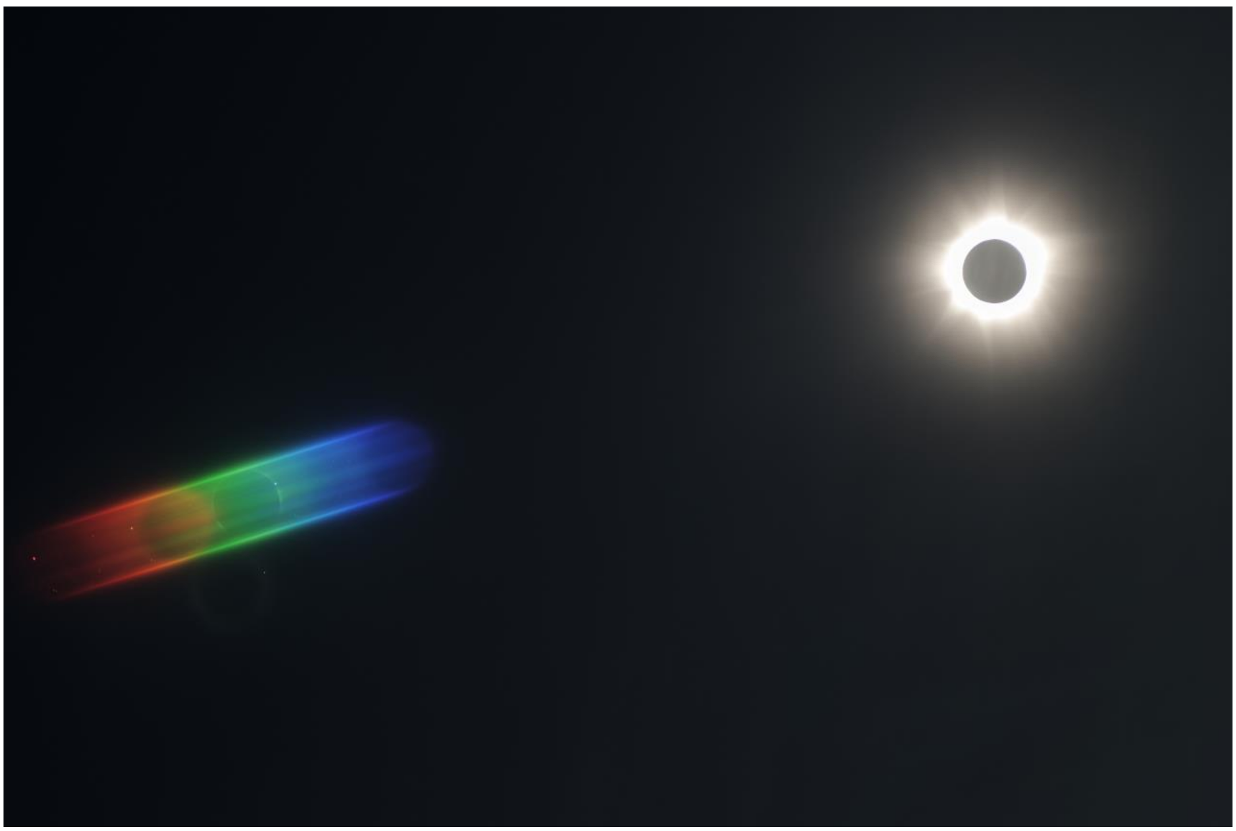
The third contact flash spectrum was part of a burst sequence of 15 at a rate of 2/second beginning at 7 seconds before the contact. Settings: f/4, 1/50, ISO 200.



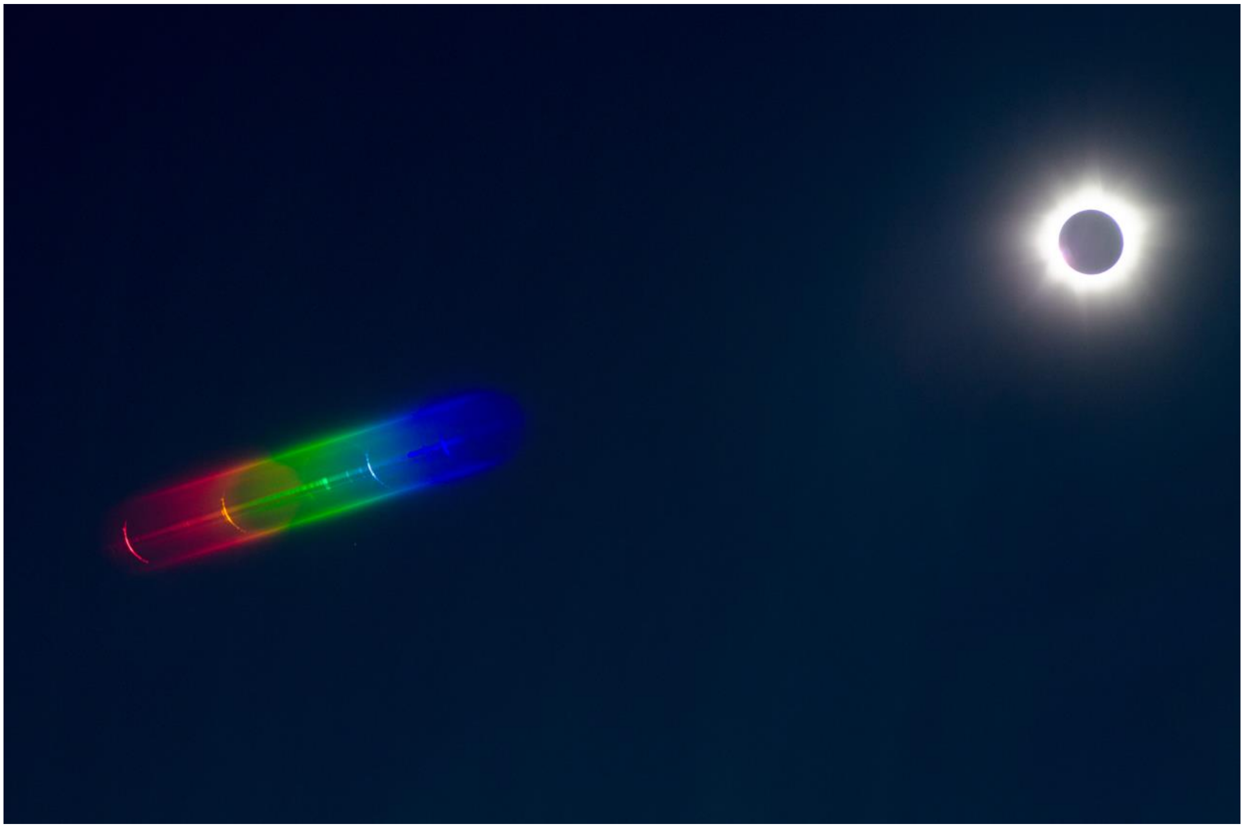
#54115: Second contact at 13/11/2012, 20:37:43



#54115: Details of flash spectrum at second contact with annotated lines and wavelengths.



#54137: Spectrum of the solar corona 13/11/2012, 20:38:57. Note the very strong green Fe XIV line at 5303 A and the Weak red Fe X line at 6376 A. This is around solar maximum.



#54149: Third contact at 13/11/2012, 20:39:43

Appendix F
Spectra 2015

This coronal spectrum was a handheld image from Jet2's Boeing 737 aircraft at 38,000 feet over the Atlantic between the Faeroe Islands and Iceland. Flight LS6048 departed and returned to Glasgow.

Camera: Nikon D7000, Lens: Nikkor 105/2.5, Settings: f/2.5, 1/320, ISO 640. This image was processed in Capture One where the exposure was increased by 2.4 stops, so effectively the ISO is 4000 or the shutter speed is effectively 1/60. The 1/320 shutter speed was selected to minimize any movement and ISO 640 was used to keep the noise down.

I was able to image this with a faster shutter speed than normal because of the altitude. It helps to have 80% of Earth's atmosphere underneath. However, the aircraft's windows and the lens produced artifacts. The renowned Nikkor 105/2.5 is a lens for film cameras and reflections of the solar corona bounce off the sensor and the rear element, producing a ghost image.

We see that, even in a declining phase of the solar cycle, the green Fe XIV is prominent.

#28052: 20/3/2015, 09:44:02

Appendix G
Spectra 2016

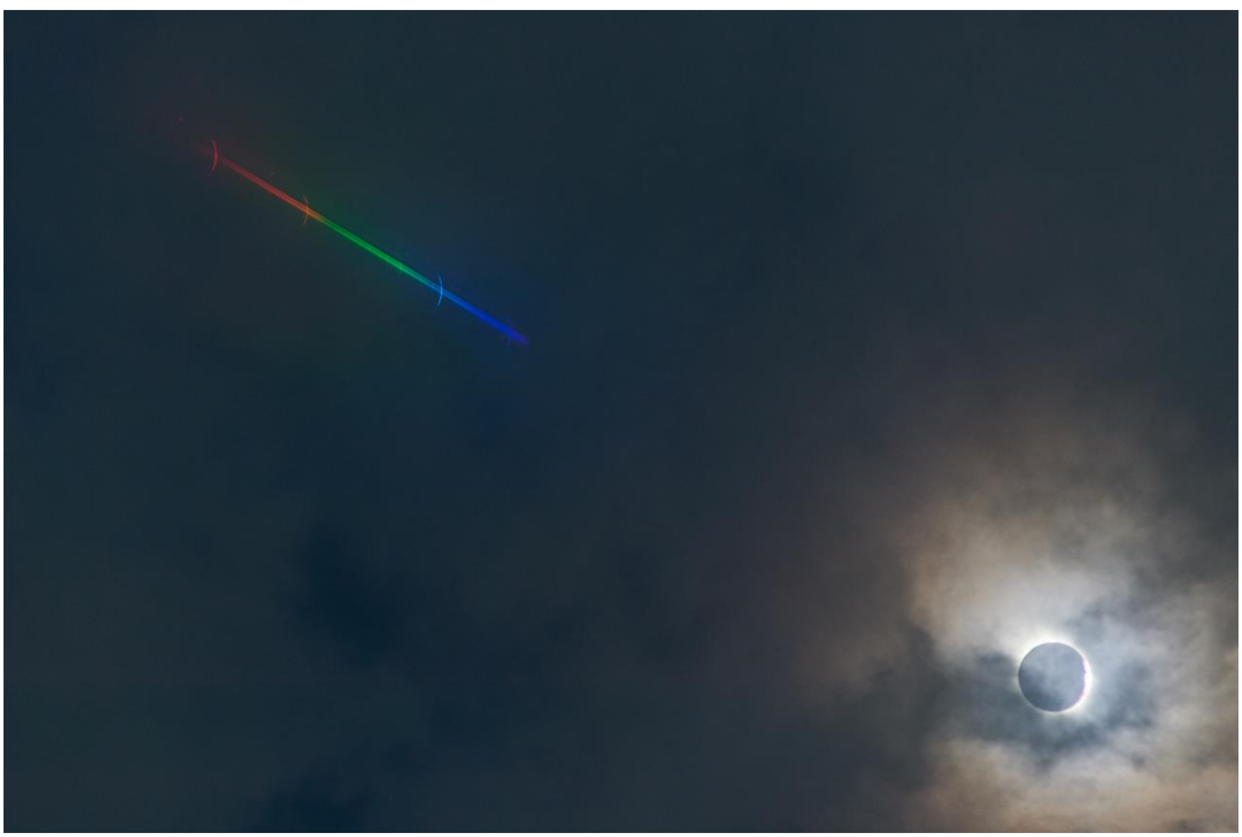
These images are from Ternate, Indonesia on 9-8 March 2016. The centerline passed south of Tidore Island, which my wife Elisabeth and I could not get to because it required an amphibious landing. Therefore we observed from the ballroom balcony of the Bela International Hotel.

Camera: Nikon D700, Lens: Nikon 80-200/2.8 at 155mm., Settings: f/4, ISO 200. For the flash spectra, exposure time was 1/50 second; for the coronal spectrum, the exposure time was 1/15 second.

The approaching Moon cooled off air and clouds formed at mid-levels. This resulted in less-exposed images. I used Capture One to enhance the images with exposure corrections and additional adjustments. For second contact, the correction is +.58 stop, for the coronal spectrum, +.94 stop and for third contact, +1.03 stop. Additional adjustments were applied.

#8384: Second contact at 9/3/2016, 00:51:36

#8410: Spectrum of the solar corona 9/3/2016, 00:53:06.   Note the very strong green Fe XIV line at 5303 A. The red Fe X line cannot be discerned.   Solar activity was in the process of declining.



#8384: Third contact at 9/3/2016, 00:54:19

Appendix H
Spectra 2017

These images are from Casper, Wyoming, USA on 21 August 2017. In order to get the longest duration of totality in the immediate vicinity, we located five km south of centerline. Being on centerline means that the contact points for totality diametrically oppose each other and make it easy to orient the diffraction grating correctly for both contacts.

However, I chose for the longer totality. A lunar valley may create an attractive “Baily’s Bead” but that bead interferes with the spectrum and can obliterate the view of ionized plasma close to the sun. This low-lying plasma consists of heavier metallic ions. The prominent red, yellow and blue lines are of lighter ions of lighter hydrogen, helium and hydrogen again, respectively.

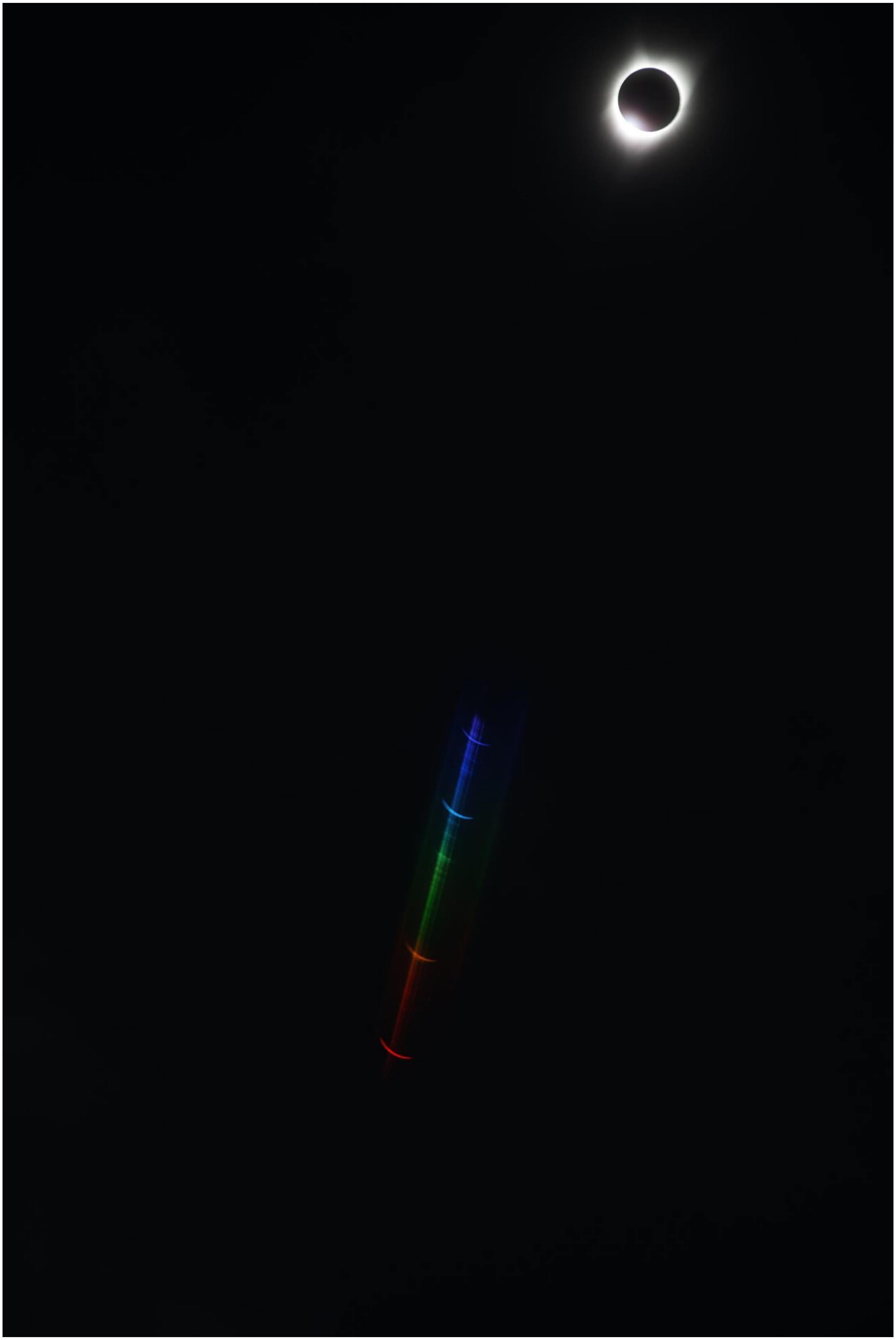
We went to Wyoming for the altitude and best chances for clear sky and mobility. A weak trough passed over Casper four hours early, laying scattered cirrus across the eclipse. That affected some of the images. However, we see the continuing decline in solar activity with a weakening green Fe XIV line and a slightly strengthening red Fe X line, although that red line is still difficult to detect.

The challenges here involve the high altitude of the eclipse in the sky. Tripod heads designed for cameras are difficult to work with at these high altitudes and it shows here with the aiming and possible vibration. High sky altitude eclipses are better imaged with some type of equatorial mount, the stronger the mount, the better. Cameras need to be secured well to the mount.

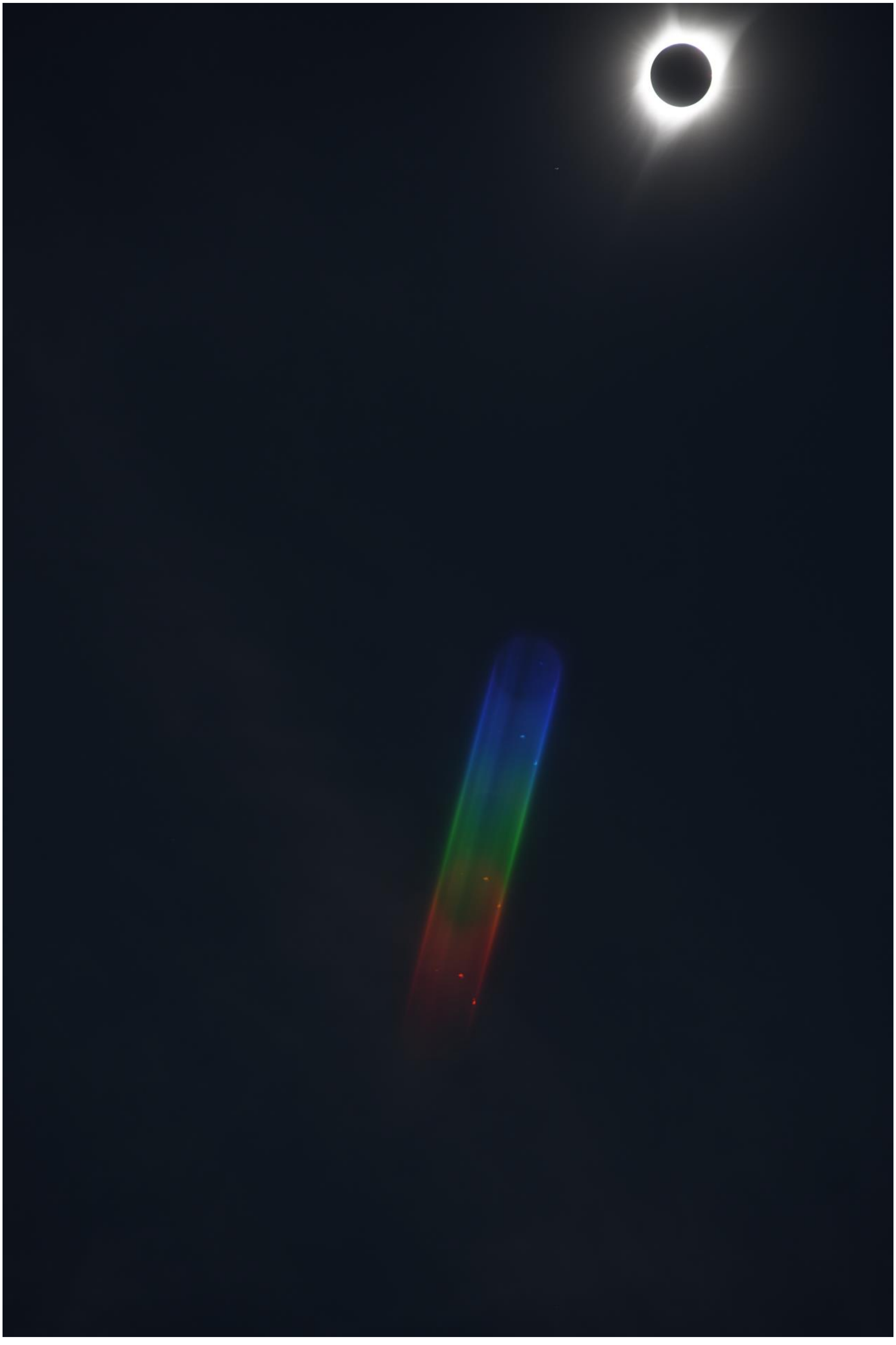
With this eclipse I used a fixed length lens, not a zoom. Longer lenses require more precise the aiming. A zoom lens may be optically inferior, but the diffraction grating degrades the primary image anyway and the spectrum is what we want.

Shutter speeds with DSLR cameras at 1/30-1/8 second risk poor definition. It may be better to raise the ISO to 800 and use 1/200 second for the flash spectrum and 1/30 second for the corona and live with the extra noise. This is something that should be tested with outdoor mercury or sodium vapor street lighting or neon signs.

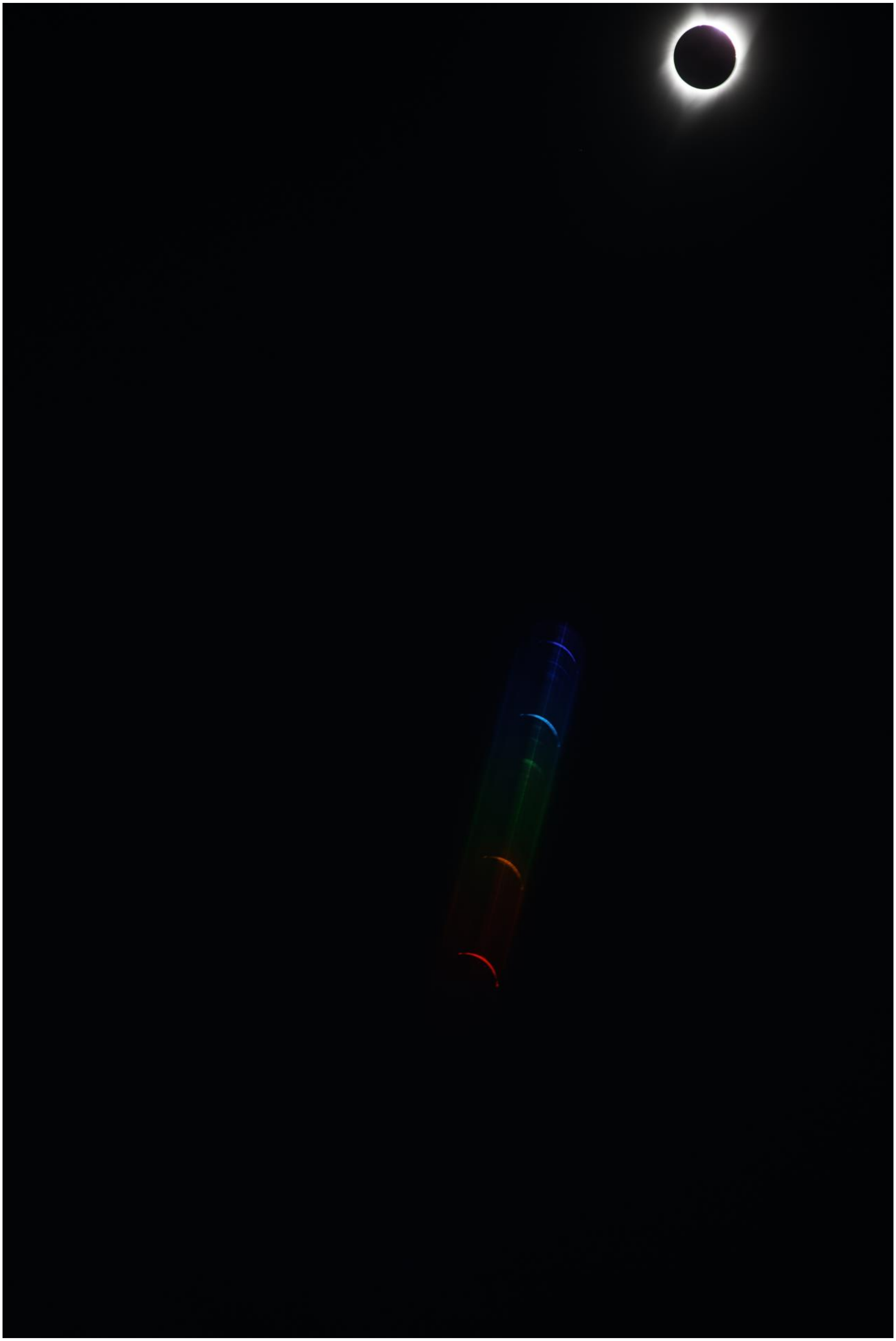
Camera: Nikon D800, Lens: Nikon 180/2.8. Settings: f/4, ISO 200. For the flash spectra, exposure time was 1/50 second; for the coronal spectrum, the exposure time was 1/8 second with adjustments in Capture One.



#8384: Second contact at 21/8/2016, 17:42:33



#55336: Spectrum of the solar corona 21/8/2017, 17:43:51.



#55361: Third contact at 21/8/2017, 17:44:50

Appendix I
Spectra 2019

These images are from Las Flores, Argentina on 2 July 2019. In order to get the longest duration of totality in the immediate vicinity, we located about five km north of centerline for the same reasons mentioned in 2017.

We were downwind, east, of the main ridge of the Andes, in a valley between that and the second ridge. Mountians over 6000 meters high are an effective barrier against moist Pacific air. This was another 'no excuse' eclipse.

Our altitude was at about 1940 meters. Despite the eclipse's low altitude, the sky remained clear and there were no clouds capping the Andes. The challenge was atmospheric extinction.

The computer controlling the spectra imaging worked, as opposed to the one controlling the coronal cameras. For this application, having computers controlling the exposures is best and things generally worked out; my wife and I achieved most of our objectives.

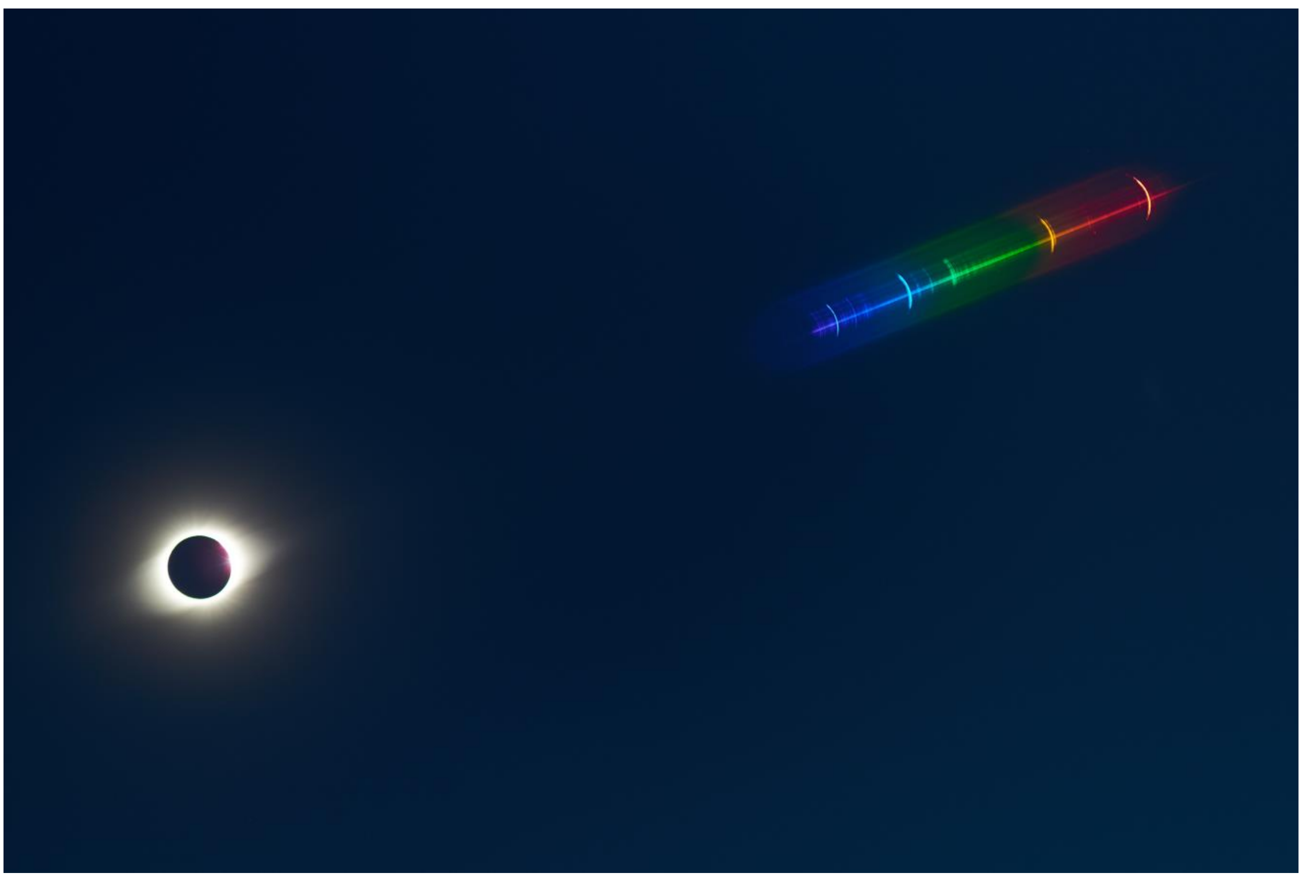
In anticipation of this being an eclipse at solar minimum, I used a Nikon D800 modified for Hα imaging. This modification changes the standard blocking filter to one made to pass more through red light. The spectra are now extended into the near infrared, to about 8000 A. We can see the water vapor in the atmosphere absorbing the sunlight (dark lines) at 7600 A in images before and after totality.

The most interesting aspect of these spectra is the now-prominent red Fe X line at 6376 A and virtually no green Fe XIV line at 5303 A. The green line can be teased out of the images in post-processing. This indicates very low solar activity. Over 75% of the days in 2019 had no sunspots.

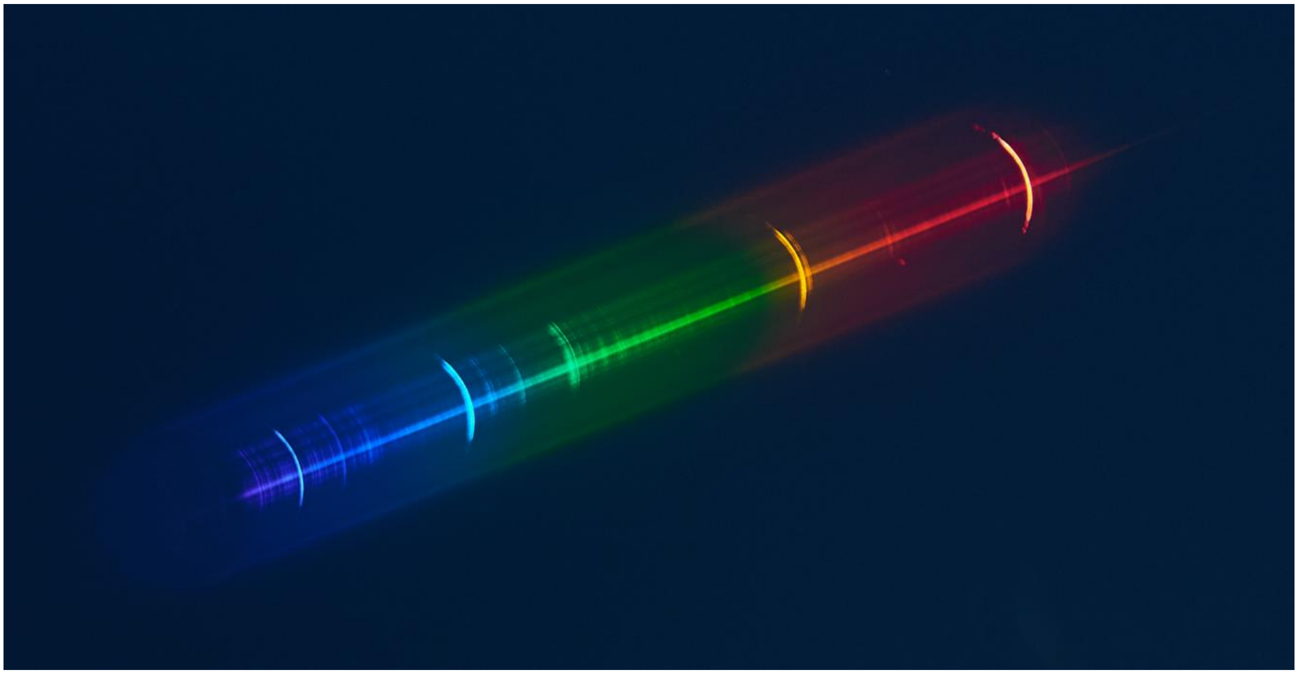
Camera: Nikon D800 modified by Spencer's Camera. Lens: Nikon 180/2.8. Settings: f/4, ISO 200. For the flash spectra, exposure time was 1/50 second; for the coronal spectrum, the exposure time was 1/15 second. Some slight adjustments done in Capture One but none require increasing exposure. These settings work perfectly as long as skies are clear.

.

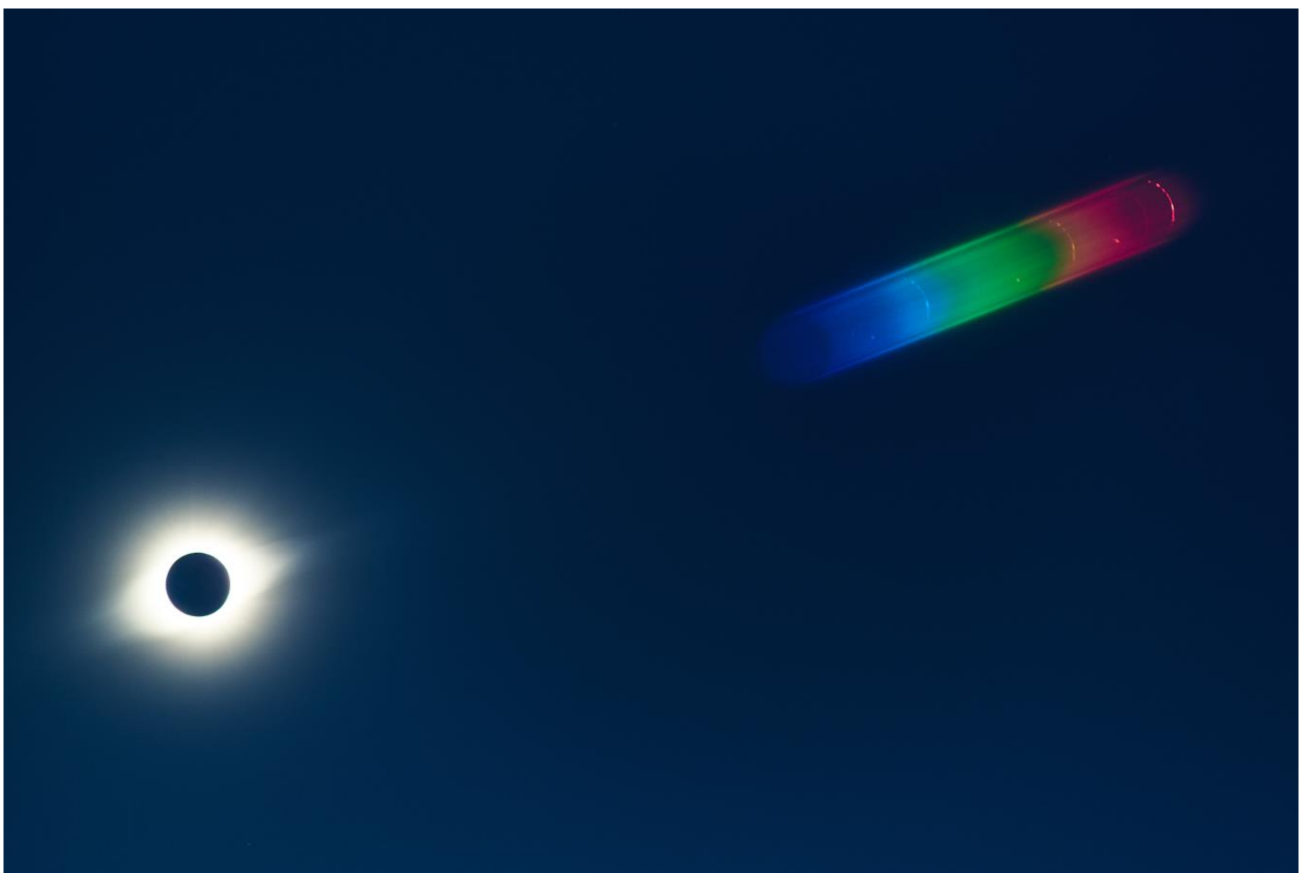
#184844: 2 seconds before second contact at 2/7/2019, 20:40:22. Note the dark lines in the red continuous spectrum right of The bright Hydrogen-alpha line.



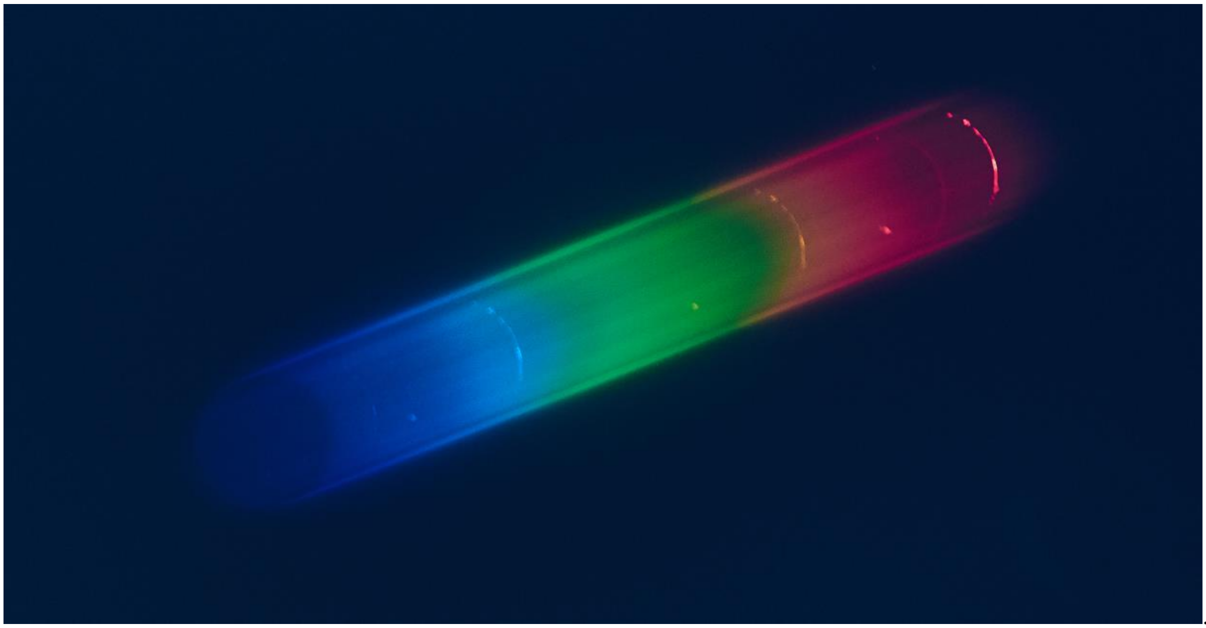
#184848: Second contact at 2/7/2019, 20:40:24.



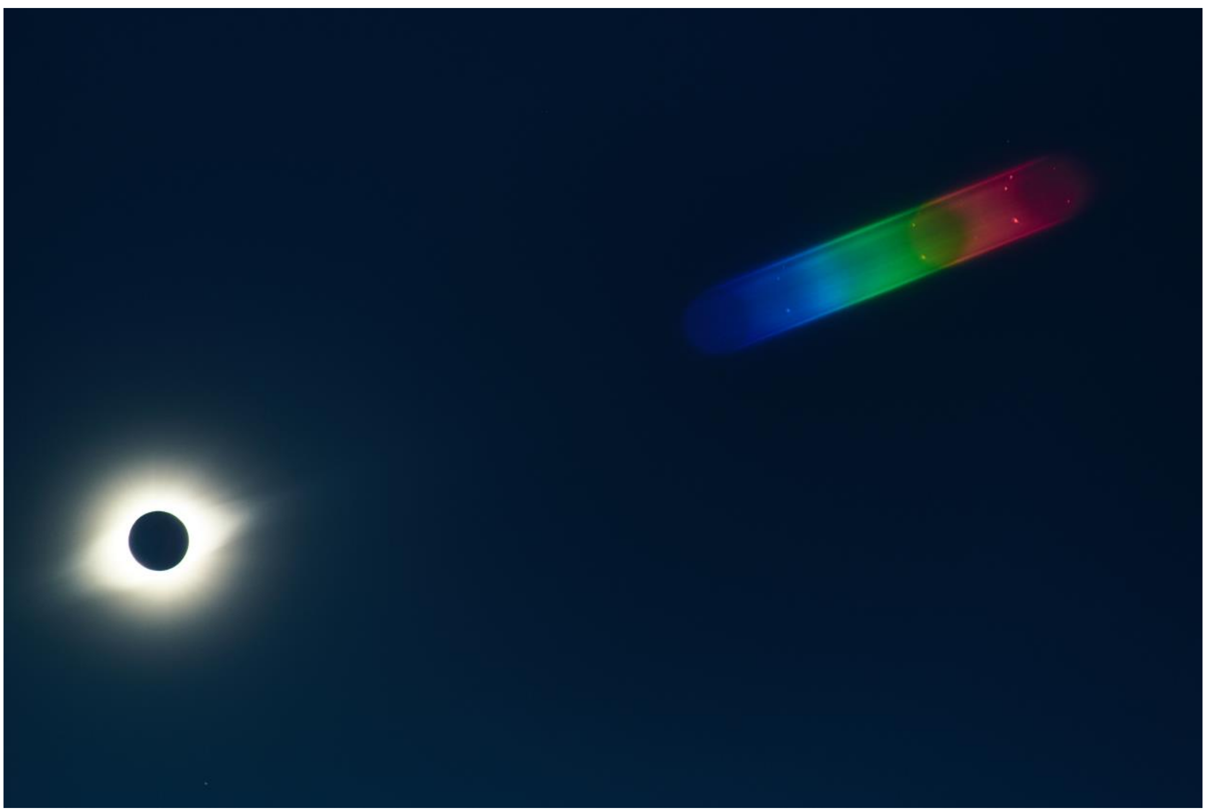
#184848: Second contact at 2/7/2019, 20:40:24.   Detail of flash spectrum.



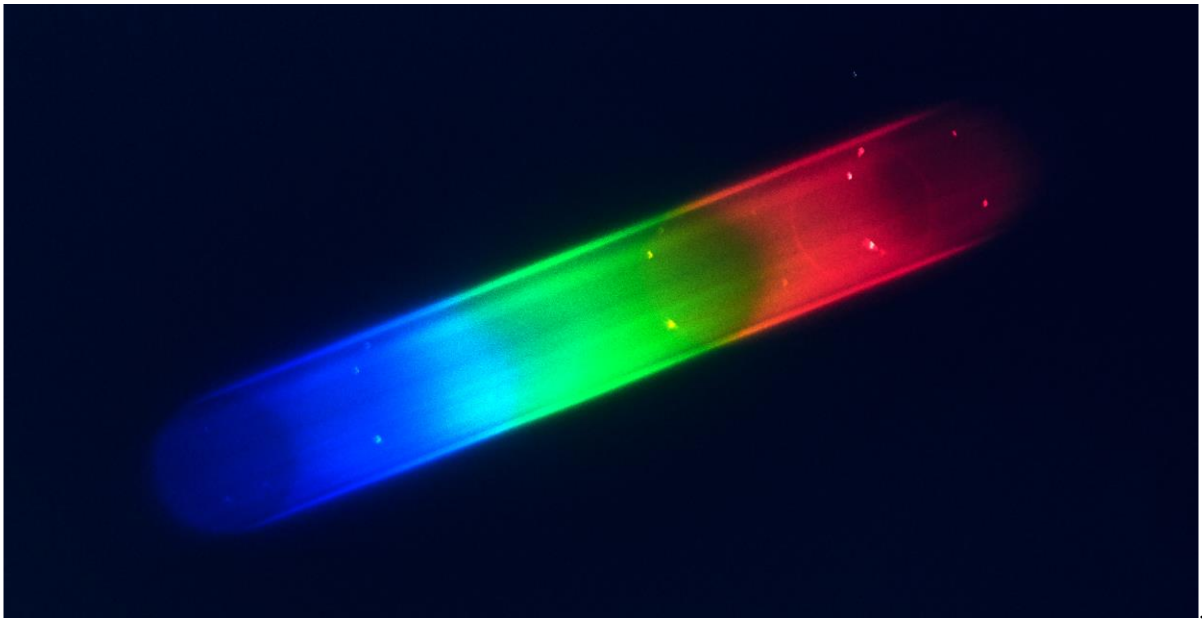
#184866: Coronal spectrum at 2/7/2019, 20:40:40.



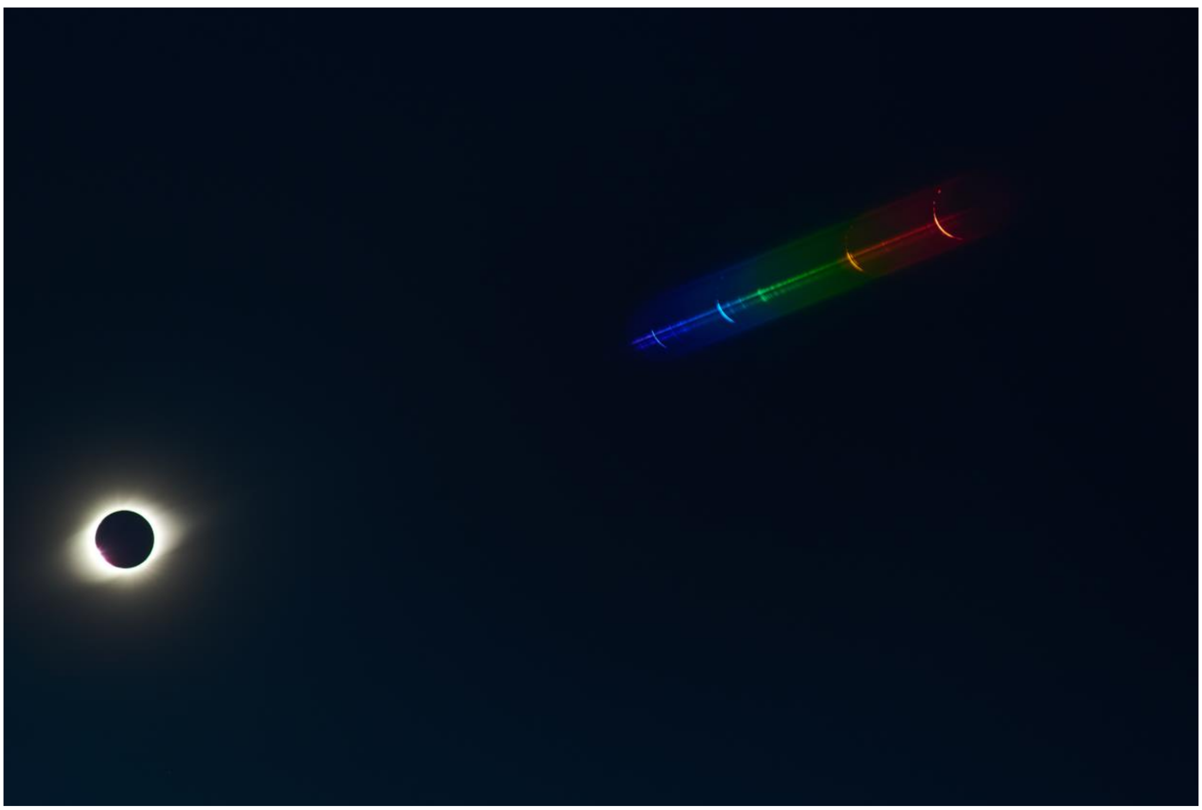
#184866: Coronal spectrum detail at 2/7/2019, 20:40:40. The red Fe X line is prominent here. It is extremely difficult to detect the green Fe XIV line.



#184886: Coronal spectrum at 2/7/2019, 20:41:43

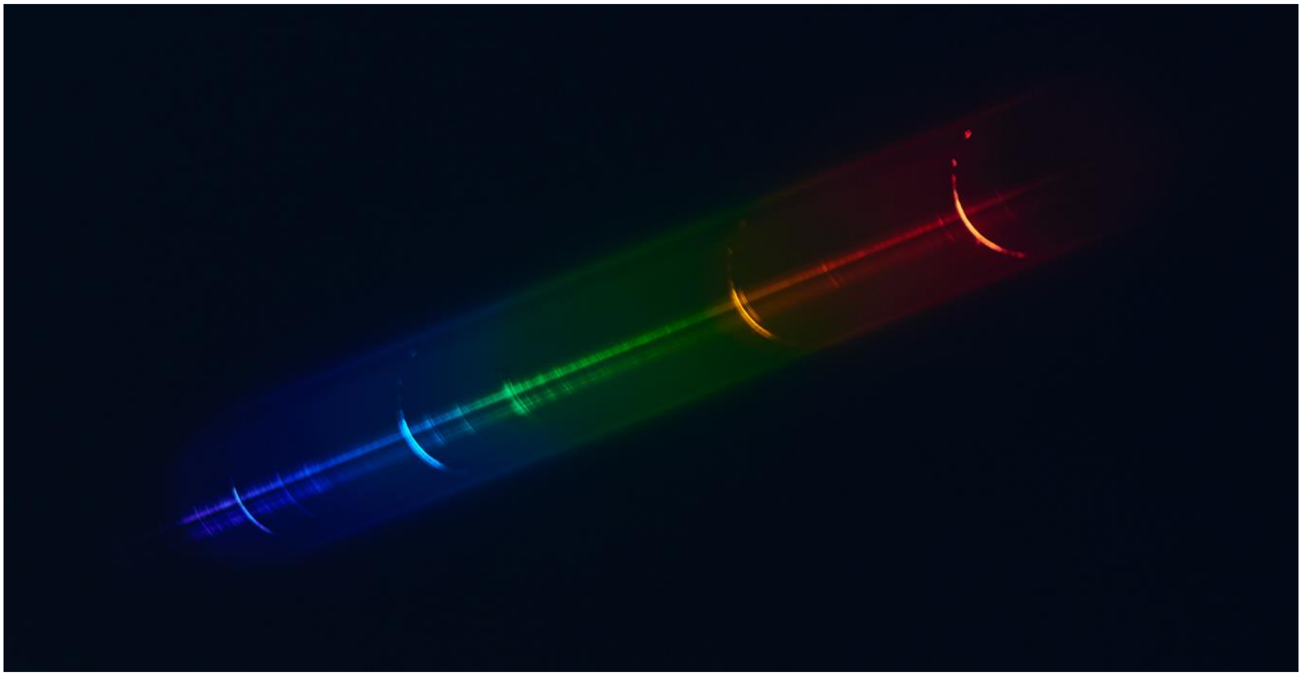


#184886: Coronal spectrum detail at 2/7/2019, 20:41:43. The red Fe X line is more prominent in the red; we cannot see the green Fe XIV line.



#184917: Third contact at 2/7/2019, 20:42:52. This imaging session was on a fixed mount. With a 180mm lens, precise positioning is important so that the image remains in the field. Note the motion between the first image of the series this one at the end of totality. A good zoom lens or a shorter focal length of 135mm in the FX format may be better.

If you want only the spectrum, then use a longer lens, perhaps 300mm, for better resolution. However, I prefer having the eclipse in the frame as a better targer. For DX format cameras, divide these focal lengths by about 1.5.



#184917: Third contact st 2/7/2019, 20:42:52. Detail of flash spectrum.