

American 2017 Total Solar Eclipse



Reports by Ivor Clarke and Mike Frost

The Total Solar Eclipse at Jackson Hole, Wyoming, USA. Monday 21st Aug. 2017 Perfect conditions, blue sky, no clouds. From Jackson the eclipse lasted 2min 15sec and felt like 30 seconds! All taken with a SONY DSC-10M3 camera, at 220mm (equivalent of 600mm on a full frame 35mm). All partial phases taken at 1/800 @ f5.6 ISO 64; 220mm, Baader Mylar filter. Start at the top left to right at 10.18am, 10.28, 10.48, 10.56, 11.07, 11.24, 11.31. Background shot showing Sun's corona with the lines of force of the magnetic field of the Sun. Regulus is at the lower left. Taken at 1/50 @ f5.6 ISO 200. Two shots showing prominences of red hydrogen gas at the Suns edge, taken at 1/2000 @ f5.6 ISO 200. Eclipse end L to R at 11.44am, 11.52am, 12.01pm, 12.11, 12.22, 12.46, 12.54

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The 2017 Solar Eclipse in America

By Ivor Clarke

The last total eclipse my wife and I saw was in August 1999 at a charming lakeside village in Austria called Mondsee. So for this years eclipse it was a case of spending time looking at all the options available as a trip to the USA was going to cost a lot more. We needed to get booked up well over a year in advance as there are only a finite number of places to stay. Also this year was our 50th wedding anniversary, so lets splash out a little we decided. We had looked at the specialist astronomical trips going and most were fully booked or lasting just a few days either side of the 21st August eclipse date. The weather predictions were that the further west you were the better, the less cloud you have on eclipse day the better!

We had been into our local travel agent in town in early 2015 and made enquires about the eclipse. Of cause they had not heard of it but looked up what they could find and did unearth a couple of holidays with the right dates; but one was for a week only and incorporated a trekking holiday in the Rockies. If you are going on holiday to the USA a week was not very long for our anniversary visit. Then with 15 months to go we received the latest Travelsphere 2017 travel brochure. We had been with them before and on their mailing list luckily. In the front was a trip called "*Epic Wonders of the National Parks, Solar Eclipse*" a 17 day holiday through some of the most amazing places on the planet. My wife popped into the travel agent that afternoon and discovered that there were only 14 places available. Next morning we went in and found there was 9 places available, it was make-your-mind-up time. So we booked.

This eclipse was the next one in the Saros series Number 145 which began long ago on January 4th 1639 when it grazed the north polar regions and will end on April 17th 3009 when it leaves the south polar area. This Saros Series 145 lasts 1370.3 years and has 77 eclipses of which 41 are total. That eclipses run in a series was discovered over 3,000 years ago by the ancient Babylonians and they used this knowledge to predict when the next eclipse would occur. At any one time there are a number of Saros series in operation overlapping each other. Each consecutive eclipse in a Saros lasts 223 lunations or 6585.32 days (just over 18 years). After which time the Sun, Moon, Earth and the nodes of the Moon's orbit return to almost exactly the same relative positions. But not exactly, the Earth will have turned through 120 degrees or a 1/3 of a day. So after 3 Saros periods, 54 years and about 30 days, an eclipse will occur over the same part of the Earth again but further down south. For instance, England's last but one eclipse of 29th June 1927 was 4 Saros periods ago. The one on August 11th 1999 was at a little lower latitude and the next will be lower still and so on until they miss the south pole region and the series ends. So the next in this Series was the one on Aug 21st 2017. It started in the north Pacific and swung across the USA from Oregon in the northwest touching 14 states to South Carolina before heading out over the Atlantic towards Africa. The next in this series is on September 2nd 2035, it starts in Western China, goes over Beijing, North Korea and Japan, not quite touching north Tokyo. Before heading off into the Pacific Ocean ending near

the mid ocean equator. The maximum eclipse time will be 2.54 minutes.

Our holiday started at Heathrow with a BA flight to Denver in Colorado where our tour began. Our guide was called Tim and was a Londoner who had lived in the States for about 20 years, then the 43 of us on this trip after an overnight stay in Denver boarded a brand new coach to drive the 400 odd miles through the prairie grasslands to South Dakota and Rapid City via Fort Laramie. From Rapid City we went west into the Black Hills to visit Mount Rushmore, with the carvings of the four presidents, George Washington, Theodore Roosevelt, Thomas Jefferson and Abraham Lincoln high above in the granite mountain. All this area of the Black Hills is a tourist paradise with hundreds of attractions and parks for all ages plus the scenery is marvellous. If you are a US citizen over the age of 62, you can buy a Lifetime Senior Pass for \$10 which lets you into all the National Parks! Next to the Crazy Horse Memorial (the worlds biggest on-going carving), the 87 feet high face of the Indian Chief Crazy Horse is the only part finished, he is pointing the way forward for his people sitting on his horse, this 563 foot high memorial is a work in progress having been started in 1948.

In the afternoon we travelled east to a small town called Wall which seemed to consist of huge grain towers, a railway track and the largest Drug Store you have ever seen! It had everything you could think of under one roof, including a museum and a massive cafe/restaurant for lunch, plus coffee at 5 cents a cup. From there we headed into the Bad Lands, 244,000 acres of barren eroded landscape full of fossils of early mammals from 25 - 37 million years ago. The coloured stripes in the sedimentary rocks layers are very striking and form many miles of barren landscape with cliffs, gullies and odd rock formations.

Next day we also visited Deadwood, and a tour with a hilarious guide in an old yellow school bus around town and up into the hill top Mt. Moriah Cemetery, where the graves of Wild Bill Hickok and Calamity Jane lie along-side each other, along with thousands of others. A small detour took us to the 1,267 foot high Devils Tower National Monument (the landing spot for the aliens in the 1978 film *Close Encounters of the Third Kind*) and one of the sacred sites of the Lakota Indian tribe. This is the stump of an ancient volcano millions of years old, and the first national monument designated by Roosevelt in 1906.

Our tour continued the next day to the Little Bighorn Battle Field with an Indian guide, Rose, who joined the coach to explained how Custer's 7th Cavalry got caught out by the overwhelming number of Indians, about 7,000, from at least 7 different tribes who had come together for the battle and wiped out the 250 men of the 7th Cavalry in this famous battle. The Indians lost between 60 - 100. We travelled several miles along small roads on top of a ridge looking down on the areas where the Indian camps had been situated along the Little Bighorn River.

The Yellowstone National Park was next, a fantastic place to visit with the first views of the many geysers steaming

away and shooting out jets of super heated steam. Then to one of the most photographed spots in Yellowstone: the Lower Yellowstone Falls from an area called Artist Point. The falls are 308 feet high and have formed over the years a deep, steep sided canyon of multi-coloured sandstone with a forest of fir trees at the top. We also went to see "Old Faithful" near the famous old Yellowstone Lodge. This geyser erupts every 90 minutes or so and lots of visits are planned to coincide with it doing its stuff. Except it is some times 20 minutes early or 20+ minutes late, this time it was late. . .

Next day we walked around a number of geysers at a site called Fountain Paint Pot on a set of boardwalks. Most of these are just set around the geysers with no hand rails so care is needed as most extend over the running water and pools of strange coloured muds and clays. Later we walked round an area called the Midway Geyser Basin with two large steaming pools of bright blue water, with the largest called the Grand Prismatic Spring having water at 160°F and a bright orange runoff area caused by the thermophile microbes living in the hot water. Next, just south of Yellowstone are the Grand Teton National Park with its beautiful range of mountains, one of the newest range of mountains on Earth, only 15 million years old, before arriving in Jackson Hole, Wyoming to see the eclipse.

Jackson is a small town surrounded by high hills, some are used as ski runs in the winter, with a cable car to the highest. It is a wealthy town with lots of nice buildings, shops, restaurants and hotels. There seems to be an art gallery on each corner with lots of expensive paintings and sculptures filling them.

Our large motel was near the town centre and newly refurbished in an Ikea style, with wall-paper of mountain scenes and maps of the area. We had arrived on the Sunday afternoon, the day before the eclipse, in time to explore the town before the shops shut and get dinner. All the advice was that it would not be easy to travel next day and find anywhere to park a large 45 foot long coach nearer the centre line of the eclipse track. Every available parking spot and camping site was booked solid and had been for months. Our guide Tim was thinking of trying to get to a charming lake side viewing area a few miles north. But after talking to a few of us and with the eclipse track map of the area I had, he and we decided to stay in Jackson where we had all the amenities we

needed, like loos and coffee in our rooms! And we wouldn't have to get up at the crack of dawn to get stuck in a traffic jam. The eclipse track is about 60 miles wide, with the shadow moving at around 1,000mph and lasts for 2 minutes 21 seconds at the centre line. As we were only about 7 miles south of the centre line of the eclipse, which passed right over Jackson Airfield north of us and through the bottom of Grand Teton National Park the eclipse would last for 2 minutes 15 seconds so we would loose about 4 or 5 seconds off the centre line time.

Sunday was a hot sunny day and the Monday was the same with just a few early morning clouds which soon disappeared. After a leisurely breakfast about half of our tour group started meeting outside of our ground floor room on the edge of the footpath near the local bus stop with a couple of seats. The town was strangely quite with hardly any traffic, most of the shops were closed for the morning and people started gathering in groups at nearby hotels and in the local parks and squares. Down the tree lined road from us a group gathered around a couple of telescopes set up on the sidewalk. The ski lift was in use transporting all who had booked to the top of one of the nearby hills. Next day the *Jackson Hole Daily* newspaper said 800 people had rode to the top of Rendezvous Mountain for the event.

The Sun climbed higher into the cloudless sky and we got out the stools from our rooms to sit on and find a location to pitch tripods and start photographing the Sun. I attached my camera to the top of a 4 foot tall carpark post with a clamp, no chance of camera shake with a 4" metal post set into tarmac. At about 10.17am the first contact was due from Jackson and soon a tiny bit of the Sun was missing. To photograph the partial phases I was using a Baader Solar Filter over the camera lens in a home made mount in a Cokin filter holder. Having tried this at home I had established the exposure for the partial phases at 1/800 @ f5.6 with an ISO of 64. The lens on my SONY DSC-10M3 extends to 220mm, which is the equivalent of 600mm on a full frame 35mm camera. I had been surprised by how sharp the Sun looked with a set of sun-spots across it at full extension.

Every 10 or so minutes several of us photographed the partial phases as the Moon crept over the disc of the Sun. By 11.20am it was getting noticeable darker with the shadows on the ground going banana shaped, it was time also to put on a coat or jumper as it was getting cooler. After all Jackson is about 6,250 feet above sea level and it makes a different. Just before totality I placed my iPhone on a stool near the kerb and set it recording a video of us watching the eclipse, it proved a hit with all of us as we all clapped and cheered as the Sun disappeared behind the Moon. Cheering could be heard coming from all directions in the town as we were all plunged into darkness. The total phase was at 11.36am. And seemed to last just a few seconds, just time to look and pull off the solar filter and try and shoot the corona and the pink prominences of red hydrogen gas along the edge of the Sun peeping over the edge of the Moon. Most modern cameras now have lots of settings for Sunsets, Landscapes, Sea, Portraits, Sport, Flash, Micro and so on, but you will look in vain for an Eclipse setting! Just when you really do need help. The contrast between the Sun and the corona is a million or more to one, even the eye can't take it in so a camera has no chance. What you can do is to make a range of different exposures as quickly as possible and hope that the best shows the wonderful spectacular view above.



Eclipse watching in Jackson



Shadows of leaves with the Sun about 95% covered by the Moon

Luckily my SONY camera will give a good range of bracketed exposures just by holding down the shutter button on one of its programme memory settings. It was an exciting moment, a black hole in the sky with a stripy white glow of the corona around it showing the magnetic lines of force of the Sun. All too soon Phil standing next to me shouted "Diamond Ring!" and very suddenly we were back into daylight. A crow had landed in a tree behind us just before totality and darkness and now it was day again, it took off again telling everyone how cross it was by the short 'night'. We all had a laugh at the poor confused bird. Later someone told us a herd of elk in the Teton Park went frantic for a while, animals do get confused by total eclipses as its the only one they are likely to experience. Most of us stayed to photograph the partial phases as the moon left the sun, by 1.00pm the Sun was whole again.

At six o'clock there was a gun fight. A cross-road is cornered off next to Jackson Square Park and members of the local theatre stage a gunfight with the baddies and goodies and gal's for 15 minutes. When the baddies are 'dead' they have a collection and walk the two blocks to the oldest building in town, the PlayHouse Theatre, 102 years old!!! We had booked a table earlier and went there for dinner at 7.00pm. The cowboys and cowgirls served dinner and sung western/cowboy songs and if you knew the chorus, joined in. At our table was a couple who were on another eclipse trip with Dr John Mason in the Tetons Park. We all had a wonderful evening to finish off a remarkable day.

After leaving Jackson we spent the morning driving to Salt Lake City and a look round the centre of the city and the Mormon Church and Tabernacle in the afternoon. Next day we went to the Great Salt Lake, a vast area of salty water which the first explores thought was the Pacific ocean as it was salty and the far shore out of sight. It is the second most salty body of water after the Dead Sea. Next we visited a replicated village high above Salt Lake with lots of old buildings lovingly restored and rebuilt, showing life in the old west 150 years ago. From there we drove to the imposing Utah State Building, a wonderful white classical roman looking building complete with a large dome, set on a hill over looking the Mormon city. The entrance has large white columns topped with Corinthian capitals. This is not a museum but a working building where the Utah State Senate holds its meetings and where the Governor Office is located. We were shown around by a very knowable lady who took us

to all the parts open to the public, even some of the side rooms where meetings were being held.

Next day we headed to the Arches National Park. Tim our guide took us on a 1 mile walk called Park Avenue(!), it was mostly down hill or level and as it was midday about, 95°F. "Take a bottle of water each." was sound advice for the 45 minute walk. The cliffs of dark orange/red Entrada Sandstone towered each side with sheer walls and outcrops caused many stops for photographs along the walk. We could not go to the arches Tim had wanted us to visit as the road was being reconstructed, so we walked up a hill to see another arch from a distance. The following day was a visit to the Masa Verde National Park (Spanish for 'green table') with a local guide Dave, a farmer and archaeologist who gave us an excellent description of how the ancestral Pueblo People lived in the cliff dwellings. It wasn't until the 1880's that these ancient stone buildings were discovered by archaeologists even through the local Indians and ranchers in the Masa Verde knew about them. Most of the cave sites were in use from around 750AD until 1300AD when it was deserted, with most of this area at around 7,000 feet the weather can be extreme and some years very little rain falls. But why they suddenly left is a mystery.

There is only one place in America where 4 states meet and its called the Four Corners, Utah, Colorado, Arizona and New Mexico join at this point so you have to have a picture of yourself in four states at once standing on the bronze plaque on the ground. Then on to the desert. This was a drive with a Native American, a member of the Navajo Tribe, into the Monument Valley in an open sided 4WD bus to get a close-up view of the incredible scenery. We bounced around in the back of the bus as he described the various types of rock formations, before stopping at one of the locations where a lot of old cowboy films had been shot. This was another place with red/orange sandstone stretching to the horizon with strange rock shapes and pinnacles some over 1,000 feet high. When we got back it was luxury to get onto a air-conditioned coach after 2 hours in 104°F heat. Phew! Later that day we stopped off at the South Rim of the Grand Canyon at a point called Desert View with a watchtower you can climb and nearby a viewing platform giving spectacular views down onto the Colorado River over a mile below.

The next morning we visited the Village, again with spectacular views of the canyon with the far North side rim over 10 miles away. This is the main complex on the South Rim of the canyon with hotels, restaurants, camping grounds and plenty of parking for all the sightseers and walkers who like to walk the rim or descend down one of the many trails into the canyon. One trail called the Bright Angle can be hiked to the bottom or you can hire a pony to ride down and up in a group. But if you walk down you need to be fit to get back up and as the rim is at 7,000 feet you can feel that the air is 30% thinner than we are use to. We didn't have time to walk too far and by lunch time we were off to a town called Kanab, stopping off to walk across the bridge over the Colorado River next to the large Lake Powell Dam. Kanab grandly calls itself a city but is just a small town, famous for being in the centre of the old film making area. Many of the old cowboy (and cowgirl) film stars stayed in the town and most houses have signs outside telling who stayed where including John Wayne in a tiny shack.

Next day we travelled north to Bryce Canyon National Park and went to Bryce Point at an elevation of 8,300 feet. From here there is an amazing view of the canyon stretching

out for miles with thousands of bulbous columns called hoodoos in shades of orange and cream coloured rocks lined up in rows. Down on the canyon floor are fir trees looking like grass in the distance. Hills on the horizon can be up to 100 miles away in the clear air. We also stopped off at Inspiration Point which was a little lower at 8,100 feet! Walking along the rim of the canyon you get a feel for its size and incredible views. After lunch we went to Sunrise Point and many of us went for a hike down into the canyon to walk part of the Queen's Garden Trail and go to a rock formation called Queen Victoria, well it properly did look like Victoria once. It was hot work getting back up to the rim in the thin air, but we all felt proud of ourselves for doing it.

After being at the top of the rims of canyons the next day was a visit to Zion National Park in Utah, with a walk along the floor of the canyon following the small river. We were dropped off at the Zion Canyon Visitors Center, and given a

map so we could explore the area. All along this part of the canyon run free shuttle buses, so to get to the Temple of Sinawava and the start of the river side walk was 8 stops, easy. It was a very pleasant walk along the path to the end in the shade of the trees with the river running past on the left. At the end of the path you needed to paddle across the river to continue up the trail. It was busy with lots of people walking the path but not too crowded and a very pleasant change from being on top of a canyon rim.

From there it was to Las Vegas for a night before the flight home at the end of 18 days of adventure, 9 states and 3,700 miles of travel.

This was one of the best travelling holidays we have had, great company, lovely hotels, good meals and memories to last a lifetime. This trip can be recommended to all who enjoy spectacular scenery.

The Great American Eclipse

By Mike Frost

On August 21st 2017, a total eclipse of the Sun swept across the United States of America, from Oregon to South Carolina, crossing fifteen of the states on its way. It was the first total eclipse visible from the USA since 1991, when the path of totality crossed Hawaii; the first to cross the Continental USA since 1979; and the first to cross both the Pacific and Atlantic coasts of America since 1918.

Of course I went to see it! I've lived and worked in the United States so I'm comfortable traveling there independently. But where was I to observe it from? Fred Espenak and Jay Anderson, two greatly respected umbraphiles, had produced an eclipse bulletin (Fred used to do this for NASA but after retiring now produces them independently; Jay is a Canadian meteorologist). From graphics of average cloud cover it became abundantly clear that the western side of the United States was a much better bet than the centre or east.

My final decision came after conferring with Professor Jay Pasachoff, who spoke at the joint meeting of the BAA

historical section and Society for the History of Astronomy at Greenwich in March 2015. Jay has seen more solar eclipses than anyone else in history, so I asked him where he was going to view the 2017 eclipse from. Madras, Oregon, was his answer. I had never been to Oregon before, so that sounded like a good choice.

There was one problem – Oregon is not the most densely populated part of the US. Towns like Madras are small (around 20 000 people), few and far between. By the time I got round to looking, a year in advance, all hotels there had already been booked up. There were also warnings that traffic into central Oregon would be gridlocked. So I chose a location, Pendleton, in the north-east of Oregon, as my base.

On Friday August 18th I turned up at Heathrow for my flight to Seattle, via Vancouver, Canada. The Canadian stopover, it turned out, nearly wrecked my holiday completely. In the months since I had booked my flights, Canada had introduced a pre-vetting scheme similar to the US's ESTA. Even though I wasn't passing through Canadian passport control, I wasn't allowed on the flight until I had acquired a Canadian ETA. I spent a very uncomfortable 80 minutes applying online and waiting for the application to be approved, before finally being allowed to check in. This is why I like to arrive at the airport three hours in advance!

My flight into Vancouver, and then the shuttle flight across Puget Sound to Seattle, gave a taste of the beautiful country which I got to explore later in my trip. The Cascade Mountains, the westernmost part of the Rockies, overlook both of the two cities, and both have appealing locations in sheltered harbours – Seattle lies on Puget Sound and Vancouver Island protects Vancouver city.

I worried that there would be an eclipse-related shortage of hire cars, but I collected my vehicle without incident, and stayed overnight in Tacoma, south of Seattle. The next day I set off towards Oregon. My route took me through one of



Mt Rainier

Washington State's national parks and over the shoulder of one of the state's most notable landmarks, the 4392 m (14,411 ft.) volcano, Mount Rainier. Wherever you are in the Seattle area, Mount Rainier is visible in the background, beautiful and menacing – a large eruption could cause great loss of life on the slopes and even reach into metropolitan Seattle.

Fortunately Mount Rainier didn't erupt the day I drove over it. The bigger risk to me was from forest fires, which caused the closure of the route I was hoping to take. Fortunately there was an alternative route to the south. The smoke from the forest fires was a potential disruption for viewing the eclipse from Oregon; indeed, the threat of forest fires on eclipse day worried the authorities. Hundreds of thousands of people were going to be visiting Oregon. Many of them were not used to camping out, or setting fires. And all it would take was one dropped cigarette, smouldering campfire, or overheated catalytic converter...

As I made my way over the Cascades, the scenery changed radically. The western slopes are lush and forested, but as I drove south-east towards Oregon, the landscape became ever more bare and arid. Eventually I crossed the Columbia River, the boundary between Washington and Oregon states, and joined the freeway crossing the rolling plains of eastern Oregon. My destination, Pendleton, was by the foothills of the next mountain range, the Blue Mountains.

Pendleton, despite being outside the zone of totality, was a popular base for eclipse chasers. Being a city on the freeway system, it had a large selection of hotels. I was worried when I found that my hotel had changed ownership, as there had been reports of cheap early reservations being cancelled and replaced with much more expensive rates, when hotel owners realised that they could charge what they liked around eclipse week-end. But the new owners of my hotel honoured my booking, for which I am very grateful. They got five stars from me on TripAdvisor – thanks guys!

Pendleton is a city of 16,000 people. These days it is best known as the site of the annual Pendleton round-up, a week-long rodeo in a large stadium on the outskirts of town. In its 200 year history, Pendleton has been a stopover on the Oregon Trail, a cowboy town, a gold-rush town, a halt on the railway, an air force town.

For most of its history, it was a pretty wild place. At its height the central four blocks of town contained 32 bars and 14 brothels. The streets were not safe, and most activity in town took place in the extensive network of basements and tunnels running underneath the city streets (also useful in winter when the streets were blocked by snow). I joined the excellent "Underground Pendleton" tour of the basements, where we visited reconstructions of gold rush bars, speakeasies, opium dens and Chinese laundries.

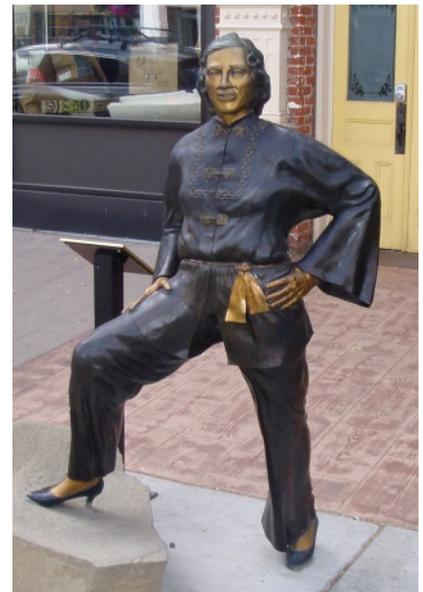
The highlight of the tour was a visit to "The Cozy Rooms", the bordello run by the irrepressible Stella Darby, one of the most famous characters in Pendleton history. Madame Stella looked after her girls; our first stop was the bordello chapel, where on Sunday afternoons a local preacher ministered to women who were not welcome in other churches

on Sunday morning (of course, the girls were busy Saturday evening, so it was also convenient that Sunday morning was a lie-in). One Sunday morning in 1953, one of the local preachers announced that he had in his possession two lists. The first list was of all the girls employed in Pendleton bordellos, the second list was of all their customers. If everyone on the first list hadn't left Pendleton by next Saturday, the preacher continued, he'd read out the second list the following Sunday morning. Next Saturday, a fleet of buses arrived in Pendleton, and the girls departed.

Six weeks later Madame Stella snuck back into town. She was able to continue because she had woven herself into the fabric of the town – if any family was going hungry, there would be a food parcel from Stella Darby. The Cozy Rooms remained in business until Stella's retirement in 1967, and these days there's a statue of Stella outside. The statue of Aura Goodwin Raley, "mother of Pendleton", looks at her sternly across the street.

I digress (but it's a great tour!). From Pendleton I had two choices for eclipse day. Drive south on local roads towards the tiny city of John Day, or south-east on the freeway toward the Oregon / Idaho border. I was worried about being stuck in traffic on eclipse day, and reasoned that I stood a better chance of being able to move freely on the Interstate. Additionally, whilst the weather forecast was excellent all the way across Oregon and into Idaho, the smoke forecast from forest fires was rather worse to the west, so moving eastwards seemed to me a better bet.

I ate out early on Sunday evening with Callum Potter (the BAA's incoming president) and his wife Morag, who were staying in Pendleton, en route for Long Creek, just north of John Day. Then I went to bed early. Eclipses aren't really



Stella Darby



Snake River and Burnt River confluence

eclipses unless you have to get up in the middle of the night and drive into the middle of nowhere. The Great American Eclipse was no exception - my alarm went off at 3:30AM.

By 4:00AM I was packed and heading south-east on I-94. Traffic was free-flowing, plenty of cars like me but also long-distance truckers who would have no interest in the eclipse. After an hour, between La Grande and Baker City, I entered the zone of totality, and began to relax. I made a pit stop; the service area was packed, full of eclipse chasers sleeping in their cars. The skies were clear, Venus shone brightly in the east.

As dawn broke I was dropping down from the Blue Mountains, into the steep valleys which ran into the Snake River, my chosen destination. This is wild, deserted country with very few settlements. I passed Durkee, which was host to a large eclipse music festival. Then Lime, site of an abandoned cement factory, right by the side of the motorway. With cars, vans and motorcycles parked everywhere, it looked like something out of "Mad Max"!

At 6AM I turned off the freeway and headed for the small town of Huntington. This was virtually on the centreline, and even early in the morning, people were advertising parking space on waste ground near the town centre. I carried on straight through. I had two observing sites in mind, both on the Snake River. One was Farewell Bend State Park, two miles south of Huntington. But an enquiry about observing sites to the SEML eclipse mailing list had produced an alternative. Many months previously Dr. Donald Kennerly had traveled along the centreline, videoing potential viewing sites. He assured me that Farewell Bend was a perfectly good location, but suggested that I consider an alternative site just to the north, at the confluence of the Burnt and Snake Rivers. This was also scenic, as Donald's video confirmed; it was also closer to centreline, giving a couple more seconds of totality. He also advised that if clouds did start to form, they would be less likely over the head of a valley. I have no idea if this is true, but it sounded convincing.

So I went with Dr. Kennerly's recommendation, and followed the Burnt River east from Huntington down to the confluence, just downriver from the railway bridge into Idaho. As I turned off the road, it became clear that 50 or so other people had had the same idea as me (several, it turned out, had seen Dr. Kennerly's video). Many had camped out overnight – the authorities had helpfully provided Portaloo's, but otherwise there were no facilities.

The site was indeed a good choice. The Snake River was about to make its way into a steep gorge. So to the north there were high, bleak hills, topped with wind turbines. To the east, across the river, was Idaho; a few campers could be seen on the far side of the river. To the south was the railway bridge; as I watched, a huge freight train announced itself noisily in the distance, then chugged slowly and noisily across the bridge into Oregon, and up the Burnt river valley. How very American! I imagined Casey Jones at the engine...

I breakfasted on the dried fruit and nuts I had brought with me, then began to set up by the riverside ready for the eclipse. This didn't take long, as I don't aim to do anything technical for eclipses, filming with my tablet just before totality but observing the total eclipse with binoculars. I had brought a few "experiments" to try out during the partial phases – for example, my trusty "Hello Mum" pinhole card, which was showing its age. At the suggestion of Sky and Telescope Magazine, I also tried a rather different experiment – instead of a pinhole, I cut larger circular hole, two inches

across, into cardboard. The idea was to see a positive image of the partially eclipsed Sun, formed by interference from the edges of the hole. One other favourite was my Shadow Band Detection System, formed by a white bed sheet, "borrowed" from the hotel and weighed down by rocks.

With plenty of time before the eclipse started, I also had opportunity to meet my fellow umbraphiles. Steve, from Idaho, welcomed me to the site, and promised me that the wispy cloud overhead would be gone by totality time. Mark and Jenny, from the Seattle area, were busy setting up telescopes and cameras. Another serious observer was Christian, from Stuttgart, setting up his cameras in the wind shade of his car. Rather more laid-back was a group of Canadians, who set up chairs overlooking the river to enjoy the eclipse in comfort.

9:10AM arrived and the eclipse started. Early cloud had completely disappeared, just as Steve predicted. We spent the next hour and a quarter doing all the things you usually do during the partial phases of the eclipse – checking progress through eclipse glasses, photographing the pinhole images of the eclipse. The experiment to see the positive image of the Sun was a complete failure, I couldn't make out anything at all. A separate experiment to enhance the pinhole images using a magnifying glass was abandoned when we were about to set the sheet on fire.

Second contact, the onset of totality, was at 10:24. The sky remained clear although we could see one or aircraft contrails. Maybe a little heat haze but no sign of forest fire smoke. Venus came into view three minutes before totality.

As in my previous two eclipses, I was intending to video the last 90 seconds or so before totality on my tablet. I started filming early, over two minutes before second contact, because there were already very clear shadow bands on the white sheet. I'd seen shadow bands previously at Curacao in 1998, and very strongly after the end of totality in Longyearbyen, Svalbard in 2015. I tried to video the white



Mike Frost's Eclipse Viewer

sheet whilst watching out for everything else (stars and planets flicking into view, the arrival of the Moon's shadow, the breakup of the Sun's crescent into Baily's beads, and so on), and trying to provide a running commentary for those watching their first eclipse.

Totality was quickly upon us. The shadow bands went berserk for the final second or two, and the light level plunged dramatically. I stopped videoing and raised my binoculars. The corona was typical of solar minima, with three large spikes. There were prominences on both sides of the Sun, meaning that those on the trailing side were going to be particularly dramatic. The sky colours were nowhere near as spectacular as the golden horizon glow seen at last year's eclipse in Tidore, Indonesia. I thought I saw Mercury below and to the left of the Sun, though in hindsight I think it was actually Regulus. The prominences began to grow stronger on the right hand side of the Sun. I might have watched them develop but I chose instead to put the binoculars down and watch just for the diamond ring just with the naked eye. Maybe I did this too early.

All too soon the Sun sprang out from behind the Moon – the diamond ring. I glanced down and began filming the shadow bands which had promptly re-appeared. My fellow observers began to whoop and congratulate each other. "Next performance 2024!" I cried. On my video, a little girl can be heard saying "it was so pretty mom". The shadow bands continued for at least 90 seconds before subsiding into the background.

For the next 75 minutes I did what I usually do – make sure I've got pictures of crescents and pinholes, swap email addresses with the other participants. Ordinarily I toast success too, but I had a long drive ahead of me so I abstained. Once fourth contact was over and the eclipse finished, I bade farewell to my new friends and headed up the hill to Huntington, which was still busy with its celebrations. I bought a T-shirt in the local store; in the post office, I sent off several first-day covers featuring the extraordinary eclipse stamp, designed by Fred Espenak, which changes to reveal details of the Moon's surface when you apply heat by touching it. I listened to the last act in the eclipse concert, then bought a burger for lunch from one of the impromptu barbecues, though not from the one run by the local cannabis shop!

My last act before returning to Pendleton was to drive south from Huntington to my alternative eclipse viewing site,

Farewell Bend State Park. This, it turns out, would also have been a lovely site to observe from, a green riverside oasis. A plaque in the park revealed that the bend was named because this was where the wagon trains who, long ago, had followed the river across Idaho, turned away from the river and headed into the mountains. You can still see some of the wagon ruts by the side of the Huntington road.

The journey back to Pendleton was exhausting. Mostly the traffic flowed freely, but at two points, where roadworks narrowed the carriageway to one lane, there were queues. I got back to my hotel around 6 PM but was too exhausted to do anything else that day. Eating an entire family-size pack of dried apricots didn't help, either – who'd have thought that they acted like prunes...

The next day I looked around Pendleton's Station Museum – OK but nowhere near as much fun as the Underground Pendleton Tour. Then I drove the 200 miles along the Columbia River, through the spectacular Columbia Gorge, to spend the next night in the suburbs of Portland, Oregon's largest city. I caught the bus into Portland for a day so that I could enjoy the craft breweries that the city is famous for. I didn't actually get very far from the city block which has Powell's City of Books (one of the world's largest bookstores) on one corner, Henry's brewpub on another, and the excellent Deschutes brewery and restaurant just down the road. Henry's featured an "Eclipse of the Hop" IPA, Deschutes contributed a "Black by Popular Demand" in celebration of the eclipse. Powell's bookstore was simply wonderful! The whole city is very laid back.

For my last two days of my holiday I headed back into Washington and explored this beautiful state. First I meandered up the Pacific coast, stopping off in Westport to sample the excellent Blackbeard Brewing Company's beers and pizza. From my base in Olympia, at the bottom of Puget Sound, I drove up the side of the Olympic National Park. It isn't really a park accessible to motor vehicles, but what I saw was very spectacular, particularly lovely Lake Cushman. Port Townsend, at the head of the Olympic peninsula, was a pretty good place to break for a late lunch; fish and chips and local beer, eaten on a terrace overlooking the sea. I hoped to return to Olympia over the famous Tacoma Narrows Bridge – the replacement for Galloping Gertie, the suspension bridge which flapped in a steady breeze and broke up during particularly strong winds in 1940. But I was worried about being unable to pay the bridge tolls (these can now be electronic, and subject to hire car company surcharges) so took another route.

That's about it for the holiday – uneventful flights back to the UK; a drive back home; laundry; back to work. How quickly normality resumes!

I swapped stories with my many friends who had viewed the eclipse (mostly successfully) from along the route. Oregon, Idaho and Wyoming were clear; from Nebraska eastwards the weather became cloudier, though people still saw totality, particularly if they were able to travel to more promising locations.

I suspect I'm unlikely to ever return to north-east Oregon. But I'll remember fondly my eclipse day by the Burnt and Snake Rivers.

Great eclipse!



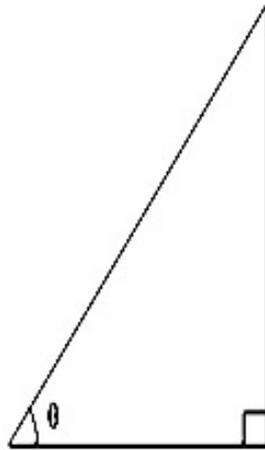
Olympic National Park, Lake Cushman

Parallax and its use in Modern Astronomy

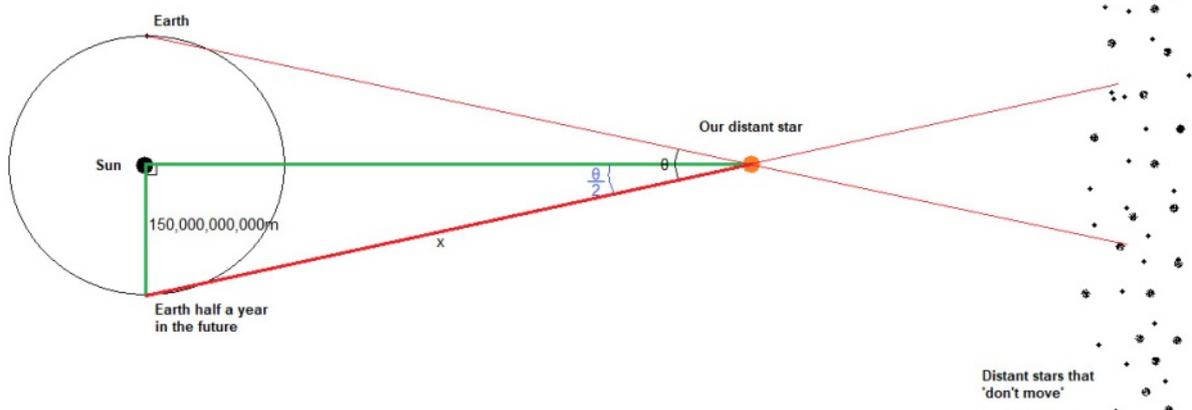
By Daniel Hollingsworth

As early as the nineteenth century, astronomers sought to measure the immeasurable. We knew a lot of what was going on up in space, yet we had no sense of distance. We knew the bright, flickering lights in the sky were hot balls of gas, releasing radiation into the universe. But just how big were they? Just how far away were they from us? These questions seemed almost impossible to answer – we sure couldn't use a measuring tape. Everything was seeming rather hopeless. But then high school maths came to the rescue, and solved all our problems*!

Yes, that's right. The answer to calculating the vast distances to alien worlds lies in your old maths school textbook – trigonometry. We are doing normal trigonometry, just with numbers and scales vastly larger than you were used to. Suppose we could draw a right-angled triangle big enough that one side went from the Earth to the Sun, another from the sun to our distant star, and the hypotenuse (the longest side) from the Earth to that same faraway star. Not looking too dissimilar from this diagram, although maybe a little more stretched, as our star will be further away.



Well, now the problem is made a whole lot easier! All we need is some lengths and that angle θ , and we are on our way to calculating the distance of our star from us. All we had to do was wait some time and, as our Earth moved around the sun and changed position in space-time, the star would move across our sky progressively throughout the year relative to a background of much more distant stars behind it, which for simplicity we will count as not moving (as they are so far away from earth, our movement makes no difference to their position in the sky – we can, in theory, class them as 'not moving' from our perspective, relative to us). This phenomenon is actually known as parallax. We can measure that angle and, with the distance from the Earth to the Sun (which we already know), use some basic trigonometric functions to calculate our stars distance from us. Solved!



Well. . . not quite, the problem comes along with that little rascal θ . Because, we here on Earth can only measure angles to a certain value, or else the angle is just too small for technology to compute. So, we can't just wait a day or two, we had to wait a whole half a year! This makes the angle large enough to reduce any uncertainties, and make the value as large and as accurate as possible. Simply all we do is calculate this angle, halve it and we can build up a right angled triangle as shown below. (For simplicity we will denote this new half angle in our calculations – just to make it look easier.)

To solve this problem, we have to use a bit trigonometry and rearranging. You may recall that $\sin \theta = \text{opposite} \div \text{hypotenuse}$. So rearranging this gives us: hypotenuse (the value we want to calculate – the distance from us to our distant star) = opposite (the distance from the Sun to the Earth) $\div \sin \theta$. With this, we have solved the mystery that has bugged astronomers for centuries.

So, to clarify that thought, let's assume we are workers at NASA, and want to send a probe to a distant star, but need to know how far away it is. So we set our telescopes to the star, and wait for 6 months before coming back to our telescopes, and find that our desired star has moved across the sky by 10° in relation to the distant background stars. So to find θ , we half this (5°) and slap it into our rearranged equation. (Make sure you are calculating in degrees, and not radians or radians).

$$\text{Hypotenuse} = \text{opposite} \div \sin \theta$$

$$\text{Hypotenuse} = 150,000,000,000 \div \sin (5)$$

Now if you plug this value into your calculator, you will get an answer in the ball-park of 1,700,000,000,000 m, which is over 10 times the distance from here to the Sun. So there we have it. Finished. Terminado.

Well. . . not really. In fact, if you noticed the little asterisk at the end of the first paragraph, then it is my sad job to break it to you that, in fact, this is not the end of our struggle to calculate distances in our universe.

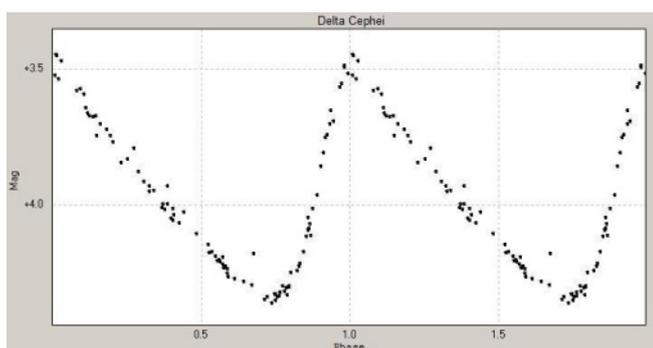
As we have noted, our technology even today can only measure angles so small. So as the distances of stars increase, that angle θ gets so small that we cannot measure the difference – our parallax has become useless. Luckily, scientists are a very clever bunch, and managed a way around this tricky little brain-teaser. . .

Cepheid Variable Stars and their use in Determining Distances

By Daniel Hollingsworth

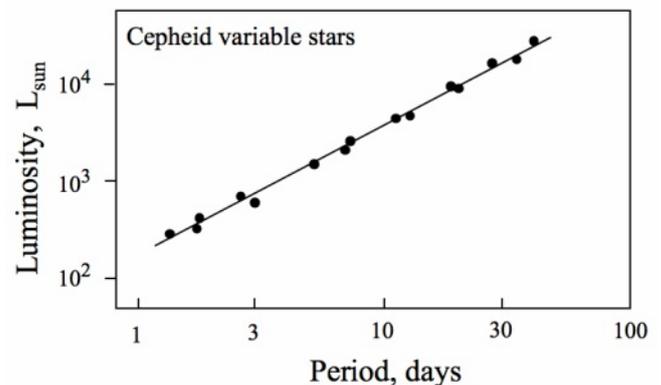
We have already talked about how distances to stars can be measured by observing their progressive movements through the skies compared with very distant stars behind it, using some simple trigonometry. But, alas, that was where our next problem lay, for what about the distant stars which, according to us and our technology, do not move at all? (Of course, they do move, but as the distances of stars from us increases, the amount by which they move decreases to only the slightest fractions of angles; far beyond that we can measure). Sadly, parallax could no longer provide the answer to the distances of all stars. So, scientists had to look for a new way of calculating distances. Cepheid Variable Stars provide a satisfying answer to this question.

Cepheid Variables are stars that have finished their main sequence of fusing hydrogen nuclei to form helium, and have entered the Cepheid instability strip. This means that the star regularly pulsates, by expanding and contracting various layers of the star, which ultimately causes changes in luminosity. To understand why these stars pulsate, imagine that the star is simply made of hydrogen in the core, and He^+ and He^{2+} ions in the outer layers. He^{2+} ions, which absorb the radiation emitted from the core, begins to get heated and expands. This means little light leaves the core, and so this is the dim part of the pulsation. As the star expands, the outer layers of the star become cooler again. This decrease in heat means the electrostatic attraction between electrons and nuclei becomes more dominant than the heat pushing them apart and one electron combines with each nucleus to form predominately He^+ ions, which are more transparent, letting light through. This is the bright part of the pulsation. As these ions are cooler, they no longer expand and begin to contract again; heating up and creating more He^{2+} ions – restarting this ongoing cycle. The process from dim to bright luminosity is much quicker than the opposite process, as shown in the diagram.



Between 1900 and 1910, Henrietta Leavitt discovered that some stars within the night sky pulsated, and changed in luminosity over a cycle that was entirely constant and predictable. Her work was predominately in the Large and Small Magellanic clouds. As these stars were in the roughly same region, Leavitt made the assumption that the stars were approximately the same distance away from Earth and so the luminosity of these stars should be approximately relative to each other. For instance, if one was brighter than another, we

can assume that this is true in the Magellanic Clouds as well and not just because the brighter one is much closer to Earth than the dimmer one! Otherwise the following data would be very wrong and provide no strong correlation. In other words, any observed difference in magnitude of luminosity on earth corresponds to a difference in real absolute magnitude of luminosity of the stars themselves. Leavitt noticed that there were also differences in the period of these stars (the time taken for the star to go from maximum luminosity to minimum and back to maximum again). Crucially, Leavitt plotted a graph of luminosity against period for these stars, and noticed a clear linear relationship (as shown below). When repeated with more Cepheid variable stars, the relationship still stood – showing that there appeared to be a universal relationship between luminosity and period for all Cepheid Variable Stars*. This is particularly useful for solving our distance problem!



For example, say we look up into the night sky and spot a pulsating star and, seeing as we are now mini-experts in this field, proclaim that we have clearly found a new Cepheid star that, upon rigorous investigation, has never been discovered! So, we take note of the luminosity of the star over, say, a month, and notice a pattern. The star displays a constant cycle of luminosity (similar to the diagram above) with a clear period of 11 days. All we have to do now is compare this with the luminosity-period graph, to get an absolute luminosity value of around -4.3. But the luminosity we get from the night sky is +7.5 (remember that the higher the value, the dimmer the star). This decrease in luminosity is important, because with it we can now calculate its distance using the distance modulus equation**. When we plug our values into the equation, we end up with an answer of roughly 2,300 parsecs, which corresponds to around 7500 light years.

By using this method, we are now able to calculate distances that are unimaginably larger than those provided by parallax – while parallax can provide distances to lengths of around 300 light years, Cepheid variable stars can provide lengths of at least 65 million light years. This revolutionises how we determine distance of not just stars within our own galaxy, but even those in other galaxies and in between – something parallax could not even get close to doing!

*In reality, there are actually different types of Cepheid Variable Star – Type I (or classical) and Type II (or W Viginis). There are also periodic stars that change in luminosity called RR Lyrae stars, which can also be used as standard candles. All of these stars show the same inherent properties, but are drawn as different lines on the luminosity-period graph. This is because RR Lyrae stars typically have lower luminosity readings and shorter periods than Cepheids. As well as this, RR Lyrae are less massive than Cepheids, but do display a linear relationship. Due to these factors, RR Lyrae stars can measure distances, but only those much smaller than Cepheid variable stars.

**This is a tough equation to explain, so we shall not, instead showing it here.

$$m - M = 5 \log_{10} d - 5$$

m – Apparent magnitude of the star

M – Absolute magnitude of the star

d – distance of the star

Plugging our values into the equation, we get

$$(7.5 - (-4.3) + 5) \div 5 = \log_{10} d = 3.36 \Rightarrow d = 103.36 = 2291$$

parsecs

Ouro Preto Observatory

By Mike Frost

In March this year I spent four weeks working with colleagues in Minas Gerais, Brazil. This a mountainous state in the industrial south of the country. We were based in Betim, a suburb of the city of Belo Horizonte, which lies eight hundred kilometres north of Rio de Janeiro. The job we were doing, the factory acceptance test for a computer system to be installed in Argentina later in the year, was difficult and so we worked very long hours, only getting two days off in the whole month I was there.

Nonetheless we made the most of our time off. On the first Sunday I drove to the historic towns of Sabara and Caete, to the east of Belo, and then visited the extraordinary mountain Serra Piedade. This 1746m-high summit is home to a hermitage, dating from 1767, which attracts thousands of pilgrims – so many, that on a Sunday, all visitors have to park half-way up the mountain and then walk the last 2 km to the top (there's a minibus service for the more infirm pilgrims). In addition to the hermitage there is a worship centre, visitor centre and outdoor amphitheatre. More relevantly to me, at the far end of the summit ridge is the Frei Rosario observatory, a rather impressive building run by the Federal University of Minas Gerais. There are two domes: the larger one contains a 60 cm diameter f/12.5 Cassegrain reflector, the

smaller a 15 cm f/15 Coude refractor. Unfortunately the observatory only opens infrequently, primarily for school parties.

For our second Sunday break, we selected the world heritage site of Ouro Preto, 100km to the south-east of Belo. Ouro Preto is over three hundred years old, an elegant city spread across a series of very steep hills. The town was originally named Vila Rica, or "rich village". During the first half of the eighteenth century Minas Gerais was developed by Bandeirantes, bands of prospectors and slavers. One such group was exploring the valley when one of the slaves picked up a peculiar black rock in the river. Examined more closely, it turned out to be gold. Ouro Preto means "Black Gold" in Portuguese, and the town was the centre of the Brazilian gold rush. In 1750, Ouro Preto was the most populous city in the New World, containing around eighty thousand people, twice as many as New York and ten times the population of Sao Paolo.

Across Minas Gerais, 850 tonnes of gold was shipped back to Portugal by four hundred thousand colonists and half a million slaves. But not all the gold made it back to Portugal! Ouro Preto is full of beautiful churches, built (presumably) with money from surreptitiously smuggled gold. We visited two churches, Nossa Senhora do Carmo

(Our Lady of Mount Carmel) and São Francisco de Assis (St. Francis of Assisi). The latter features spectacular statues by the Brazilian sculptor Aleijadinho.

In 1789, Minas Gerais was the site of the *Inconfidencia Mineira* uprising, an independence movement which took inspiration from the American revolution thirteen years previously, and triggered by the economic decline of the gold-rush. Unfortunately



The Serra Piedade Hermitage built in 1746



The Frei Rosario Observatory

the Ouro uprising was swiftly and brutally crushed. The ringleader, Tiradentes (Joaquim Jose da Silva Xavier), was hanged in Rio de Janeiro and his body parts distributed around Minas Gerais as a warning to potential future conspirators. The main square of Ouro Preto is named for Tiradentes and there's a museum of the uprising overlooking it. It's fascinating to speculate what might have happened if the Ouro Preto uprising had been successful and Brazil had achieved independence shortly after the United States.

In its day, Ouro Preto was the state capital of Minas Gerais, but as the terrain gave it little room to expand, a new, planned capital, Belo Horizonte, was built; metropolitan Belo now has five million inhabitants. These days Ouro Preto still has a population of around 80,000 people; it is a tourist destination and a university town. Foremost amongst the colleges of higher education is the Ecolas do Minas, or school of mining, established in 1876. It is housed in an imposing white building also overlooking Tiradentes square. These days, much of the building is taken up by a science museum, although there are still classrooms for the students. It's rather a good museum, covering most of the sciences, although it leans towards geology, crystallography and metallurgy. As engineers in the steel industry, we were impressed by the room devoted to the science and engineering of metal processing, sponsored by one of Brazil's steel companies.

The highlight of the museum is the display of gems, crystals and other precious minerals, housed in a fortified and guarded display room. No photos are allowed inside, so I can't show you what we saw – but it was impressive. From an astronomical point of view, there were several meteorites, although actually the best one, a 3.1 kg meteorite which fell on Uberaba,

Minas Gerais in 1963, is on display in the astronomical gallery.

As an astronomer, of course, I was most looking forward to seeing the observatory which sits on the roof of the Ecolas do Minas. There's actually a separate entrance to the observatory at the back of the building. The entrance door has a plaque by the side, announcing that the observatory is for "SEAOP – Sociedade de Estudos Astronomicos de Ouro Preto" (Society of Astronomical Students of Ouro Preto). There are two separate domes, with what could be a helioscope between them.

The website for the science museum, via google translate, tells us that "There are permanent displays of meridian and equatorial lunettes, celestial charts, lunar and planetary globes, dating from 1718, telescopes, sextants and astronomical theodolites. The Observatorio Astronômico, which was built in 1926, houses a refracting telescope of German origin, manufactured at the beginning of this century, one of the largest in Brazil of its type." The Federal University of Ouro Preto's website gives a little more detail on the main telescope, revealing that it's a refractor by Gustav Heyde

(1846-1930) of Dresden.

So I was looking forward to seeing the observatory. Unfortunately, a brief note at the entrance to the science museum told us that the observatory was closed for refurbishment, opening again in April 2017, a few days after I departed Brazil. Oh well ... somewhere to return to on my next visit to Minas Gerais.

The science museum website is:

<http://www.museu.em.ufop.br/museu/astromia.php>

The Federal University of Ouro Preto's website for the observatory is:

<http://www.ufop.br/noticias/comunidade/observatorio-astronomico-e-aberto-visitacao-quartas-e-sabados>



The Ouro Preto Observatory