
A Travel to Dark Sky Places in the USA 2014

Dark Sky Places in the USA (3-4/2014)

The aims of the travel to the United States were to:

- study the sky quality of some of the darkest sky regions in the Southwest which mostly have gold status of the IDA tiers and where therefore really dark skies could be expected,
- study how and with which methods these dark skies are protected and promoted,
- compare lighting habits in the US and in European countries,
- time development of lighting in Las Vegas with changes due to LED lighting in the last years could be tracked,
- lighting of two cities of similar inhabitants in the US (Flagstaff) and Germany (Fulda) is compared

Some general remarks to the photos and measurements:
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The night sky pictures were taken with a Canon EOS 1000 D or a Canon EOS 550 D with either Sigma fisheye 2.8/4mmm (typical exposure times 180 and 300 s) or a 1.4/30mm (different exposure times). Camera setting was at ISO 800, RAW and jpg format.

RAW pictures have been converted to TIF pictures without compression that they are comparable.

Some of the fisheye pictures were tracked (without guiding which proved to be unnecessary with this focal length and exposure time) with a Nano Tracker, but for comparison with earlier pictures also unguided photos have been taken, where star trails are visible.

Sky brightness measurements were taken with a SQM-L (ser. Nr. 2536) at the zenith which was at this time of the year not disturbed through the Milky Way in the evening sky.

Comments are welcome!

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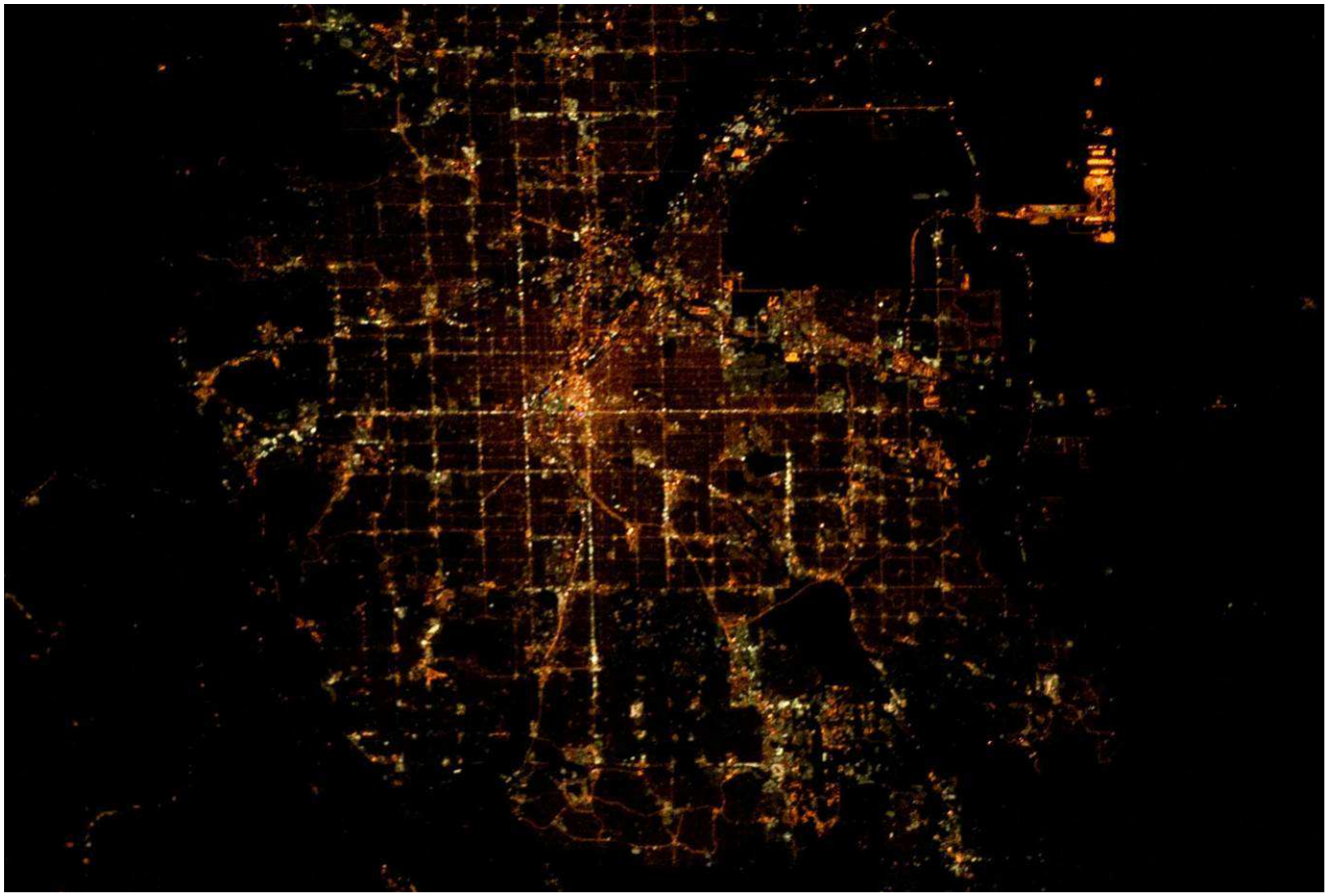
The lights of Denver and Golden

The region of Denver has about 635 000 inhabitants, the metropolitan region about 2.6 mio. inhabitants. Golden is a small city in Jefferson County with about 19 000 inhabitants situated about 20 km west of Denver.
A view was also possible from the plane on the flight towards Denver. Bright spots due to fracking are very conspicuous (one can be seen in the foreground of the picture).

A good overview over both cities is possible from the outskirts of the Rocky Mountains from the street to the Lookout Mountain over Golden. A picture with a different camera and shorter exposure time as well as a day time picture are given for comparison. Dominating light sources are the (America's largest private) brewery (on the left) and bright patches that are mainly due to car dealers which are excessive brightly lit, while road lighting is comparable to European lighting levels.

Brightly illuminated car dealer

Illumination of the Colefax Ave., in the background Denver



The Denver area as seen from the ISS (NASA), the airport is to upper right, Golden in the idle left.

Great Sand Dunes (Colorado)
2014, Mar 19th, 21.8 mag/arcsec²

The VIIRS map shows the light sources surrounding the national Park of Great Sand Dunes:

The dry Medano Creek close to the observing place

The zodiacal light was conspicuous at the western horizon, at the left horizon the light dome of Alamosa

The Great Sand Dunes National Park and Preserve lies about 44 km NE of the city of Alamosa (9000 inhabitants) in the S of the state Colorado and as an area of 344km². It is situated at the eastern part of the San Luis Valley at the feet of the Sangre De Christo Mountains. The dunes are situated at an altitude of 2450 m. *Duriscoe* (2013) describes the park as “remote from cities”.
The ranger at the entrance (2014 $3/person) recommended the Dunes Parking Lot as observing place at night. During the observations only one car passed at the parking.
Lights within the park are very few and faint. The interior of the visitor’s centre is illuminated, at the park entrance station are some lights, at Dunes Parking Lot only the restrooms were illuminated and faintly visible from outside. At the amphitheatre parking only some faint lights were visible.
The zodiacal light was directly very conspicuous.

The light of the restrooms at the parking illuminating the surrounding

The great Dog with the light dome of Alamosa and moonlit sky

The measurements showed that it is the darkest place that I have measured, however the light dome of Alamosa is well visible, while the many lights distributed through the San Louis Valley did not produce an observable light dome. A weak light dome towards the North is also visible in *Duriscoe*’s data and due to Canyon City (16 400 inh., 84 km) and mainly Pueblo. (107 800 inh., 100km). The moon rose this evening already at 22:30 and the brightening of the zenithal sky was visible very early. Soon the moon illuminated the landscape and the sky in the following pictures is brightly illuminated and appears blue.

View of the San Louis Valley to the SW of the Great Sand Dunes Nature Park with many scattered lights, Alamosa is to the left.

Though the distributed light in the San Louis Valley seem to not yet produce a detectable light dome, the future development of the lighting in this region should be observed and eventually controlled to protect the darkness of the national park..

The moon illuminates the sand dunes and the Sangre De Christo Mountains in the background.

Clayton Lake State Park (New Mexico)
2014, Mar 20th, 21.7 mag/arcsec² (covered)

Entrance to the state park


The dinosaur tracks at the eastern end


Overview of the park

This state park was created around a reservoir in the Northeast of New Mexico near the borders of Colorado, Oklahoma and Texas. It is mainly used for recreational reasons like fishing and boating, and in 1982 dinosaur tracks were swept free due to flooding near the dam, becoming a new attraction. The park is situated about 25 km northwest from the city of Clayton (3000 inhabitants), which appeared remote and relatively poor as there were many ruined houses (entrance to the state park $5/car/day).

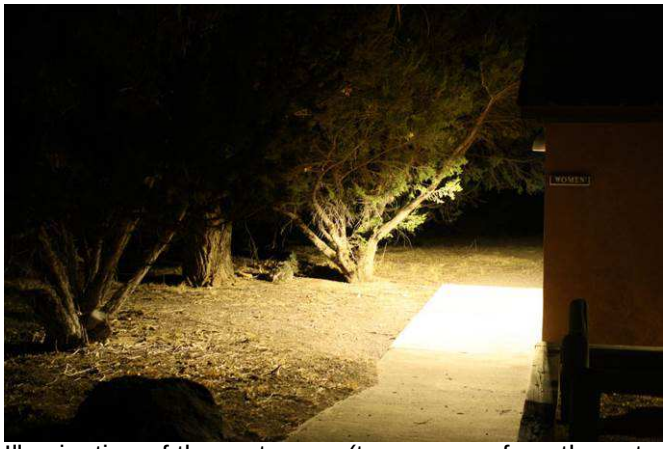
An observatory was erected In the western part of the park with a 12” RC telescope that is used by the Clayton Astronomy Club for their observations and public sessions. The local barber *Art(hur) Dean Grine* is very engaged with astronomy and the park.

The park was designated IDSPark in 2010, as it is situated in a dark environment and measures to reduce light pollution within the park were taken. But the lighting in the park made curious: at the boat ramp there were fixtures that certainly were not cut-off (below right) and security lightings were also not cut-off (below centre): will they be switched on at night?



The observatory hut, security lighting and the street lighting at the boat ramp

Though the weather forecast previewed only slight clouds for the night, the sky was mostly covered and only planets and bright stars were visible.
The measured sky brightness of 21.7 mag/arcsec² with clouds indicates a very dark clear sky, in the application 21.6 is given. The dominating light dome in the South East is caused by the city of Clayton.



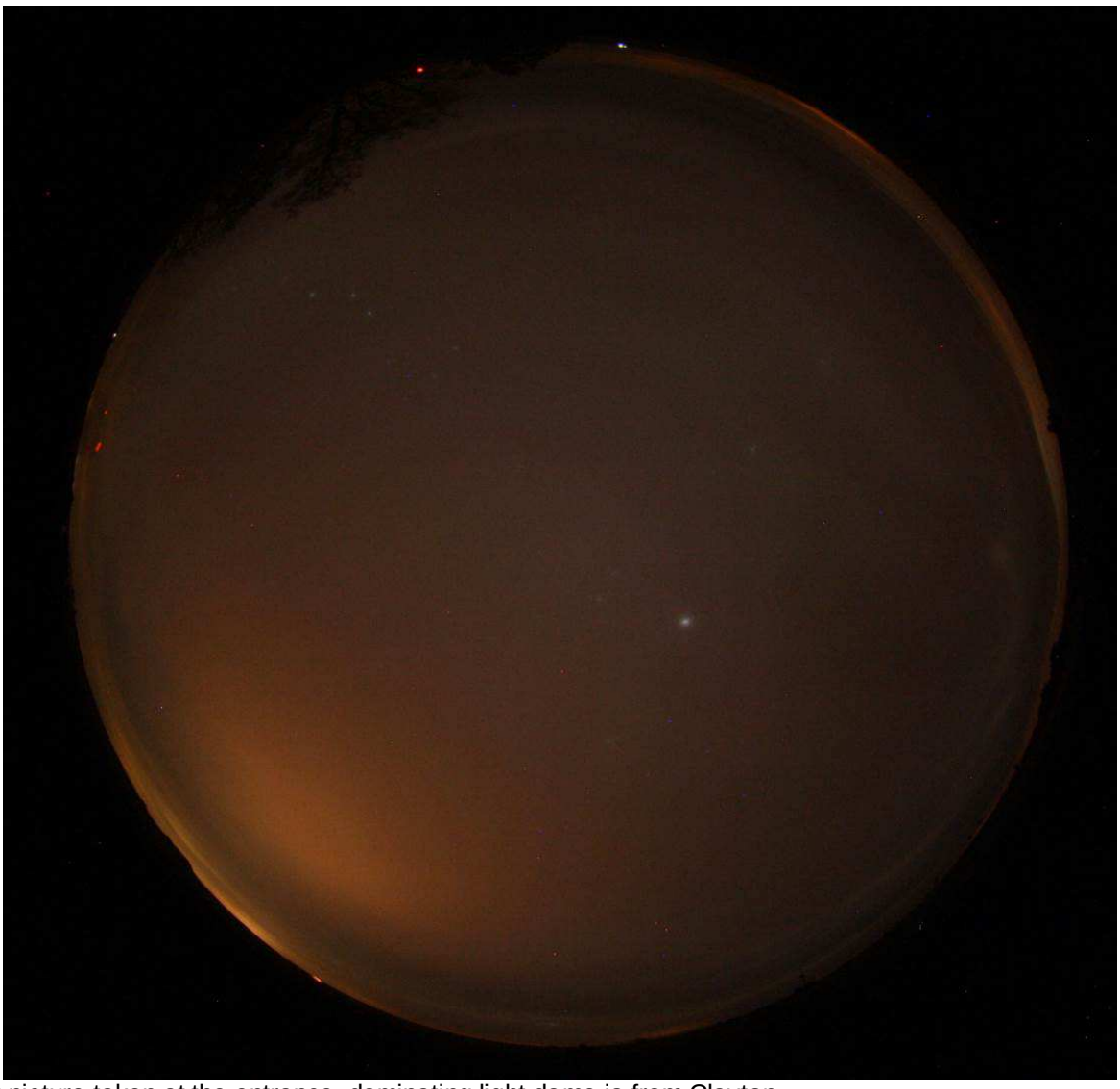
Illumination of the restrooms (top as seen from the entrance)

The luminaire at the boat ramp (top as seen from the entrance)

Security lighting at the guard's house

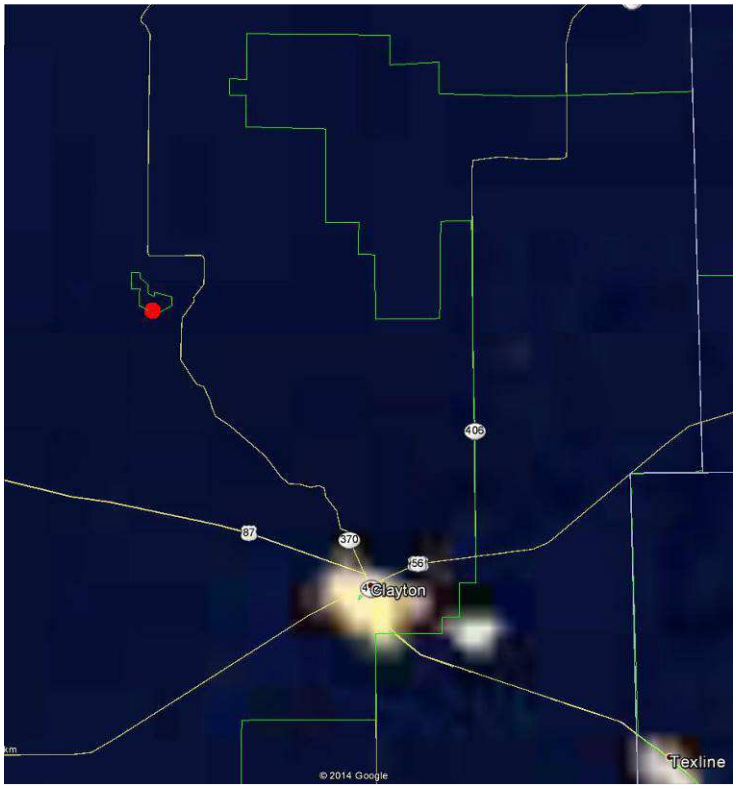
Butterfly at the illuminated information table at the visitor's centre

Bright lights were visible in the park: the lamp at the boat ramp was a on, a bright sodium high pressure lamp, which was not cut-off and even illuminated the opposite shore of the lake. Security lights at the house of the guard switched on several times and also were not cut-off. The luminaires at the restrooms and the centre were on all the time, the fixtures were full cut-off but too bright cfl lamps (24 W according to the application) that attracted insects. Lower wattages and/or coloured (bug-)lamps would help to better protect the nocturnal environment.



All-sky picture taken at the entrance, dominating light dome is from Clayton

The lights of Clayton as seen from the NM state route 370 towards the lake, the bright light on the left seems to be from the prison near Clayton.



VIIRS map of Clayton surroundings, the bright spot east of the village is the security light from the prison

Mc Donald Observatory and Big Bend national Park

It was planned to continue the excursion towards the South to Mc Donald Observatory and Big Bend National Park. Due to the far distance to there and as the weather forecasts for the next days for this region were not favourable while for the Colorado Plateau it was better, the travel was continued towards this direction.

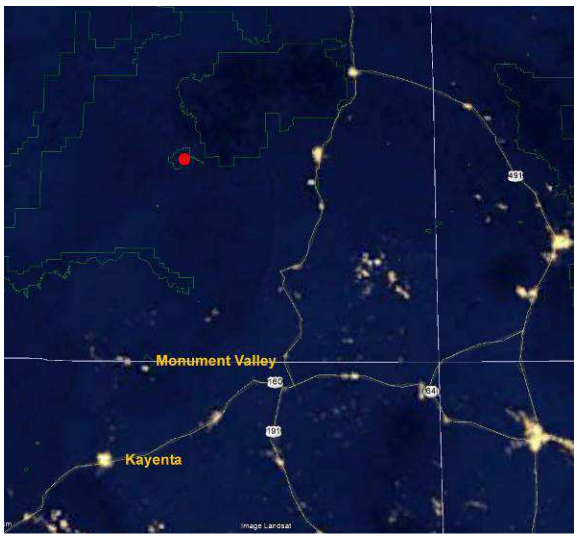
Just at the time being there, degrading sky quality at the observatory due to bright fracking light sources in the surrounding were discussed in the media. Therefore comparison measurements would have been desirable.

Cortez, Mesa Verde NP

The next clear night was at Cortez (population 8500, Montezuma County 25.500 inh.), but as the arrival was very late, measurements were only taken west of Cortez (road towards Hovenweep near Sand Canyon, 15 km west of Cortez), which was relatively bright (21.47 mag/arcsec²) due to nearby illuminated houses. In the city a value of 21.2 mag/arcsec² was measured.

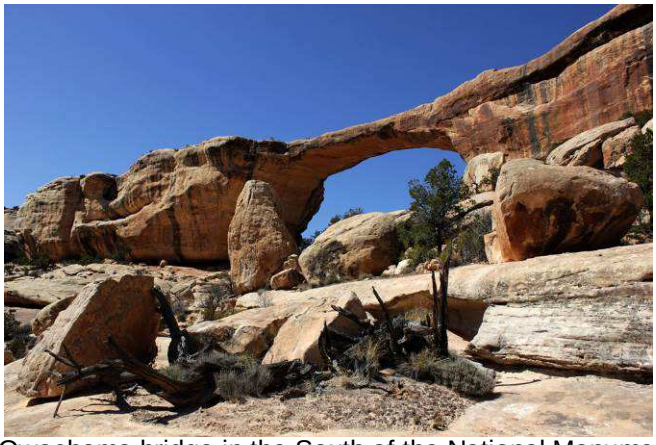
The measurements of the National Parks Service (NPS, *Schelz & Richman* 2004) at Hovenweep National Monument showed already that the region is relatively bright, their measurements gave nearly the same sky brightness value (21.4 mag/arcsec²) though the observing places are about 25 km and the measurements at least 12 years apart.

Natural Bridges National Monument
2014, Mar 23, 21.68 mag/arcsec²



Natural Bridges Monument was designated in 1908 by President Theodore Roosevelt as a National Monument (the first in Utah) for the natural bridges formed through erosion in the Permian sandstone. The 30.9 km² large park is accessible through a 15 km long loop drive with observing possibilities at the parking lots (entrance fee $6.00/car). The nearest settlement to the east is Blanding (3500 inhabitants) at a distance of 44 km.

Observations were made at the parking lot in front of the visitors centre at an altitude of 2000 m.



Owachomo bridge in the South of the National Monument

Parking lot in front of the visitors centre

The visitors centre at night (only yellow lamps at the restrooms) and at day.

Natural Bridges was in 2007 the first International Dark Sky Park designated by IDA. The darkest measurement with the NPS equipment is reported to be 21.95 mag/arcsec² and the park was classified as Bortle class 2 in the application. Earlier studies at nearly the same place (*Schelz & Richman* 2004) indicated even Bortle class 1, a sky brightness of 21.7 mag/arcsec² and a limiting magnitude of 7.1 to 7.2 mag.

Again the zodiacal light was very impressive in the west. With the naked eye no light domes were visible at the horizon, only in the south a faint glow was visible, that can also be seen on the all-sky pictures (Kayenta/Monument Valley). Further on, some lights in the southeast which are intensified by some cirrus clouds, might originate from Blanding.

On Apr. 13th was the opposition of the asteroid (4) Vesta, which became so bright (6.1 m) that it should be visible by naked eye, which was indeed easily possible. Nearby (1) Ceres was however fainter (7.3 m).

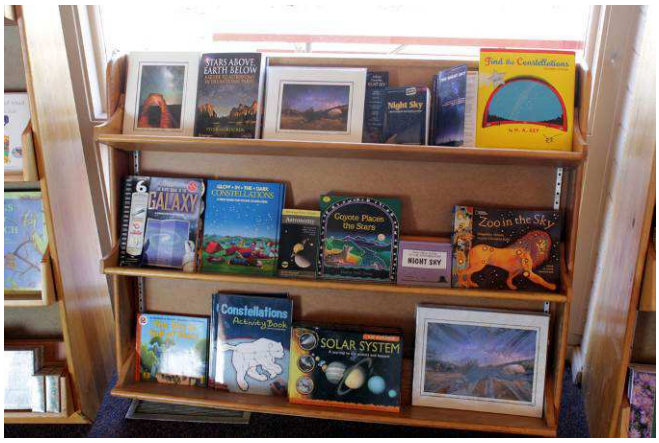
Mars, Vesta and Ceres in the sky.

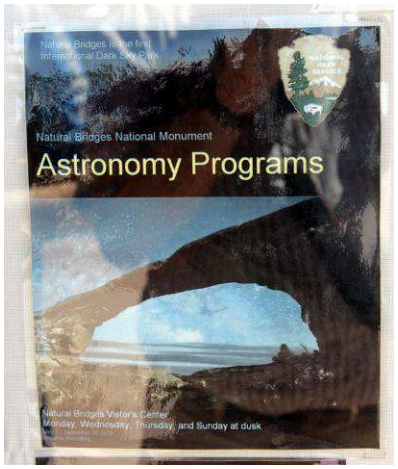
Identification picture (5s exposure) with Mars and the asteroids.

Some light is visible in the Southeast (from Blanding/Cortez?)

Great Dog with Sirius and Orion setting in the West

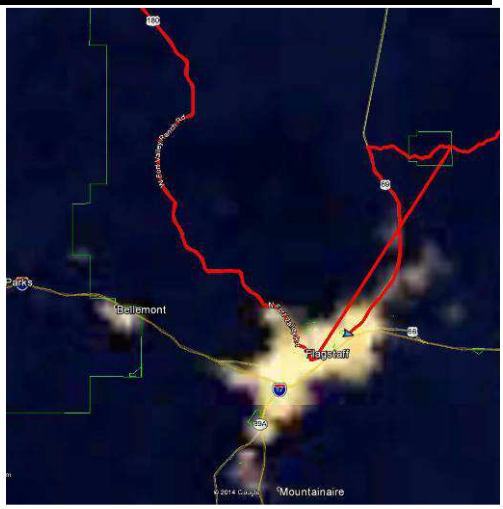

The entrance of the visitors centre with a buglight lamp with motion detector (was not on at night)




Astronomical information and a large selection of astronomy books in the visitors centre.

Flagstaff
Observations at Cinder Hills Overlook Parking
2014 Mar 25, 21.5 mag/arcsec²



This place is situated in the Sunset Crater National Monument (entrance fee $5/person) about 25 km from the centre of Flagstaff. This city (about 67 500 inhabitants) became in 2001 the first International Dark Sky Community. The protection of the night sky in Flagstaff originated in 1958 when the first ordinances prohibited searchlights. In the city mainly full cut-off sodium low pressure lamps are used and the total outdoor luminous output is limited to 25 to 0.6 lm/m² (depending on the lighting zones and not valid for public streets). *Duriscoe et al.* (2013) estimated the total luminous output of the city with 158 Mlm.

Measurements were also taken by *Duriscoe et al. (2007*) at the same place (Lava Flow trail parking) and gave 22.16 mag/arcsec² as darkest value.


Clouds over Flagstaff are brightly illuminated by the city (left) while further away they become dark (right).

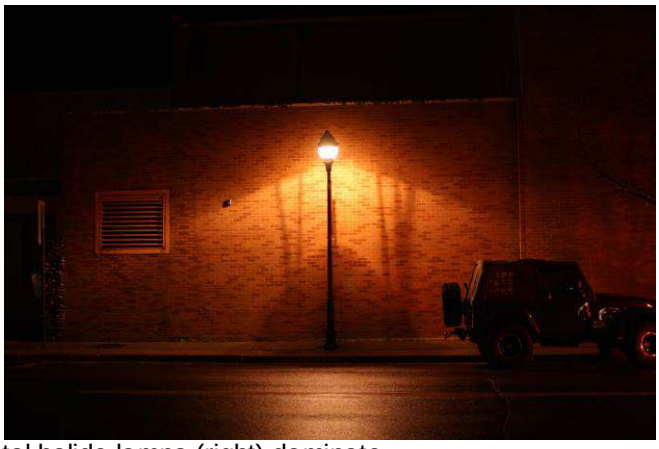

Towards the East and the North no lights are visible on the horizon.


Orion setting over the illuminated clouds and the Pleiades over dark clouds.

Lowell Observatory
2014 Mar 26, 20.4 mag/arcsec²

A panoramic view is possible from a parking lot in front of Lowell Observatory on Mars Hill, about 60 m above the city. For comparison day and night time views are given.

The parking of Lowell Observatory is illuminated with full cut-off luminaires and yellow (partially low pressure sodium) lamps.



In the city low pressure sodium (left) and warmwhite metal halide lamps (right) dominate

Full cut-off luminaires for sodium low pressure (left) and high pressure (right) lamps.

Part of a street in the East of Flagstaff was illuminated with neutral white LED, while other parts (in the background) are still illuminated with low pressure sodium light.

Commercial lighting is dominated by bright windows while the illumination of the parking lot is full cut-off.

When visiting the city, a weekend “Lights out Flagstaff” started for the “Year of the Night Sky 2014”, which was promoted everywhere in the city.

Comparison of lighting Flagstaff - Fulda

Both cities have about the same number of inhabitants (Flagstaff 67500, metropolitan region 134 400, altitude 2100m, Fulda 64800, metropolitan region 106 000 inhabitants, altitude 270m).

Both pictures (Flagstaff top, Fulda bottom) were taken with identical camera settings and 1 s exposure time. The picture in Flagstaff was taken from 70 m above the centre which is about 1 km away, in Fulda 140 m above and about 2.5 km from the centre. It seems that Fulda is not much brighter than Flagstaff, but a comparison is difficult, as the structure of the two cities is very different. But at dark places close to Fulda 20.6 mag/arcsec² could also be measured. Information about the lighting in Fulda would make a comparison possible.

A direct comparison of the photos towards the centres with identical exposure data and reduction method.

Tucson

The city has adopted lighting codes already in 1972 to protect the nearby observatories. This was initially Kitt Peak observatory, more (Mt. Hopkins, Mt. Graham) have been installed later. But due to the rapid expansion of the city (500,000 inh., 1 mio. in county Pima with typ. 20% increase during 10 years) the total amount of light has increased considerably. The total outdoor luminous output is limited to between 85 and 0.75 lm/m².

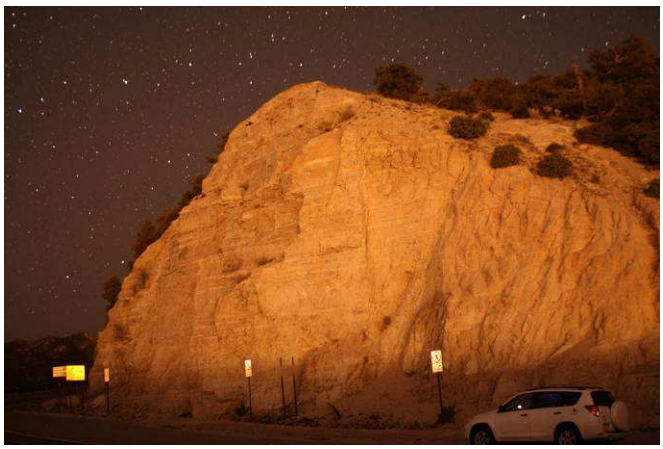
Street lighting in Tucson: bright main roads and faintly lit or not at all light roads (standard exposure 1/20s)

A parking lot where sodium high and low pressure lamps are used, high pressure lamps are switched off at a certain time.

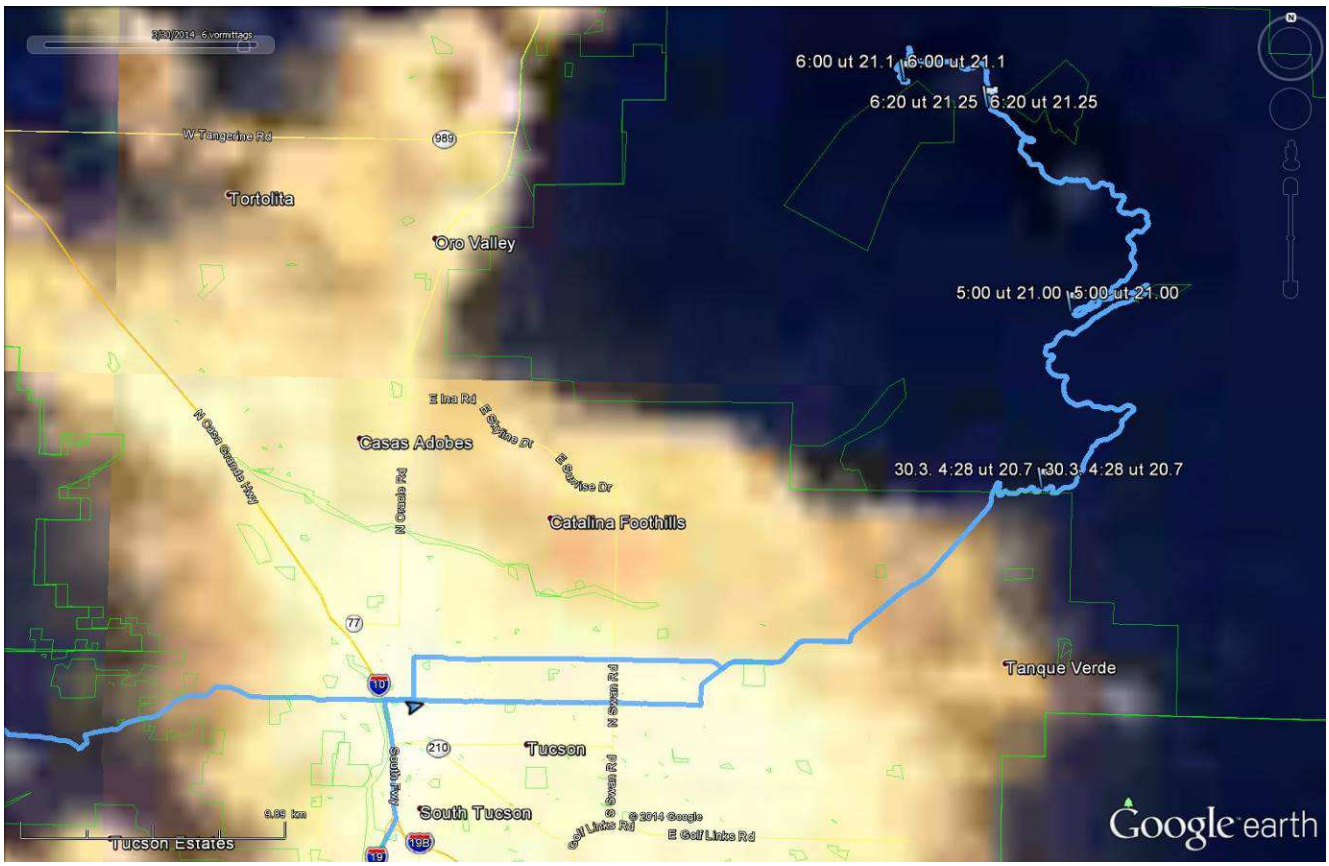
A SQM measurement of 18.4 mag/arcsec² has been taken in the De Anza Park (opposite University Inn motel)

Mt Lemmon
2014 Mar. 29, 21.4 mag/arcsec²

Mt. Lemmon is situated about 28 km northeast of Tucson and nearly 2800 m high. It can be reached easily over the Catalina Highway. As it lies over 2000 m higher than the city several telescopes of the 1 – 1.5 m diameter are operated (mainly from Steward Observatory), therefore a dark sky could be expected.
However even directly in front of the entrance gate to the observatory, the bright city lights are always visible and therefore the sky is bright.



Even the landscape at the observing places in the middle (left) and the top observing places are illuminated by the city lights from Tucson.

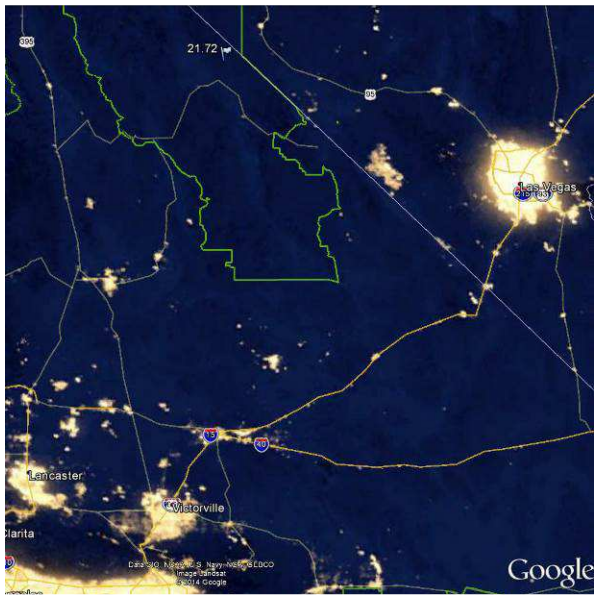


The path of the drive up to Mt.Lemmon with the measurement points overlaid on a VIIRS map.

Death Valley
2014 Mar 30, 21.75 mag/arcsec²

Death Valley National Park is one of the lowest points in the western hemisphere and it is the place where the hottest temperature was measured. Due to the remoteness it has a dark sky and was designated IDSPark in 2013. Measurements by the NPS Sky Team (2004) and Duriscoe et al. (2007) gave values of 22 mag/arcsec², but reported that the light dome of Las Vegas (160 km) is high and even Los Angeles (300 km) is visible.

Observations were done at Hells Gate parking (fee $20/car) in the east at an altitude of 700 m. At this place the light dome of Las Vegas (180 km) was partially covered by mountains, while the light dome from Los Angeles (330 km) was well visible.



Well visible were also the lights from Furnace Creek, others are from driving cars, as can be seen on the comparison pictures from night and day. Furnace Creek (with the visitor's centre) even produces a faint glow.

Further measurements at Daylight pass (1350 m) showed a bit darker sky, which was even darker at the eastern park entrance, where the light domes of Las Vegas were very conspicuous and a faint light dome of Beatty could be seen.

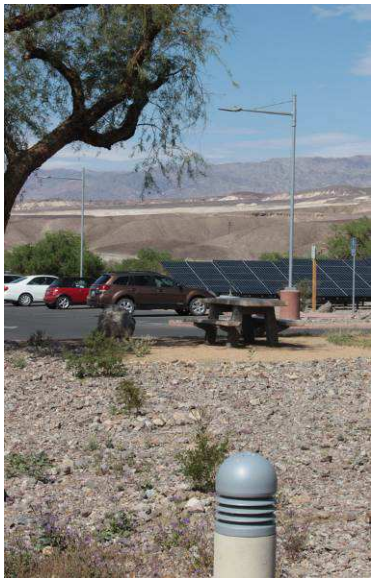
The light dome of Las Vegas as seen from Hells Gate

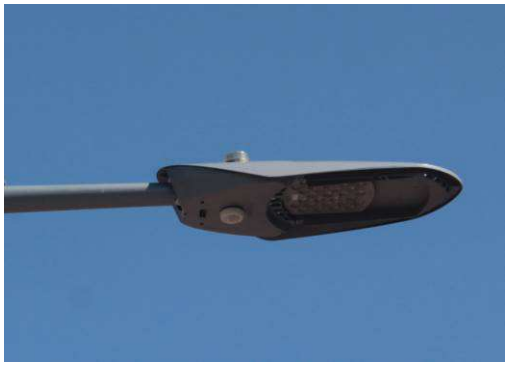
Light dome of Las Vegas as seen from the eastern Park entrance

Light dome of Beatty as seen from the same place.

A sign at the visitor's centre clearly showed the designation of the International Dark Sky Park to Death Valley National Park. Programs three times per week have astronomical themes, the bookshop offers a range of astronomical literature, post cards, star maps, flash light etc. The parking was equipped with "dark sky friendly" (as told by a park ranger, but the colour temperature is unknown) LED lighting, but at the wall several not fully shielded fixtures were installed.

Sign, program and merchandises at the visitor's centre.

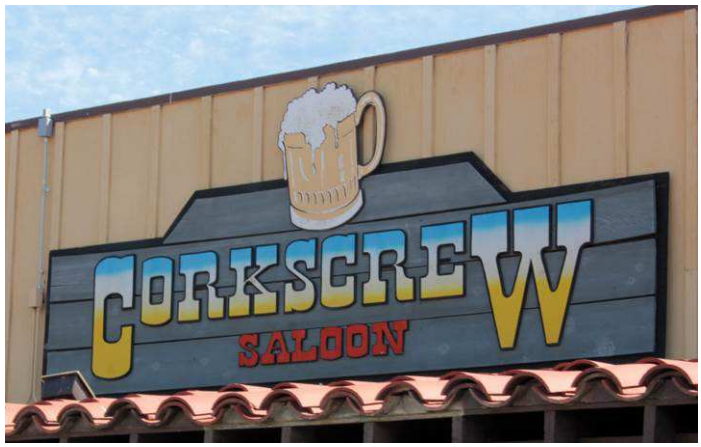




Lighting around the visitor's centre.

The exhibition in the visitor's centre demonstrated the influence of light domes on the visibility of the stars.

As the park ranger mentioned, Furnace Creek is privately operated and therefore lighting could not be regulated. It was not possible to check the globe lights and the sign illuminations at night, if they are switched on, how bright they are or if they are yellow.



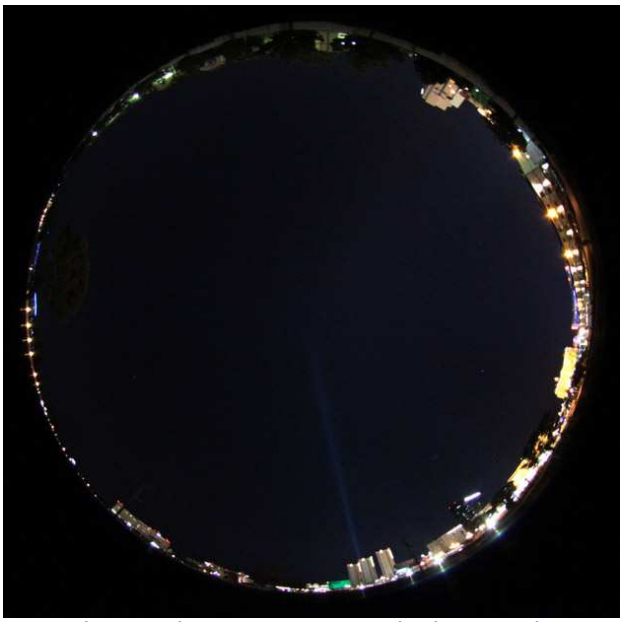
Globe light and certainly not well oriented floodlighting at Furnace Creek.

Las Vegas
2014 Apr 2, 16.3 mag/arcsec²

Las Vegas is said to be the brightest illuminated city, which proved to be true.

Panorama of Las Vegas as seen from the northwest, with the region of the Strip especially bright.

At the same site the landscape on the opposite is well illuminated by the city lights



The measurement could be taken in relatively dark environment close to the centre as seen in the ISS picture. A bright beam of a hotel is visible over the whole sky, but was switched off at 1am.

Tracking lighting changes in Las Vegas/Clark County on ISS pictures

Las Vegas at Night as seen by the astronauts (NASA)

Las Vegas at night has been photographed quite often by ISS astronauts that lighting changes can be tracked, especially as colour differences can be recognized in the digital images.

Especially the pictures between 2007 and 2013 show some clear changes:
Since 2010 in the City of Henderson (in the Southeast) 26000 luminaires have been retrofitted from sodium high pressure to induction and LED lighting (Henderson, 2010). This can be recognized already in 2010 by change of the lighting colour, but also a reduced amount of upward lighting (certainly due to better shielded fixtures). The city expects 30-60 percent less energy consumption and an annual saving of $800 000 in energy cost.

In Las Vegas (in the Northwest) till mid 2013 45 000 of 55 000 luminaires have been exchanged from mercury and sodium high pressure to LED lighting, the city expects savings of 30.84 million kWh and $2 million annually. The changes can be recognized very well in the 2013 ISS picture. (Sustainable city, 2014).

Clark County, which governs the famous Strip has installed mainly energy efficient high pressure sodium lamps, but at intersections LED lighting is installed. (Clark County 2012)


LED street lighting in the Northwest of Las Vegas


A crossing on the Strip illuminated with LED light.

Grand Canyon-Parashant National Monument, AZ

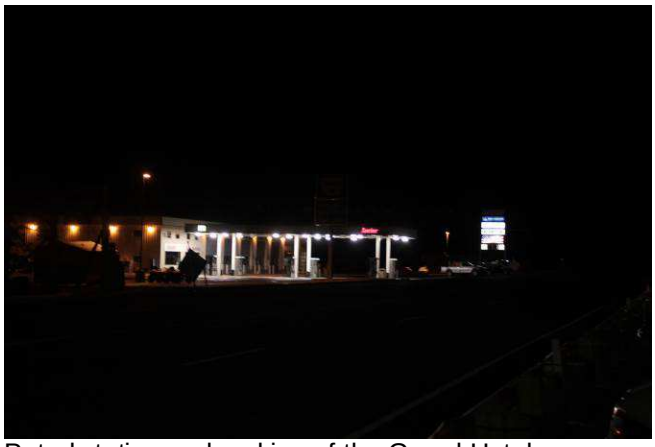
This National Monument is 4242 km² large and situated at the Northwest side of the Grand Canyon National Park. It is very remote, no paved ways lead into the park, and therefore it could not be visited with a rented car. Only 5 places with light (administrative buildings and ranches) lie within the park. Sky brightness measurements are reported from autumn 2013 to be between 21.8 and 22.0 mag/arcsec². Dominating light domes are from Las Vegas (typ. 150 km), and St. Georges (75.000 inh. at the northern border). This remote park was designed IDSReserve in March 2014.

Bryce Canyon National Park

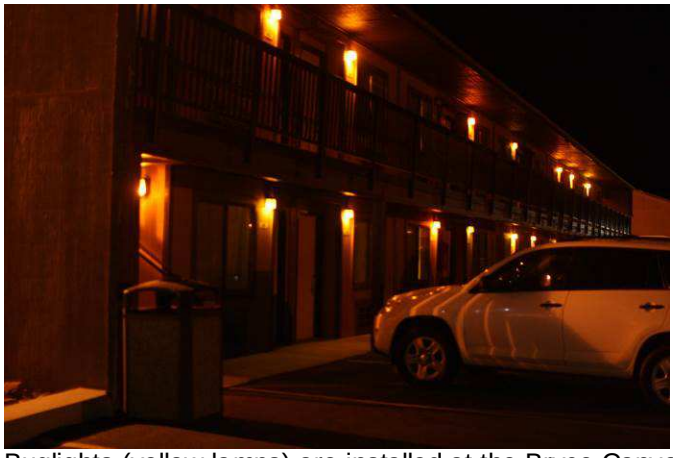
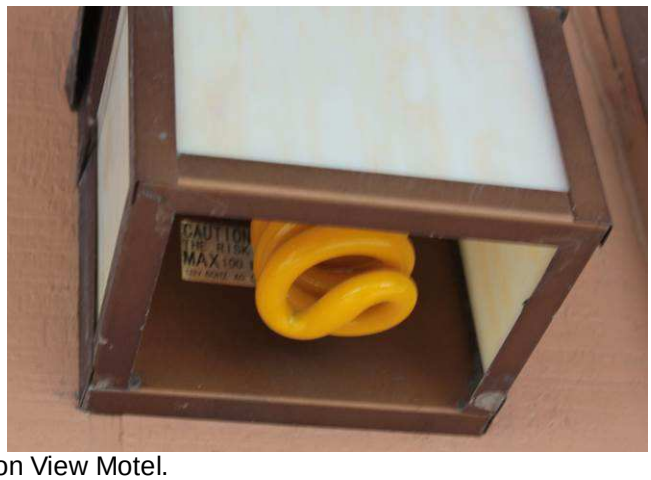
The National Park of Bryce Canyon is known for the geological features of the hoodoos, but due to the dark skies astronomy programs have been offered for a long time and also attract a lot of tourists (Collison & Poe, 2013) In spite of these activities the park has not yet applied for an IDSPark status.
Due to bad weather (snow fall) no observations of the night sky were possible.

While within the national park artificial light seems to be not disturbing, many lights in Bryce village are bright and even glaring while others are full cut-off.

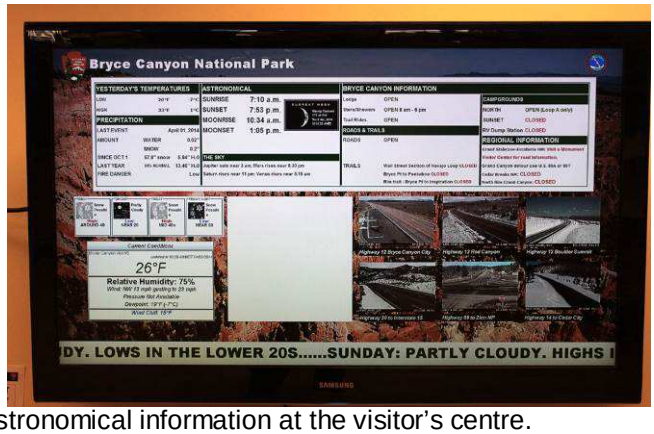
Full cut-off luminaires at Bryce View Lodge and astronomy literature at Ruby's Inn

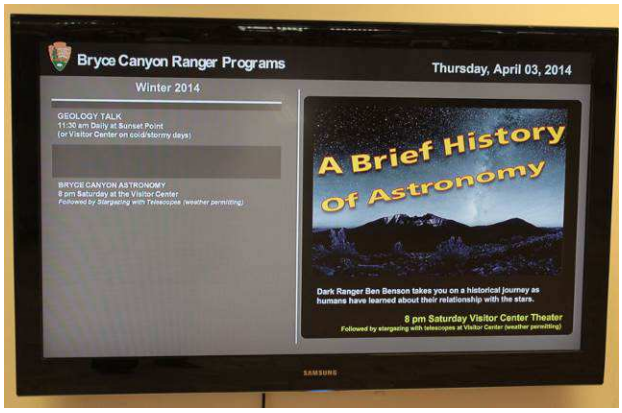


Petrol station and parking of the Grand Hotel.

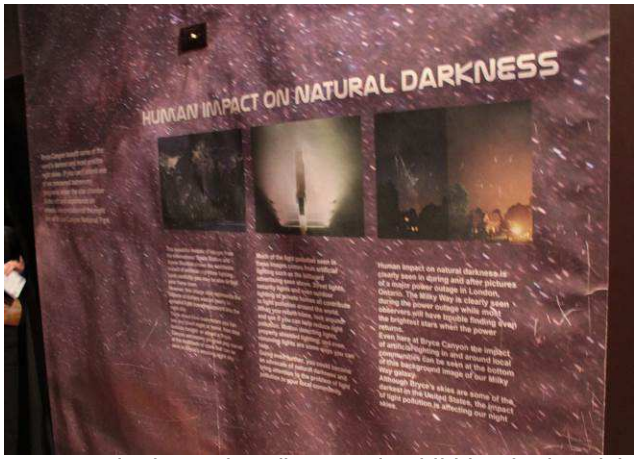
Buglights (yellow lamps) are installed at the Bryce Canyon View Motel.





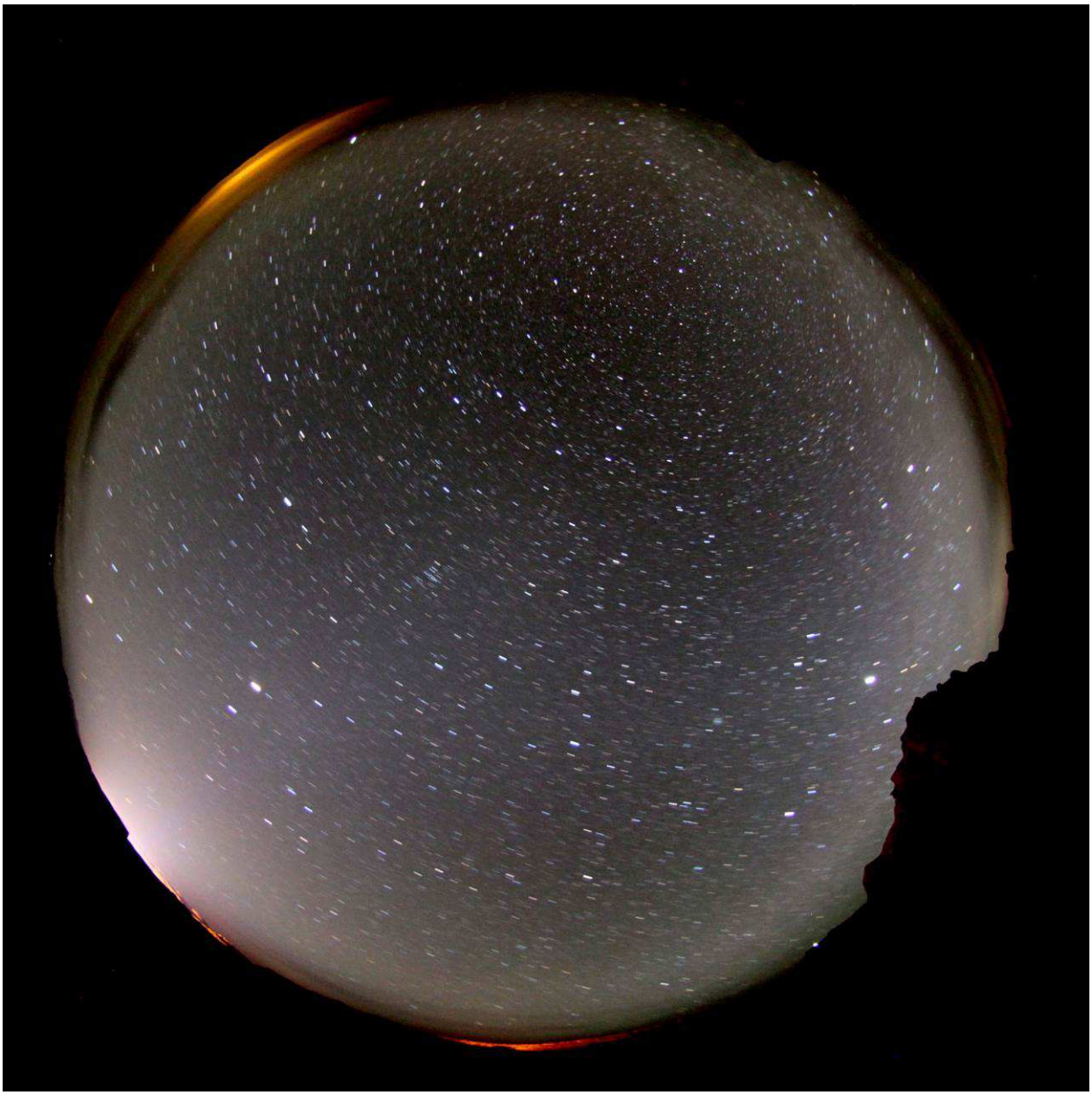
Astronomical information at the visitor's centre.



Astronomical merchandises and exhibition in the visitor's centre.

Arches National Park
2014 Apr 4, 21.6 mag/arcsec²



The Arches National Park was created to protect the geological structures of sandstone arches (Fee $10/car). Lightscape and the Night Sky is an important theme of the park. Observations were made at the La Sal Mountains Viewpoint parking, 8 km from the town of Moab. In the beginning the moon disturbed till it set at about midnight.
In the east the lights of Grand Junction (100 km, 60 000 inh.) reflected at clouds could be seen and the light dome of Moab (5000 inhabitants) was dominant. Observations by *Schelz & Richman* (2003) also identified the dominating light dome of Moab even farther inside the park (18 km away).
As the surroundings still offer very dark skies and the population is increasing, it should be desirable that the lights in the city are controlled (in direction and intensity).





The moon setting behind a rock (left) and rocks illuminated by the Moab city lights (right).



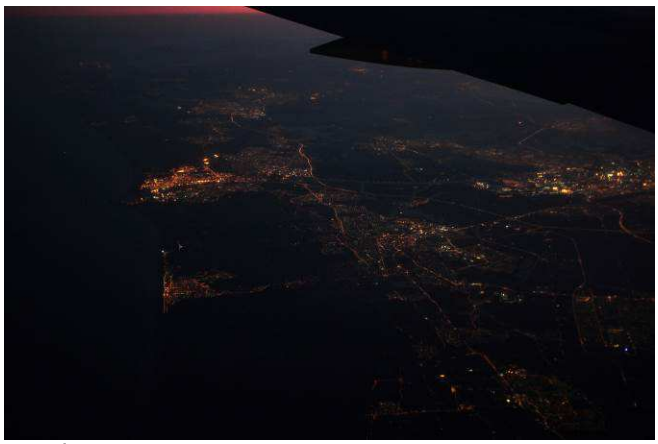
Grand Junction (100 km away) in the east illuminates the clouds (left) and the light dome and illuminated rocks of Moab (right)



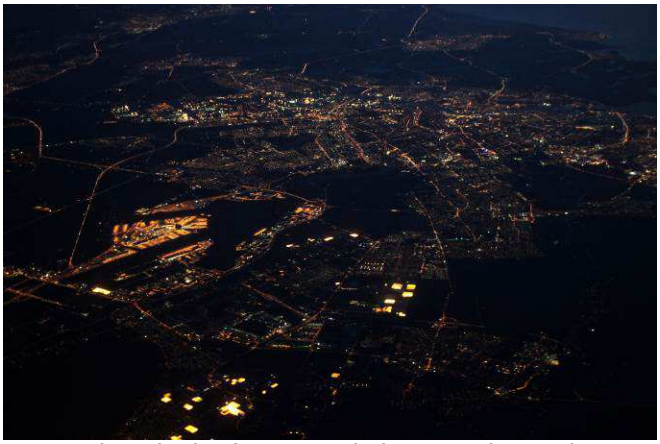
Crossings in Moab are illuminated with LED lamps (left) while residential roads are faintly illuminated (right).

Flight views of illuminated Netherlands

On the flight back home, I felt like an astronaut seeing all the illuminated cities of the Netherlands.



Haarlem



Amsterdam, in the foreground airport and greenhouses

Hilversum

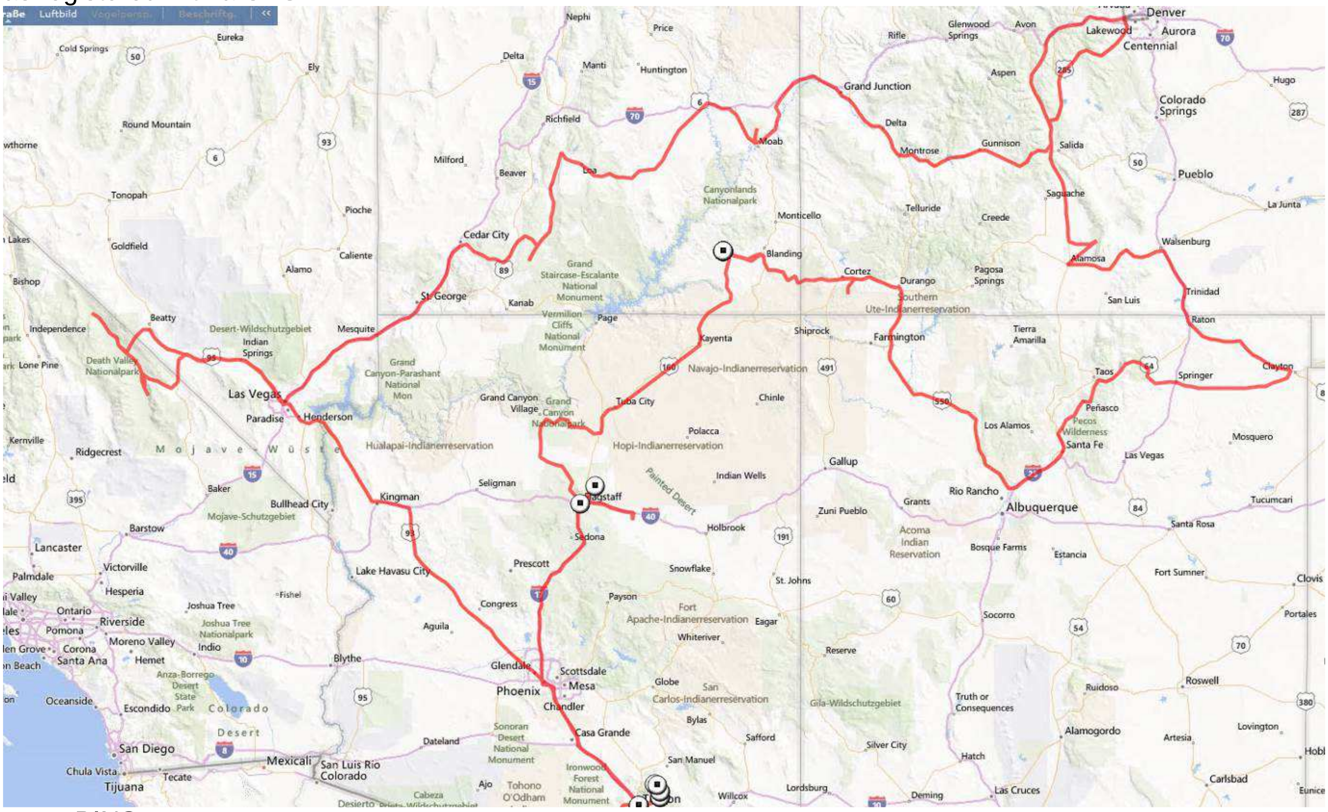
Amersfort

Luminaires in the US

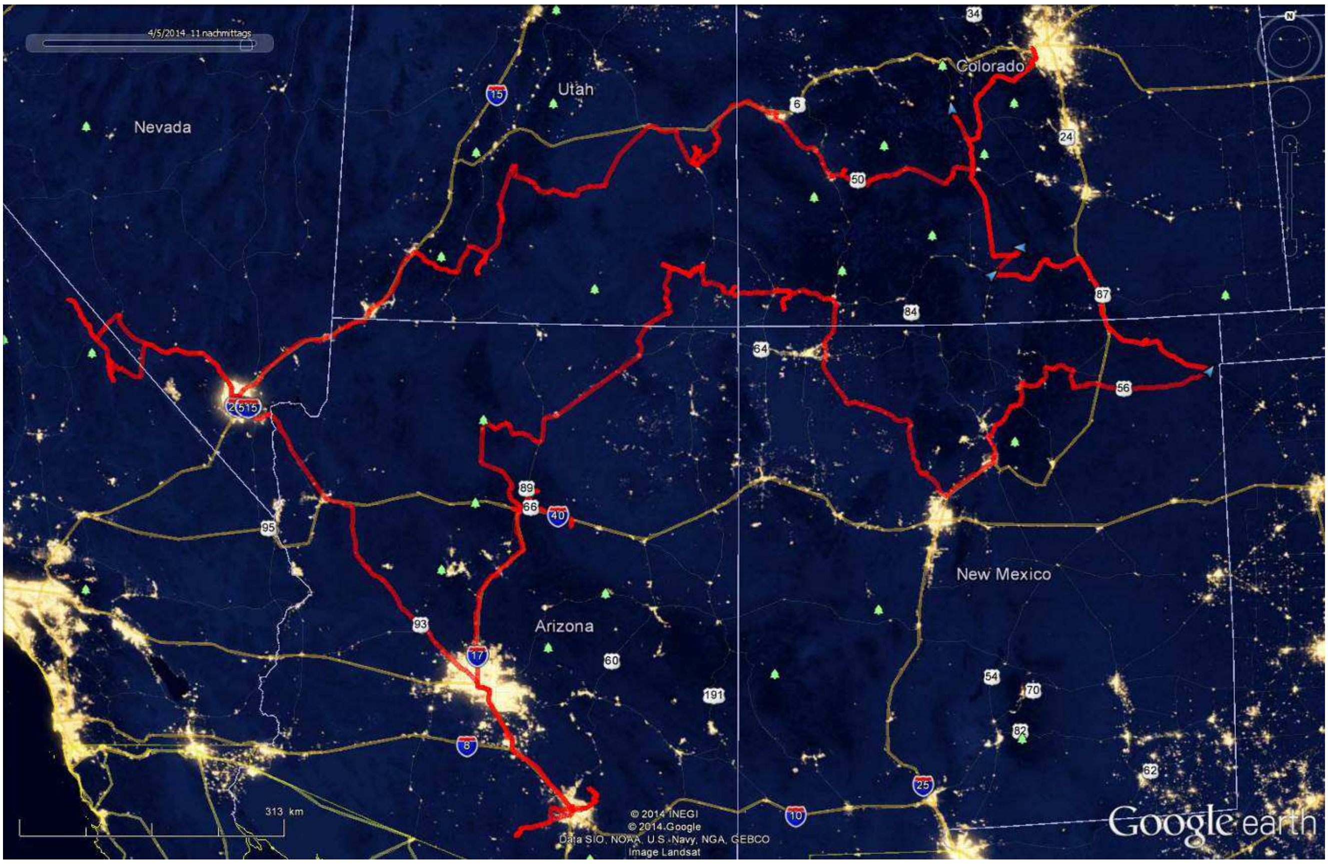
These are good and bad luminaires found in the US:

The total trip

as registered with a GPS:



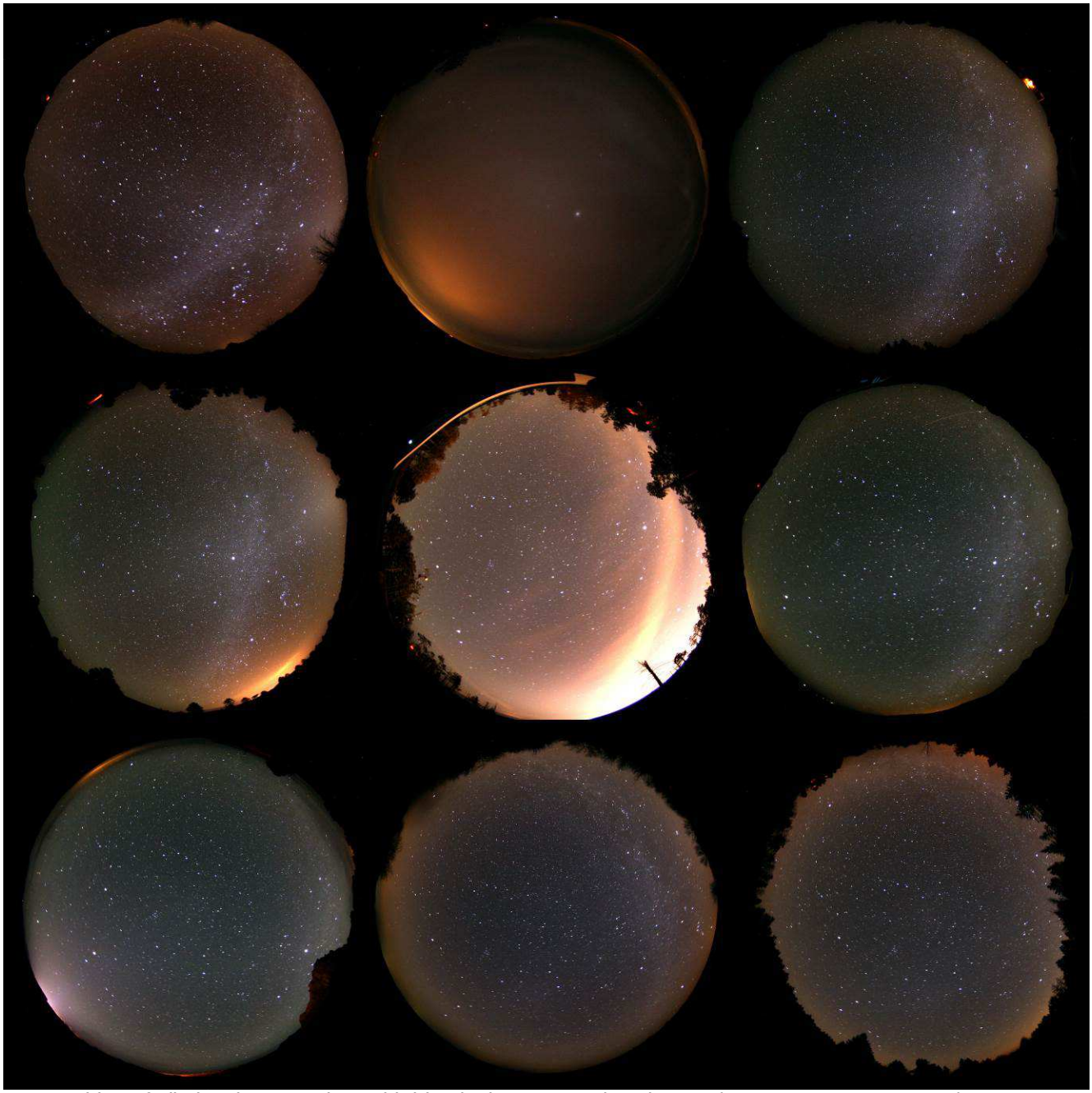
… on BING maps…



… and the VIIRS data

All together 4726 mi = 7606 km!

Conclusions



Composition of all-sky pictures taken with identical exposure data (4.5mm/1:2.8, ISO 800, WB sun/5200K, 180s, Canon D1000) and reduced as identical TIFF images at the following places:
Great Sand Dunes – Clayton State Park – Natural Bridges
Flagstaff, sunset crater – Tucson, Mt. Lemmon – Death Valley
Arches – Rhön, Lange Rhön – Rhön, Rotes Moor

- The very low sky brightness in Germany can be reached only in few very good nights per year, while in the American National Parks much more clear nights can be expected.
- Due to the altitude (generally 2000 m high) and the southern latitude, zodiacal light and Gegenschein are often well visible.
- All over the Colorado Plateau about the same sky brightness near the natural background can be observed outside of the villages.
- The lighting practice is not brighter than in Europe, residential streets are often not illuminated at all.
- No reduction of the public street lighting during the night can be observed.
- The technical standard of many luminaires seems to be relatively low with no good light control and simple electrics.

The Sky Brightness measurements

Date	UT	Place	Longitude	Latitude	H (m)	mag	mcd/m²
2014-03-20	4:00	Great Sand Dunes NP	-105.51748	37.73871	2455	21.80	0.21
2014-03-21	3:10	Clayton Lake	-103.30160	36.57224	1610	21.70	0.23
2014-03-23	4:10	Cortez, westl.	-108.74642	37.33197	1730	21.47	0.28
2014-03-23	4:45	Cortez, Knight Inn	-108.59581	37.34348	1300	21.20	0.36
2014-03-24	4:00	Natural Bridges, Visitors Center	-109.35431	37.46241	1980	21.68	0.23
2014-03-25	4:30	Tuba, Dine Inn Motel	-111.22752	36.11990	1480	20.15	0.94
2014-03-26	4:00	Flagstaff Sunset Crater	-111.49012	35.37209	2144	21.50	0.27
2014-03-27	3:20	Flagstaff, Lowell	-111.66223	35.19926	2180	20.40	0.75
2014-03-29	4:45	Tucson, De Anza Park	-110.97128	32.23504	725	18.40	4.71
2014-03-30	3:28	Tucson Mt. Lemmon	-110.72363	32.31049	1060	20.70	0.57
2014-03-30	4:00	Tucson Mt. Lemmon	-110.71655	32.36846	2015	21.00	0.43
2014-03-30	5:00	Tucson Mt. Lemmon	-110.78393	32.44083	2750	21.10	0.39
2014-03-30	5:20	Tucson Mt. Lemmon	-110.75149	32.43353	2415	21.25	0.34
2014-03-31	5:00	Death Valley, Hells Gate,	-116.97797	36.72414	700	21.72	0.22
2014-03-31	5:30	Death Valley, Daylight Pass	-116.93174	36.78880	1350	21.75	0.22
2014-03-31	5:45	Death Valley, O-Eingang	-116.88063	36.83198	1084	21.78	0.21
2014-04-02	5:50	Las Vegas, Super 8 Inn	-115.16360	36.11154	635	16.30	32.62
2014-04-04	5:45	Arches, La Sal Mts. Viewpoint	-109.59101	38.62632	1362	21.60	0.25

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