

General considerations for relatively dark starlight/dark-sky¹ areas with few or no direct cultural connections

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The end of night²

One way to look at the value of an intact night-sky for world heritage in our context is to look at the challenges posed to the integrity and authenticity of existing sites by the relatively recent dramatical rise of artificial sky brightening connected to light pollution. While a relatively intact night was self-evident even long after astronomers first noted light pollution in the 19th century, it is now evident that the night-time situation has significantly changed the appearance of many world heritage sites at night. Part of this may even come from efforts to enhance the appearance of the heritage itself – by lighting the site at night. At least partly this was necessary to counteract the trend of sites disappearing from the skyline or landscapes due to the ever increasing urban night-time light-levels and the conversely appearing and concurrently spreading “dark-corners”³ and flat perspectives that are created as a side effect.

Thus we approach the question of evaluating the comparative increase in evidence of the value of sites with a good night sky that is concurrent with the spreading of the use of artificial light at night by following the proven path of getting a hint for understanding a value by looking at how it diminishes and what might have been lost at existing sites.

Similar to the situation of living species facing extinction, the value of the now almost lost authentic night-time culture of many areas and periods rises with the diminishing asset. Given their proximity to the Großmugl site that we discuss in an extended case study for astronomy and world-heritage we use the two world heritage sites in Vienna: its historic centre and the Schönbrunn Imperial Castle to illustrate what integrity and authenticity, and their loss, may mean at night in a cultural environment.

A loss of integrity – half the time for most of things?

Light is an integral part of access to any artefact, as our visual system is a key pathway towards “grasping” nature and human artefacts – our visual door of perception is comparatively wide. Thus light is often the primary medium that physically connects the human with its tangible heritage. By modulating this connection it is a key factor in authenticity whenever seeing plays a role.

Protecting the integrity and authenticity of the night time environment may well be upon the most outstanding challenges of world heritage efforts in populated areas⁴. A Starlight Oasis is the instrument for that.

The integrity of the night-view and night-scape and the authenticity of night-culture is presently a

- 1 We note that the notion of a “dark sky”, that is the custom in the English language when referring to a night sky little effected by artificial light at night, in itself is reflecting a modern situation that the sky initially looks dark from when stepping out of places with artificial lighting or when stepping out of modern transport machinery. With the eye adapted by following the changing light through the twilight a clear sky is a source of light – the starshine - even without the moon when the starlight is not obstructed by clouds.
- 2 Title page and main article, *National Geographic Magazine*, November 2008,
- 3 A consequence of high luminous density emitted by artificial light creating high contrast “light-spots” causing the pupila to shrink an “stop down” the eye's sensitivity in adjacent low intensity parts of the image.
- 4 An estimated 20% of the Earth's population have no access to electric light, whereas billions of people face the consequences of its intense use in urban areas.

general challenge. As it is the case for many other sites, there is little perspective to see the buildings of the heritage site of the historic centre of Vienna in the authentic night-light of the time when most of them were built. Until approximately the enlightenment⁵ landscapes, buildings, sacral and representational as well as monuments were seen in starshine and moonshine. So evident for the contemporary as is the daylight view for us now. These night-time views certainly were key if not the cause of the link for festivities connected to the moon. Like for the mayors until the mid of the 19th century, that switched on artificial lighting only in dark moonless nights it was obvious that there is enough light at night with the moon up or outside the long winter nights of central and northern Europe.

Yet today it is impossible to see Schönbrunn-castle or the St. Stephens cathedral in the historic centre of Vienna as the contemporaries could for about half of the time. Actually much of the representative “luxury” of such sites may well be related to the particularities of night-culture.

To illustrate that we briefly move from one “enlightened” court to the other, the one of Friedrich II, in Potsdam, (Figure 1) in a period of repeated warfare between them. In “enlightened” courts the ultimate luxury was the crown-light (candelabrum), one (not *the* one in Figure 1) in use by the King who enjoyed dining with Voltaire cost the equivalent of 5 annual salaries of his court musician Karl Phillip Emanuel Bach⁶. There is now considerable evidence that the extension of activity into the night by itself was a highly paid privilege and constituted a key element of the ultimate luxury. Being able to afford to sleep during the day and sustain night-time activity against the classical dangers of darkness was a very high, maybe one of the ultimate social privileges.



Figure 1: 1852 painting of Friedrich II playing the flute under the “crown-light”, symbol of ultimate luxury – light levels were 5 Lux measured in a recent reconstruction experiment.

A surprise came to technicians and custodians of the “Stiftung Preussischer Schlösser and Gedenkstätten” when with large effort – candles are not the best friends of fire-chiefs in precious castles - they reproduced the 18th century light situation of the flute-playing monarch in the *Konzertzimmer* of the *Neue Palais* at Potsdam: 5 Lux⁷ at most was the shocking result, and a very “dim” impression for all involved, yet they discovered the fascinating way the room came to live with all the candles in all the mirrors and the crown-light creating a “Christmas tree” atmosphere. Of course unlike in the old days the people came into the royal light not from a dark park outside, not through a sequence of court-rooms with slowly increasing candle-contingent and smaller crown-lights, they came from rooms housing a couple of modern ceiling floodlights to show all the Pracht/splendor as close to the daylight view as present lighting technology can provide. Certainly what was also lost is the “art of seeing” at night – we are culturally night-blind.

Night-time integrity and Night-time authenticity

We return to the outside and back to Schönbrunn castle. In a way the Großmugl Starlight Oasis can be viewed as also protecting a night-time part of the nearby world heritage sites of the city of Vienna and the imperial castle at Schönbrunn. For the latter a significant effort was made to reconstruct the authentic daytime view as part of the integrity of the façade not to the least because the “Schönbrunn-yellow” colour that was an iconic colour of the Austro-Hungarian empire. But

5 cf.: Regularly scheduled public lights: Paris 1667, Amsterdam 1669, Haag 1673, Hamburg 1675, Vienna 1687, Berlin 1682, London 1736 (Hess 1902); 1884 first electric street-lights on continental Europe in Steyr/Austria.

6 A typical of 3000 Taler for a deluxe candelabrum of the “Neue Palais” compared to 300 Taler Jahresgehalt für Karl-Phillip-Emanuel Bach candelabrum (heute 500 000 €). candelabrum for 6000 Taler were offered.

7 Measurements gave 4-6 Lux as typical for the room, a little more directly under the candelabrum

while the daytime colour now delivers an authentic framework for the representation-ensemble at Schönbrunn the night-time colours and appearance are modern in many aspects of the world. The Gloriette decoration building will not appear as a moon-lit accent in the imperial gardens in pale moonlight as viewed from a candle-lit mirror ball-room, it has to fight for contrast with modern ball-room illumination, a fight for the attention of the indoor viewer that can only be won using lighting technology on the megawatt scale.

All this is clear evidence that night-time authenticity in general should go on a red list of culture facing extinction in most places relevant for world heritage.

It illustrates what we are losing at a moment when the (integrity and authenticity of) night-culture is mostly neglected and the apparatus for a scientific description is in status nascendi. Even the expert is in difficulty to make progress in intellectually grasping the masterpiece without the original at hand, without an authentic perspective.

The Starlight Oasis – a place where people live with a relatively good sky – provides a conservation tool for night views, night-scape and night culture: I will progress with putting together astronomical/physical references that are necessary for keeping the light of a site intact⁸. During the night-time we de-facto have the technical means to fully control the light, the contrast and the colours of anything. So far this opportunity has often been used to change the night-light of world heritage sites in a way that arguably compromised night-time integrity and night-time authenticity.

In summary and emphasising the return to the positive value of a moderately intact night-time environment⁹, from the absence of a problem to the presence of a value/asset, to quantify what is a valuable “night-sky-ruin” if you like: a comparatively well preserved night-sky provides not only the astronomical authenticity of a site – including a physical context for astronomical narration – but also the upper half of landscape integrity, the integrity of the night-light and in consequence the integrity of the night-time environment (e.g. by allowing the original species to sustain life and exhibiting their authentic behaviour¹⁰) and thus the basis of an authentic heritage of natural and cultural monuments and artefacts – indoor and outdoors. When the curator's effort to show pieces of art by bringing the daylight into the exhibition is action towards the goal of authenticity, the Starlight Oasis is the tool for similar efforts at night. It brings the night light to our heritage in places where people still live and conserves the night-time authenticity.

In conclusion, a site that preserves the integrity of night-time phenomena in an inhabited area is the only way to preserve culture at night in an authentic way, thus the role of a Starlight Oasis reaches far beyond the gateway to the skies and the astronomical heritage¹¹.

8 Note that the situation is “naturally” kept intact during daylight – except for cases of severe air-pollution – because the sun still dominates the outdoor daylight by orders of magnitude and we do not have at hand the technical ability to change that significantly. Even in special set-ups like a theatre or film studio this is still a challenge.

9 In terms of the application of the Convention, it is difficult to see how the criteria for assessing tangible cultural heritage could be extended to the sort of negative definition of a property (the absence of artificial light) that would characterise a ‘Starlight Reserve’ or ‘Dark Sky Park’ (Case Studies 16.1 and 16.2). Instead, we must consider this issue in terms of natural value: a dark sky is an aspect of the quality of the environment of a cultural site. That said, in terms of scientific value (and cultural value in general) connected with the history of astronomy, it is quite valid to recognise the absence of light as a prerequisite for the satisfactory observation of the night sky. *Thematic Study ...*, p.277, The visibility of the sky.

10 e.g. bats and spiders nor hunting at lights

11 Beyond its manifestation as modern ‘rational’ science (and arguably in that case also), practices related to astronomy are inextricably linked to broader assemblages of cultural activities. It follows that the material heritage of astronomy in the form of artefacts and constructions will often be deeply integrated within material heritage of a broader nature and significance. The Viña del Cerro site in Chile (Case Study 3.4), for example, provides an excellent example of astronomy in a broader, integrated context of resource exploitation, sacred places, calendar and landscape. This implies in turn that we should not focus exclusively (or even, possibly, most of the time) upon ‘astronomical heritage sites’ per se but upon sites exhibiting an important set of valuable attributes, astronomy being just one component among others. (Thematic Study, p. 262f)

“Relatively” dark starlight areas – Zodiac and Milky-Way as pragmatic references

The Starlight Reserve document gives the skies of inhabited areas, of small villages reasonably free from light pollution as a prototype for a Starlight Oasis¹². That implies access to the Milky Way in the better cases and roughly reflects the pre-light-pollution situation of the 1960s when the Milky Way still could be seen from cities with more than a Million inhabitants.

We will therefore assume a conspicuous appearance of the Milky Way and the visibility of the classical constellations including the Zodiac as the typical context for the following discussion¹³.

To visualise what this means we note that this essentially results in a naked-eye sky showing all the types of phenomena integrated into the state-of-the-art sky-simulator “Stellarium”¹⁴. Stellarium – as the sky in a Starlight Oasis – is not complete¹⁵ but it shows a practical essence of what is generally needed for educational and cultural purposes.

The night-sky of a site as a tool of visual astronomy and a monument of science

An important part of science is the concept of evaluating the quality of a theory (or falsifying a competing theory) by comparing with “measurements” that are based on a reality – an objective world or “world one” in the Popperian context - that can be measured. Measuring usually means to quantify with a given “measure” or “unit” or “standard” following rules of measurement or measurement concepts. The resulting “number” in terms of the “unit” then allows to connect to a mathematical language that is constituting/system-forming in particular for astronomy. That method has been the epistemological model for a dominating stream in many sciences.

While records of measurement are a key practical element, they are not the primary source for the progress ranking in the competition of theories, because they may contain not only errors but hidden often implicit assumptions made by the “observer” during the measurement process. They may also lack contingent (german: kontingent (adj.)) information (say the air temperature when the measurement was taken) that turn out to be necessary to evaluate the number relevant for the comparison with the theory and to decide its correctness or passing or failing a test in the language of critical rationalism.

The “physical basis, the real system” is an essential part in the authenticity of scientific culture as it is the ultimate reference for correctness. It is the authentic original of the phenomenon explained by a theory for its claimed “domain of applicability / domain of validity”¹⁶. The very concept of “truth” as a correspondence of theoretical results to “facts” relies on the availability of the reality-reference.

An illustrative example are units and standards used in measurements. To get a representation for the unit a standard has to be measured. The most famous one may be the meter-prototype (mètre des archives, Urmeter). This is the factual basis of the meter. To determine a distance in meters, in a way that other people can check, first the prototype has to be measured and then the distance in

12 *Starlight Reserve Concept*, p. 13-15.

13 This results in requiring a sky with a visual limiting magnitude of 5 or higher. Limiting factors are the Milky Way and faint constellations as Pisces, Libra, Ursa Minor where key stars exceed 4.5 mag.

14 This does not mean all the stars or all the nebula in the Stellarium software because extensive catalogues are used to support zooming, telescopic views etc., but it is a good reference for what is a simulated credibly sky in the sky-simulator that is most popular also under amateur and professional astronomers and educators.

15 Incompleteness means absence of very low surface brightness naked eye phenomena: (1) seasonally the Zodiacal Light, (2) the Zodiacal Band, (3) the Gegenschein, (4) some extended nebular structures, e.g. the Galaxy M33 in Triangulum but not M31 in Andromeda.

16 e.g. as Newtonian mechanics with a validity in weak gravity fields and for speeds that are small with respect to light.

question. Thus the prototype is necessary as a factual basis of the method. If the method of measurement changes, usually in search for better accuracy, the prototype is remeasured and so on. While the meter is now realised by a time-interval and the speed of light, the most striking example in our context is the kilogram prototype for mass that is still a carefully kept piece of metal near Paris. It is the factual basis of mass in our measurement system.

For the astronomical systems as the reference-systems for motion, Earth-rotation or solar-system relations the standard is what is in the sky. As an example the coordinated universal time is measured with high-accuracy clocks but carefully adjusted to the Earth's rotation by monitoring it relative to astronomical objects. This is one “applied” example of the central role of the factual basis in the astronomy and science in general.

We discuss the “sky” here as a “fact harvesting field” that constitutes the “reality” that is the basis of the central progress paradigm of science: the factual reference. A theory is a better theory if it has a better correspondence with measurements i.e. derived numbers from a measurement practice. That measurement practice operates on an agglomerate of natural phenomena that is approached in a particular way. These “measurement conventions” are integral part of deriving a scientific result and are adapted to the local situation by separating “contingential” information that allow certain approximation to be applied to arrive at the measurement numbers¹⁷.

For example to obtain a position of a celestial body it needs to exceed a particular contrast with respect to the sky in the background. That stars are not seen during the day is a consequence of the fact that the sky is too bright during daytime. Similarly the fact that the stars and planets relevant for forming the fact-basis for the Western Renaissance Astronomy are visible and thus can be used in the “truth” system of science depends entirely on the sky quality. The cornerstone sky-features for Kepler's laws are for example the stars of the ecliptic band to obtain, as Tycho did, high precision planetary position relative to them and to allow the respective coordinate systems to be built with their help in particular the foundations of a good equinox, and last but not least planet visibility.

For the astronomical renaissance the sky necessary for authentic science is in practice a sky showing planets, their visibility phenomena and the respective reference stars. The easiest way to quantify that as a criterion of authenticity for this body of science is to use Tycho's catalogue or method and require roughly stars down to magnitude six to be visible with the naked eye. That again brings us to the Milky-Way sky of a Starlight Oasis.

For ancient Egypt the authentic sky would be one at least showing the stars forming the Decans joined with a large gap concerning importance the planets and the Egyptian and Hellenistic constellations.

For Babylonian astronomy a sky constituting the “fact-basis” would be one preserving the respective constellations, normal stars, ziqpu stars and again the planets as well as the cornerstone rise-setting phenomena for stars contained in the body of cuneiform texts. Certainly this would also



Figure 1: Kepler at Linz: The bright planets Jupiter and Venus are readily visible to the right of the statue, but perception of constellations is even compromised in the conspicuous case of Orion (to the left) under the urban conditions in the city of Linz. It is one of the values of a Starlight Oasis to conserve the authentic sky at a site as a monument of science of important epochs. Image: March 2012, Herbert Raab, Linzer Astronomische Gemeinschaft.

¹⁷ E.g. in Babylonian astronomy and beyond the renaissance atmospheric refraction and extinction were ignored, though Ptolemy was aware of the “foggy” conditions of the sky near the horizon.

serve the goal of conserving the authentic Zodiac as a landmark of Western (astronomical) culture.

An authentic appearance of the moon is assumed to be self-evident here but issues might concern the “first light” under some circumstances and city light levels recently lead to the loss of the authentic appearance of total lunar eclipses. However, given the fast growth in light-levels at night it is not unthinkable that we might lose the moon for certain lunar-phases in urban areas unless they are protected.

The question of authenticity may arise if Starlight Oasis are used as the monuments for a scientific sky of an epoch somewhat outside the historic centres of that particular epoch, the historic city of Vienna, say for the Großmugl case. Evaluation of that issue rests on what displacement renders a sky not characteristic for its use. As the changes are overall minor on the naked-eye scale we may take Ptolemy's climates as a reference for sky-locality classification. A more quantitative way would be to compare the typical accuracy of archeoastronomical alignments that is for a number of reasons¹⁸ on the few degrees scale, just as a starting point. If we take the Keplerian-sky as one spanning in spread the localities in Kepler's biography we also arrive at a spread of a few degrees in latitude and longitude for the authentic range of “Kepler-skies”¹⁹. Thus we consider a sky authentic for a particular location or epoch as long as it is a few geographical degrees within that locations or historic centres of the epoch, respectively and consequently the sky (not the landscape horizon) of a Starlight Oasis is considered authentic for distances on the order of two geographical degrees or ~250 km. This gives an interesting perspective of globally conserving an authentic sky of all human cultures and epochs by a network of Starlight-Oasis separated by approximately 500 – 1000 km.

In summary, the relatively dark sky of a Starlight Oasis conserves that factual basis of the intangible part of the scientific tradition and constitutes a key element of its truth- and progress²⁰-concepts. While from a positivistic point of view the factual basis is *a/the* reality, from the point of view of other schools of thought it is a construction or narration, but undisputed is its role as *a*, if not *the* most important component of the scientific method. Protecting this component of the method in the case of astronomy means protecting its origins. The particularities of the night-sky at a given location and the authentic situation for an epoch make it a monument of science for the scientific tradition at the site. This complements and completes the heritage of instruments, which was often the human eye alone until the telescopic revolution changed everything.

The authentic sky of an epoch- Starlight Oases supporting the culture of the night and authenticity of heritage sites

While the progress on science heritage is a key objective of the thematic study, the night-time environment or night-time landscape constitutes a part of the integrity and authenticity of many sites. While it is a standard conservation issue to protect the landscape and setting of a site under pressure by human activities (building pressure, deforestation) it is much less common to consider the pressures on the sky. That is mainly because until relatively recently we did not have the technology or it was much less practical to modify the sky compared to the landscape. Humanity developed abilities to manipulate stones, building-blocks or the shape of a landscape but not the sky. With industrialisation that changed dramatically and even more so with the availability of electric light and in particular the availability of the energy necessary to change the sky.

18 Apart from weathering and other conservations issues that includes long-term (secular) changes in the Earth-Moon system e.g. on the tilt of the Earth axis and the star-ecliptic relation due to precession.

19 Kepler's home-skies: Weil, 48°45' N, Tübingen 48°31' N, Graz 47°04' N, Prague 50°05' N, Linz, 48°18' N, Sagan 51°37' N, Regensburg 49°01' N.

20 That is progress by-better correspondence of theory with measurements and observations.

Western natural-light night-time culture essentially started to be modified with the introduction of public urban light (starting with Paris 1625). It was challenged by introduction of electric street-lights concurrent with industrialisation (in continental Europe, Steyr 1884) and started to rapidly disappear with the energy-boom of the second half of the 20th century. As a natural consequence and concurrently professional activities in natural night light largely moved to the remote astronomical mountain-observatories as the only remaining unlit sites. Professional practice in near natural night conditions was confined to navigation (sea and air) where the human vision still provided unparalleled quality in orientation with a strong trend in special (military) night-time tasks being increasingly performed with vision enhancement systems that brought an end to professional natural human night-time orientation once image-intensifier tubes and infra-red-equipment became more practical and often superior for particular tasks as search and rescue operation than human night-sight. For technical and partly traditional reasons astronomical use of the eye partly²¹ continued in astronomy until the 1970s because the eye still being superior on certain time-scales and for certain tasks.

While many recreational cultural activities dealt with the night-time by using artificial light for daytime extension, astronomy by construction remained the guardian of western night culture.

A Starlight Oasis is not able to satisfy the highest standards of telescopic astronomy that can be better served by changing the cultural context and moving to a remote site. However a relatively natural night-sky can preserve the most important astronomical features – we restrict ourselves to include the classical constellations in particular the Zodiac and the Milky Way – *and* preserve the cultural, natural and geographic context.

The cultural context is obviously important since a desert's sky cannot replace the authentic overall setting of a night-time Renaissance city. The natural context determines for example the seasonal behaviour of plants and birds (singing times and -seasons) by changing twilight patterns and in case of migrating birds navigation-stars.

The geographical context has to be considered in addition to the relation with localities of culture and landscape and dependence of day/night twilight and setting phenomena on *latitude*, that were discussed above. If tidal-phases or other phenomena that break the astronomic rotation-symmetry, play a role geographical *longitude* is an issue.

To illustrate that clearly: culture under the sky cannot generally be preserved in an authentic way on a tropical island or a west-continental desert that has the perfect conditions for telescopic astronomy. While one of the highlights of astronomical perfection in measurement and the development of science and technology these places are a mere drop in the ocean of the night-time culture of humanity.

A northern polar sky with its polar nights, seemingly endless twilights, the midsummer brightness and the often aurora-decorated northern constellations creates a specific and genuine cultural atmosphere that cannot even remotely be compared to the sunset and quick appearance of stars in the tropics - not to mention the practically daily phenomenon of the Zodiacal Light near the equator.

An other example are the unique Aegean skies. A particular wind pattern linked globally to the Monsoon causes a dehumidification of air above sea resulting in perfectly blue sea-views and a deep blue sky above the sea, that has qualities of a dry desert sky, but occurs over water.

It is this particular way that the universal heritage of the sky becomes important in a characteristic, unique variation to a particular culture or epoch by the local conditions (geographical, climate and natural) shaping the authentic night-time environment.

21 In particular applications where integration techniques could not be used and rapid response was needed as the “guiding” of the telescopes by a human operator during long-time exposures on photographic plates.

With light pollution becoming a universal pressure on integrity of sites the authentic urban night for many epochs and certainly the integrity of night will be restricted to very few places and disappear if not actively conserved.

A light from the Renaissance and any other pre-industrial period, in practice can only be or shine authentic in a Starlight Oasis with the present and foreseen pressures of light at night.

Sky-landscape systems – an integrated approach to value and integrity

Modern astronomy emphasises the intrinsic nature of celestial bodies and conceptually separates them from their appearance, the *apparent* phenomena in the sky that follow as a consequence of their geometrical relation and physical interaction of their light with a site. Much of the everyday effects, beauty and scenic quality are the consequences of this interaction that produces night-scapes which give a framework for night-time culture²².

For the consideration in the world heritage framework all the aspects at a the site are equally important²³.

Astronomically the celestial phenomena produce light that interacts with the "airspace"²⁴ connected to a site and contributes to the sky. The sky and its phenomena then interact with the landscape forming the *sky-landscape system*²⁵ of the site. Any given situation at a site and thus the de-facto basis of evaluating its integrity is partly the consequence of the interaction of astronomical phenomena with the landscape and the local atmosphere.

The sun disappearing behind the landscape horizon, for example, triggers a change of light caused by the shadow thrown by the topographical feature that causes the sun to disappear. The sunlight scattered by the atmosphere down onto the landscape determines the lighting-situations, contrasts and thus the appearance of what is inside the shadow²⁶. The property of this light in the shadow is the prerequisite for the integrity of the "blue hour" that is of such key importance in all the visual arts. It is determined by an interaction of sun, sky and landscape and is essential for an authentic cultural post-sunset setting.

Because of such interactions it is essential to discuss *sky-landscape systems* to evaluate the integrity of a site with key astronomical contributions to the universal value.

The local world surrounding us at a site may be perceived as a unity, the *environment* in modern terms that includes air and sky conditions. Any separation of the environment into space, sky and landscape is likely to be cultural²⁷.

Astronomical phenomena including the superlative ones often require the same site-integrity as what are atmospheric phenomena in modern terms: auroral lights, lightning, daylight, twilight, night-light.

The geometrical separator between sky and ground is the landscape-horizon, the physical separator

22 TS: p. 266, Cultural an natural ...: At the same time, natural sites used for astronomical purposes (both in the present and in the past, where there is clear evidence to support the assertion) could fall in the 'cultural landscape' sub-category.

23 TS: p. 267, the visibility of the sky: ... we must consider this issue [dark sky] in terms of natural value: a dark sky is an aspect of the quality of the environment of a cultural site.

24 The volume of space above the site but also as the concept in international law.

25 We use the term to emphasise interaction of the sky including the astronomical objects with the landscape whereas with *nightscape*, we refer to the night-time landscape.

26 much as water on a petroglyphs makes them often more readable.

27 The classic example is the Aristotelian categorisation of what belongs to the eternal heavens and what to the changing sub-lunar world.

between the atmosphere, the contribution of our planet to the sky is the exosphere²⁸ – the roof of the sky and the beginning of space, if you like.

Separating ground/landscape and the sky is closely interrelated to the development of scientific understanding²⁹ and the physical conditions for that contribute to integrity and, when embedded into a tradition or narration – as arguably also the scientific value of a site is -- also to authenticity.

Modern astronomy is focussed on *separating* the phenomena in space, i.e. above the exosphere from the apparent phenomena, the “localities” appearing on the night sky – physical situations that are due to the site, its landscape-horizon, atmospheric and weather-patterns. A phenomenon marking the borderline and that is alive in many traditions are the meteors or shooting stars.

At the same time *connecting* the ground to the sky by treating them as an integral system is of great historical and cultural significance³⁰ including all rise/set phenomena, the twilight, time-keeping and all calendars. “Interactions” of the sky and the ground, as e.g. Martian dust-storms that shape the astronomical appearance of a planet and large meteor impacts that act as pacemakers of the Earth's geological and biological history (natural history) made that fact most obvious also for large scales in the 20th century.

Geologic records in the sky of a site as the Moon, Mars and Vesta and the small solar system bodies also known as Asteroids and Minor Planets are key elements that require an intact sky-landscape system to conserve their integrity as night-sky phenomena and as geological on-site evidence in particular of the early stages of Earth formation – as a rule of thumb the oldest rocks on Earth reach to the ages of the youngest areas on the moon. The oldest records of the history of our changing planet are in the sky of a site.

This geological evidence in the sky has interesting properties concerning the convention. With reference to the thematic study conclusions we note that they are in a sense tangible – though only by high-tech means, not fixed but immovable in the sense that their state of motion cannot be changed by any foreseeable human intervention, although artificial deflection of dangerous near-earth-objects may change that one day.

An intact sky is essential to protect the integrity of Meteor-streams that are primary and most original witnesses of the evolving solar system. In fact a Meteor-stream and its narrations can only be protected at a starlight site under present pressures on conservation³¹.

Astronomical phenomena contributing to the scenic value are transient in the sense that they are intermittent (usually not visible in daylight and under cloudy conditions). A key question is then of how to evaluate sky-landscape systems with their integrity not only depending on the site and the surrounding landscape but also on how the light passes through the system to create the view/impression/characteristics of the site.

The operational guidelines offer advice of how to proceed in a case that is similar, a waterfall³².

28 That is the location about 150 km above the ground where the our atmosphere cannot be viewed as a continuum any more and does not belong to the planet's equilibrium.

29 In order to identify our most exceptional astronomical heritage, it is important to recognise the continual interchange between the 'tangible' and 'intangible' categories, which is part of the fundamental paradigm that constitutes the scientific process in general. *TS*, p. 268, „Evaluating an astronomical heritage site“

30 Meton's observations may well have made use of the visible horizon (formed by a hill 3 km away). In this sense, the natural landscape formed part of the 'instrument' and so directly forms part of the astronomical significance of the place. *Thematic Study*, p. 276.

31 Historically this was at the origin of the development of the Großmugl Starlight Oasis.

32 See note on waterfalls contributing to OUV in the 2011 op. guidelines, I.I.E. § 92: Properties proposed under criterion (vii) should be of Outstanding Universal Value and include areas that are essential for maintaining the beauty of the property. For example, a property whose scenic value depends on a waterfall, would meet the conditions of integrity if it includes adjacent catchment and downstream areas that are integrally linked to the maintenance of the aesthetic qualities of the property.

That phenomenon is transient in the sense that it depends on the changing often seasonal supply of water, the flow to the drop and the runoff. That is much like the night-time phenomena depend on the supply of light, its progress to the ground and conditions for it to successfully reflect back thus shine on the landscape – sunshine, moonshine, starshine. A beautiful illustration of that on the moon is the Earthshine.

Like light passing through the site creating an impression upon interacting with it, a waterfall is formed by a medium (the water) originating from an often remote place after precipitation directly or via an intermediate body of ice causing delays for a time on the geological scale and create the phenomenon of value at the site by interaction with it. The operational guidelines call for protection of the inflow and outflow of the water in addition to protection of the landscape of the site itself. In case of the “lightfall” that can be achieved by letting the light pass into the site without dilution by light pollution – no excessive water extraction or “pollution” by imissions in the water case – and let it interact with the site to create the authentic light phenomena (shadow-cast to make a relation between sky and ground temporary physical and “reveal” it³³, ground contrast and various illumination, reflection and colour properties) – the characteristic night-light of the site. By protecting the flow of light into the site and the authentic interaction with it, the integrity of the nigh-time appearance of the site can be assured.

Thus the “astronomically intact” sky of a landscape sheds light onto the site that is modulated by its landscape to create the authentic appearance of an artefact or a landscape feature (think of the tumulus at the Großmugl site) in moonshine or starshine. At the same time the standard inventory of astronomical phenomena constituting the foundations of western astronomy – e.g. risings and settings would be preserved.

Thus a Starlight Oasis shows the local apparent astronomical phenomena, the nightscape in its authentic appearance as a consequence of the sky-landscape interaction, the “lightfall” onto and across the site as well as all interdependent phenomena of the regional culture of the night. To determine its value the physical integrity and artistic authenticity of the light of a site needs to be considered.



Figure 2: Pico del Teide (right) and IAC's Observatorio (left) at Izaña, Tenerife in moonlight. Note the blueish sky with Orion and Sirius, the reddened moonlight on the snow-covered volcano and the greenish vegetation. An example of the role of colour at night. Image by A. Santerne and the author.

Integrity/Authenticity and the essential role of night time perception

The authentic view of a site at night is closely related to human perception. As night falls, the human visual system fully adapts to the reduced light levels on the time scale of the tropical twilight that lasts for about an hour.

There is usually little mention of the role of light for the authentic view of a site during daytime because the elasticity of human vision produces a stable visual impression over a wide range of

³³ Human constructions incorporating astronomical alignments are also, of course, ‘connected’ in a cognitive sense to the astronomical body in question: this connection was periodically ‘revealed’—reaffirmed visually—when the sun, star, etc actually rose or set in the alignment. Light-and-shadow ‘hierophanies’ (e.g. Case Studies 9.3, 11.2) represent another case where a direct connection between a human construction and a celestial body is periodically ‘made physical’. It is also true that in a more general sense all astronomical heritage sites have a connection to the very sky to which they related.

light levels (height of sun), light distribution (hard, spotlight type desert-sunlight to soft, diffuse light at high humidity or under complete overcast) and colour (warm sunlight to reddish sunset atmosphere or the unique light of the “blue hour” around civil twilight).

That changes dramatically as human vision adapts to the night. Human night vision applies a mixture of receptors (rods, cones and at least one other the photosensitive retinal ganglion cells) and “processing” across the entire field of vision to create the perception that we are used to or at least where used to when referring towards the lower light levels. Technically three regimes are distinguished: (1) the photopic daytime vision that also drives much of artificial lighting efforts, dominated by the colour mediating cones (2) the mesopic, “twilight” vision where both receptors cones and rods are important and (3) the scotopic “night-time” vision, dominated by the black/white mediating rods. Every one of these types of vision mediates a particular impression to us and correspondingly has its own cultural and artistic tradition and representation systems.

Roughly we can associate the three types of vision to three regimes of natural light: (1) daylight and including the civil twilight, (2) moonlight, nautical twilight and, depending on the site, astronomical twilight and (3) the astronomical night under natural conditions that is the domain of scotopic vision³⁴.



Figure 3: The moon above the Gesäuse National Park, with the exit of the Enns-river from the canyon – partly covered by fog-patches – on the left. The bright moonlight brings out colours in this image that are visible in a moderated way to the human eye in mesopic mode. Note the stars in blue sky. Image: Norbert Fiala, Kuffner-Sternwarte.at

The consequence of this variation of human vision depending on the light-level is that for an authentic night-time perception and atmospheric setting a site has to have an integrity in light-levels in order to be perceived in the respective vision mode.

Light at night has led to increased background and sky brightness with the result that the contrasts of heritage sites illuminated by natural light were reduced conversely. The reaction often was to add artificial light on the site to re-emphasise a landscape-feature or artefact but that meant increasing the absolute level of light with consequences for the mode of visual perception.

The typical result is that the eye – or more precisely the active field of view – is in daylight mode when viewing sites also at night. Not only the relation to the starry sky

is destroyed but also the colours have lost their integrity or are severely compromised.

³⁴ Civil twilight: from sunset to the sun six degrees below the horizon; illumination-levels: sunset: 700 lx, end of civil twilight: 3 lx, end of nautical twilight 0.006 lx; Siedentopf, H. and Scheffler, H., Dämmerungs- und Nachthimmelshelligkeit --- Brightness of twilight and of the night sky, sect. 1.5.3., p.60, in Landoldt-Börnstein, Zahlenwerte und Funktionen aus Naturwissenschaft und Technik, Neue Serie, Gruppe IV, Bd. I, H. H. Voigt, ed., Springer, Berlin, 1965.

The only practical way to get the authentic (i.e. night-time vision) view is to take measures to allow the human eye to stay in the respective (authentic) mode – mesopic³⁵ or scotopic when viewing the site. The only straightforward way to achieve this is to protect the site against light pollution.

To illustrate that we show images taken in moonshine with a camera, Figure 2, 3, 4.

The night-sky appears blue but with stars and the colours of the landscape as during daytime³⁶ but “paler”. That is no wonder because the light of the moon is sunlight reduced by the moon’s poor reflectivity (Albedo) but with practically identical colours.

The beautiful blueish-pale moonshine that we once where all used to is a result of our eye going into the mesopic mode and gradually moderating the colours. Of similar origin are the authentic colours of the stars and planets. Finally in pure starlight we perceive the world essentially without colours – an impression generated by our scotopic mode of vision – and all cats are finally black at night. The authentic factual basis of this latter cultural narration is also under pressure of light-pollution.

We note that starlight – the light of all the stars shining at a site – differs from moonlight also by the fact that the Moon, like the Sun is a relatively small (spot-like) light source creating strong shadows with relatively sharp edges. The very hard shadows of moonlight – which together with blueish colours are a signature of the “nuit americaine” used by film makers to create night-time “narrative authenticity” - are a consequence of the low absolute levels of light inside moon-cast shadows. The light-level inside those shadows are near or in the scotopic domain of the eye and thus perceived differently than the daylight shadows that, relatively, are as dark compared to sunlit places but are still perceived in the photopic daylight mode of the eye.

In short artificial light at night often leads to a loss of integrity of a site. Acknowledging recent progress in “industrial light”, the only practical pathway to authentic light at night, and authentic appearance of the landscape, etc. at a site is a near natural sky, that in an urban environment constitutes a *Starlight Oasis*. Only under these conditions we are able to appreciate an intact night-site and preserve its integrity and authenticity in an integral approach to the OUV.

We note that effects similar to the ones discussed also effect photopic perception but are less obvious. That includes the physiological memory of the eye during daytime.

For brevity we did not discuss the significant time-dependent adaptation-phenomenon in mesopic and to the scotopic regime that may effect the authenticity in the field of vision. With the “twilight hour” as the natural gateway to night-time perception³⁷ they should naturally be taken care of, but blinding is an issue to be observed in conservation plans to guarantee authentic landscape perception with starlight.



Figure 4: moonshine picnic at the tumulus observing site in the Großmugel Starlight Oasis. Note the colours of the sky, the green grass, the red in the blanket and marker and the long moon-shadow cast by the person in front. Image: Norbert Fiala kuffnersternwarte.at

35 CIE TC1 -58 , mesopic region $0.001\text{cd m}^{-2} - 10\text{ cd m}^{-2}$.

36 There are subtle differences in infra-red “colour”-bands but not in the visible part of the spectrum.

37 The eye needs about five minutes for the first (cone-determined) step to dark-adaptation and about 45 minutes for full adaptation (rod-related) to the night mode of vision.

The physics and astronomy of cultural and landscape night-time integrity

The most basic quantity characterising the night-time appearance of a site is the amount of light that shines towards the ground from the sky. It provides the framework and the light-level basis for all other elements of night-time (and daytime) appearance³⁸. It includes the effects of the changing atmospheric conditions as weather phenomena and in an indirect way the artistic and architectonic effects of artificial lighting.

For the lighting technology directed towards humans the relevant quantity is the horizontal illumination – the amount of light per area that by international convention is useful for human daylight vision³⁹.

More generally the total amount of light falling on the ground at a site may be measured. Irrespective of whether it is useful for human⁴⁰ vision or for other seeing beings or just of relevance for the physical sciences. This quantity called total radiation is used e.g. by environmental and climate sciences. It measures the amount of light and therefore energy received by the ground. For example it quantifies how the sun drives the climate by heating the ground⁴¹.

These quantities complement the astronomical measures of how the sky emits light between the sources (i.e. between the stars etc.) that are conventionally specified in equivalent stellar brightness (“magnitudes”) per unit solid-angle (“sky-surface area”) often as magnitudes per square-arcsecond ($\text{mag}/\text{arcsec}^2$) or equivalent flux/number of stars of magnitude 10 ($S_{10\text{vis}}$). While these quantities specifying background sky emission are related to light pollution and the amount of light at a site they do not directly specify the amount of light the shines on the site that includes all sources with the moon being the most prominent example but also e.g. the planets, the Milky Way and Zodiacal Light constituting a significant contribution to authentic natural-light.

In the appendix, table I we give numbers for reference points of astronomical and cultural



Figure 5: moonrise at Großmugl tumulus – note the reddened moon, coloured clouds and blue sky with stars (Cas, And, Peg). The colours of the moon physically are the colours of the sun – same spectrum, same scattering: the moon-lit night-sky is blue as during the day with the same shadow casting. Perceived through the human eye in mesopic/twilight mode the unique moon-shine appearance is created: blueish colour tones and hard pitch-black shadows. Image: Norbert Fiala, Kuffner-Sternwarte.at

38 Natural illumination conditions are primary attributes that must be taken into account in protected areas and when dealing with sensitive habitats and wildlife species, as well as some factors that may have a negative effect on biodiversity conservation. (*Starlight Reserve Concept*, p.19, sect. Core-zone, Criteria).

39 This convention (CIE tech. Rep. No. nnn) by itself is an element of culture and the result of a few centuries of artificial lighting. It focuses on the human daylight perception – the photopic seeing – plausibly a result of the dream of turning the night into the day.

40 These are: daylight (photopic) mode, the transitional twilight (mesopic) mode and the night-time (scotopic) that is dominating human visual perception only under conditions of a moonless natural night beyond astronomical twilight.

41 E.g. total radiation was found to increase in Alpine and Western European cities in the last decades as a consequence of reducing more than half of the unwanted aerosol heritage of industrialisation and thus produces the hard to notice daylight-brightening of our cities.

phenomena associated with different light levels at night. For easier comparison to technical lighting and the fact that the horizontal illumination is the present cultural lingua franca of light, we tabulate Lux-levels but note that for human night-time vision (approximately below the full-moon brightness), other species and biological and physical conservation issues, the total radiation is the more general and in many cases the more useful concept.

Night-time integrity as opposed to daytime-integrity of a site is shaped by photometric and physical measures of light. We note that it is often the particular light that is a key element of an artistic style, contributes significantly to the character of a landscape or is an architectonic cornerstone or a signature of a school of art.

Notes on the comparative analysis

While the astronomical night-sky – thought as the celestial sphere – by nature, by being the window to the universe is universal for the world it defies the comparative, its interaction with the landscape and atmosphere is diverse. Modern astronomy uses this diversity to optimise observing conditions for given scientific objectives (e.g. see the *thematic study*, windows to the universe and conclusions).

Sky-horizon systems are specific for a site: with (1) the horizon determined by the landscape, (2) the particular orientation of the celestial sphere (location of the celestial pole) determined by the geographic latitude, (3) the particular rotation angle relative to earth by time and longitude, (4) the particular atmospheric conditions at the site (weather and climate).

Sky horizon system may result in extreme cases in a spot with stars viewed from a well, or a narrow band of stars as is often the case in the Enns-canyon in the heart of the Gesäuse national park or in the wide open skies of the Großmugl Starlight Oasis or at Sea. The latter are almost ideal in the sense of corresponding to the model of a celestial hemisphere with no atmosphere and a “mathematical” horizon, i.e. one without considering curvature and refraction.

While it is relatively easy to find an authentic sky with narrow horizon, the authentic conservation of many important astronomical phenomena (as e.g. helical rises or access to rising and setting azimuths or plainly the view of planet Mercury) require wide skies that have the property that lights can be seen over large distances and require large zones without disturbing or blinding lights.

From mountaintops the ground and in particular the atmosphere and clouds can be seen for hundreds of kilometres and in consequence authentic views of the night-sky have to be highly valued for wide horizons. In fact the lack of that value is a key limitation for educational use of the night-sky in many places; it is easier to find a narrow sky that is uncompromised by blinding lights but it is correspondingly much more difficult to get oriented and understand such a sky, not to mention that a shielded sky is astronomical incomplete, be reminded of the visibility of Mercury.

Conclusion: The Light-Tide and the “Abu-Simbel” of Astronomy

The starlight declaration states a right to starlight at the places where the people live in the spirit of the right for an intact environment to live in. Applied to the World-heritage-convention that arguably would call for authentic and intact skies above the sites where people live, i.e. the historic centre of Vienna and the Schönbrunn castle for our context. But the industrial and post-industrial flood of light has increased light pollution levels such that in the largest cities even all stars have drowned in light and moonlight became a hard to notice addition to prevailing light levels.

Now one way would be to accept the loss and e.g. go with the compromise of shining electric light

onto the sites at night to compensate for the insufficient contrast, of a monument compared to the prevailing light at night, caused by the relatively reduced moonlight and starlight. But that is accompanied (and amplifies) a severe loss of “astronomical” and night-time authenticity in particular for sites and monuments built with a “sky-connection”.

Given the fact that most of the skies lost their authenticity above the historic observatories of European astronomy, accepting the rising flood of light, keeping in mind the relative non-locality of the sky, and, that cases exist where a small relocation gives sky access in nearby suitable places, we should consider a pragmatic approach to conceptually connect the city observatories – or urban sites more generally - to nearby Starlight Oases skies. One should consider the argumentation that accepting less than 60 km distance results in a change of angular situations by less than half a degree – the nautical mile with 1.85 km corresponds to an arc-minute or $1/60^{\text{th}}$ of a degree.

While a small loss of authenticity has to be taken into account, the integrity of the historic skies can be protected with a realistic effort by viewing the historic urban skies from the safe havens of Starlight-Oases. This uses that fact that stars are far away and thus one may speak of “authentic infinity”. Thus the astronomical phenomena are provided without a noticeable difference to the nearby historic observatory sites. The visual sky impression and the natural light conditions as well as the complete factual basis of the instrumental astronomy of the European astronomical renaissance remain authentic.

While the relocation of Abu Simbel is an irreversible loss of part of the authenticity, those generations that live after the water reached the level of Ramses' toes have access to the masterpiece. The increased Nile water-level at Assuan is reversible in principle, as is light pollution. The loss of a living culture – our relation to a natural night-sky and natural night light and the ability to access the factual basis of the science of a key epoch – would be as irreversible as the destruction of a monument. Our culture of the night would be archeological, historic or a reconstruction like in a Planetarium – it already is in mass culture. Any such conservation would be without the authentic factual basis for the concept of science that connects ideas, words on paper and “reality” by measurement of natural events.

A heritage gap may rapidly become a heritage loss, as we all are reminded by being confronted with a generation that lost the Milky Way and having tried to answer the question of how to find it. For most people in most places the Starlight Oases will be remembered as the place where they see a part of their heritage that is shared with all the cultures⁴², but with narrations as diverse as they are: their stellar-constellations and their way of viewing the Milky Way and the firmament. Their marvel may lead them to the origins of the world's science heritage – on a path that is itself authentic.

42 “Astronomical heritage, however, has the advantage of being universal, in the sense that every human culture has a sky and ‘astronomy’, which we take, broadly, to mean the cultural interpretation and use of what is perceived in the heavens.”, *Thematic study ...*, opening par., p. 260.