Introduction

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Background to the ICOMOS–IAU Thematic Study

This ICOMOS–IAU Thematic Study was conceived in 2008 following a period of intensive activity relating to Astronomy and World Heritage, driven mainly by the UNESCO World Heritage Centre (WHC) and by the International Astronomical Union (IAU).

The central aim of this study is to extend these efforts by presenting a global survey of astronomical heritage from the standpoint of the identification and evaluation of heritage sites relating to astronomy and archaeoastronomy that might have the potential to demonstrate outstanding universal value (OUV)—the term of recognition for the value properties need to manifest in order to be inscribed on the World Heritage List.

UNESCO's Astronomy and World Heritage Initiative commenced in 2004 following a decision reached by the World Heritage Committee at its 28th session (28 COM 9). It reflected a recognition that astronomical heritage was underrepresented both on the World Heritage List itself and in the Tentative Lists of the various State Parties to the Convention. It also followed an expert meeting on 'World Heritage and Monuments of Astronomy' held in Venice on 17–19 March 2004, organised by the UNESCO Regional Bureau for Science in Europe (ROSTE) with the support of several State Parties.

The 29th session of the World Heritage Committee confirmed its interest and involvement in this thematic initiative particularly "as a means to promote … nominations which recognize and celebrate achievements in science" (July 2005).

At the outset, the Astronomy and World Heritage Initiative proposed the following types of cultural property associated with astronomical heritage:

- Properties which by their concept and/or the environmental situation have significance in relation to celestial objects or events;
- Representations of the sky and/or celestial objects or events;
- Observatories and instruments;
- Properties with an important link to the history of astronomy.

The initiative benefited initially from the creation of a database of sites and properties connected with astronomy, supported financially by the Royal Astronomical Society (UK) and hosted on the website of the World Heritage Centre.

In January 2008, the Inter-Union Commission on the History of Astronomy (ICHA)—a joint Commission of the IAU and the Division for the History of Science and Technology (DHST) of the International Union for the History and Philosophy of Science (IUHPS)—produced its own preliminary list of important ancient and historical cultural properties relating to astronomy.

In October 2008, UNESCO and the IAU signed a formal Memorandum of Understanding (MoU) committing them to work together to implement and progress the Astronomy and World Heritage Initiative. This provided a strong and secure framework for further progress. Shortly afterwards, the IAU created a Working Group on Astronomy and World Heritage in order to discharge its responsibilities under the Memorandum.

The decision by both UNESCO and the IAU to proclaim 2009 as the International Year of Astronomy served to raise the public profile of the initiative.

Meetings Throughout this period there have been various meetings that have served and continue to serve to implement, progress, and publicise the initiative. These include:

- A regional round table related to the Astronomy and World Heritage Initiative organised by the Institute of Astronomy of the Russian Academy of Sciences in May-June 2005.
- An international conference on 'Astronomy and Heritage' organised by the European Society for Astronomy in Culture in Sardinia, Italy, in June-July 2005.
- An international symposium on 'Cultural Heritage: Astronomical Observatories (around 1900) from Classical Astronomy to Modern Astrophysics', organized by ICOMOS Germany in Hamburg, October 2008.
- An international conference on 'Astronomy and World Heritage: Across Time and Continents', organized by the Russian National Commission for UNESCO, held in Kazan, Russian Federation, in August 2009.
- An international seminar on 'Astronomy and World Heritage: Across Ages and Continents', organized by the Egyptian National Commission for UNESCO, held in Cairo, Egypt, in February 2010.

Broader context and significance The words posted on the UNESCO WHC website emphasise the context and what is at stake:

> "As there are few properties related to science on the World Heritage List, and the scientific value of cultural properties related to astronomy is not always recognized, the World Heritage Centre, in close collaboration with the State Parties and ICOMOS, have developed the thematic initiative Astronomy and World Heritage in response to the ever-growing concept of World Heritage, and the Global Strategy for a Balanced, Representative and Credible World Heritage List adopted by the World Heritage Committee in 1994." http://whc.unesco.org/en/astronomy

In order to aid the recognition of global astronomical heritage and to help promote the inscription of the most outstanding astronomical heritage sites on to the World Heritage List, it is essential to undertake a scientific study of such heritage. A natural step, therefore, was for representatives of the IAU and ICOMOS to meet together, and such a meeting took place in October 2008. The decision was taken at that point to undertake a joint project of Thematic Study, taking as broad and open a view as possible, and the current publication is a direct result of this collaboration.

Aims, objectives and broad methodology

This Thematic Study sets out to undertake a wide-ranging survey of astronomical heritage, i.e. the material evidence relating to astronomy and to social uses and representations of astronomy. It suggests tools for the definition, identification, and assessment of the significance and, potentially, OUV of this specific type of heritage. It also gives examples of the identification, protection, conservation, management and promotion of such heritage. Since astronomical heritage represents scientific heritage in its cultural context, the Thematic Study thus aims to implement and develop one of the main objectives of the Astronomy and World Heritage Initiative.

Like all ICOMOS Thematic Studies (http://www.icomos.org/studies/), it has been produced in order to support possible nominations to the World Heritage List[1] by summarising the available documentation in a specific field. It aims to highlight the potential of all regions to contribute to the World Heritage List, especially in association with the global strategy for a 'balanced, representative and credible List'. It does not aim to identify OUV in individual sites, as this might compromise the subsequent process.

The list of themes we are proposing (see below) aims to provide a short and clear overview of the recognised evidence relating to astronomical heritage. It is an open list that acts as an initial framework for promoting and supporting the global recognition of astronomical and archaeoastronomical sites of possible significance, including those with potential OUV. It defines the main fields now well recognised by the international community and encourages State Parties to the World Heritage Convention to identify potential astronomical and scientific sites in their Tentative Lists.

The case studies aim to provide short examples of the methodological process of recognising heritage properties in astronomy and/or archaeoastronomy. The intention is to help State Parties identify potential sites and undertake comparative studies. We also hope to show how the value of the sites might be demonstrated and the World Heritage criteria met. Sites are inscribed on the List only if they are of outstanding universal value and have a broader significance than simply at the local, regional or national level. The evaluation process is based on the clear identification of the attributes that substantiate the OUV of the site.

A crucial step for every nominated property is the comparative study. In general terms this serves to define the true value of a property in an international and trans-cultural perspective. More specifically, its purpose is to demonstrate that there is room on the World Heritage List for the property and that there are no other comparable sites that might be nominated. This needs good specialists in the thematic field aware of the specific aspects of heritage evaluation and management constraints. This ICOMOS–IAU Thematic Study intends to provide some well-structured examples produced in this way. It has benefited from the professional advice of a range of specialists identified by the IAU, including many members of the ICHA and the Working Group on Astronomy and World Heritage, together with recognised specialists in the History of Astronomy and Archaeoastronomy/'Cultural astronomy', university academics, and members of the International Society for Archaeoastronomy and Astronomy in Culture (ISAAC). The advice of ICOMOS' experts was required for the value assessment of the various examples studied.

Some preliminaries about the nature of astronomical and archaeoastronomical heritage

In this section we propose some initial approaches to preparing and assessing evidence for the heritage of astronomy. The aims are to provide guidance in

- preparing an inventory of the astronomical heritage associated with a given place;
- understanding the issues inherent in identifying a potential astronomical World Heritage site; and
- developing a suitable methodological approach for undertaking preliminary studies and, if these are encouraging, to prepare a nomination dossier.

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[1] See the *Convention Concerning the Protection of the World Cultural and Natural Heritage* (UNESCO, 1972) and the *Operational Guidelines for the Implementation of the World Heritage Convention* (UNESCO, 2008), particularly para. 45 (definition of cultural heritage) and para. 77-78 (criteria for the inscription of properties on the UNESCO World Heritage List.

A vital starting point is to consider both the tangible and the intangible heritage of astronomy. The interplay between the tangible and the intangible is an inherent and fundamental aspect of astronomical heritage, as indeed it is of science heritage in general, and to a lesser degree of all properties on the World Heritage list.

Global methodology

There are three main aspects of the 'astronomical system' associated with a given place and thus contributing to the value of a site:

- material evidence of the astronomical place in the form of fixed property and/or moveable objects;
- the results of scientific activities (in the broadest sense), including but not restricted to astronomical observations; and
- socio-cultural applications and uses of astronomy at a given moment or over a given period for the site.

Each of these three main categories gives rise to both tangible evidence and intangible heritage. Following the World Heritage Convention, the tangible evidence must be divided into two subcategories: moveable heritage and immoveable heritage. Immoveable heritage is central to the application of the Convention but moveable heritage is not, strictly speaking, covered by the Convention.[2]

Thus, for example:

	Tangible immoveable heritage	**Tangible moveable heritage**	**Intangible heritage**
Property / objects	Architecture; permanent constructions and structures, fixed instruments	Plans; moveable artefacts; moveable instruments	Practical/technical expertise; rules of use and maintenance; structural/ architectural history of the site
Results of scientific activities (in the broadest sense)	Stone carvings; wall paintings; iconography; palaeography; symbolic representations	Records/accounts of observations; printed and digital data; sky maps; scientific publications	Knowledge and understanding; calculations and theories
Socio-cultural applications and uses	Astronomically aligned architecture; light-and-shadow hierophanies; urban planning and landscapes constructed using astronomy	Archives; drawings; maps and plans, tools or instruments using astronomical properties[3]	Calendars; ideology; predictions of the future (whether rational or irrational from modern perspectives)

While incomplete and begging many issues, such as the imprecise boundaries between certain types of evidence, the table suffices at this stage to highlight the important question of the relationships between material evidence, as the main focus of the application of the World Heritage Convention at the present time, and intangible heritage, as evidence for the value of material manifestations. Within the tangible category, we must also examine the relationships between fixed (immoveable) and moveable objects: again, only the first of the two is currently relevant to the World Heritage Convention.

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[2] The term 'immoveable' is used in a juridical sense, to mean something that has not been globally displaced from its position in the soil, in other words something that has permanent links with the architectural framework of its construction or of its natural foundation. In this sense, it actually means 'fixed in its original position' or 'not moved [yet]'. On the other hand, 'moveable' has its common-sense meaning.

[3] For example, sextants for maritime purposes or moveable sundials in social use.

In this Thematic Study we seek to understand what characterises the specificity and originality, and hence contributes to the outstanding universal value, of astronomical sites. In order to do this it is important, on the one hand, to clarify the boundaries between the types of evidence and, on the other, to have an open discussion of the continual exchange that exists on many levels between astronomical endeavour and material evidence, both fixed and moveable. Similar considerations apply to scientific heritage in general (and to a lesser degree to all heritage), and we intend that this study of astronomical heritage will provide a paradigmatic example that informs the broader discussion.

Themes

In the following chapters we have attempted to identify a set of themes that span the wide range of types of astronomical heritage but nonetheless provide a coherent framework for the development of case studies

In the main, the principal themes are related to a broad chronology of the major human cultures and to different types of astronomical discovery, knowledge and practice, including but not confined to recognisable stages in the development and use of modern scientific astronomy.

It is recognised that the scope and boundaries of each theme are often unclear.

The topics are:

- Earlier prehistory,
- Later prehistoric Europe,
- Pre-Columbian America,
- Indigenous uses of astronomy,
- Ancient and medieval Far East,
- India,
- Mesopotamia and the Middle East,
- Ancient Egypt,
- The Classical World,
- Islamic astronomy,
- Medieval astronomy in Europe,
- Astronomy from the Renaissance to the mid-twentieth century,
- The development of radio astronomy,
- Applied astronomy in modern times,
- Space heritage, and
- 'Windows to the universe'—starlight, dark sky areas, and observatory sites.

Each chapter presents a general overview of the theme in accordance with the particular disciplinary competence and experience of the author(s) concerned. The chapter authors were also invited to co-ordinate, under their scientific responsibility, a limited number of case studies that would provide significant examples of methodology in the context of their thematic essays. Some have been written by the chapter authors themselves, and some by independent authors.

Astronomical heritage as tangible heritage: inventory and identification

The following may be identified as the principal types of tangible astronomical heritage:

- Observatories as 'scientific monuments'. In most respects normal, well-accepted practices can be followed, but a critical question may arise with the section on authenticity (see below). The architectural approach may only be a limited part of the assessment of a scientific site.

- Fixed and moveable instruments. Tangible astronomical heritage raises the question of the borderline between fixed property and moveable artefacts, i.e. portable instruments, moveable domes or floors, etc. This is not a straightforward issue, since an instrument in the form of a fixed 'monument' could serve exactly the same purpose as a personal portable instrument or a 'semi-moveable' instrument located in specific places for observation. This issue in not peculiar to astronomy but applies to science and technology heritage in general. Concerning collections of moveable instruments, the UNESCO initiative 'Movable Heritage and Museums' may be relevant to some aspects of this type of heritage.
- Material representations of the results of astronomical observations and cognitive understanding:
  - Tangible representations of observations, events and predictions (calendars, time measurements, predictions of eclipses, zodiacs, celestial representations, etc);
  - Cosmological and symbolic representations (iconography, palaeography).
- The material products of the application of astronomy: constructions, architecture and urbanism related to applied astronomy and/or bearing astronomical information.
- Properties whose design and/or landscape setting have significance in relation to celestial objects or events.
- Cultural landscapes related to the history of astronomy and/or human cultural practices related to astronomy.
- Dark night sky areas where the ability to see natural starlight preserves the visual links to the sky that have connected humankind to the cosmos throughout history.

The distinction between property and moveable objects is important from the juridical and heritage perspective, but has no real significance for astronomers. What is important is the scientific function of the instrument and its technical performance. The distinction between a fixed instrument and a moveable instrument is only a question of dimension, technology and materials, precision of observation, stability, the necessity of moving the instrument for observation, etc. It is merely a practical and technical consequence of a scientific project. What is more pertinent is the distinction between a 'collective instrument', shared by a professional group of astronomers in some context, and an individual instrument. The notion of the personal use of astronomical instruments—for example, not only for scientific research but also for navigation, leisure purposes, etc.; or not only for astronomical observations but also for decoration, collection, etc—could easily be linked with the broader application and/or social use of astronomy, but only more rarely with a decisive improvement in observational techniques and/or theoretical progress at the level of universal exceptional value.

A collection of rare or unique moveable instruments authentically associated with the history of an observatory is obviously a major part of the latter's heritage value. The task of assessment must therefore involve making a detailed study of the functionality and of the construction and use of each instrument, exactly as would be necessary for a moveable part of a technological monument or for a 'machine-tool' in industrial heritage. For the scientist, this is the real core of the material value of the observatory, perhaps more than walls and architecture, which could be really poor in some major examples of the history of astronomy.

A remark arises here about the materiality of the celestial objects that we observe. Are stars and planets themselves part of our natural heritage? In one sense, yes, but it is more important to recognize that the sky is a cultural resource common to all of humanity. In consequence, astronomy forms part of the efforts by all human beings to comprehend the observable world—the cosmos—within which they dwell and to understand their place within it. At any level, the quest to make sense of the cosmos by imposing a perceived order upon it—whether by registering associations, recognising patterns and cycles, making predictions, or identifying generic relationships expressible as mathematical laws—can be regarded as a form of 'science'. Consequently, astronomy has been characterised by the observation and coherent

interpretation of celestial objects and events from the earliest stages of human evolution through to the modern world, including (but not confined to) the history of contemporary science. In heritage terms, human scientific understanding of the sky and its links with cultural practices invariably represents the production of meanings by human beings and hence the production of 'intangible heritage' in context.

In assessing the material heritage of astronomy, it is clearly impractical to include the celestial objects and events themselves, even though this creates an epistemological difficulty in heritage terms. However, we cannot dissociate astronomical sites from the celestial objects studied by them: it is therefore important to recognise and, where possible, to strive to preserve, the visible link between the two. It is also conceivable that, just as some mixed properties derive their outstanding universal value from a combination of their cultural and natural heritage, so some properties may combine a cultural heritage of astronomy with the natural heritage of the dark night sky.[4]

Archives and documents: links between tangible and intangible scientific heritage

The scientific corpus that represents the core heritage of astronomy comprises the material sources of the history of astronomy: its archives and documents, in the broadest sense. An item of this type could be a tangible drawing or engraving on a monument or a palaeographic inscription, but it is frequently a 'moveable legacy' such as a written document, map or printed matter. The recording and transmission of information has certainly been a crucial issue throughout the history of astronomy. It is manifested in cave art, papyri, cuneiform tablets, paper-books of observations, paper archives, books and ephemerides, photos in visible and non-visible wavelengths, spectra, and digital databases.

Obviously, a major part of the evidence for the development of ideas in astronomy exists in the form of moveable documentation contained in archives, collections and bibliographies. Such documentation provides material support for the recording of observational results, prediction, calculation, theory, the use of astronomy, etc.

These documents are the product of scientific activities in their cultural context. The core of scientific knowledge is mainly intangible. It is an intellectual framework of the human spirit using specialised languages (written language, mathematics, etc) and images (drawings, maps, photographs, physical information such as spectra, and so on).

Archaeoastronomical and astronomical documentation is mainly related to:

- records of observations and events, tables of observations;
- physical images and information (photos, spectra, radio maps, etc);
- interpretation and theories (physical laws of the universe), cosmology (global theories and interpretations of the sky and universe);
- calculations and predictions (ephemerides, calendars, astronomical interpretations and predictions);
- social uses of astronomy, whether or not rational in modern scientific terms (calendars, navigation, agricultural practices related to the moon, astrology);
- symbolism, faith and religious uses of astronomy; and
- art and decoration.

In fact, the production and retention of archives could be considered the very heart of the scientific productivity of a laboratory or observatory. They are moveable underpinnings for collections of data emanating from sky observations, calculations, predictions and theoretical interpretations. It is in this way that the 'intangible property' represented by archives in a

[4] 'Inscribing the sky' itself is a nonsensical concept, since the 'sky' is something that one sees/perceives from a place on the Earth, so is an attribute of the place. The physical universe and the objects within it are another matter, but not what is under discussion here.

broader sense is most directly linked with the scientific activities and reputation of the 'astronomical property'.

Links between buildings, instruments and archives are clearly important for documenting sites but are also crucial in order to demonstrate their outstanding universal value through the justification of the criteria. For instance, beyond the material and static starting point of its architecture and instruments, one measure of the importance of a given site could be how influential were the data contained in its archives. The scientific OUV of a site could certainly be demonstrated in this way. A global approach focusing upon the contents of value at an observatory/laboratory site should consider it as a stable node within a regional (and, more recently, global) network of astronomers. The conservation of archives and the sharing of the data and information contained within them has always been a crucial part of the international activities of scientists, in every geographical and historical context. For example, when NASA was preparing to conquer the moon with the Apollo missions, it gathered together all the old data and calculations in the papers and manuscripts of the best astronomers from the 17th century through to the 1950s, preserved in the archives of the main European observatories. The aim was to confirm and verify NASA orbital calculations. Other examples also exist of a living archive being used in astronomy.

Such facts offer a specific link between past and present, and between modern projects and the past compilation of data preserved in archives. In heritage terms, astronomical archives have considerable importance as well as the potential for further use while they are in the hands of astronomers inside observatories. This parallels the archaeological value of objects in their material context and the enormous decrease in the value when the objects are removed from that context. Furthermore, this archival material taken in context constitutes an inter-regional/international network of knowledge in astronomy, as a global scientific achievement during a given historical period. A similar network approach could be proposed for instruments, with the notion of specialisation of sites and subdivision of work between astronomers. The contribution of a site to these global regional networks through its 'intangible' and 'moveable' evidence must be taken into account in order to assess its value.

In heritage analysis terms, the various types of heritage typically involved in sites related to astronomy may call to mind serial nominations in their precise geographical and cultural context. In this case, a specific systemic link must be established following the sequence:

- Celestial object/subject of observation,
- Site/observatory monuments/landscapes,
- Instruments/scientific and technical system,
- Archives/products of intellectual and symbolic human activity;
- Networks of sites/ instruments/ archive centres, etc.

Links between astronomical heritage and other types of cultural heritage

The material evidence of astronomical practices and uses is often associated with tangible heritage and social value lying outside the domain of science in the modern sense. The legacy of astronomy is rarely isolated but forms part of a broader cultural legacy. Often, the tangible heritage of astronomy must be understood within a broader category of global material legacy of properties, such as a particular type of instrument or observatory, or the places related to astronomy located within a particular historical city or cultural landscape.

This immediately raises the fundamental question of the re-evaluation of sites now on the World Heritage List. Properties—such as monuments, group of monuments, urban sites or cultural landscapes—or individual elements within those properties could have important astronomical value even though the OUV at the time of inscription did not reflect this value. For example, Ulugh Beg's observatory in Samarkand is one of many elements within an historic city of outstanding civil, military and religious buildings. Such sites might be re-nominated

and re-evaluated as major heritage places of the history of astronomy and for astronomical practices among civilizations, with their own outstanding universal value.

Frequently, human beliefs and practices form a fundamental part of astronomical heritage even where they do not constitute 'rational behaviour' as judged in modern scientific terms. The question of rationality (as we would judge it) is a secondary question because in each age, and each cultural context, astronomy operates within and is constrained by in a framework of cultural and ideological paradigms that define their own rationality. The definition of intangible cultural heritage—cultural practices and human behaviour—could be far from the modern definition of astronomical laws and facts. We have to take account of human attitudes to astronomical observations and predictions that have crossed many human cultures. For example, astrological practices based upon the complex but predictable movements of the sun and planets within the zodiac have been a common theme in many cultures over the centuries. They are far from today's rational astronomical attitude derived from the 'scientific revolution' of Western civilisation, but remain a cultural fact within human history. Other examples of the relationship between astronomy and culture are not so black and white, but all must be understood as part of the historical anthropology of astronomical practices and eventually linked with the assessment of sites.

Such links between astronomical sites and human cultures could be summarised as:

- Cosmologies, theories and beliefs about the universe, sun, Earth, moon, planets, stars, etc.;
- (Modern/contemporary) Scientific paradigms, 'rational' (in the above sense) laws governing celestial objects;
- False/'non-rational' (in the above sense) astronomical determinations for predictions or astrology;
- The cultural influence of celestial objects on daily-life and human attitudes; and
- The 'magic' and the religious dimension of astronomy in cultural and historical contexts.

The intellectual process of astronomy in the context of any particular cultural property always operates in a broader social context and in some cases in the context of global culture. It may or may not conform to modern scientific logic. A framework of processes that characterise the historical anthropology of human practice in the field of astronomy might be as follows:

- The progression from astronomical observations themselves to the results of those observations;
- The progression from raw results to notation, understanding and interpretations of those results;
- The integration of interpreted results into a cosmological system and/or global human thinking and knowledge;
- The compilation and transmission of knowledge;
- The eventual application, practical uses and material consequences of that knowledge;
- The eventual influence within social practices and spiritual beliefs; and
- The social, political and scientific context and decisions regarding observation projects and their organisation (which leads back to the top of the list).

Astronomy is characterised by a continual interplay between tangible and intangible aspects, and between facts and culture, within a given human society. Analysis of this network of relationships provides an indispensable basis for the assessment of a site's value, helping to justify the selected criteria and eventually to demonstrate OUV.

The issues of 'integrity and authenticity' in the context of scientific heritage

Generally speaking, it is essential to tackle these two issues in order to give a credible demonstration of the OUV of cultural properties nominated for inscription on the World Heritage List. In this section we briefly examine integrity and authenticity issues that are specific to the evaluation of an astronomical site and, by extension, to any scientific site.

At the outset, we must emphasize the close connections that exist between technological sites and scientific sites. Innovation and modification are traditional and necessary in science as in the development of technology. A technical achievement, an industrial production process or a scientific tool are designed and frequently constructed to evolve, to change, and to take account of innovations and improvements in science and technology. The capacity for change and evolution typically forms part of the value of material devices in science and technology. This distinguishes science and technological heritage, as a class, from many other forms of heritage for the purposes of integrity–authenticity analysis, and suggests that it may be productive to develop particular ways of approaching these two concepts for this class.

Integrity concerns the completeness of all the attributes that contribute to the value (and, potentially, the OUV) of a site. Focusing on astronomical heritage, physical integrity is manifested in different and complex ways for mechanical, optical, or electronic instruments, computer software, etc., and the complexity of the physical and technical attributes increases rapidly when we reach modern and contemporary astronomy. Added to this, attributes may include not just physical objects but also their uses, innovation, and types of maintenance. Integrity analysis must take into account the logic of maintenance and innovative evolution of instruments, in the context of the duration of their uses for continuing and successive astronomical objectives. In order to support the concept of integrity at a science or technological heritage site in general, it may be useful to regard the site as a *global scientific instrument*, demonstrating its integrity through a typological analysis of the evolution of the site and its constituent instruments (components of the whole 'instrument'). Moreover, through the Convention and the *Operational Guidelines*, the material attributes of the property need to be identified as supporting its OUV; the integrity issue then is whether they are all within the site and none is under threat.

Attributes such as the architecture and the landscape skyline of the site are merely a part of the overall integrity of the property. Of course, they do form an important and symbolic element of popular landmark recognition, an example being the traditional European 'dome observatory'. Furthermore, the architecture and the completion of the landscape are important attributes that contribute to the assessment of the value of the laboratory/observatory, but they may not be the most important. On the other hand, in the case of archaeoastronomy or modern astronomy when applied to monuments and territory management, the architectural and cultural landscape attributes remain crucial components of integrity.

There is a similar situation for the concept of authenticity, which relates not only to the architectural components of the laboratory/observatory but also to each element of the machine or instrument. Authenticity is about the ability of the attributes of OUV to convey their meaning truthfully. In terms of scientific sites, the use of the instruments and the buildings that encompass them could be key attributes of OUV, in which case authenticity relates to how well they still display those uses. Questions could also be raised about the authenticity of design of the laboratory/observatory itself, viewed as a global contrivance, through its evolution and changes.

In order to maintain its efficacy, a working machine/instrument must be maintained over a period of time under strict conditions. For example, fragile or dynamic elements must be carefully checked, and in some cases regularly adjusted, or replaced with new spare parts. If not, the use and consequently the 'living state' of the instrument could be compromised.

Furthermore, the use of astronomical instruments with a high level of scientific efficiency must follow the innovations and improvements regularly offered through the availability of

new technical components that are stronger, more precise, etc., and sometimes through radically new individual or collective technical solutions to existing astronomical problems. The renewal of materials and instruments, and sometimes their rebuilding and/or complete replacement to make a 'new' instrument/machine, is a living aspect of science/technology in general, and of instrumental astronomy in particular. A key question, then, is how the value of a property is balanced between its original components and the ability of each instrument to continue functioning. This is a question that every potential dossier must study in depth, in relation to the other attributes of the site's value.

At the same time, outside the sphere of modern scientific astronomy and its precursors, regular reinforcement by direct observation may not be necessary to the continued perception of, say, a sacred or religious site as directly connected with the sky or with particular celestial objects or phenomena. Thus modifications to a structure that render impossible a direct observation do not necessarily detract from the meaning of the site that derives from that observation. Indeed, in some cases a direct observation that is perceived to underlie the value of the site may never need to have been made at all.

These dimensions of change must be carefully studied through site authenticity analysis. In the case of modern scientific instruments the issues are typical of science heritage in general, and of movable objects in particular. But there are also significant consequences for traditional architecture. From the science heritage perspective, architecture might well be seen as an environmental aspect of the materiality of science, and not as the core attribute of the property. The relevant concept would then become that of 'architecture as part of a global machine', in other words as a protective envelope for the core process. The leading principle of the evolution of buildings is firmly imposed by the strategy of the group of astronomers in charge of the property with a clear scientific mission. The terms used for naming theses constructions—observatory, great telescope dome, spectroscopy lab, hall of heliometers, etc—are also important, and totally justified, in terms of the meanings of the property. The buildings certainly have a specific architectural function, but their historical role and value is directly dependent upon the scientific purposes of the site. They need to be assessed in the material and instrumental context of their construction and in their history of use, not just for their architectural associations and for the way the form of the buildings displays their purpose.

The complete history of the property should pay careful attention at every stage to the correlations between scientific purpose and architectural choices. Thus a building analysis of an astronomical property that is only couched in terms of the history of architecture and urbanism, referring only to dimensions, harmony of forms and landscapes, is totally insufficient. Conversely, a detailed chronology of use and evolution of the site is an essential prerequisite. Thus giant and monumental forms of construction that lack appropriate materials such as (in the historical or modern case) associated documentation, or whose function was relatively limited, or where only secondary scientific results were achieved (for whatever reason—such as a poor strategic scientific decision) might not reach outstanding universal value. In the case of archaeoastronomical sites, the appropriate materials would need to include strong archaeological/archaeoastronomical evidence supporting the case for astronomical significance.

In these ways, astronomical heritage sites, and science heritage sites in general, require. professional evaluation of the material and intangible issues to which these dual concepts give rise. Authenticity of use is probably a central issue in assessing the level and quality of the scientific operation of instruments by important astronomers, for a significant region, nation or internationally, and for a clearly identified historical period. The relevant notion may be 'authenticity in its scientific context and use'.

Management: general considerations

Measures for the protection, conservation and management of properties nominated to the World Heritage List need to be set out in the nomination dossier. They should be presented as an overall management system, and may be set out in the form of a Management Plan for the property, put into practice with the engagement of stakeholders and the approval of the State Party who will need to respect and apply it. The *Operational Guidelines* for the implementation of the Convention give a range of advice on this matter (items 96 to 98, 108 to 119 and 132–5; see also items 99–102 [the property] and items 103–7 [the buffer zone]). 'Protection' involves national, regional and local laws and planning regulations. A relevant and efficient juridical system must be presented to protect the property against all types of threat to the attributes that contribute to its outstanding universal value, both in the property itself, in its setting, and in relation to particular environmental issues that could affect its scientific function. The central idea is to maintain the integrity and authenticity of the property for the present and for the future—to sustain its OUV.

The overall management should rely upon professional competence in a range of different fields, such as architecture, construction, urbanism, archaeology and history, or whatever is relevant for the property.

The various aspects of protection and conservation should each be combined with the other aspects of property management—such as tourism organisation and facilities, and education, interpretation and outreach—with regard not only to the property itself, but also covering neighbour relationships, etc. For management to be effective, there must be sufficient and guaranteed funds to support the overall process.

It is worth emphasizing that for an astronomical heritage property the various general components of the dossier should be formulated in exactly the same way as they are for all other properties, with the same professionalism in addressing the different aspects of juridical protection of the property and its setting, and in the management system. The specificities of astronomical heritage management must be included in the management system as a separate topic, fully coordinated with the general issues and addressing, for example, the conditions for careful use and maintenance of the astronomical instruments, the availability of advice from astronomers the need for controlled scientific interpretations, and programmes of scientific education linked to the particular significance of the property.