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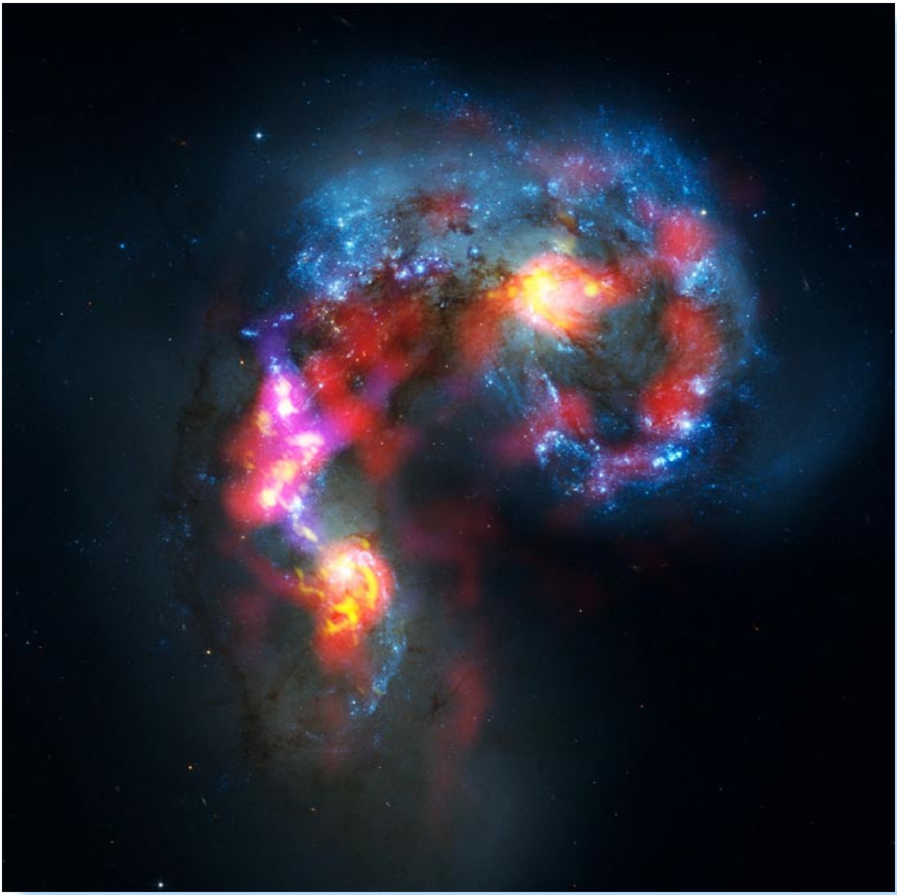

• SALT's Re-inauguration • International Astronautical Congress •
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• Distribution of Solar Planets • Photographing Lunar Parallax •

monthly notes of the astronomical society of southern africa



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**Antennae Galaxies composite of ALMA and Hubble observations**

This composite image by ALMA and Hubble of the central regions of the Antenna Nebula shows the visible light in blue, and the three ALMA bands in red, pink and yellow respectively.

Source: http://www.eso.org/public/news/eso1137/

mnassa
Monthly Notes of the Astronomical Society of Southern Africa
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news notes

# Second Light

Kechil Kirkham

Six years ago, in November 2005, the Southern African Large Telescope (SALT) was inaugurated. In August the following year the first scientific results were reported by Dr Darragh O' Donoghue. It described a polar binary star system, containing a white dwarf with a very strong magnetic field, which strongly influences how the hot gases from its relatively ordinary companion reach the white dwarf surface. However, things did not continue so smoothly, and, as is typical with a complex scientific instrument, technical problems were encountered. A series of issues meant that serious science had to be put on hold as they were one by one investigated and resolved.

On Monday 10 November 2011 there was a special ceremony to mark the re-launch of SALT where the scientific and funding communities met to mark this important milestone. Speeches were given, there was a lunch, local schoolchilren sang and two coach loads of people travelled to Sutherland and back in a day.

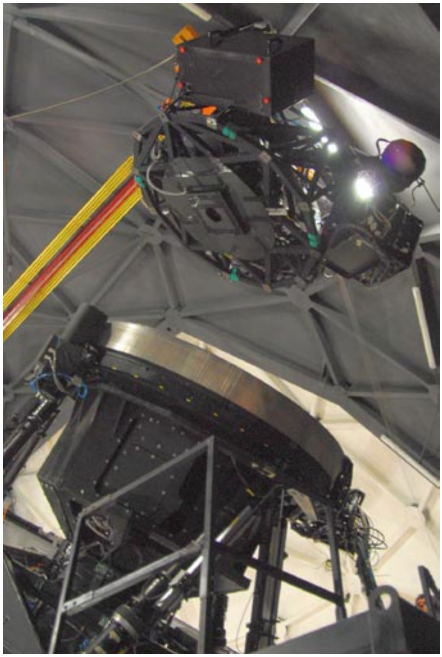
Much of the previous director, Professor Phil Charles's term at the SAAO was taken up with ensuring that SALT reached its observational design specifications. Commissioning and performance verification of the various instruments were carried out during his tenure. He was amongst those present at the re-launch.

Alongside a host of minor glitches, there were two main difficulties to tackle; image quality and throughput of the Robert Stobie Spectrograph (RSS). Both of these have been reported in detail in previous issues of *MNASSA* (*MNASSA* Vol. 70 nos 3 & 4, April 2011, p.61). Below is an overview of the two major problems.

**Image Quality**

Lisa Crause reported in her blog (http://saltiqmission.blogspot.com/) on 17 April 2009: "Three years of ruthless detective work investigating & characterising the image quality (IQ) problems of SALT have led us here: time to bring the Spherical Aberration Corrector (SAC) down and sort out the optics..."

**The SAC being lowered by the dome crane. Picture: Lisa Crause**



**The RSS about to be lowered onto the SALT prime focus payload. Picture: Lisa Crause**

A good overview of the SAC problems can be found in Dr Darragh O'Donoghue's paper (http://www.salt.ac.za/fileadmin/files/science/Publications/7739-24-IQ.pdf). In summary, they found problems with the interface of the SAC to the Non-Rotating Structure and the optics needed to be re-aligned. The technical complexities in both determining the problems and restoring the SAC to working order are non-trivial and earned Dr Darragh O'Donoghue the Gill Medal, presented at a Cape Centre meeting in August this year (*MNASSA* Vol. 70 nos 9 & 10, Oct. 2011, p.169).

**Robert Stobie Spectrograph Throughput**

The RSS was removed in 2006 to investigate the reasons for its low throughput. Following the successful re-integration and testing of the RSS at SALT, it was finally installed on the telescope on 9 April 2011. During the period of SALT's engineering stand-down to address its image quality problems, the spectrograph optics were modified in order to address the issue of diminished throughput, particularly in the UV/blue region. At the same time some improvements were also made to the reliability of the many mechanisms controlling the instrument.

On-sky re-commissioning observations then began on 11 April, directed by the RSS Principal Investigator, Ken Nordsieck, assisted by the SALT operations personnel. Some of the initial observations were to verify basic instrumement performance (imaging characteristics, spectral performance, control systems).

**Re-launch**

The presentations were introduced by NRF CEO, Prof Albert van Jaarsveld, who praised the international partnership and the government for its far-sightedness. Val Munsami, deputy director in the Department of Science and Technology, mentioned SALT's role in helping South Africa in the SKA bid. He also talked about the newly formed South African National Space Agency (SANSA) and the proposed South African National Astronomy Agency (SANAA). He said it was vital that these two agencies had a close working relationship.

Speaking at the re-launch, Patricia Whitelock, acting director of SAAO, said that when one thought of the work that was going to be done by SALT, the telescope became more than just a work of science, engineering and art. "It is truly phenomenal," she said. It was an impassioned speech and an appeal to the explorer in us, as she likened the audience to the early mariners (and here one thinks of Magellan and his namesake dwarf galaxies), not knowing what may lie over the horizon. "Don't look at me" she said, "look behind at that telescope. Isn't it beautiful!" she exclaimed.

Rutgers University Professor Ted Williams, present with other members of the international SALT board, also spoke. The final speaker was acting premier of the Northern Cape, Honourable Cjiekella.

**Real Astronomy**

After the speeches, SALT impressed the audience by turning on its pneumatic cushions and the dome rotated to the delight of the guests. Chatting to astronomers Patrick Woudt and Amanda Gulbis at lunch, they were brimming over with excitement at the previous night's observations. The seeing had been perfect with


**Albert Van Jaarsveld (left), Ted Williams and Premier Cjiekella unveiling the plaque. Picture: Lisa Crause**

"just a few cirrus clouds and minimal perturbations", said Patrick. Amanda had carried out scores of scheduled observations, but to top it all, Patrick had observed a Magnetic Cataclysmic Variable "going off". He writes:

"This system was discovered in outburst by the Catalina Real-Time Transient network (using a telescope in Australia) on 3 November. We were on the telescope at the same time and decided to study this object in detail whilst it was bright, only to discover rapid variability on a time scale of 6.5 minutes. We deduced that that must be the rotation of the white dwarf – the central star rotates once every 6.5 minutes – and it suggests the presence of a strong magnetic field channeling the accretion flow on to the white dwarf via field lines. We immediately asked our colleagues on the 1.9-m telescope to take a sequence of spectra the next night (whilst it was still bright) to confirm the magnetic hypothesis, as well as alerting another colleague to get access on an X-ray satellite for definitive proof of magnetic fields. Both confirmed our hypothesis within a day, a mere two days after the initial report of an outburst! A telescope such as SALT frequently operates in a 'target-of-opportunity' mode, whereby observations are triggered by transient phenomena. This really highlights the way 'transient astronomy' works, it truly is real-time astronomy."

Bookending O' Donoghue's early paper, it was a fitting start to a new wave of science at SALT. The politics, the funding, the engineering and testing, the computer technicians and massive infrastructure needed to make SALT work, converged at this one moment of discovery and it all made worthwhile sense. ☆

## International Astronautical Congress held in Cape Town

The 62nd Congress of the International Astronautical Federation, under its President, Berndt Feuerbacher, was held in Cape Town 3-7 October 2011 at the Cape Town International Convention Centre. Dr Peter Martinez (SAAO), a former President of ASSA, was Chairman of the Local Organising Committee. The event was attended by about 3 000 delegates from about 80 countries. Among the notables attending were Charles F Bolden, Administrator of NASA and NASA astronaut Dr Catherine Coleman.

This annual congress can be regarded as the international indaba and trade fair of the space industry, covering consultancies, research, development, space agencies and universities involved in space science besides the industry proper. For most of the delegates, the importance of the event lay in the vast number of presentations made on almost all areas of concern to space industry and national space programmes worldwide, from human biology issues to space debris. One of the Congress's most interesting features

**Minister of Science and Technology, Ms Naledi Pandor (left), Minister of Trade and Industry Mr Rob Davies, President of the IAF Professor Berndt Feuerbacher, NASA Administrator Charles Bolden and Jean-Jacques Dordain, Director General of the European Space Agency. Credit G Withers/IAC2011**

was the `trade' exhibition with about 80 stands sponsored by space agencies from around the world as well as numerous companies in the business of providing space hardware and services.

This first occasion on which the International Astronautics Conference was held in Africa placed South Africa firmly on the global map of nations involved in space and provided a timely boost for the new South African National Space Agency.

Dr Martinez was awarded the Yangel medal at the Congress. This prestigious medal is a once-off award, coffered by a jury of six international and six Ukrainian experts. It is named after the rocket scientist Mikhail Yangel, a renowned missile designer for the Soviet Union.

**South African participation**

South African exhibitors included the Post Office, the IAU Office for Development, The SA Space Association (SASA), the Department of Science and Technology, the Square Kilometre Array (SKA), the Aerospace Industry Support Initiative and the Cape Peninsula University of Technology. Though South Africa has only recently formalized its space interests, space technologies are becoming ubiquitous in our everyday lives. For example, most forms of transport are dependent on GPS, telecommunications are routed via satellites and land-survey satellites have replaced many laborious ground-based procedures.

South African government entities with space interests currently include:

- Department of Trade and Industry, including the South African Council of Space Affairs, headed by Dr Peter Martinez (SAAO)


SAAO and Head Space Science & Technology Dr Peter Martinez (left), Professor Berndt Feuerbacher, President of the IAF and Minister of Trade and Industry, Dr Rob Davies. Picture credits G Withers/IAC2011

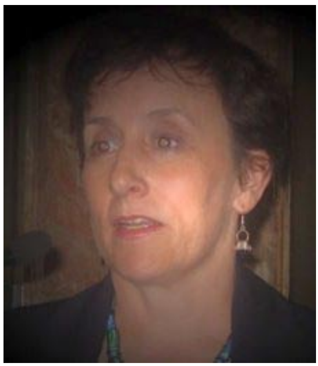
- The Department of Science and Technology, whose expenditure on Space Science-related programmes amounts to about R658 million for the 2011-2012 year, mainly devoted to the SKA, MeerKAT and the South African National Space Agency, under which is to be consolidated most ongoing space activities and research.

- The Department of Communications

- The SA National Defence Force, which supports the development of a range of tactical missiles through Denel Dynamics, and the Denel Overberg Test Range

In addition, over 20 companies are involved in space-related work. These involve such fields as satellite-based communications, remote sensing services, military equipment, space hardware and rocketry. ☆

## Christina Scott, Africa's foremost science journalist dies



Acclaimed South African science journalist, Christina Scott has died in a tragic car accident in Cape Town. Until her unfortunate death on 31 October 2011, Christina was the managing editor at Research Africa, Cape Town.

She was a stalwart of African science journalism, an author, broadcaster and journalist of repute. Christina hosted the weekly *Science Matters* programme on South Africa's main national English-language station, SAfm.

She was the President of the South Africa Science Journalists Association (SASJA) between 2009 and 2010 and a strong force in the African Federation of Science Journalists, was the science editor at the South Africa Broadcasting Corporation between 1994 and 2004 and between 2007 and 2009 was the Sub-Saharan editor for SciDev.Net. As an active member of the World Federation of Science Journalists (WFSJ), she mentored a crop of African science journalists under the federation's first SjCOOP (science journalism co-operation) between 2006 and 2009. She also attended the recent science journalism conference in Doha, where she shared her experience and expertise.

Christina held a degree in English literature from the University of Alberta and a Masters degree in media studies from the University of KwaZulu-Natal in South Africa.

She authored the book *Nelson Mandela: A force for freedom* and won many awards during her life time. These include the 2007 TWAS prize for public understanding and popularizing science. In 2005 she was co-winner of the reporting microfinance award from the Inter Press Service news agency and the International Fund for Agricultural Development. In 2000 she was awarded a Jack E Scripps science journalism fellowship from the California Institute of Technology (Caltech), USA and in 1999 she won the CSIR science and technology award for radio.

Christina will also be remembered for her quick, sharp humour, her passion, energy and enthusiasm and never let her lack of height get in the way of doing what she did best; spreading the word of science in Africa. She is survived by three children and her elderly mother. ☆

## *Science* awards 'Universe Awareness'

A website that aims to inspire young children by teaching them about the immensity of the universe and the wonder of the night sky has won the Science Prize for Online Resources in Education (SPORE). Carolina Odman-Govender, who developed the site into a global resource reaching forty countries, said that the website was intended to give a sense of perspective to everyone who uses it. The universe can be seen as a big and beautiful place in which we fit.

*Science* magazine developed the Science Prize for Online Resources in Education (SPORE) to promote the best online materials in science education. The acronym SPORE suggests a reproductive element adapted to develop, often in less-than-ideal conditions, into something new. In a similar way, these winning projects can be seen as the seeds of progress in science education, despite considerable challenges to educational innovation. Each month, *Science* publishes an article by a recipient of the award, which explains the winning project.

The Universe Awareness (UNAWE) website that Odman developed reaches out to children between the ages of four and ten, especially in underprivileged areas throughout all the regions of the world. Its resources come from an army of 400 volunteers all over the world. Everything is checked for accuracy by qualified astronomers. Odman says one aspect of its importance is that astronomy allows the children to "see the world as it really is, without real borders between countries."

For further details see: www.unawe.org/press/UNAWE1103/ ☆



# Moonset Lag with Arc of Light Predicts Crescent Visibility

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**Abstract:** I investigate the question of crescent visibility relying on modern data. The specific focus is a promising criterion for visibility when viewing by naked eye or binoculars (as later specifically defined), although telescopic observation will also be taken into consideration. The criterion makes use of the moonset lag (delay between sunset and moonset), together with auxiliary input based on the arc of light (angular separation between the Sun and Moon).

**Key words**: Moon — visibility

## Introduction

An extensive literature and lore exists about how to achieve greatest success at sighting the crescent. Even assuming that all due preparations have been undertaken to seek out the clearest conditions, to know accurately where and when to look, and optionally to make effective use of optical technology, it can also be an asset to have a good advance concept of the level of detection difficulty. From a scientific standpoint, and in the context of a very specific mode of observing, when can one make a prediction that visibility will be either (1) normally possible, or (2) so marginal and dependent on ungaugeable factors as to be irreducibly uncertain, or (3) guaranteed to be impossible (for that mode of attempted sighting)?

Odeh (2006), Hoffman (2005), Caldwell & Laney (2000), and Yallop (1997) give thorough contemporary overviews of the issues involved with developing such lunar visibility prediction criteria, so that an exhaustive exposition of the subject can be forgone here. In essence, for the crescent to be perceived, its illuminance has to be humanly detectable as contrasting sufficiently with the brightness of the adjacent sky. Scholars and scientists have parameterized (i.e. computationally modelled in terms of useful indicators) the circumstance in which the crescent can have attained that illuminance threshold after conjunction (waxing moon), or the symmetrical boundary case before conjunction (waning Moon), by experimenting with the use of a variety of indicators. These include the Moon age since conjunction, the time lag between the Moon and Sun rise or set, the detectable width or circumferential extent of the crescent, the angle of separation between the sun and moon from the geocentric perspective using known laws of gravity (referred to as the arc of light), and the altitude and azimuth displacement angle between the Sun and Moon from the "topocentric" viewpoint of the observer.

By employing one or a combination of several such parameters, the above authors and others have aspired to devise a criterion that dependably gauges the emergence of the crescent from an invisible to a visible status. The critical threshold value for the criterion is calibrated by (i.e. matched to the outcomes of) past sightings of record. Besides yielding a reliable judgment as to sighting possibility, a secondary desideratum is for a criterion to be straightforwardly calculable, on a location by location basis, by easily available means, as well as sufficiently comprehensible to the educated public that its misconstruction and resulting disputations are unlikely. Caldwell & Laney (2000) identified that, under very specific provisos, the moonrise/set lag [hereafter, lag] as a function of the arc of light, defined above, offers particular promise when applied to naked eye [hereafter, visual] and binocular sighting. The crescent visibility insight from the lag versus the arc of light is the subject of this study.

**Provisos**

Crescent visibility study has a large following and the field is flourishing in diverse and novel directions as technology and enterprising techniques have developed. There are traditional twilight visual sighting, sighting with binocular, by telescope, by telescope-coupled CCD (i.e. charge coupled device) camera, and by telescope/CCD-coupled computerized differential imaging. There is airborne as well as ground-based. Besides twilight crescent sighting there is also peri-solar midday optically-aided viewing. [Hereafter, twilight will be discussed in terms of dusk, although dawn is equally intended when appropriate]. Telescopic, CCD, airborne and daytime-style sighting are hereinafter explicitly excluded unless cited in a particular context. For acquaintance with these modes not analysed here, the website http://www.icoproject.org/record.html is a commendable starting point.

The societally relevant lunar calendar enjoins the pursuit of visual crescent sighting. Binocular visibility thus also retains direct relevance since it is the sighting mode extending the perception grasp one simple step beyond the visual technique, as well as often being the pointing aid for the visual attempt to follow. The other sighting modes (airborne, midday, computer- processed, etc.), though promising and fascinating, do not in any obvious way contribute more understanding of the visual observability than afforded simply by direct perusal of the visual plus binocular results on their own terms. I will classify as a binocular-level (as opposed to telescopic-level) event, any attempted sighting with an optical device of aperture 150mm or less, whether double-barrel or not (for example "finder" or "spotting" scopes of compatible aperture would belong), whereas any larger aperture device will be classed as telescopic and thus excluded.

**Event Collection**

Data selection or exclusion is an important issue in science, and the danger of post-facto omission to support a prejudice (even unconsciously) must be avoided by clearly setting up the "selection rules" independently of the analysis itself. The current data set (appendix A and B) is foundational for this study and consists of 36 positive visual and 58 positive binocular sightings. These numbers may appear to be surprisingly small, but this is because in a typical lunar cycle, sighting the young crescent at any given location is normally either fairly easy or completely impossible. The marginal cases that define the limits of visibility are relatively rare.

The sources of the basic data for the sighting events come from the published literature, together with the online data base of crescent sighting results at the Islamic Crescent Observation Project (www.icoproject.org/) [hereafter, ICOP]. Many published literature sources may be conveniently accessed at ICOP as well, and therefore this paper forgoes citing a vast bibliographical foundation for the synoptic and historical background of the subject. Important specific sources for the current sighting events include: Odeh (2006), Hoffman (2005), Hoffman (2003), Caldwell & Laney (2000), Yallop (1997), and Ilyas (1994). Lastly, the extensive fund of sightings [hereafter, "sighting" encompasses both positive and negative sighting attempts as appropriate] reported worldwide and logged on an ongoing basis at ICOP was carefully studied to bring the available sighting data up to date.

Some exclusions have been applied as follows. It was decided to exclude sightings prior to 1980. This does not disparage earlier achievements but more modern results are increasingly numerous, while many older results are relatively harder to find out much background detail for. A relatively high fraction of older recorded sightings tend to involve crescents too unchallenging to be of interest in this work. The very sparsity of the early results coming down from several generations past, gives rise to some concern about their homogeneity with the contemporary body of consistently executed and well-reported sightings. A lag cut-off of 45 minutes was imposed, as sightings of the crescent where the lag is greater than this value are generally too easy to aid in defining the limits of visibility.

Some previous analyses have opted to synthesize both sightings and non-sightings as complementary guidance. The useful interpretation of non-sightings is however encumbered by distracting extraneous effects that they interject, for example about either local meteorological or putative observer procedural hindrances. The present study will hold off summarizing the import of negative sightings until a stage where the interpretation of the inherently more clear cut information from the positive sightings has first been assimilated.

**Questions**

Natural questions at this point are: what is a sighting really, and why turn to this set of sighting reports and not others?

Difficult crescent sightings such as collected and analysed here differ notably from a non-practitioner's likely concept of happening to notice the crescent. A sighting by a skilled practitioner generally follows much of the following template, with the maximum effort by eye and brain. (a) Attention is focused on the right track of sky at the right clock time. (b) For roughly two minutes preceding true visibility, stimuli of a local brightening are perceived up to several times, strengthening into a perception of a brightening with frustrating location and completely uncertain shape. Reporters use such terms as fluctuations or glimpsings. (c) Location becomes rather secure but shape remains elusive. (d) True visibility arrives when location and shape perception, and repeatable finding looking away and then back, are attained.

Experienced crescent observers, at the edge of perception bordering from case (c) to (d) must do their best in a contest with their own objectivity, as well as fight off eye fatigue from prolonged staring, which conceivably could induce spurious impressions. The burden for objectivity cuts both ways, to be willing to see what your espoused criterion may subconsciously influence you to fail to see, and to be willing to concede a non-sighting, that you subconsciously worry could cast doubt on your previously secured sightings. Experienced observers can also gauge the self-deception danger from wisps of cloud or edges in haze layers. Isolated well delineated cloud bodies in the same part of the sky need not hinder a sighting claim, but a deceptive "blue band layer" that supposedly penetrates a very cloud-mottled horizon sky should almost without exception invite observer scepticism.

The current post-1980 data set includes all available published or at ICOP, excepting some extremely few in journals that increasingly these days are no longer shelved in academic libraries, as well as being unobtainable online. They are in my opinion collectively representative of a high threshold of experience, a fair threshold of carefulness and objectivity, and an additional element which is a degree of peer scrutiny resulting from the logging or critiquing/publishing process. The observing conditions of these particular observations were by and large good to excellent, particularly near the visibility boundaries to be discussed. Sightings that went un- published, or unlogged, could not be used for lack sufficient original details when read about in later undetailed second-hand accounts. This will not bias our results if the reason their details remained unavailable is not an effect of the cause being that the adequate details of these rumoured sightings were prevented from reaching a published or online-logged form for the very reason of their implications being discordant with the body of sightings which did manage to have their adequate details appear in available formats. In short we posit that our data set is not biased because of prejudicial omissions.

**Data Tabulation**

Appendices A and B give the data tabulation form of the 36 visual and 58 binocular positive crescent sighting events, respectively. The tabulation was filled out starting with the key source information, and then adding values calculated with the MICA Multiyear Interactive Computer Almanac (www.usno.navy.mil/USNO/astronomical-applications/software-products/mica) from the USA Naval Observatory. Columns 1-3 give the Universal Time [hereafter, UT] year, month, and day of the sunset or sunrise associated with the event of that line in the table. Note that this can validly differ from the (also valid) civil date appearing in the raw report, for some (especially western N. American) longitudes and seasons.

Column 4 is the lag in minutes (see under column 12-15 below). The moonset lag is the difference between time of sunset and time of moonset. During this interval the twilight sky grows dimmer, boosting the contrast between the sky and the lunar crescent. Greater lag also correlates with more leeway to sight the crescent before its becoming screened by the very high opacity atmospheric layer that occupies the few degrees starting right at horizon level. Columns 5-8 give the observer longitude and latitude in degrees and minutes. In a few cases of multiple nearby observer locations, a simplified joint figure was used for the location, because the small geographical spread has negligible effect on the really important quantities, viz. the lag and the arc of light.

Columns 9-11 give the UT day, hour, and minute of the geocentric conjunction (New Moon) corresponding to the other facts on the same line. Columns 12-13 give the UT sunset (or sunrise) moment in hours and minutes. Columns 14-15 give the UT moonset (or moonrise) moment in hours and minutes. The lag in column 4 was initially calculated as the difference, which can, about 1 time in 4 (depending on precision), give rise to a 1 minute round-off error. Although ±1 minute is minor, we enhanced the calculation to the time-seconds level of precision for any lag figure of 30 minutes or less. (The very few cases where column 4 differs from the inference of columns 12-15 by one minute, denote such adjustments.) The rise/set times include the factors of refraction, semi-diameter, and topocentric parallax, but no adjustment for site elevation. As it is only the difference of the times that matters in the lag context, and as the appropriateness and method (absolute or only relative to the surrounding topography) of applying elevation corrections is very context dependent, I concluded that there no justifying the complication of using individualized elevation adjustments.

Columns 16-19 are the astrometric geocentric (equator J2000) right ascension and declination of the sun, in hours, minutes, degrees, and arc minutes, at the mid-lag moment between sunset and moonset. Columns 20-23 correspondingly give the sky position for the moon. Finally column 24 gives the arc of light [hereafter, arcl], namely the separation of Sun and Moon centre gauged at the mid-lag time, using:

$$\cos(A) = \cos(90 - B) \times \cos(90 - C) + \sin(90 - B) \times \sin(90 - C) \times \cos(15 \times (D - E)) \quad (1)$$

where A is the arcl, B and C are the declinations of the Sun and the Moon, in decimal degrees, and D and E are the right ascensions of the Sun and Moon, in decimal hours. As the arcl is not a large angle in this context, the planar geometry approximation:

$$(A)^2 = (B - C)^2 + (15 \times (D - E) \times ½ \cos((B + C))^2 \quad (2)$$

is sufficiently accurate for the purpose: the median and the maximum absolute deviation from the rigorous results are only 0.003° and 0.041°, respectively. The arcl from physics principles bears a nearly one-to-one correspondence with the continuous degree of intrinsic dimming and brightening that the crescent undergoes as its orbit returns to and then departs from conjunction, accompanied by the decrease and then increase of its illumination phase angle.

Since the arcl continuously varies, its use as a parameter requires a decision about the appropriate moment to takes its measure. That moment should logically coincide with the carrying out of the sighting attempt for which the arcl is supposed to provide a part of the criterion. A standardized evaluation moment must be adopted, and the estimated moment of easiest visibility (Sultan 2006 and references therein) is a leading choice. Another is the estimated time of first visibility (Hoffman 2005). This study uses the mid-lag moment, but in fact any standardized point of time in the range from sunset to moonset is suitable as long as it is used consistently across all the events that are being intercompared on an equal footing. No single choice really stands superior, because the practical effect of all of them is merely small shifts to the arcl parameter scale, which is being used as only a relative indicator, not for its precise quantitative figure.

Another rather purist consideration that turns out to be immaterial has to do with the almanac coordinate system for expressing the sun and moon celestial sky position. There exist subtly distinct coordinate system choices that have to do mostly with valid alternatives for specifying the origin ("zero zero") and principal plane of each system. However, since the only physical reality that matters is the great circle angular separation between sun and moon, and not the detailed figures of the coordinates (except for scholarly cross-checking purposes) which after all amount merely to a man-made book-keeping system, it is again a case of clearly setting out and consistently employing a single reasonable coordinate basis, rather than the choice of which coordinate basis.

Topocentric times are relevant for observer witnessed events like rising and setting, but I chose to use geocentric measures of the growth of the moon's brightness hour-by-hour because the effects proceed more uniformly without adding topocentric-incurred scatter, for a superior one-to-one correspondence with intrinsic brightening function (Caldwell & Laney 2000). Another minor clarification is that for some events the declination equals zero degrees minus some arc minutes, i.e. referring to a sky position less than one degree south of the celestial equator. For such cases I have set the southern declination minus sign by the arc minutes column. This is the computer-friendly remedy for preventing declination expressions using "−00", which most software cannot correctly read as input.

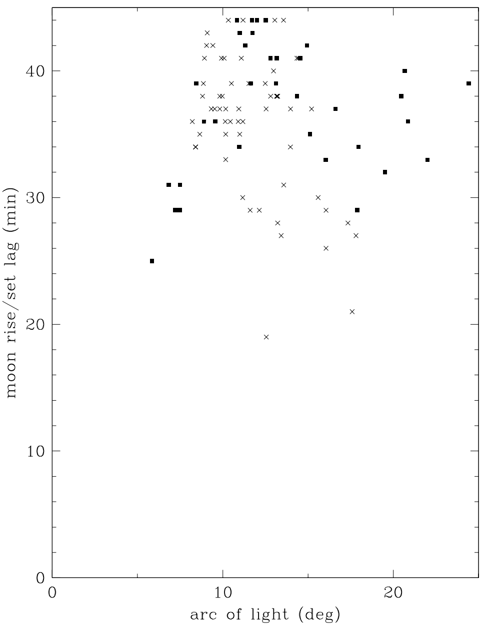


**Figure 1. The moonrise/set lag (viz. lag) versus the arc of light (viz. arcl) for positive visual sightings (squares) and positive binocular sightings (x points).**

**First Look**

Fig. 1 shows the result of plotting the lag at these positive sighting events versus the arcl of the same. Black squares are visual sightings while x points are binocular. Given the 30-plus years of collection baseline, the data yield seems surprisingly modest. There are two explanations. Firstly, there do actually exist many more positive visual sightings than shown here, but they without exception cluster at larger lag than these critical events. Most sightings occupy a preferred swath with lag longwards of 45 min and arcl in the range 10-15°. That class of very ordinary, numerous, "run-of-the-mill" sightings is precisely the kind I intentionally bypassed by selecting a sample that probes the limits to visibility. A second factor is that a significant fraction of the reported attempts falling into the plotted lag:arcl range turned out to be non- sightings, which abundantly occupy the zone directly below that of the points plotted here, plus a sprinkling upward where non-visibility also was the outcome, but most probably for meteorological reasons, since comparably difficult cases were positively sighted at other events, viz. the ones plotted. My deliberate choice of paring to just the most solid clues lies behind the plot appearance.

In terms of gross trends, there is an absence of sightings with low lag, yet there also appear to be clear exclusion zones toward the upper left and lower right of the diagram. With the exception of five visual points on the lower left, there seems to be a fairly clear but modest trend of smaller lag sightings becoming enabled by compensatingly larger arcl. There are also two binocular sightings standing off at low lag from the data consensus. I will argue below that the five visual and two binocular outliers should be interpreted separately, and so putting those aside, we concentrate on the lay of the visual and binocular sightings relative to each other. In terms of the reported sighting procedures, it is as a rule true that any binocular positive sighting is identically a visual negative sighting: had visual sighting succeeded, the report would have been processed into the visual positive (black squares) category.

It was notable in some of the report descriptions how the observers at events pushing the lower lag and lower arcl boundaries drew attention to the extreme and, for each individual, unaccustomed level of difficulty at that achieved sighting event. Both from such comments and also from the bands where binocular (Yes)/visual(No) points lie, it seems clear that for some small value of the lag, which depends partly on arcl, even with excellent conditions and observing prowess, the eye simply lacks the requisite degree of stimulus to trigger a real perception response. The light amplification provided by binoculars allows the eye to perceive the crescent at a somewhat more challenging visibility level. Progress beyond this first cut at interpretation requires simulating some features of the lag:arcl plane as well as further scrutinizing the outlier sighting points.

**Closer Look**

Fig. 2 shows the result of taking a closer look at these data and also running some simulations of the lag and the arcl for arbitrary values of the observer latitude. I start by discussing the vertical dotted band with arcl value 7.0-7.5°. This is the Danjon Limit (Danjon 1932, 1936) which has been thoroughly discussed by Sultan (2007), Fatoohi etal (1998), and Schaefer (1991, 1993). It sets a minimum arcl for crescent visibility because the length of the visible crescent (from cusp to cusp) shrinks as the arcl decreases. In Schaefer's words, "the shortening [is] a natural consequence of the crescent's rapid bright-

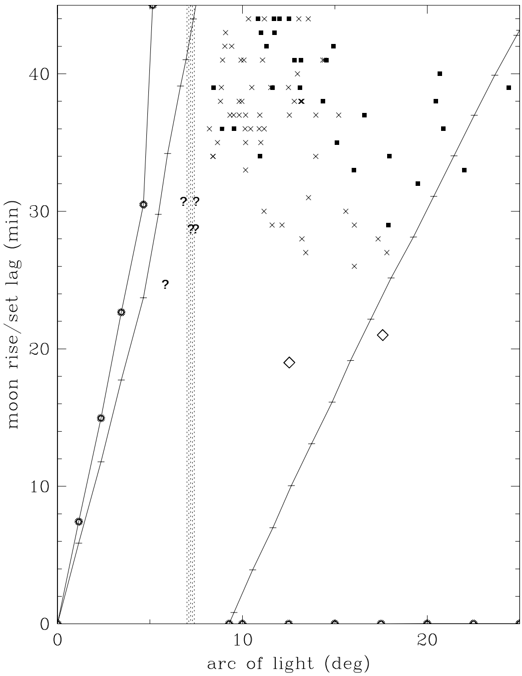


**Figure 2. As Fig. 1 but also with Danjon's Limit (dotted vertical band), simulated possible range of lag:arcl for absolute latitude 0-35° observers (bracketed by the two diagonal lines with cross-dashes), and for absolute latitude 45-55° observers (filling in the rectangle above and right of the two lines with dotted circles).**

ness decrease towards the cusps" and all these works confirm nonvisibility by an arcl cutoff of about 7.0-7.5°.

Turning now to the five exceptional visual sightings at low lag and arcl, marked as "?", is there any way to infer why they are different? Indeed all these, and only these, data come from a sole source, a citation by Ilyas (1994) of a publication by Qurashi (1991), which is said to contain a series of reports of record-setting Pakistani sightings. Unfortunately the actual Qurashi reports were not available for this current study, only the Ilyas citation of them. I will refer to the Qurashi-supplied sightings in a later section but set them aside unused in the analysis section of this paper.

Turning to the two exceptional binocular sightings around lag 20, is there any way to infer why they are different? Indeed they, and only they, used a special new technique as follows. The usual binocular sightings use careful pointing (sometimes with theodolite assistance) and a slight amount of small-amplitude scanning for the crescent during nearly the full lag duration. The two exceptional binocular sightings, as they were very thoroughly reported at ICOP, include novel features. (1) The single best visibility moment (from theory) for the entire lag interval is pre-calculated. (2) The crescent altitude-azimuth location at that future moment is pre-calculated. (3) The top grade binocular equipment has its pointing calibrated on the night preceding the attempt, and is locked into position. By using the nighttime sky as a pointing reference, there is absolute assurance about the pointing validity, unlike customarily where one sets up in the daylight sky just preceding the attempt, and uses pre-tested equipment gauges or local horizon landmarks, to get close to (within about a degree of) the correct altitude-azimuth track of the crescent descending to the horizon. (4) Finally the sighting is carried out with a burst of effort only at the ideal couple of minutes of best opportunity. Even then, the crescent was reported to have taken maximum effort to see, and to be unlikely to be ever viewable with any further incremental difficulty burden whatsoever.

So far we know that visibility is blocked, firstly, at low arcl and, secondly, at low lag for a typical arcl, but what about very large arcl? We know that large lag (but moderately low arcl) sightings are extremely common (the ones not shown in this work with lag longwards of 45 min and arcl 10-15°), while on the other hand, high arcl (but low lag) sightings are extremely uncommon (in fact no reported instances). Key facts about the lag are that it depends roughly speaking on the moon's altitude at sunset and its rate of travel toward the horizon. The latter depends on the diurnal angular velocity (proportional to the inverse cosine of the Moon's declination) and upon the Moon's diurnal angle of descent to the horizon (proportional to the inverse sine thereof), where the angle of descent F is given by:

$$\cos(F) = \sin(\text{latitude}) / \cos(\text{declination}) \quad (3)$$

(Smart 1962, p.53). The altitude at sunset that the moon attains depends on its celestial path after conjunction. That path is determined by the moon's orbit, which is inclined by 5.15° relative to the ecliptic (the plane of the earth's orbit around the sun). The ecliptic in turn is at an angle of 27.43° to the celestial equator (the projection of the earth's equator onto the sky). An added complication is that the points where the moon's path crosses the ecliptic change considerably with time. There are also relatively small but complex changes in the lunar orbit itself, but these are not vitally important here.

Thus the moon's celestial path since conjunction, as seen from a viewpoint near the Earth's equator, subtends a range of possible angles ±32.6° from the vertical. At middle to high Earth latitude, that 65° spread in the range of possible Moon elongation directions, is tilted toward the south in the northern hemisphere, or towards the north in the southern hemisphere, and so the crescent altitudes being compressed toward the horizon, moonset lags are consequently decreased. Contrariwise the descent angle, which is 90° at the equator regardless of declination, from the above formula also becomes compressed to shallow angles from a middle-to-high latitude perspective, depending on the moon declination within its circumscribed range. For high enough latitude the descent angle goes to zero as the moon declination reaches deeply enough into the contrary hemisphere. The lags are therefore increased as the descent angle wanes, so that simply put, high latitude can work both ways influencing the lag.

To understand the lag and arcl effects better, a simulation was run of all Moon elongation ascent (viz. the celestial path taken post-conjunction) and diurnal descent angles for the full year pattern, at choices of latitude, starting from conjunction up to the a maximum of 48 hours accumulated elongation, which encompass the first two moonsets following conjunction, plus some margin. The current study sighting data have a very marked (absolute) latitude distribution [hereafter, southern and northern are discussed as merged since the physics is symmetrical]. The distribution has a median absolute latitude of 32°, a first quartile of 31°, and a third quartile of 33°, with but few extending to the equatorial and to the temperate zones. None is at high latitude. It appears that the statistically clear weather, milder or less severe twilight outdoor conditions relative to higher latitudes, and cultural factors have combined to give the achievement of champion category sightings an overwhelming latitude imprint.

Now we can better understand the lay of the data in the diagram. For low to moderate latitude (0-35°), the elongation and descent angles range over all possibilities such that for a small lag, no large arcl is possible, and correspondingly for a small arcl, no large lag is possible. This simulated range is shown in Fig. 2 by the two diagonal lines with crossed dashes running up their length. The actual data fill between the said lines, except as expected the sightings lapse both lower down and leftwards to the Danjon boundary. For higher latitude (45-55° was used for contrast and because population and hence conceivable sighting activity decline rapidly beyond that) very large lags are enabled by very low descent angle, while very low lag is in principle also enabled by very low ascent angle of elongation. This second simulated range is shown by the left boundary dotted with circles and the bottom right bottom along the lag = 0 axis. The low lags that can potentially result emphasize that for geographically middle to high latitudes, very different sighting geometries with descent angles much compressed to the with their characteristically substantial descent angles.

When the arc of light has a full 48 hours to grow (assuming only the first two post-conjunction moonsets are relevant), what prevents seeing crescents down to nearly zero lag? The property is one known as “phase space,” meaning that while such an undertaking from high latitude vantage is not formally impossible, the range of possibilities is such that a very large boost to the lag is statistically the prevalent outcome from a large ensemble of large arcl crescent sightings as pursued from high latitude. To concoct the viewing geometry for a sighting in the far lower right regime of Fig. 2 requires excessively fine-tuned special conditions, because most stochastically transpiring scenarios will undergo a substantial boost in the lag time. The likelihood to land in the favoured lag ≥ 45 sighting zone overwhelms the likelihood of getting the combination of diurnal descent angle and elongation ascent angle just right so as to witness an event exhibiting high arcl jointly with low lag.

**Visual Visibility Based on Lag and Arc of Light**

Fig. 3 summarizes the gist of the evidence amassed. The pattern of sightings as a group reinforce the impression of a visibility drop-off at low lag, but increased arcl definitely plays a facilitating role. Disparate observing conditions (principally different haziness) have the asymmetric character that poor conditions eventuate in every degree up to "super-poor," but excellent conditions have no corresponding extension to "super-excellent" because the aerosol, smoke, dust, ash etc. load in the air, for a given geographical location, can attain only a limiting air quality and not beyond (on a human not geological time scale). Therefore it is justified to identify the observed cut-offs of this sighting ensemble as illuminating the threshold of "the best you can realistically expect to do." You could encounter slightly worse visual sighting conditions (viz. the overlap zone of visual and binocular sightings) due to slightly variable haziness or any combination of small (ungaugeable) probabilistic effects (a "zone of uncertainty" which is expected near any visibility transitional boundary). However decades of experience justify concluding that one does not anticipate valid visual sightings far surpassing the celestial (lag,arcl) difficulty of these shown. It bears re-emphasizing that numerous negative sightings by reliable observers (see sources in Introduction) repeatedly and abundantly affirm that crescent visual/binocular invisibility is axiomatic in the low-lag, low-arcl quadrant of the data plot, in full consistency with the positive sightings analysed here.

To summarize the boundaries, visibility criterion lines are suggested as follows. Line (A) numerically traces a visual sighting boundary. Line (B) does the same for

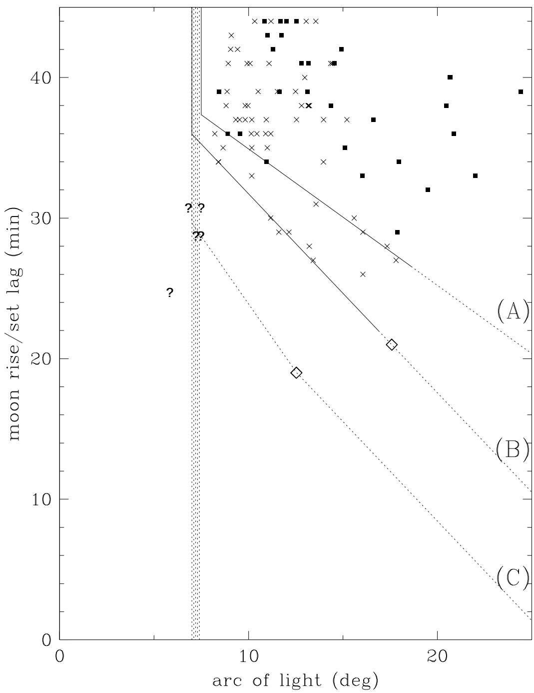


**Figure 3. Three criterion lines (A), (B), (C) as described in the text, give interpretation to the crescent visibility implications from combining the moonset lag and the arc of light as indicators.**

the generally practiced binocular sighting method. These become dashed when extrapolated into the lower-lag, higher-arcl, low-phase-space (increasingly improbable chances of such an occasion being obtained, proceeding to the lower right, as explained above). Criteria such as these, when calculated on the globe for each lunation, generate lunar date line curves that divide the globe into positive prediction and negative prediction zones. Even in favourable weather and air quality, it is unavoidable that there be an interleaving geographical zone of uncertainty within which the prediction loses decisiveness (becomes a 50/50 guess) because of the ungaugeable nature of the process right at the borderline of visibility. The specially executed binocular viewing at low lag (lowest diamond) is a reasonable anchor for the extreme uncertainty range of the criterion. At lower arcl than that, I expect it will be harder to achieve as much added visibility grasp despite the massive, team-intensive, input of added preparation and execution labour, while at larger arcl little is known or will easily become known. I denote that guessed zone of ignorance with a dashed line (C) with a nod to the Qurashi input; all dashed lines are merely speculative whereas only the solid lines have real, though tentative, support, awaiting the slow fruition of more such labours. The equations for lines (A), (B), and (C) are:

(criterion A) lag = -0.9709 arcl + 44.64
(criterion B) lag = -1.4150 arcl + 45.88
(criterion C) lag = the larger of
-1.9230 arcl + 43.13
or -1.4150 arcl + 36.76

where the interpretation is: visual sighting possible to (A), improbable to (B), impossible below; binocular sighting possible to (B), improbable to (C), impossible below.

**Conclusions**

I have summarized the real evidence that, as expected from physical principles, true sighting grasp of the crescent must lapse for unfavourable enough celestial (low lag, low arcl) circumstances, specifically with reference only to the ground based, twilight, visual or binocular method. However to decide on the basis of lag, the arcl must be taken into account as well, and the criteria presented here supply a guideline for that.

Additional insights gained while undertaking this work can also be mentioned here, mostly in nature of opinions rather than established facts. (1) Twilight telescopic observations probably yield positive sighting potential in the indicated uncertainty zone marked (C) but not much below that. Examples are slowly accruing but remain too sparse to proceed beyond such an anecdotal assessment. (2) It is important not to confuse the public with informational attempts that mix the various sighting modes together willy-nilly as this quickly confuses the issue of what predicted visibility outcomes can rationally be expected, distinguished according to method. (3) With any large enough scale undertaking, there is normally a residual of false positives that are immune to being discounted by any available indications for doubt. In the light of this, one approach is that "Extraordinary claims require extraordinary proof" (http://en.wikipedia.org/wiki/Marcello Truzzi etc), which could be interpreted to mean that a digital or analogue recording of such sightings is a requirement. This is a high bar to set and rather selectively dismissive tack, especially since normally the full detailed description supplied by the observer is taken as adequate input on its own. A fairer recourse would seem to be to collect the fullest possible information documenting such very divergent "super-observations" on a probationary and separate basis, pending confirmatory repeat findings. Where digital or analogue proof is lacking, and the observations fall into the low-lag zone where many other observers have reported negative results, especially where the only available source is second-hand (the Qurashi points), one can then justifiably classify such input as unsubstantiated and expired in terms of the next large-scale and comprehensive synthesis reviewing the field.

**Acknowledgments**

C. David Laney and Mohammad S. Odeh are thanked for useful comments. ☆

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## Appendix A

36 Critical Positive Visual Crescent Sightings in 24 Data Columns

| 01 | 02 | 03 | 04 | 05 | 06 | 07 | 08 | 09 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1987 | 04 | 28 | 31 | 71 | 24 | 34 | 01 | 28 | 01 | 34 | 13 | 55 | 14 | 26 | 2 | 22 | 14 | 10 | 2 | 43 | 18 | 46 | 6.82 |
| 1989 | 04 | 06 | 29 | 73 | 05 | 33 | 40 | 06 | 03 | 33 | 13 | 32 | 14 | 00 | 1 | 2 | 6 | 38 | 1 | 19 | 12 | 31 | 7.22 |
| 1989 | 10 | 01 | 32 | 34 | 43 | 31 | 24 | 29 | 21 | 47 | 15 | 26 | 15 | 58 | 12 | 32 | -3 | 24 | 13 | 36 | -14 | 52 | 19.50 |
| 1990 | 02 | 25 | 39 | -83 | 30 | 35 | 36 | 25 | 08 | 54 | 23 | 25 | 00 | 04 | 22 | 36 | -8 | 51 | 23 | 2 | -3 | 25 | 8.44 |
| 1990 | 04 | 25 | 29 | 74 | 13 | 31 | 20 | 25 | 04 | 27 | 13 | 38 | 14 | 07 | 2 | 12 | 13 | 16 | 2 | 27 | 19 | 50 | 7.48 |
| 1990 | 04 | 25 | 31 | 73 | 05 | 33 | 40 | 25 | 04 | 27 | 13 | 45 | 14 | 16 | 2 | 12 | 13 | 16 | 2 | 27 | 19 | 51 | 7.50 |
| 1991 | 01 | 16 | 25 | 73 | 05 | 33 | 24 | 15 | 23 | 50 | 12 | 23 | 12 | 48 | 19 | 52 | -20 | 57 | 20 | 16 | -19 | 24 | 5.84 |
| 1993 | 02 | 23 | 39 | 18 | 25 | -33 | 55 | 21 | 13 | 05 | 17 | 30 | 18 | 09 | 22 | 28 | -9 | 36 | 23 | 49 | 4 | 9 | 24.42 |
| 1996 | 01 | 21 | 34 | 18 | 25 | -33 | 55 | 20 | 12 | 50 | 17 | 58 | 18 | 32 | 20 | 13 | -19 | 55 | 21 | 18 | -11 | 5 | 17.96 |
| 1996 | 10 | 13 | 41 | 34 | 39 | 31 | 48 | 12 | 14 | 14 | 15 | 11 | 15 | 52 | 13 | 16 | -8 | 3 | 14 | 7 | -10 | 28 | 12.81 |
| 1997 | 02 | 08 | 33 | 18 | 25 | -33 | 55 | 07 | 15 | 06 | 17 | 46 | 18 | 19 | 21 | 30 | -14 | 47 | 22 | 28 | -7 | 23 | 16.03 |
| 1997 | 05 | 07 | 39 | 34 | 39 | 31 | 48 | 06 | 20 | 46 | 16 | 26 | 17 | 05 | 2 | 59 | 16 | 58 | 3 | 47 | 15 | 22 | 11.63 |
| 1997 | 08 | 04 | 35 | 35 | 13 | 31 | 46 | 03 | 08 | 14 | 16 | 33 | 17 | 08 | 8 | 59 | 17 | 5 | 9 | 55 | 10 | 30 | 15.10 |
| 1998 | 02 | 27 | 38 | 18 | 25 | -33 | 55 | 26 | 17 | 26 | 17 | 25 | 18 | 03 | 22 | 42 | -8 | 13 | 23 | 37 | -3 | 47 | 14.37 |
| 1998 | 04 | 25 | 38 | 51 | 24 | 35 | 36 | 26 | 11 | 41 | 01 | 50 | 01 | 12 | 2 | 10 | 13 | 5 | 0 | 58 | 2 | 58 | 20.47 |
| 1999 | 05 | 14 | 40 | 34 | 39 | 31 | 48 | 15 | 12 | 05 | 02 | 46 | 02 | 06 | 3 | 22 | 18 | 30 | 2 | 9 | 7 | 53 | 20.67 |
| 1999 | 05 | 14 | 40 | 35 | 31 | 31 | 48 | 15 | 12 | 05 | 02 | 42 | 02 | 02 | 3 | 22 | 18 | 30 | 2 | 9 | 7 | 53 | 20.67 |
| 1999 | 05 | 14 | 40 | 37 | 06 | 31 | 42 | 15 | 12 | 05 | 02 | 36 | 01 | 56 | 3 | 22 | 18 | 30 | 2 | 9 | 7 | 51 | 20.69 |
| 2000 | 01 | 07 | 34 | 18 | 25 | -33 | 55 | 06 | 18 | 14 | 18 | 01 | 18 | 35 | 19 | 13 | -22 | 23 | 19 | 59 | -20 | 5 | 10.96 |
| 2000 | 04 | 03 | 36 | 35 | 13 | 31 | 46 | 04 | 18 | 12 | 03 | 25 | 02 | 49 | 0 | 50 | 5 | 24 | 23 | 41 | -6 | 22 | 20.86 |
| 2000 | 07 | 31 | 36 | 03 | 24 | 06 | 30 | 01 | 19 | 20 | 18 | 05 | 18 | 41 | 8 | 45 | 18 | 3 | 9 | 25 | 17 | 23 | 9.55 |
| 2000 | 09 | 28 | 44 | 34 | 53 | 29 | 38 | 27 | 19 | 53 | 15 | 30 | 16 | 14 | 12 | 21 | -2 | 19 | 13 | 9 | -1 | 54 | 12.00 |
| 2000 | 12 | 26 | 42 | 20 | 49 | -32 | 23 | 25 | 17 | 22 | 17 | 46 | 18 | 28 | 18 | 23 | -23 | 20 | 19 | 12 | -22 | 31 | 11.31 |
| 2001 | 03 | 25 | 36 | 18 | 25 | -33 | 55 | 25 | 01 | 21 | 16 | 51 | 17 | 27 | 0 | 19 | 2 | 2 | 0 | 54 | 0 | 24 | 8.90 |
| 2001 | 07 | 21 | 43 | 73 | 18 | 04 | 06 | 20 | 19 | 44 | 13 | 23 | 14 | 06 | 8 | 4 | 20 | 23 | 8 | 51 | 20 | 40 | 11.01 |
| 2002 | 03 | 12 | 33 | 51 | 24 | 35 | 36 | 14 | 02 | 03 | 02 | 50 | 02 | 17 | 23 | 28 | -3 | 27 | 22 | 14 | -15 | 50 | 22.01 |
| 2002 | 03 | 15 | 43 | -111 | 06 | 32 | 13 | 14 | 02 | 03 | 01 | 32 | 02 | 15 | 23 | 39 | -2 | 16 | 0 | 26 | -2 | 26 | 11.74 |
| 2003 | 01 | 31 | 37 | 51 | 42 | 32 | 36 | 02 | 10 | 48 | 03 | 29 | 02 | 52 | 20 | 53 | -17 | 32 | 19 | 49 | -24 | 53 | 16.61 |
| 2003 | 09 | 27 | 41 | -111 | 00 | 32 | 24 | 26 | 03 | 09 | 01 | 16 | 01 | 57 | 12 | 13 | -1 | 24 | 13 | 5 | -3 | 40 | 13.18 |
| 2003 | 10 | 26 | 42 | 50 | 10 | 33 | 15 | 25 | 12 | 50 | 13 | 54 | 14 | 36 | 14 | 2 | -12 | 25 | 15 | 1 | -16 | 50 | 14.93 |
| 2004 | 01 | 22 | 44 | 03 | 42 | 32 | 30 | 21 | 21 | 05 | 17 | 08 | 17 | 52 | 20 | 17 | -19 | 43 | 21 | 10 | -21 | 35 | 12.53 |
| 2004 | 09 | 15 | 39 | 35 | 00 | 31 | 53 | 14 | 14 | 29 | 15 | 46 | 16 | 25 | 11 | 35 | 2 | 45 | 12 | 26 | 0 | -20 | 13.11 |
| 2004 | 12 | 13 | 41 | -110 | 56 | 32 | 26 | 12 | 01 | 29 | 00 | 19 | 01 | 00 | 17 | 22 | -23 | 9 | 18 | 23 | -27 | 56 | 14.55 |
| 2006 | 07 | 26 | 44 | -104 | 01 | 30 | 41 | 25 | 04 | 31 | 01 | 55 | 02 | 39 | 8 | 21 | 19 | 31 | 9 | 7 | 20 | 13 | 10.84 |
| 2008 | 12 | 28 | 44 | 51 | 42 | 32 | 36 | 27 | 12 | 12 | 13 | 36 | 14 | 20 | 18 | 31 | -23 | 15 | 19 | 22 | -23 | 58 | 11.70 |
| 2010 | 10 | 09 | 29 | -104 | 01 | 30 | 41 | 07 | 18 | 44 | 00 | 33 | 01 | 01 | 12 | 57 | -6 | 6 | 13 | 56 | -16 | 40 | 17.89 |

| | | | | | |
|---|---|---|---|---|---|
| (01-03) | year,month,day of SS or SR | (12-13) | hour,min of SS or SR | (20-21) | R.A. of moon in hour,min |
| (04) | lag from SS to MS or MR to SR | (14-15) | hour,min of MS or MR | (22-23) | decl. of moon in ° ' |
| (05-08) | longitude ° ', latitude ° ' | (16-17) | R.A. of sun in hour,min | (24) | arc of light |
| (09-11) | day,hour,minute of conjunction | (18-19) | decl. of sun in ° ' | SS = | sunset   MS = moonset |
| | | | | SR = | sunrise   MR = moonrise |

## Appendix B

58 Critical Positive Binocular Crescent Sightings in 24 Data Columns

| 01 | 02 | 03 | 04 | 05 | 06 | 07 | 08 | 09 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1983 | 11 | 05 | 44 | -84 | 06 | 37 | 12 | 04 | 22 | 21 | 22 | 35 | 23 | 19 | 14 | 43 | -15 | 48 | 15 | 37 | -17 | 33 | 13.05 |
| 1984 | 11 | 23 | 38 | -81 | 00 | 34 | 00 | 22 | 22 | 57 | 22 | 17 | 22 | 55 | 16 | 0 | -20 | 34 | 16 | 55 | -24 | 13 | 13.22 |
| 1989 | 05 | 06 | 42 | -97 | 00 | 30 | 18 | 05 | 11 | 46 | 01 | 08 | 01 | 50 | 2 | 53 | 16 | 32 | 3 | 20 | 23 | 30 | 9.42 |
| 1991 | 03 | 17 | 44 | -110 | 42 | 32 | 24 | 16 | 08 | 10 | 01 | 31 | 02 | 15 | 23 | 46 | -1 | 33 | 0 | 12 | 6 | 29 | 10.33 |
| 1995 | 01 | 02 | 43 | -106 | 00 | 33 | 00 | 01 | 10 | 56 | 00 | 08 | 00 | 51 | 18 | 49 | -22 | 58 | 19 | 20 | -17 | 30 | 9.09 |
| 1996 | 01 | 21 | 41 | -118 | 04 | 34 | 13 | 20 | 12 | 50 | 01 | 10 | 01 | 51 | 20 | 10 | -20 | 5 | 20 | 36 | -13 | 40 | 8.93 |
| 1997 | 03 | 08 | 40 | 34 | 39 | 31 | 48 | 09 | 01 | 15 | 04 | 01 | 03 | 21 | 23 | 15 | -4 | 53 | 22 | 24 | -7 | 43 | 12.98 |
| 1997 | 05 | 07 | 36 | 50 | 48 | 36 | 00 | 06 | 20 | 46 | 15 | 29 | 16 | 05 | 2 | 59 | 16 | 58 | 3 | 45 | 15 | 16 | 11.18 |
| 1997 | 05 | 07 | 37 | 51 | 42 | 32 | 36 | 06 | 20 | 46 | 15 | 19 | 15 | 56 | 2 | 59 | 16 | 57 | 3 | 44 | 15 | 15 | 10.94 |
| 1997 | 12 | 30 | 34 | 18 | 25 | -33 | 55 | 29 | 16 | 56 | 18 | 00 | 18 | 34 | 18 | 40 | -23 | 8 | 19 | 35 | -17 | 43 | 13.97 |
| 1998 | 01 | 27 | 41 | -95 | 22 | 29 | 46 | 28 | 06 | 01 | 13 | 14 | 12 | 33 | 20 | 39 | -18 | 25 | 19 | 57 | -17 | 6 | 10.08 |
| 1999 | 09 | 10 | 44 | -77 | 00 | 38 | 48 | 09 | 22 | 02 | 23 | 25 | 00 | 09 | 11 | 15 | 4 | 49 | 12 | 9 | 3 | 13 | 13.56 |
| 2000 | 01 | 07 | 39 | 53 | 21 | 32 | 42 | 06 | 18 | 14 | 13 | 36 | 14 | 15 | 19 | 12 | -22 | 25 | 19 | 49 | -20 | 18 | 8.87 |
| 2000 | 04 | 05 | 39 | 103 | 07 | 05 | 20 | 04 | 18 | 12 | 11 | 16 | 11 | 55 | 0 | 59 | 6 | 18 | 1 | 41 | 5 | 9 | 10.51 |
| 2000 | 07 | 02 | 37 | 101 | 53 | 02 | 45 | 01 | 19 | 20 | 11 | 25 | 12 | 02 | 6 | 47 | 23 | 0 | 7 | 29 | 21 | 30 | 9.83 |
| 2000 | 07 | 02 | 38 | 102 | 24 | 02 | 18 | 01 | 19 | 20 | 11 | 22 | 12 | 00 | 6 | 47 | 23 | 0 | 7 | 29 | 21 | 30 | 9.83 |
| 2000 | 12 | 26 | 41 | 35 | 30 | 30 | 12 | 25 | 17 | 22 | 14 | 45 | 15 | 26 | 18 | 22 | -23 | 20 | 19 | 5 | -22 | 33 | 9.93 |
| 2001 | 08 | 19 | 34 | 56 | 48 | 29 | 30 | 19 | 02 | 55 | 14 | 49 | 15 | 23 | 9 | 56 | 12 | 37 | 10 | 30 | 14 | 8 | 8.41 |
| 2001 | 08 | 19 | 37 | 35 | 30 | 30 | 12 | 19 | 02 | 55 | 16 | 15 | 16 | 52 | 9 | 56 | 12 | 36 | 10 | 34 | 13 | 49 | 9.33 |
| 2001 | 10 | 17 | 36 | 102 | 24 | 02 | 18 | 16 | 19 | 23 | 10 | 58 | 11 | 34 | 13 | 29 | -9 | 22 | 14 | 10 | -8 | 37 | 10.15 |
| 2002 | 09 | 07 | 34 | 56 | 30 | 31 | 06 | 07 | 03 | 10 | 14 | 30 | 15 | 04 | 11 | 4 | 6 | 0 | 11 | 37 | 7 | 52 | 8.40 |
| 2002 | 11 | 05 | 33 | 56 | 24 | 30 | 00 | 04 | 20 | 34 | 13 | 25 | 13 | 58 | 14 | 42 | -15 | 43 | 15 | 24 | -17 | 7 | 10.17 |
| 2002 | 11 | 05 | 35 | 52 | 00 | 30 | 00 | 04 | 20 | 34 | 13 | 42 | 14 | 17 | 14 | 42 | -15 | 43 | 15 | 24 | -17 | 11 | 10.17 |
| 2002 | 11 | 05 | 36 | 35 | 36 | 31 | 42 | 04 | 20 | 34 | 14 | 45 | 15 | 21 | 14 | 42 | -15 | 44 | 15 | 27 | -17 | 24 | 10.91 |
| 2003 | 01 | 03 | 44 | 03 | 42 | 32 | 30 | 02 | 20 | 23 | 15 | 52 | 16 | 36 | 18 | 56 | -22 | 49 | 19 | 44 | -25 | 2 | 11.19 |
| 2003 | 04 | 02 | 38 | 35 | 30 | 30 | 12 | 01 | 19 | 19 | 15 | 57 | 16 | 35 | 0 | 46 | 4 | 56 | 1 | 26 | 5 | 38 | 9.98 |
| 2003 | 04 | 30 | 26 | 51 | 24 | 35 | 36 | 01 | 12 | 15 | 01 | 44 | 01 | 18 | 2 | 28 | 14 | 35 | 1 | 32 | 6 | 18 | 16.06 |
| 2003 | 04 | 30 | 29 | 51 | 42 | 32 | 36 | 01 | 12 | 15 | 01 | 48 | 01 | 19 | 2 | 28 | 14 | 35 | 1 | 32 | 6 | 18 | 16.06 |
| 2003 | 08 | 28 | 41 | 102 | 54 | 05 | 18 | 27 | 17 | 26 | 11 | 17 | 11 | 58 | 10 | 26 | 9 | 47 | 11 | 11 | 10 | 24 | 11.09 |
| 2003 | 09 | 27 | 38 | -111 | 48 | 41 | 48 | 26 | 03 | 09 | 01 | 18 | 01 | 56 | 12 | 13 | -1 | 24 | 13 | 5 | -3 | 41 | 13.19 |
| 2003 | 10 | 26 | 41 | 59 | 12 | 32 | 56 | 25 | 12 | 50 | 13 | 19 | 14 | 00 | 14 | 2 | -12 | 24 | 14 | 59 | -16 | 42 | 14.44 |
| 2003 | 11 | 25 | 37 | -112 | 00 | 41 | 30 | 23 | 22 | 59 | 00 | 02 | 00 | 39 | 16 | 1 | -20 | 37 | 17 | 4 | -25 | 13 | 15.21 |
| 2004 | 01 | 22 | 35 | 52 | 00 | 30 | 00 | 21 | 21 | 05 | 14 | 00 | 14 | 35 | 20 | 16 | -19 | 45 | 21 | 2 | -22 | 7 | 11.00 |
| 2004 | 05 | 18 | 39 | 51 | 42 | 32 | 36 | 19 | 04 | 52 | 01 | 33 | 00 | 54 | 3 | 40 | 19 | 35 | 2 | 49 | 16 | 34 | 12.49 |
| 2004 | 09 | 15 | 37 | 59 | 00 | 36 | 36 | 14 | 14 | 29 | 14 | 11 | 14 | 48 | 11 | 34 | 2 | 46 | 12 | 23 | 0 | 4 | 12.54 |
| 2004 | 09 | 15 | 38 | 50 | 06 | 33 | 18 | 14 | 14 | 29 | 14 | 46 | 15 | 24 | 11 | 34 | 2 | 46 | 12 | 24 | 0 | -4 | 12.81 |
| 2004 | 10 | 15 | 29 | -97 | 52 | 30 | 24 | 14 | 02 | 48 | 00 | 01 | 00 | 30 | 13 | 21 | -8 | 33 | 14 | 5 | -12 | 48 | 11.61 |
| 2004 | 10 | 15 | 29 | -110 | 56 | 32 | 26 | 14 | 02 | 48 | 00 | 52 | 01 | 21 | 13 | 21 | -8 | 33 | 14 | 7 | -13 | 1 | 12.14 |
| 2004 | 11 | 13 | 39 | 114 | 48 | 04 | 54 | 12 | 14 | 27 | 10 | 02 | 10 | 41 | 15 | 16 | -18 | 6 | 16 | 0 | -23 | 19 | 11.53 |
| 2005 | 02 | 09 | 37 | 51 | 42 | 32 | 36 | 08 | 22 | 28 | 14 | 13 | 14 | 50 | 21 | 33 | -14 | 32 | 22 | 15 | -15 | 13 | 10.17 |
| 2005 | 03 | 09 | 27 | 51 | 42 | 32 | 36 | 10 | 09 | 10 | 02 | 51 | 02 | 24 | 23 | 18 | -4 | 32 | 22 | 19 | -14 | 51 | 17.81 |
| 2005 | 05 | 09 | 42 | -104 | 01 | 30 | 41 | 08 | 08 | 45 | 01 | 39 | 02 | 21 | 3 | 4 | 17 | 20 | 3 | 36 | 22 | 22 | 9.05 |
| 2005 | 09 | 03 | 36 | 46 | 34 | 33 | 23 | 03 | 18 | 45 | 02 | 29 | 01 | 53 | 10 | 48 | 7 | 35 | 10 | 25 | 13 | 33 | 8.22 |
| 2005 | 09 | 05 | 41 | -110 | 56 | 32 | 26 | 03 | 18 | 45 | 01 | 44 | 02 | 25 | 10 | 56 | 6 | 51 | 11 | 51 | 2 | 34 | 14.35 |
| 2005 | 10 | 04 | 31 | 52 | 32 | 29 | 37 | 03 | 10 | 28 | 14 | 12 | 14 | 43 | 12 | 42 | -4 | 30 | 13 | 31 | -10 | 36 | 13.58 |
| 2005 | 12 | 02 | 28 | 51 | 42 | 32 | 36 | 01 | 15 | 01 | 13 | 27 | 13 | 55 | 16 | 35 | -22 | 0 | 17 | 27 | -28 | 1 | 13.22 |
| 2005 | 12 | 02 | 27 | 50 | 10 | 33 | 15 | 01 | 15 | 01 | 13 | 32 | 13 | 59 | 16 | 35 | -22 | 0 | 17 | 28 | -28 | 2 | 13.43 |
| 2006 | 02 | 28 | 35 | 51 | 44 | 31 | 40 | 28 | 00 | 31 | 14 | 30 | 15 | 05 | 22 | 45 | -7 | 54 | 23 | 19 | -5 | 59 | 8.65 |
| 2006 | 10 | 23 | 30 | 62 | 31 | 27 | 15 | 22 | 05 | 14 | 13 | 14 | 13 | 44 | 13 | 51 | -11 | 26 | 14 | 45 | -20 | 5 | 15.59 |
| 2006 | 12 | 21 | 38 | 51 | 44 | 31 | 40 | 20 | 14 | 01 | 13 | 34 | 14 | 12 | 17 | 58 | -23 | 26 | 18 | 53 | -27 | 52 | 13.15 |
| 2007 | 09 | 12 | 19 | 50 | 10 | 33 | 15 | 11 | 12 | 44 | 14 | 51 | 15 | 10 | 11 | 21 | 4 | 12 | 12 | 3 | -2 | 41 | 12.55 |
| 2008 | 07 | 03 | 38 | 45 | 06 | 37 | 33 | 03 | 02 | 19 | 16 | 24 | 17 | 02 | 6 | 52 | 22 | 54 | 7 | 30 | 24 | 20 | 8.82 |
| 2008 | 11 | 28 | 37 | -82 | 20 | 29 | 39 | 27 | 16 | 55 | 22 | 30 | 23 | 07 | 16 | 21 | -21 | 18 | 17 | 17 | -27 | 0 | 13.98 |
| 2009 | 03 | 27 | 30 | 103 | 07 | 05 | 19 | 26 | 16 | 06 | 11 | 17 | 11 | 47 | 0 | 25 | 2 | 42 | 0 | 55 | 11 | 2 | 11.17 |
| 2009 | 08 | 21 | 28 | 51 | 52 | 32 | 00 | 20 | 10 | 02 | 15 | 10 | 15 | 39 | 10 | 3 | 11 | 58 | 11 | 1 | 2 | 16 | 17.34 |
| 2010 | 09 | 09 | 21 | 51 | 42 | 32 | 36 | 08 | 10 | 30 | 14 | 48 | 15 | 09 | 11 | 11 | 5 | 15 | 12 | 5 | -6 | 3 | 17.59 |
| 2010 | 12 | 06 | 36 | 51 | 42 | 32 | 36 | 05 | 17 | 36 | 13 | 27 | 14 | 03 | 16 | 51 | -22 | 30 | 17 | 36 | -24 | 3 | 10.45 |
| 2011 | 03 | 05 | 37 | 52 | 32 | 29 | 37 | 04 | 20 | 46 | 14 | 31 | 15 | 08 | 23 | 3 | -6 | 6 | 23 | 25 | 1 | 41 | 9.53 |

(01-03) year,month,day of SS or SR
(04) lag from SS to MS or MR to SR
(05-08) longitude ° ', latitude ° '
(09-11) day,hour,minute of conjunction
(12-13) hour,min of SS or SR
(14-15) hour,min of MS or MR
(16-17) R.A. of sun in hour,min
(18-19) decl. of sun in ° '
(20-21) R.A. of moon in hour,min
(22-23) decl. of moon in ° '
(24) arc of light

SS = sunset, MS = moonset
SR = sunrise, MR = moonrise

# Distribution of Orbital Distances of Solar Planets

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**Abstract:** Planetary distances have been investigated within the context of the protoplanetary model of planetary formation. It is found that, if initially some stable protoplanetary objects are assumed to have formed in a belt near Jupiter, then mass loss from a set of protoplanets initially identical in mass, chemical composition and spin angular momentum can account for the observed distances of the planets of given mass as observed today.

**Key words:** Protoplanet; planetary distance; planetary formation; angular momentum.

## 1. Introduction

One known feature of the solar planetary system is the distribution of the planetary distance. The planets having different masses are found to lie approximately on the same plane at different distances from the Sun. These distances are approximately given by the Titius-Bode relationship, i.e., $r = 0.4 + 0.3 \times 2^n$, where $n = -\infty$ for Mercury, 0 for Venus, 1 for Earth, 2 for Mars, 4 for Jupiter, 5 for Saturn, 6 for Uranus and 7 for Neptune, $r$ is in AU. Observed distances of the planets do not differ much from the Titius-Bode values. One noticeable feature is that, the distance of each outer planet except Uranus increases from the Sun with decreasing mass while the distance of each inner planet except Mars increases from the Sun with increasing mass. Observed masses and distances of the planets are available in Allen (1973). The origin of the planetary spacing is believed to lie in the formation process of the solar system. But details of the formation process are still under investigation and so far no general agreement exists on how the system was formed. One theory of planetary formation suggests that some gaseous giant protoplanets of Jovian mass formed first from a solar nebula via disk instability. These initial protoplanets, with mass and composition roughly similar to the present day Jupiter, are identical to one another, identical in mass, radius and composition before segregation occurs (see Donnison & Williams 1985; Williams & Bhattacharjee 1979). The present day planets are believed to have formed from these protoplanets by contraction, segregation and mass loss from all the bodies except from Jupiter (e.g., Boss 2001; Rich et al. 2003; Pickett et al. 2003; McCrea 1960). It has been found that mass loss from a set of identical protoplanets can account for the differences in mass, chemical composition and the spin angular momentum of the planets (e.g., Williams & Bhattacharjee 1979). In this communication we intend to show that mass loss can also account for the observed distribution of the planetary distances as we observe today.

## 2. The rate of mass loss

Mass loss in a protoplanet is a complex problem. According to Williams & Bhattacharjee (1979), it might occur as a consequence of many effects, such as solar heating, solar wind bombardment, tidal effects, energy released in core formation etc. No explicit expression for the rate of mass loss from a protoplanet is available in the literature. Williams & Bhattacharjee (1979) and Bhattacharjee (1983) estimated a mass loss rate from the kinetic theory approach in explaining the distribution of spin angular momentum of the planets. The investigations show that the amount of angular momentum taken away by the mass loss from a set of identical protoplanets is in excellent accordance with observation. In our calculation we have adopted this mass loss rate.

Considering a nonrotating atmosphere whose molecules, each of mass $m_0$, obey a Maxwellian velocity distribution related to a temperature $T$, the probability that a molecule has a velocity component in the range $u_o$ to $u_o + du_o$ in a prescribed direction can be given by

$$\beta^{\frac{1}{2}}\pi^{-\frac{1}{2}}\exp(-\beta u_0^2)du_0\,,$$

where the set of axis is assumed rectangular and $\beta = m_o/2kT$, $k$ being Boltzmann's constant.

If the number density of the molecules near the surface is $n$, then the mass escaping through an area $ds$ in time $dt$ is given by

$$-nm_0\beta^{\frac{3}{2}}\pi^{-\frac{3}{2}}\iiint\limits_{\substack{w_0\geq 0,\\ u_0^2+v_0^2+w_0^2\geq v_e^2}} w_0\exp(-\beta(u_0^2+v_0^2+w_0^2))du_0dv_0dw_0dsdt\,,$$

Where $u_0$, $v_0$, and $w_0$ being the components of velocity in three mutually perpendicular directions, $w_0$ being in the outward normal direction and $v_e$ is the escape velocity. For a rotating atmosphere, where *ds* has a rotating speed *V*, the rate of mass loss, following Williams & Bhattacharjee (1979) and Bhattacharjee (1983), can be given by

$$\frac{dm}{dt}=-nm_0\beta^{\frac{3}{2}}\pi^{-\frac{3}{2}}\iiint\limits_{\substack{w\geq 0\\ u^2+v^2+w^2\geq v_e^2}} w\exp[-\beta(u^2+(v-V)^2+w^2)]dudvdwds \qquad (1)$$

where, *u*, *v* and *w* are now the velocity components of the molecules in the rotating frame. For mass loss to occur $\beta\, v_e^{\,2} < 1$. If the integral in Eq. (1) is evaluated over the entire spherical surface of a slowly rotating protoplanet and the approximation is made as in Bhattacharjee (1983), then we can write

$$\frac{dM}{dt}=-\pi R^2\rho_s W\,, \qquad (2)$$

where *W* is the mean thermal velocity of the surface molecules and $\rho_s$ is the surface density at any time. *t* Ignoring any small variation in the temperature and density of the surface molecules, and eliminating *R* in terms of *M*, we have from Eq. (2)

$$\frac{dM}{dt}=-cM^{\frac{2}{3}}\,, \qquad (3)$$

where *c* is an unknown constant. If we assume that a protoplanet took about a million years to lose most of its volatile elements, then *c* is found to be $\sim 10^{-3}$ . However, since we are interested in determining the effect of mass loss on the protoplanetary orbits, exact value of *c* is not needed. But in the terrestrial planet region the protoplanets are subject to rapid mass loss due to both evaporation and tidal effects caused by the relative proximity of the Sun (Donnison & Williams 1985).

**3. Equation of motion and its solution**

We start with an isolated initial gaseous protoplanet with mass as suggested by several authors (e. g., McCrea 1960; McCrea & Williams 1965; Williams & Handbury 1974) as $10^{30}$g that moves in the gravitational field of the Sun suffering mass loss. The motion is then considered to be two-dimensional. We assume that both the Sun and protoplanets are spherical and that mass loss is spherically symmetric so that this mass can always be considered concentrated at the centre. So Newton's theory is applicable. Let $M_\odot$ be the mass of the Sun with centre at the origin and $M$ denote the mass of the protoplanet at any time. Since $M << M_\odot$, $M$ can be considered to move about the centre of the Sun. If $r$ be the distance of the protoplanet at any time $t$ relative to the Sun, then the equation of motion of $M$ about $M_\odot$ is given by

$$\frac{d}{dt}(M\frac{d\mathbf{r}}{dt})=-\frac{GMM_e}{r^3}\mathbf{r} \qquad (4)$$

where *G* is the gravitational constant.

Equation (4) can also be written as

$$M\frac{d^2\mathbf{r}}{dt^2}+\frac{d\mathbf{r}}{dt}\frac{dM}{dt}=-\frac{GMM_e}{r^3}\mathbf{r} \qquad (5)$$

If the coordinates of *M* be (*x,y*), then the Eq. (5) can be written in component form as

$$\frac{d^2x}{dt^2}+\frac{1}{M}\frac{dM}{dt}\frac{dx}{dt}=-\frac{GM_e x}{r^3} \qquad (6)$$

$$\frac{d^2y}{dt^2}+\frac{1}{M}\frac{dM}{dt}\frac{dx}{dt}=-\frac{GM_e y}{r^3} \qquad (7)$$

Where $r=(x^2+y^2)^{1/2}$

Now, from Eq. (3), we have

$$-ct = \int_{M_0}^{M} M^{-2/3} dM \,,$$

which, on simplification, gives

$$M = \left( M_0^{1/3} - \frac{1}{3} \times ct \right)^3 \qquad (8)$$

where $M_0$ is the initial mass of the protoplanet.
Substituting $M$ in Eqs. (6) and (7), we get

$$\frac{d^2x}{dt^2} = \frac{3c\frac{dx}{dt}}{3 \times M_0^{1/3} - ct} - \frac{GM_\odot x}{(x^2+y^2)^{3/2}} \qquad (9)$$

$$\frac{d^2y}{dt^2} = \frac{3c\frac{dy}{dt}}{3 \times M_0^{1/3} - ct} - \frac{GM_\odot y}{(x^2+y^2)^{3/2}} \qquad (10)$$

To determine the orbit we have to solve Eqs. (9) and (10) with known initial conditions. It should be noted that to avoid tidal disruption a protoplanet must have formed outside the Roche limit defined by

$$R = R_\odot \left( \frac{\alpha \rho_\odot}{\rho} \right)^{-\frac{1}{3}} \qquad (11)$$

where $R_\odot$ and $\rho_\odot$ are the radius and density of the Sun and $\alpha$ a dimensionless parameter whose numerical values lie between 1 and 3 (e.g., Williams 1977) and $\rho$ is the density of the protoplanet. With appropriate values of the parameters this distance is $R = 4.34 \times 10^{13}$ cm. So the initial distance of the protoplanet must be $> 4.34 \times 10^{13}$ cm. As the initial conditions, for the interior protoplanets we take
$x_0 = 5 \times 10^{13}$ cm, (< Jupiter's distance), $y_0 = 0$,
$\dot{x}_0 = 0$ and $\dot{y} = x_0\omega_0 = 1.6 \times 10^6$ cm/sec (> Jupiter's velocity),
while for the outer protoplanets we take
$x_0 = 10^{14}$ cm, (>Jupiter's distance), $y_0 = 0$ ,
$\dot{x}_0 = 0$ and $\dot{y} = x_0\omega_0 = 1.1 \times 10^6$ cm/sec (< Jupiter's velocity)
As is usual in numerical work, the equations were non-dimensionalized. In our numerical calculation we take $M_0 = 10^{30}$ g and all other quantities involved in the problem except $c$ have been assumed to have their standard values. For interior protoplanets the value of $c$ is taken around $5 \times 10^{-3}$ , whereas for outer ones it is taken around $5 \times 10^{-4}$. Inserting all the parameters involved together with the above initial conditions we have solved Eqs. (9) and (10) by the standard fourth order Runge-Kutta method. It is found that in each case, the orbit of a mass losing interior protoplanet spirals in towards the Sun while the outer one is pushed outwards. The result of our calculation for $c = 5 \times 10^{-3}$ in the case of an interior protoplanet is shown in Fig.1, while Fig. 2 depicts the result for an outer protoplanet with $c = 5 \times 10^{-3}$.

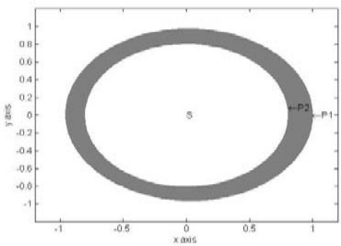


**Fig.1. Orbital positions of an interior mass losing protoplanet in a two body system. P1 is the initial position of the protoplanet and P2 is its position after 1.6 x $10^4$ years and S is the position of the Sun.**

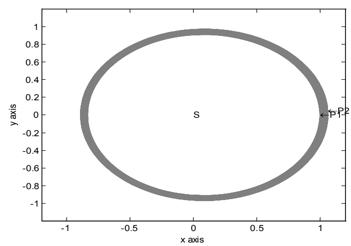


**Fig. 2. Orbital positions of an outer mass losing protoplanet in a two body system.. P1 is the initial position of the protoplanet and P2 is its position after 1.6 x $10^4$ years and S is the position of the Sun.**

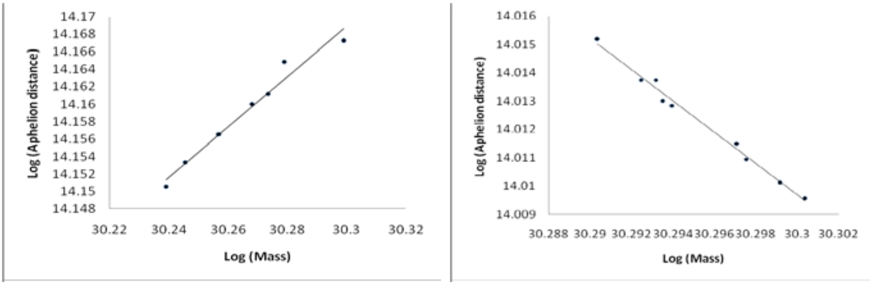


**Fig. 3: The predicted mass-distance relation, (left) for interior protoplanets and (right) for outer protoplanets.**

### 4. Comparison with observation

With our calculated data, we draw a plot of log (aphelion distance) against log (mass) and is shown in Fig. 3. It is found that the mass-distance relation is given b

$$D \propto M_p^{\ \alpha},$$

where $D$ represents aphelion distance, $M_p$ represents mass and $\alpha$ is a parameter whose values depend on $c$ in the respective cases. However, the best result in the case of an interior mass losing protoplanet can be obtained for with $c = 5 \times 10^{-3}$, while for an outer mass losing protoplanet it can be found for with $c = 10^{-3}$. For these values of $c$ the values of $\alpha$ can be found as follows

$\alpha = -0.5485$ for outer planets
$= +0.2735$ for the inner planets.

If $D_J$ and $M_J$ are the values of the parameters for Jupiter, then from the above relation we can write

$$\frac{D}{D_J} = \left(\frac{M_p}{M_J}\right)^{\alpha} \qquad (12)$$

Now, the aphelion distance of any planet with known value of $M_p$ be easily calculated using Eq. (12). Our theoretically predicted distances with the observed distances of the present day planets are shown in table 1.

**Table 1. Comparison of the predicted distances with observation**

| Planets | Mass(g)× $5.9736\times10^{27}$ | Observed aphelion distance (cm)×1.52098 $\times10^{13}$ | Predicted aphelion distance (cm)×1.52098 $\times10^{13}$ |
|---|---|---|---|
| Mercury | 0.0553 | 0.4590 | 0.4399 |
| Venus | 0.8150 | 0.7162 | 0.9573 |
| Earth | 1.0000 | 1.0000 | 1.0156 |
| Mars | 0.1074 | 1.6385 | 0.5330 |
| Jupiter | 317.8318 | 5.3684 | 5.3684 |
| Saturn | 95.1620 | 9.9495 | 10.4207 |
| Uranus | 14.5323 | 19.7531 | 29.2933 |
| Neptune | 17.1471 | 29.9407 | 26.7453 |

### 5. Conclusion

We have investigated the effect of mass loss on the protoplanetary orbits with the Sun and the protoplanets under consideration. There is found a clear division in the effect of mass loss. For the interior protoplanets (i.e., within the Sun and Jupiter) mass loss decreases the orbital distance whereas for the outer protoplanets the orbital distances are found to be increased as mass loss proceeds. The mass-distance relation can be given by a power law form. The predicted distances of the present day planets with known masses were found to be in good agreement with the observed distances except for Mars and Uranus. We, therefore, conclude that mass loss from a set of identical protoplanets can explain the distribution of planetary distances as observed today.

**Acknowledgement**
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# Photographing the Moon's parallax

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The total eclipse of the Moon on 15 June 2011 was a great opportunity to document the lunar parallax. We all know that the position of the Moon relative to the stars depends on the observer's location on the Earth's surface. When the Moon is observed at the same time at two different sites, the difference between the two positions of the Moon relative to the background stars is the parallax.

In order to show the lunar parallax, images with both the Moon and the background stars are needed. During most of the time, this is extremely difficult to achieve, because the Moon is so bright. During a total lunar eclipse, however, the Moon is faint enough to allow taking pictures where both the Moon and the surrounding stars are visible. It is essential that the images obtained at the different observing sites are taken at the same time. When pictures from two locations are combined by matching the star patterns, the resulting image shows the background star field and two images of the Moon at different positions relative to the stars.

As far as equipment is concerned, a camera on a tripod is sufficient to obtain pictures that are suitable for showing the parallax. No large or fancy telescopes are needed. Anyone who is interested can easily get involved and take images.

**Table 1. Observers contributing images of the Moon**

| Observing site | Observer |
|---|---|
| Riesa, Germany | Christian Bartzsch |
| | Lisa Glagowski |
| | Michael Nitzsche |
| | Stefan Schwager |
| Pretoria, South Africa | Barbara Cunow |
| | Percy Jacobs |
| | Pat Kühn |
| | Neville Young |

The last total lunar eclipse took place on 15 June 2011 and was visible from Africa and Europe. We decided that this was an excellent opportunity set up an international collaboration to try to record the lunar parallax between South Africa and Germany. Members of the Pretoria Centre of the Astronomical Society of Southern Africa and of the Sternwarte Riesa in Germany were contacted for a project to photograph the totally eclipsed Moon and the background stars.

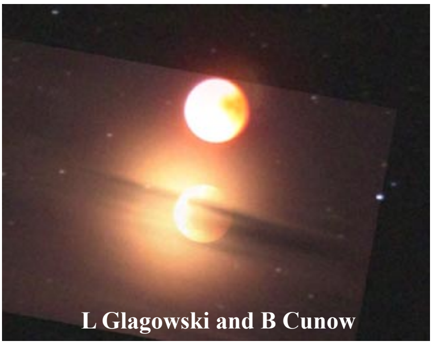
On 15 June totality started at 21:22 SAST and ended at 23:03 SAST. The eclipse was nicely visible from South Africa, but the situation was not so easy for the observers in Germany. For Pretoria, the Moon was high in the sky during the whole event, but for Riesa, the Moon only rose at the beginning of totality, and the eclipsed Moon was always close to the horizon. Therefore, it was decided to photograph the Moon during the last part of totality, when the Moon was highest for the observers in Riesa. The times for photographing the Moon were set at 22:30 SAST, 22:40 SAST, 22:50 SAST and 23:00 SAST.

During the eclipse, the skies were clear in Pretoria and the totally eclipsed Moon could be seen very nicely in front of the central regions of the Milky Way. Unfortunately, the weather was cloudy in Riesa, but a few gaps in the clouds allowed some observations at the end of totality. Both in Riesa and in Pretoria, teams of enthusiastic observers took pictures of the Moon, and we were able to obtain images at both sites for 23:00 SAST. Table 1 lists the observers who contributed pictures for this project.

Figures 1-5 show the lunar parallax between Riesa and Pretoria at 23:00 SAST. Each picture is a combination of an image taken in Pretoria and one obtained in Riesa. It shows the eclipsed Moon with the starry background. North is up and east is to the left in all images. The northern Moon is the one seen from South Africa, the southern Moon is the one observed from Germany. The parallax of the Moon is clearly visible – the two Moons are 1.7 moon-diameters apart.








**Figures 1-5: Parallax of the Moon between Pretoria and Riesa at 23:00 SAST. Each image is combination of two pictures, taken by the indivudiuls indicated.**

Our results demonstrate how large the lunar parallax is between South Africa and Germany and how easy it is to record it during a total lunar eclipse. A project like this is an excellent opportunity for an international collaboration between amateur astronomers and to show the general public how the skies at different observing sites differ apart from the effects due to different latitudes.

This project was not our first attempt to record the parallax of the Moon. During the total lunar eclipse of 27/28 October 2004 we were able to photograph the parallax between South Africa and Canada. Our pictures show a parallax of 3.3 moon-diameters between Pretoria/Johannesburg and Edmonton/Calgary, which is one of the largest parallaxes (perhaps even the largest parallax) ever recorded from the Earth's surface. Figure 6 shows the large parallax we could record between Pretoria and Calgary. The results were published as Cunow B., *Monthly Notes of the Astronomical Society of Southern Africa*, 2005, vol. 64, nos. 1&2, p. 9.

I would like to thank everyone who participated in this project. Furthermore I would like to thank the members of the Sternwarte Riesa for making me an honorary member of the Sternwarte Riesa in 2009. More information about the participants and the project can be found at the websites of the Pretoria Centre of the Astronomical Society of Southern Africa at www.pretoria-astronomy.co.za and of the Sternenfreunde Riesa at www.sternenfreunde-riesa.de and the Sternwarte Riesa at www.sternwarte-riesa.de. Finally it should be noted that in June South Africa and Germany use the same local time: South African Standard Time SAST and Mitteleuropäische Sommerzeit MESZ are identical. ☆

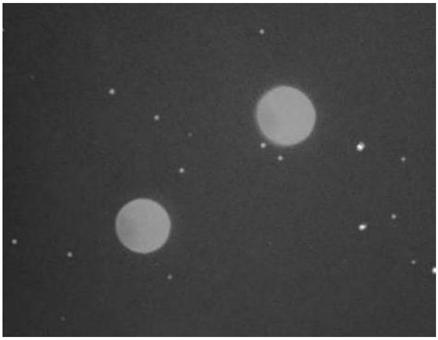


**Figure 6. Parallax of the Moon on 28 October 2004 between Pretoria and Calgary. The image is a combination of two images obtained at 4:25 SAST, the one in Calgary taken by L. McNish, the one in Pretoria by B. Cunow. North is up and East is to the left.**



# Astronomical Colloquia

These form an important part of a research facility, often as a sort of pre-publication discussion or a discussion of an individual's current research, and as such it is virtually impossible to "publish" this material. However by recording the topics discussed in the form below does indicate to those, who are unable to attend, what current trends are and who has visited to do research: it keeps everyone 'in the loop' so to speak. *Ed*

**At SAAO**

Title: **The SEDs of 250um selected galaxies in the Herschel-ATLAS**
Date: 6 October 2011
Time: 12:30
Venue: 1896 Building
Speaker: Dan Smith (University of Hertfordshire)
Abstract: I will present the results of applying a panchromatic SED-fitting technique to a sample of 1404 local galaxies selected at 250um in data from the Herschel ATLAS project.

I will discuss our results, including the determination of dust luminosities and masses, star formation rates, and a variety of other physical parameters. I will also present the results obtained by using our large sample to create a new set of empirical template SEDs for these galaxies, binned according to their physical properties, and show their differences from other currently-available panchromatic SED template libraries.

Title: **New capabilities of IRSF and a simultaneous optical g'r'i' camera TRIPOL**
Date: 13 October 2011
Time: 12:30
Venue: 1896 Building
Speaker: Takahiro Nagayama (Nagoya University)
Abstract: IRSF is a Japanese 1.4m telescope with a near infrared JHK simultaneous camera SIRIUS working from November 2000 at Sutherland. Recently, we have performed two upgrades to IRSF/SIRIUS; multi-bandpass filters and accurate photometry mode.

The new multi-bandpass filters have two transparency bands; one in the J band and another in the Ks band, and so we can obtain two narrow band images, for example, Pa Beta and Br Gamma simultaneously. The filters are installed just before the entrance window of SIRIUS camera, and so it is very easy to exchange the filters. Some images taken these filters and currently available filters are shown in my talk.

The accurate photometry mode is realized by a special self-guiding software which keeps a target at the same position on detector arrays. This software works both on-focused and defocused objects, and the target is normally kept within a pixel. Photometry relative to a reference star in the same field of view is stable within 0.002 mag for the J and H bands, and 0.003 mag for the Ks band (rms), and an 0.015 mag eclipse due to ex-planet was easily detected. Our simultaneous milli-magnitude photometry of JHKs band will be very useful to monitor very small change of colours (J-H, H-Ks).

Finally, I also introduce our new instrument TRIPOL, a simultaneous optical g'r'i' camera. The test observation is planed from 28 September to 11 October at the SAAO 0.75m telescope, and I show some results taken in this observation. I believe that a simultaneous g'r'i' milli-magnitude photometry with TRIPOL on the 0.75m telescope will be available by the same method done with IRSF/SIRIUS in a near future. Our final goal is simultaneous 6-bands (g'r'i'JHKs) milli-magnitude photometry coordinated with IRSF/SIRIUS and TRIPOL/0.75m. It will be fantastic for all kind of astronomy.

Title: **Disks, bulges, and the origin of lenticular galaxies**
Date: 20 October 2011

Time: 12:30
Venue: 1896 Building
Speaker: Olga K Sil'chenko (Sternberg Astronomical Institute of the Lomonosov Moscow State University)

Abstract: By undertaking deep long-slit spectroscopy with the focal reducer SCORPIO of the Russian 6m telescope, we have studied the stellar population properties along the radius beyond several scalelengths in the large-scale stellar disks of 15 S0 galaxies spread over a range of luminosities and settling in different environments. For the outer disks of the galaxies, we have found SSP-equivalent metallicities from the solar one down to [Z/H]=-0.4 - -0.7, rather high magnesium-to-iron ratios, [Mg/Fe]> +0.2, and mostly old SSP-equivalent ages. Nine of 15 (60%) galaxies have the outer disks older than 10 Gyr, and those are the galaxies in dense environments. The isolated galaxies possess intermediate-age stellar disks, of 7-8 Gyr old. Only two galaxies reveal the young SSP-equivalent ages of their disks of 2-3 Gyr. Just both young disks have appeared to be thin, while the other, old, disks have the scaleheights typical for thick stellar disks. The bulges at are on the contrary more metal-rich than the solar abundance and homogeneously distributed over all ages from 2 to 15 Gyr, being almost always younger than the disks. I conclude that the S0 galaxies are the primary type of disk galaxies completely shaped at z=1.5--2; they could not form in groups at z=0.4 as it is thought now. The Butcher-Oemler effect observed in the clusters at z=0.4 reflects probably some rejuvenation events confined mostly to the galaxies' bulges.

Title: **Herschel-ATLAS: The relationship between accretion luminosity and star formation in QSO hosts**
Date: 27 October 2011
Time: 12:30
Venue: 1896 Building
Speaker: Dr Dave Bonfield (University of Hertfordshire)

Abstract: We use the science demonstration field data of the Herschel-ATLAS to study how star formation, traced by the far-infrared Herschel data, is related to both the accretion luminosity of quasars selected from the Sloan Digital Sky Survey and the 2SLAQ survey. We find evidence that the star-formation in quasar hosts is correlated with both redshift and quasar accretion luminosity. Assuming a relationship of the form L_IR ~ L_QSO^theta.(1+z)^zeta, we find theta = 0.22 +/- 0.08. This shallow power-law slope in the relationship between star formation rate and quasar accretion rate is consistent with several other recent measurements, but conflicts with a suggestion (based onFIR-flux-limited samples) that a steeper slope, with theta=0.8, describes powerful quasars, which are expected to be triggered by major mergers. I will briefly discuss ways in which a shallow, non-linear relationship between star formation and black hole accretion can

arise in the context of the merger paradigm.

Title: **Mass Assembly of Galaxies over the last 10 Gyr**
Date: 17 November 2011
Time: 12:30
Venue: SAAO Auditorium
Presenter: Philippe Amram (Laboratoire d'Astrophysique de Marseille)
Abstract: Understanding how galaxies evolve and assemble their mass across cosmic time is still a fundamental unsolved issue. Processes driving mass assembly are expected to evolve on different timescales along cosmic time. A transition might happen around z=1 as the cosmic star formation rate starts its decrease. To get insight into the various processes of galaxy mass assembly, the Mass Assembly Survey with SINFONI in VVDS (MASSIV) aims at probing the kinematical and chemical properties of a significant and representative sample of high-redshift (0.9 < z < 1.8) star-forming galaxies. This sample contains 84 star-forming galaxies, selected from the VIMOS VLT Deep Survey (VVDS) and observed with the SINFONI integral-field spectrograph at the VLT. The MASSIV selection function, based on star formation criteria provides a good representation of "normal" star-forming galaxies. I will present preliminary results of this survey.

**At NASSP**
Title: **The new South African Space Agency (SANSA): Space Weather - what's up?**
Date: Wednesday, 5 October 2011
Time: 13:00
Venue: RW James C
Presenter: Dr Pierre Cilliers. Research Physicist in the Space Science Directorate of the South African Space Agency (previously the Hermanus Magnetic Observatory)
Abstract: SANSA was appointed in June 2007 as the African Regional Space Weather Warning Centre for Space Weather of the International Space Environment Service (ISES). The vulnerability of modern communications and electrical power distribution technology to space weather events is one of the reasons for SANSA's research on Space Weather and for South Africa's cooperation with various institutions on the design and development of a space weather payloads for satellites.

Dr Pierre Cilliers participated in an Antarctic expedition in December 2007 and an expedition to Marion Island in April 2010 to promote international research on Space Weather and is currently the SANSA PI for a project on Geomagnetically induced currents.

Dr Cilliers will present challenges and opportunities for research in Space Physics and

Engineering which relate to the following areas :

- space weather observations inter alia in Antarctica, on Marion Island, on Gough Island , with an emphasis on recent intense solar events.
- the prediction and mitigation of space weather impacts on technology, particularly on electrical power systems,
- the development of space weather sensors for CubeSats

Title: **The Cold Gas in Early-Type Galaxies: Past, Present, and Future.**
Date: Wednesday, 12 October 2011
Time: 13:00
Venue: RW James C
Speaker: Danielle Lucero. Danielle Lucero is one of the new SKA SARChI Postdoctoral Fellows here at UCT. She obtained her PhD in Physics (dissertation in Astrophysics) at the New Mexico Institute of Mining and Technology in March of this year. Her research interests include the interstellar medium and star formation in early-type galaxies.
Abstract: The process by which early-type galaxies form remains a key issue in the general theory of galaxies. The traditional view is that early-type galaxies are old systems that formed at high redshift, passively evolving until the present without further star formation activity. In recent years a wide variety of observational work has suggested that the formation of early-type galaxies is in actuality a very intricate process; it has been drawn out over most of a Hubble time and it is even continuing at some reduced level now. For instance, GALEX observations find UV emission from current star formation in up to 30% of nearby ellipticals. Some of the early-type galaxies have stellar population age gradients, with the central stars of the galaxy several Gyr younger than the outer stars. Many early-type galaxies also have internal structures with kinematic properties that are dramatically different from the rest of the galaxy; these kinematically decoupled cores are probably the result of a dramatic merger or accretion event. It is clear that the cold gas in early-type galaxies holds important clues to their evolutionary history--- it serves as a tracer of past accretion or interactions. It is now well established that many early-type galaxies contain detectable amounts of cold gas, sometimes settled in a disc, and recent star formation. In this talk I will discuss what the current observational evidence suggests about the origin of early-type galaxies and their gas contents.

Title: **A Search for Intermediate-Mass Black Holes at the Centres of Nearby Dwarf Galaxies**
Date: Wednesday, 19 October 2011
Time: 13:00
Venue: RW James C
Speaker: Bonita De Swardt. Bonita obtained her PhD from UCT in 2009 and is currently

a postdoctoral research fellow at the SAAO. Her research interests include studying the properties and characteristics of the faintest galaxies - broadly known as dwarf galaxies - that we observe in the nearby universe.

Abstract: The correlation between black hole (BH) mass and the bulge velocity dispersion is well established for early-type galaxies having a supermassive BH in the centres. The extrapolation of this relation to the lower BH-mass regime is strongly dependent on the existence of BHs in the mass range of 10^3-10^6MSun - called the "intermediate-mass" black hole (IMBH). The BH mass versus velocity dispersion relation infers the existence of IMBHs in dense stellar environments having dispersion in the range of 20-100km/s. Dwarf galaxies are well known to have central velocity dispersions in this range making them ideal candidates for hosting an IMBH. In this talk, I will present an ambitious project for the search of IMBHs using the Southern African Large Telescope (SALT). In particular, the results of a pilot study in the search of these objects at the centre of nearby dwarf galaxies using the SALT spectrograph will be shown. Even though the presence of an IMBH in the galaxy centre remains inconclusive with the current data, these results do however give a great deal of insight into the capabilities and limitations of SALT in our search for the elusive IMBH.

Title: **Technological applications of Geomagnetic field measurements at SANSA Space Science**
Date: Wednesday, 26 October 2011
Time: 13:00
Venue: RW James C
Speaker: Elda Saunderson

Abstract: We all know that the Earth is surrounded by a relatively weak magnetic field which protects us from radiation from the Sun and in that capacity makes life possible on Earth. This geomagnetic field is not stationary but changes all the time. We can't significantly change this field, nor can we switch it off or control it, however, we can measure it and use it to our advantage.

Geomagnetic measurements have been used for centuries by seafarers to navigate with a magnetic compass, but today we use measurements of the geomagnetic field for navigation and orientation control of satellites, some as small as 10cm$^3$, unmanned aerial vehicles such as spy-planes, weapon systems, underwater unmanned rovers and many more. We can also use measurements of the geomagnetic field to find magnetic objects (both stationary and fast moving objects), or to hide magnetic objects from someone else... We are even attempting to predict Earthquakes with super cooled magnetic sensors! ☆

# *Lepus - a Storybook Rabbit*

by Magda Streicher
*magdalena@mweb.co.za*

Lepus the Hare is generally seen as the animal being chased by Orion's hunting dog, Canis Major, but looked at differently it could also be seen as a chair in the star formation for Orion the hunter.

Looking at the constellation, the magnitude 3.2 mu Leporis could represent the rabbit's large eye, while kappa and lambda further to the north represent the two ears. These parts are directed westwards within the constellation, with Canis Major hot on the rabbit's heels on the eastern side.

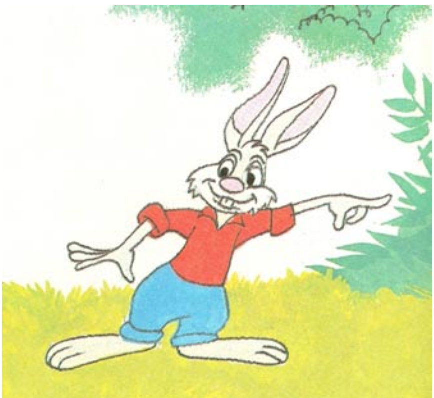
Not only can an animal story be seen in the star formation, but various land animals are also frequently assosciated with children's story books. The rabbit is a little animal like that which is a popular favourite in children's stories. Such stories enrich a child's imagination to an exciting level of enjoyment. Now people are wondering whether the rabbit constellation has any connection with the little animal we know as a rabbit. What is beyond question, however, is that the constellation holds wonderful stories of the objects located in it.

The northern part of the constellation houses a special planetary nebula, **IC 418**,

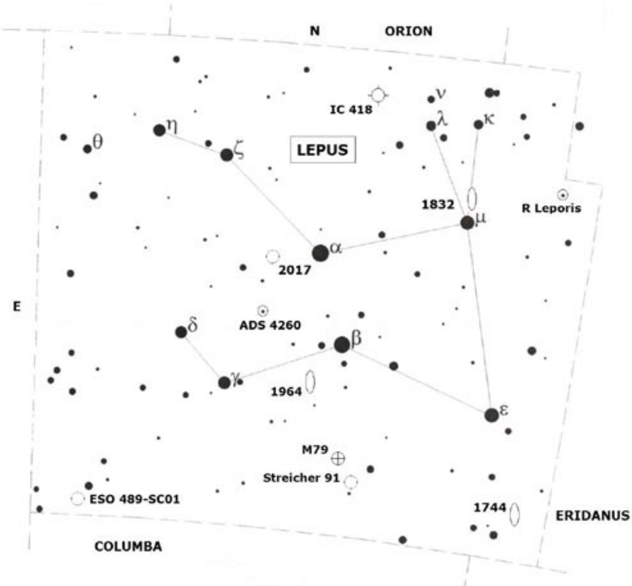
Image source: Stellarium.org

one of the best objects with its outstanding blue-green colour. Although small in size the impression is that of a light-bulb peeping through a misty halo. With higher magnification an outer frosted halo can be seen glowing around a magnitude 10 star. The north-western side is slightly hazier, but overall the planetary nebula is well outstanding against the background star field.

**NGC 1832** is situated only 30' north-west of mu Leporis and in sight of the hare's bright eye. A pretty, oval-shaped galaxy in



**A children's favourite - the Rabbit!**



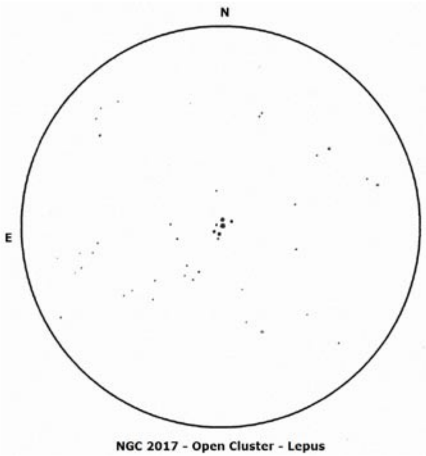

very distinctive red hue which changes from deep orange to a strong ruby-red.

The magnitude 2.6 star alpha Leporis, situated more or less in the middle part of the constellation, is also known as Arneb, which is Arabic for "hare". The unusual open cluster **NGC 2017**, which would be better referred to as an asterism, or a multiple star group,

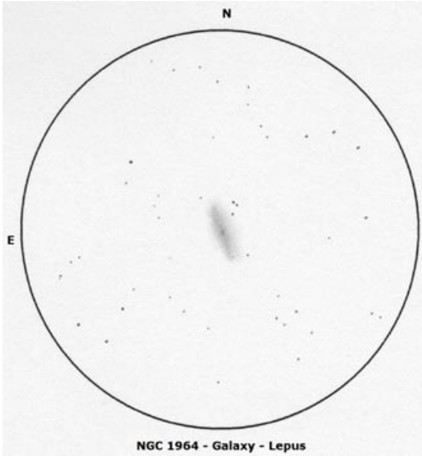
a north-south direction with an outstanding bright nucleus, although not star-like. With careful observation and high magnification through moderate telescopes a few bright spots can be picked up.

The long-period pulsating red variable star **R Leporis**, better known as Hind's Crimson Star, can be found close to 30' east of the Eridanus constellation boundary. It was discovered by the English astronomer John Russell Hind in October 1845. The variability of approximately 432 days was detected again from observations made between 1852 and 1855. Historically R Leporis varied between magnitude 5.5 and 11.7, but lately it hasn't been seen brighter than about magnitude 6. This type of red star, also known as a Mira-type, displays strong bands caused by carbon compounds. R Leporis has its own

is situated just 1.5° east of alpha Leporis. Five stars with an unusual appearance stand out clearly against the background star field. With its variety of colours it can truly be described as one of the most beautiful stellar groupings one can see. The magnitude 6.4 primary star has a very smooth grey-blue colour. Towards the south is a yellow magnitude 8.8 star, accompanied by a fainter member. On the eastern side of the group, between these two stars, the magnitude 10 star displays an ashy colour. A magnitude 7.7 star is located on the northern edge and displays a strong orange colour; it is also the most outstanding member. To conclude the grouping the magnitude 8.2, a slightly dirty-yellow-coloured star, is situated further west. These stars seem to form a physical system (see sketch). Hartung describes it as an "attractive group of six




**This small open cluster, NGC 2017, could also be thought of as an asterism.**




**NGC 1964 a rather pretty, comet-like galaxy.**

stars, which shows different colours in blue, yellow, orange blue and ashy".

The characteristic arched back of the starry hare is represented by the stars eta and zeta Leporis in the northern part of the constellation. With imagination the magnitude 4.6 theta Leporis can be seen perhaps as the fluffy tail? All sorts of shapes and impressions can be seen in the patterns of a star-filled night sky!

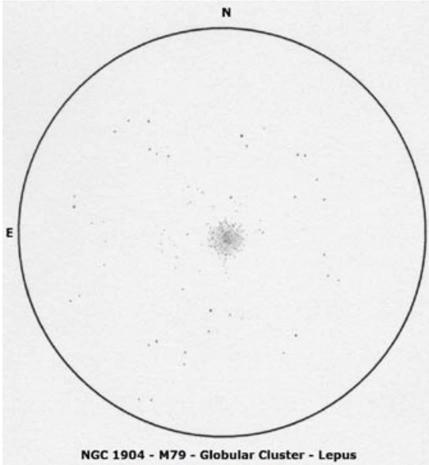
The double star **ADS 4260** forms a triangle to the north with the bright stars beta and delta Leporis and is by far one of the most beautiful contrasting-colour stars. The magnitude 6.9 primary shines crispy white, while its magnitude 7.9 companion is a seldom-seen blue-purple colour. The pair is currently in a separation of 11" with a position angle (PA) of 123°.

Situated only 1.5° south-east of the beautiful yellow-coloured beta Leporis is **NGC 1964**, a relatively bright galaxy. A first impression brings to the fore the sight of a very faint comet, slightly elongated in a north-east to south-west direction. The edge of the galaxy appears to be very hazy, fading away into a nebulous veil. Higher magnification, however, brings out the star-like nucleus surrounded by a haze halo. A triangle with three prominent stars can be seen immediately north-west of the galaxy. Faint stars are situated in the south-western part of the galaxy (see sketch).

About 2.5° south-east of the galaxy is the prominent, colourful double star gamma Leporis. It is an easily split double star with a bright yellow-coloured primary and orange companion. This double star is a member of a larger stellar collection called the Ursa Major moving group, discovered in 1869 by English astronomer Richard Proctor. This group includes the well-known Big Dipper asterism.

Of course, our little rabbit constellation does not disappoint us. Among many other beautiful objects it is also home to the exceptional globular cluster **NGC 1904**, also known as Messier 79 and Bennett 34, which is situated in the southern part of the constellation. The object brightens gradually towards the middle, which does not appear very dense. Numerous star strings on the outskirts of the globular cluster extend like lace to give a refined appearance. With higher magnification the broad core appears to be surrounded by a soft hazy envelope. The southern edge of the globular cluster displays a somewhat lengthened appearance, possibly created by faint stars. With averted vision faint stardust can be pick up covering the surface. A more prominent star string stands out towards the southern edge (see sketch).

A mere one degree south of NGC 1904 a perfect half-moon of faint stars curves its way down to the south from the magnitude 8.4 (HD 35285) star at the north-eastern tip. **STREICHER 91** contains approximately a dozen colourful stars in various magnitudes.




**NGC 1904 this beautiful globular cluster is also known as M79 and Bennett 34.**

The galaxy **NGC 1744** displays itself only as a very soft, barely visible smear of light. This spindle galaxy is very elongated in a north-south direction with just a slightly brighter nucleus surrounded by a soft halo. Two faint stars are superimposed on the dusty surface.

The grouping **ESO 489-SC01** is situated in the far south-eastern part of the constellation and consists of more or less a dozen varied-magnitude stars. The middle part of this grouping is highlighted by four stars in a square shape with fainter members intervening. The southern part of the group seems slightly busier in starlight. The brighter magnitude 10.4 (TYC 65002358) star is situated towards the south-western end of the group. ☆

| Object | Type | RA (J2000.0) | Dec | Mag. | Size |
|---|---|---|---|---|---|
| R Leporis | Variable star | $04^h59^m6$ | -14°48′ | 5.5-11.7 | Per. 432 d |
| NGC 1744 | Galaxy | 05 00 0 | -26 01 | 11.3 | 5.1′x2.5′ |
| NGC 1832 | Galaxy | 05 12 1 | -15 41 | 11.3 | 2.1′x1.5′ |
| STREICHER 91 | Asterism | 05 22 4 | -25 41 | 7 | 13′ |
| NGC 1904 M79 | Glob. Cluster | 05 24 5 | -24 32 | 7.7 | 9.6′ |
| IC 418 | Planetary Neb. | 05 27 5 | -12 42 | 10.7 | 20″ |
| NGC 1964 | Galaxy | 05 33 4 | -21 57 | 10.7 | 5.0′x2.1′ |
| NGC 2017 | Open Cluster | 05 39 4 | -17 51 | 7.5 | 4.5′ |
| ADS 4260 | Double-star | 05 39 7 | -20 26 | 6.9&7.9 | Sep. 11″ |
| ESO 489-SC01 | Open Cluster | 06 05 0 | -26 44 | 9.5 | 10′ |



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**ASSA news**



**News Notes**

**News Notes cont.**



**Articles**

**Articles cont.**



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The **Astronomical Society of Southern Africa** (ASSA) was formed in 1922 by the amalgamation of the Cape Astronomical Association (founded 1912) and the Johannesburg Astronomical Association (founded 1918). It is a body consisting of both amateur and professional astronomers.

**Publications:** The Society publishes its own electronic journal, the *Monthly Notes of the Astronomical Society of Southern Africa (MNASSA)* bimonthly and an annual printed *Sky Guide Africa South*.

**Membership:** Membership of the Society is open to all. Potential members should consult the Society's web page assa.saao.org.za for details. Joining is possible via one of the Local Centres or as a Country Member.

**Local Centres:** Local Centres of the Society exist at Bloemfontein, Cape Town, Durban, Harare, Hermanus, Johannesburg, Pietermaritzburg (Natal Midlands Centre), Pretoria and Sedgefield district (Garden Route Centre). Membership of any of these Centres automatically confers membership of the Society.

***Sky & Telescope:*** Members may subscribe to *Sky & Telescope* at a significant discount (proof of Centre membership required) . Please contact membership secretary for details.

**Internet contact details:** e-mail: *assa@saao.ac.za* homepage: *http://assa.saao.ac.za*

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