CANOPUS

The Astronomical Society of Southern Africa

Johannesburg Centre

Monthly Newsletter for January 1999

Contents:

The Sir Herbert Baker Library, 18a Gill Street, Observatory, Johannesburg
P.O.Box 93145, Yeoville, 2143

Editorial

The Leonids managed to bypass the Earth to a large extent, but seem to have caused an upsurge of interest in meteor spotting and Astronomy as a whole - and this can only be good for us as a society. Now is the time to grab all of your friends who are somewhat interested in the science, and put a pen and membership application form in their hands.

We continue the Relativity series with part 2 of Eben van Zyl's presentation, and also continue the series on "How to make a Star" by Sten Odenwald. Bill Wheaton has submitted a summary of the many interesting and exciting NASA projects which are either on the go or in the pipeline at present, and we were very pleased to hear that the DS1 Ion engine was successfully restarted as the previous issue was going to print, and is still going strong. These engines could make interstellar exploration a viable option. Brian has supplied us with the Sky events for the next couple of months, Danie has given us not one, but *four* variables of the month, and we have an article from Wolf Lange on a visit he made to the Carl-Zeiss Planetarium in Stuttgart, Germany.

This is the first issue of CANOPUS for 1999, and we once again express a plea for articles for our magazine. There must be plenty of budding authors out there - this is just the place to cut your teeth. We are ***very*** kind editors and promise not to reject any of your articles out of hand!

An(other) Apology

Oh no - not again!!! We really blew it this time! How many of you noticed that the cover of the last CANOPUS said "October" and not "November/December" as it should have! Would you believe that the error was only picked up as the envelopes were being filled. Well maybe your eye was caught by the great picture on the cover, and you never noticed; however, it was picked up by our astute envelope filler and pointed out to us………so *once again* we apologise.

The Editors

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Notice of Meeting

The **January** meeting of the Johannesburg Centre of the Astronomical Society will be held at the Sir Herbert Baker Library, on Wednesday 13th January 1999 at 8:00 p.m.

Topic:

Computers and Astronomy

by

Tony Hilton.

A letter to the Editors

We received the following letter in reaction to the photograph printed on the cover of the Year End 1998 issue of CANOPUS.

Dear Raymond and/or Lori and/or Chris,

I was thrilled to see the picture of the old Observatory building on the outer cover of the Canopus issue for October, the building where I spent so many years of my life. I had never seen this picture; probably photographed about 1905. What a wonderful observing site it must have been in those days.

And I was wondering: would there be any possibility of getting a better , possibly larger print of this? The original will probably still be languishing somewhere. Could you provide any help??

And while we are about it - although it is really none of my business - I have never been able to understand why this building is nowadays called the " SIR Herbert Baker Library". In my days it was always simply called the "Baker building" . Because the fact of the matter is that it was NOT designed by Sir Herbert Baker, but by plain Mr Herbert Baker, a promising young architect and a protege of Cecil Rhodes. I think it was Gill who suggested that he be asked to do this work. Baker was knighted in 1926, and I rather doubt whether in later years he would have been particularly proud of this early example of his work

And lastly, I looked with interest at the list of URL's in "Web Between the Worlds". My own computer is a bit too basic and too slow for these things, but they may well be of interest to other members of our Centre. Can I have permission to copy the list for their benefit?

Yours sincerely,

Jan Hers

Dear Jan,

We really do not know the answer to your query regarding the "Baker Building". Maybe one of our historically inclined members could supply an appropriate response.

The photo was supplied by Peter van Laun via Brian Fraser and we have scanned it at a reasonably high resolution in both monochrome and in colour. If you would like to have a copy of the photo, please contact the editors.

Please feel free to pass on any URLs we publish to friends and colleagues - you may also find the list of "favourite sites"on our website to be fairly interesting.

By the way, regarding the "October" issue - please read the apology printed in the Editorial.

The Editors.

JPL and NASA News

Bill Wheaton, IPAC

1999 January

A Memorable Two Months!

It has been my habit in this column to try to explore aspects of a particular mission or topic in some detail rather than attempt a synoptic coverage of all that is happening. If this works at all it is partly because space missions, especially the interplanetary missions which are JPL's special *forte*, tend to have long routine periods punctuated by occasional bursts of activity. However, since the last column so much has happened that it seems impossible to treat anything at length. So this month I will have to be content with little more than headlines. As a bonus, I will also give WWW URLs for most of the missions I have discussed here or previously.

The construction of the International Space Station (ISS) appears to be off to a fine start. Although most of you will have been following the story, yet the launch of the first elements is such a landmark event that I cannot omit it entirely. The first module, *Zarya* (also known as the "Functional Cargo Block" or FCB) was launched by a Russian Proton booster on 19 November. Approximately 13 days later, the *Unity* module was launched on the shuttle Endeavour, on STS-88. The mating of the two parts was accomplished over the next 12 days, and went with a smoothness that must have been very gratifying to those directly involved.

To my mind the biggest single justification for the station is that it seems to be the only way humans can acquire the nitty gritty experience needed to allow us to work more routinely in space. Until we do this basic technological homework, all large-scale space projects, whether scientific, industrial, or exploratory, will be like a cavalry charge -- risky, expensive, and unusual, to be undertaken only as a last resort. No doubt many difficulties lie ahead during the years of construction still to be accomplished. Nevertheless, one must regard the good beginning as promising for the overall success of the project.

The first permanent crew, of three occupants, is scheduled to take up residence in January 2000, just one year from now. Further information may be found at:

http://centauri.larc.nasa.gov/issvc97/ material.html#elements.

Meanwhile, the first of the "Mars '98" missions, Mars Climate Orbiter (MCO) was successfully launched on 11 December, and is now en route to a 23 September, 1999 arrival in Mars orbit, where it will spend 2 years mapping and collecting data on Mars' atmosphere and weather, and then three more years as a data relay station for other missions yet to be launched. As of this writing all spacecraft systems are still being turned on and checked out as the mission settles down to interplanetary cruise, but everything seems in good health so far.

The sister mission, Mars Polar Lander (MPL), remains scheduled for launch about the time you receive this, on 3 January 1999. It will arrive on 3 December 1999 for a landing at the edge of the South Polar Cap, along with two "microprobes" which will impact about 200 km from the main lander and return information from a depth of about 2 meters. Both of the Mars '98 missions were discussed here in more detail last September. A collection of links to further Mars mission information is at:

http://www.jpl.nasa.gov/marsnews/.

Deep Space 1, which we discussed in July, was successfully launched on a Delta II on 24 October. The ion drive, which is the centerpiece of this technology development mission, gave everyone a good scare when it shut down after just 4.5 min operation on 11 November and refused to restart.

The ion engine accelerates xenon ions between two grids only about 0.6 mm apart, charged to a relative potential of up to 1280 volts. Small bits of dust or other contamination are liable to short the grids and make the engine inoperable until they are somehow cleared. Such problems have been observed in ground tests and in space (smaller ion thrusters have been used for attitude and station-keeping on communications satellites) before, and methods, akin to electric "bug zappers", exist for clearing faults of this kind. Thus no one was ready to despair. Nevertheless it was a great relief that the engine operated normally when it was tried again, 12 days after its earlier failure. Since that time it has been thrusting happily away, and has already substantially exceeded the pre-defined criteria for success. In fact, despite some minor glitches, all of the new technologies (at least those that have been tried so far as of this writing; there are a total of 12 on board) appear successful. The DS1 home page is at:

http://nmp.jpl.nasa.gov/ds1/.

By chance, DS1's success comes just as the Cassini Saturn mission has performed a major midcourse trajectory correction (about 450 meters per sec, requiring a 90 minute burn of its main engine), near the aphelion of its great loop out into the inner asteroid belt before a close flyby of Venus scheduled for June.

(I have reported on Cassini's progress here before, especially in October and November of 1997; we still need to say much more about its instruments, science, and various other aspects of the mission; but for Cassini at least we have a good deal of time before it reaches its goal in 2004! Meanwhile, the JPL home page is at:

http://www.jpl.nasa.gov/cassini/ index_frames.html

for those who cannot wait.).

One other large burn of this engine is scheduled, that needed to place the spacecraft in orbit around Saturn. Some of you will recall Cassini's enormous launch mass of 5600 kgm, the largest US payload ever sent beyond the Moon. Over 3000 kgm of this was propellant needed for the burn just accomplished, and for the one to come at Saturn.

All else being the same, an ion thruster might reduce the propellant needed by a factor of about 10 with potentially large savings in launch mass and the $400 million cost of the Titan IV.

Although the electric power required for the drive -- especially at Saturn -- would certainly be a serious problem, various possible tradeoffs and solutions could not even be seriously considered, because no demonstrated ion drive existed. All that is now changed, and I suspect that the huge advantages in propellant mass offered by ion drives will prove irresistible to mission designers beginning in the near future.

A burn of similar magnitude (actually somewhat greater in velocity) is to be performed by the NEAR spacecraft less than 2 days hence (on 20 December) as it matches its velocity with the large Near-Earth Asteroid 433 Eros, prior to orbital capture.

On 10 January 1999 NEAR should settle into its initial orbit, several thousand km out. A year from now our knowledge of this fascinating little body (a mere 10^{13} tons or so) will have been revolutionized. Again I have written of the mission here, as recently as November; but all that will soon be swept away as real knowledge replaces guess and speculation. For more on NEAR, see:

http://near.jhuapl.edu/.

After several years of waiting for flight, SWAS (Submillimeter Wave Astronomy Satellite), one of NASA's original Small Explorer Missions (SMEX; SWAS was selected in 1989) has finally been launched, on 5 December, into a 70° inclination 600 km circular orbit by a Pegasus air-launched booster.

SWAS will study star formation in dense clouds by examining the emission of a variety of common intra-cloud species, such as water, O_2, carbon monoxide, and atomic carbon. The ability of such clouds to cool effectively by radiation is a major factor controlling their subsequent collapse into stars, and the emission of these molecules is believed to be their major cooling mechanism.

However, it is largely unobservable from the ground due to interference from the Earth's atmosphere. SWAS is a submillimeter wave telescope operating just on the borderline between the radio and the far infrared.

At about 500 GHz (wavelength 600µ) it may be considered on the "radio" side largely because of its use of dual heterodyne 487 GHz-556 GHz radiometers and an acousto-optical spectrometer -- detecting techniques of radio astronomy rather than methods known in the IR.

So far everything seems to be operating well, as the systems are checked out in orbit prior to the 1--2 year period of scientific observations. A URL with further links for SWAS is at:

http://pluto.harvard.edu/cfa/oir/Research/swas.html.

Another SMEX, known as WIRE, the Wide Field IR Explorer, is a mid-infrared telescope which has been proposed and developed here at IPAC, and is being prepared for launch on 26 February 1999. It is primarily intended to study the birth and evolution of so-called "starburst" galaxies, at distances where cosmological evolution is significant.

Such galaxies contain regions of extremely rapid star formation, often harboring many massive, luminous young stars, but which are typically buried in dust so thick that visible light is largely suppressed, and only infrared from the warm dust escapes.

It is based on a small 30 cm telescope operating at 12µ and 25µ, cooled by solid hydrogen to less than 7° K.

It is expected that its objectives, including the observation of tens of thousands of starburst galaxies, can be fulfilled in only 4 months. The spacecraft is based on the SWAS design. More information may be found at:

http://www.ipac.caltech.edu/wire/.

Finally, also at IPAC, the first "sampler" data from the Two Micron All-Sky Survey (2MASS) have just been publically released.

We discussed 2MASS here in March 1998. The 2MASS Sampler includes just one night of survey data, that taken by the northern observatory on 16 November 1997.

It is remarkable that just this one night of 2MASS data exceeds that from the entire year of operation of the first IPAC mission, IRAS, the Infrared Astronomy Satellite, which was flown in 1982-1983.

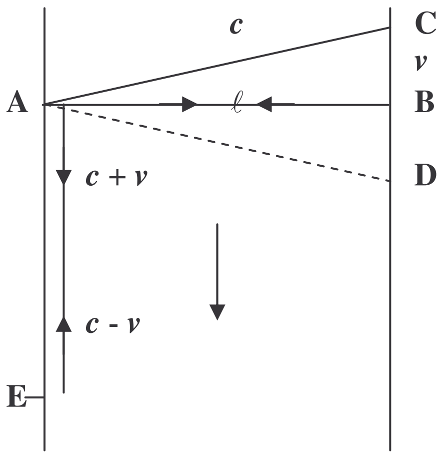
A larger data release is planned for the spring of 1999; for more information, see:

http://www.ipac.caltech.edu/2mass/.

Relativity (part II)

by Eben van Zyl

Now let us take the case of a moving medium, a river of width ℓ and flowing at a steady speed $\boldsymbol{v}$. We have two contestants, Alf and Ben, each with an identical motorboat and with identical throttle settings so that their speeds in still water are identical. Alf has to sail across the river from A to B and back. Ben has to sail downstream a distance ℓ equal to the width of the river, and then back against the stream. On the downtrip over a distance ℓ he is therefore assisted by the speed $\boldsymbol{v}$ of the stream, while on the uptrip he is retarded by the water flowing at a speed of $\boldsymbol{v}$. Alf, going across the river and back again is not accelerated or retarded by the flowing water.
Who will win, or will it be a tie? Let's vote.
Tie…. Alf wins…. Ben wins….



Alf must steer his boat in the direction AC so as to land at B. His speed is $\boldsymbol{c}$, but his effective speed is indicated by length AB.

From Pythagoras' Theorem we know that:

$$AC^2 = AB^2 + BC^2$$

$$\therefore \quad AB^2 = AC^2 - BC^2$$

$$\text{or} \quad AB^2 = c^2 - v^2$$

$$\therefore \quad AB = \sqrt{c^2 - v^2}$$

[4800 years ago, the Egyptian priests knew that a triangle with sides 3, 4 and 5, had a right angle opposite the side of length 5.]

Therefore Alf's time across and back

$$= \frac{AB + BA}{\sqrt{c^2 - v^2}} = \frac{2\ell}{\sqrt{c^2 - v^2}}$$

Ben's time down and up $= \dfrac{\ell}{c+v} + \dfrac{\ell}{c-v}$

$$= \frac{\ell(c-v)+\ell(c+v)}{(c+v)(c-v)}$$

$$= \frac{\ell c - \ell v + \ell c + \ell v}{c^2 - v^2}$$

$$= \frac{2\ell c}{c^2 - v^2}$$

$$\frac{\text{Alf's time}}{\text{Ben's time}} = \frac{2\ell}{\sqrt{c^2 - v^2}} \div \frac{2\ell c}{c^2 - v^2}$$

$$= \frac{2\ell}{\sqrt{c^2 - v^2}} \times \frac{c^2 - v^2}{2\ell c}$$

$$= \tfrac{1}{c}\sqrt{c^2 - v^2}$$

$$= \tfrac{1}{c}\sqrt{c^2\left(1 - \frac{v^2}{c^2}\right)}$$

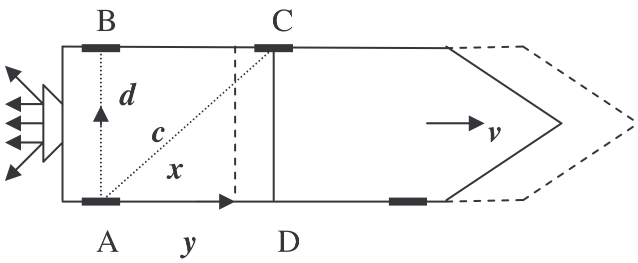
$$= \tfrac{1}{c} \times c\sqrt{1 - \frac{v^2}{c^2}}$$

$$= \sqrt{1 - \frac{v^2}{c^2}}$$

v^2 / c^2 is < 1 and 1 - v^2 / c^2 is < 1 and when $v = c$, we have $\sqrt{1-1} = 0$. When v is greater then c we have square root of 1 minus something greater than 1, i.e. square root of something less than 1, which is impossible, proving than v cannot be greater than c.

Therefore Alf must win, because his time is less than Ben's time.

Now let us leave the slowly flowing river, and consider a rocket ship whose speed is v and whose diameter is d. Consider a ray of light (speed c) being sent across the rocket



from mirror A to mirror B where it is reflected back to mirror A. This will happen as long as the ship is stationary. But when the ship moves at speed v, the mirror B will have reached point C when the ray of light reaches it.

Let the distance AC be indicated by x. Let AD (= v) be indicated by y. $y \div x$ is called the <u>time distortion factor</u> in a spacial sense. In terms of velocity, the time distortion factor is given by v ÷ c, as is clear from the diagram.

$$\frac{y}{x} = \frac{v}{c},$$

$$\therefore \quad y = x\left(\frac{v}{c}\right)$$

By Pythagoras: $x^2 = y^2 + d^2.$

$$\therefore \quad x^2\left(1 - v^2/c^2\right) = d^2$$

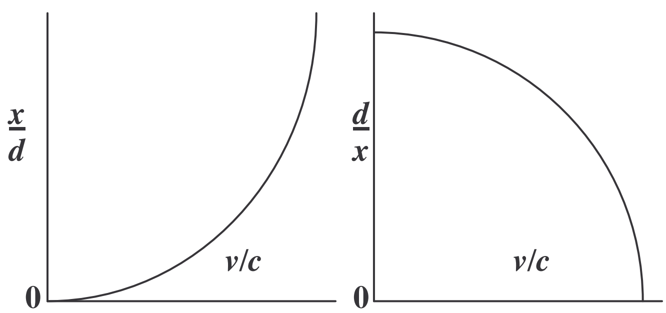
Thus $x^2\left(1 - v^2/c^2\right) = d^2$

$$\therefore \quad \frac{x^2}{d^2} = \frac{1}{1 - v^2/c^2}$$

$$\therefore \quad \frac{x}{d} = \frac{1}{\sqrt{1 - v^2/c^2}}$$

This is the time distortion factor which tells us how much further the light ray must travel when the spaceship is moving compared to when it is stationary.

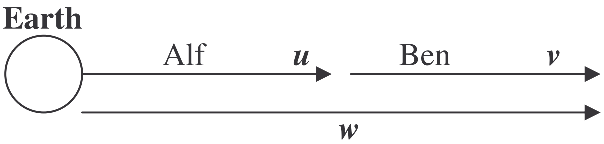
A graph of x/d against v/c shows that x/d increases exponentially for large values of v/c so that the values of x/d read from the graph, become inaccurate. But if we plot the inverse d/x against v/c, we obtain a graph from which all values of d/x can be accurately read off, for given values of v/c.



ADDITION OF VELOCITIES

If Alf moves off from the Earth at velocity $\boldsymbol{u}$ and Ben moves off from Earth at velocity $\boldsymbol{v}$, relative to Alf, what is Ben's velocity relative to Earth?

In other words, what is the sum $\boldsymbol{w}$ of Alf's and Ben's velocities? According to classical mechanics, we say $\boldsymbol{w} = \boldsymbol{u} + \boldsymbol{v}$. But if $\boldsymbol{u}$ = 0.5c and $\boldsymbol{v}$ = 0.6c, say, then $\boldsymbol{w}$ = 0.5c + 0.6c - 1.1c, which is impossible because no velocity can be greater than the velocity of light $\boldsymbol{c}$.



The product of the time distortions for Alf and Ben is $\boldsymbol{xy}$ and = $\boldsymbol{w}$.

Thus $$\frac{1}{\sqrt{1-u^2/c^2}} \bullet \frac{1}{\sqrt{1-v^2/c^2}} = \frac{1}{\sqrt{1-w^2/c^2}}$$

$$\therefore \frac{1}{\frac{c^2-u^2}{c^2}} \bullet \frac{1}{\frac{c^2-v^2}{c^2}} = \frac{1}{\frac{c^2-w^2}{c^2}}$$

$$c^2 - w^2 = \left(c^2-u^2\right)\left(c^2-v^2\right),$$

so that $$w^2 = c^2 - c^2\left(1-\frac{u^2}{c^2}\right)\left(1-\frac{v^2}{c^2}\right)$$

$$\therefore w^2 = c^2\left(1-\left(1-u^2/c^2\right)\left(1-v^2/c^2\right)\right)$$

$$\therefore w = c\sqrt{1-\left(1-u^2/c^2\right)\left(1-v^2/c^2\right)}$$

$\boldsymbol{w}$ cannot exceed $\boldsymbol{c}$ because:
$\left(1-u^2/c^2\right)\times\left(1-u^2/c^2\right)$
subtracted from 1 is < 1.

$$w = c\sqrt{1-\left(1-u^2/c^2\right)\left(1-v^2/c^2\right)}$$
$$= c\sqrt{1-\left(1-\left(0.5c^2\right)/c^2\right)\left(1-(0.6c)^2\right)}$$
$$w = c\sqrt{1-(1-0.25)(1-0.36)}$$
$$= c\sqrt{1-0.75\times 0.64}$$
$$w = c\sqrt{1-0.48}$$
$$= c\sqrt{0.52}$$
$$= 0.72$$

and not 1.1c.

A rigid measuring rod which moves at speed $\boldsymbol{v}$ will contract so that its length at rest, ℓ_0, becomes $\ell = \ell_0 \div \sqrt{1-v^2/c^2}$.

The mass of the body which moves at speed $\boldsymbol{v}$ will increase so that its mass at rest $\boldsymbol{m}_0$ becomes $m = m_0 \div \sqrt{1-v^2/c^2}$.
At 0.99c, mass increases 7 times.

Time slows down so that
$t = t_0\sqrt{1-v^2/c^2}$.

For ordinary speeds $\boldsymbol{v}^2 / \boldsymbol{c}^2$ is infinitesimally small and 1 - $\boldsymbol{v}^2 / \boldsymbol{c}^2$ is practically equal to 1 - 0 and thus equal to 1. But when $\boldsymbol{v}$ becomes an appreciable fraction of $\boldsymbol{c}$, the effect becomes noticeable.

Jets of Hydrogen are being ejected from the pulsar SS 433 at speeds of 80,000 km per second. These jets undergo precession and as they change over from approaching the Earth to receding from the Earth, there is still a residual velocity of 12,000km per sec. This is exactly 4% of the speed of light and is equal to the time dilation which takes place when the gasses are moving at 80,oookm per second or 26% of the speed of light. This is a beautiful confirmation of Einstein's theory of Special Relativity.

………to be continued

A visit to the super modern Carl-Zeiss Planetarium of Stuttgart, Germany

by Wolf Lange.

I had the privilege to visit the Carl-Zeiss Planetarium in the southern city of Stuttgart, Germany in September 1998.

Stuttgart is best known for being the home of the Head-offices of both Mercedes Benz and Porsche, this means it has potential for good sponsorship of science and technology supportive institutions such as Planetariums.

The city of Stuttgart was heavily bombed by the allies during the last war and the originally Planetarium was also damaged in the process. In 1977 the new Planetarium was opened to the public with instant appeal and had since then been visited by 3 million visitors and a further 1 million attended lectures, courses, musical programmes and art exhibitions.

It works in close association with a nearby active observatory, which like our own in Johannesburg, has been hampered by the encroaching city and associated air and light pollution. 277 visitors can been seated in the Planetarium with a further 188 and 60 respectively in adjacent lecture rooms (see diagram). One of the latest star projector: Model VI A, is in use and the normal shows run in fully programmed & automated mode from start to finished. A permanent staff of 11 run the entire complex which houses inter-alia an electronic, optical and mechanical workshop plus a photo lab and a comprehensive library.

"SPICE" (not the girls) Automatik, runs the steering mechanism and this is supported by over 300 different projectors including Allsky, Sky Skan, Talent and ROHA systems. Sound comes from 2 channel Dynacord Mixerboard with a potential of 5 000 Watt output through 67 loudspeakers with 11 amplifiers. A number of HE-NE, Argon and Krypton lasers are in use with a supporting PC driven laser graphic system.

16 to 25 shows are held weekly with focus on schools during the week and public shows over the weekend. Every two months new shows are produced, recent ones included shows on Mars, twin-triplet-quadruplet suns, dying stars, the latest southern sky observations and on comets the sojourners of our solar system. What impressed me most was a recent addition (last 10 years) of a system allowing live viewing in the foyer of the weather all over the world with pictures received from both geo-stationery Meteosat and also polar circumventing NOAA and METEOR satellites. There are also a limited number of interactive features for public use.

The Carl-Zeiss Planetarium gives some indication where things are going, as plans are being made to have their automated shows supplemented by live views brought about by various satellites and the HST. Plans are being made to share live observations from around the world and let both scientist and layperson participate in analysing, questioning and having the whole programme televised for public consumption. Astronomy courses and lectures can be vastly enhanced using these satellite and HST type inputs, allowing those who have no access to telescopes to share observations. "Far-fetched" you may say, don't you believe it, the Germans and Americans are working on this at an advanced stage. It certainly bodes well for the future of astronomy to widen its access at an affordable price to the people.

Germany being a country where music is a major part of the culture, especially of the classical variety, there is no shortage of both modern and classical music in support of all shows. Classical masters such as Strauss, Debussy, Holst, Schumann, Bruckner and others being heard as well as Pink Floyd, Kitaro, Morricone, Oldfield, Schulze and Duval mixing it in.

It was both educational and enjoyable to see this truly modern well run Planetarium at first hand. It is not easy and it would be most unfair to compare the Carl-Zeiss Planetarium to our own Johannesburg Planetarium, which is more in line with the more traditional Planetariums such as the one in Vienna and other older Planetariums. The purpose however remains the same: bringing the starry skies to the ordinary man, women and child in a very realistic way (both scientific and artistic) – enhancing our knowledge and understanding of the universe in which we reside.

How to Build a Star

PART II…..

The British astronomer R. d'E. Atkinson was the first to suggest, in 1931, that the capture of a proton by an atom could liberate enough energy to light the sun. Eight years later, Hans Bethe and C. von Weizacker presented the same idea but marshalled better evidence for it in their study of thermonuclear fusion process known as the carbon-nitrogen-oxygen, or 'CNO cycle'. The CNO cycle was soon found to work well for stars like our own sun where internal temperatures had been estimated to be about 20 million degrees. Yet, the majority of the stars in the sky were less luminous than the sun. The red dwarf stars like Kruger 60A whose core temperature was only 16 million degrees was a case in point. That slight temperature difference translated into a 100-fold reduction in energy production and a predicted luminosity for Kruger 60A about 100 times fainter than it was known to be. So, what is it that powers stars cooler than the sun?

The answer was provided by Hans Bethe who showed that a fusion reaction which converted hydrogen into helium, but not involving the CNO reaction, would work at these low temperatures. More advanced burning cycles have been studied since then which are capable not only of supplying even greater quantities of energy to support a star against gravitational collapse, but reactions capable of creating all of the known elements in the periodic table, in the cores of very massive stars. The first stellar models that showed, in detail, how a star evolves from the hydrogen fusion phase called the 'main sequence', through the red giant phase did not become available until electronic computers were developed. Prior to the advent of computers, the computations had to be done by hand using desk calculators. This led to trade-offs between using a crude model of the star's interior and taking many steps in time, or using a moderately detailed model of the interior but taking only a handful of time steps.

In 1955, R. Harm and Martin Schwarzschild published 15 ‘models’; some calculated by hand, others by using the electronic computer at the Princeton Institute for Advanced Study. The models presented the star's interior in three zones: the core, the outer envelope and the intermediate zone where convection would likely occur. Radiation pressure was ignored, as were differences in chemical composition between the zones, and no internal energy source was treated in detail. It took one full year of laborious work on a desk calculator to construct the hand-calculated models that were computed for a total of 127 time steps. The models specified the changes in 18 quantities in each of the three zones. In contrast, the computer-generated model was followed for 37 time steps and required less than a day to compute. Continuing in a steady progression as faster computers were developed, present-day computers can calculate complete stellar models in less than one minute! The computational extension of the models from the hydrogen burning phase to later stages began in earnest in 1961 with the appearance of several papers announcing detailed, independent studies of 5, 10 and 15 solar mass stars by Chushiro Hayashi, Robert Cameron and Emil Polak. They used IBM 650 and 7090 computers, splitting each star into a dozen or more internal shells. Their program followed the evolution of each star's structure, shell by shell, through the helium burning stage. For the most massive stars, the carbon and neon fusion stages were followed as well. They watched as the stars swelled to enormous dimensions and became red supergiants, as their cores collapsed switching first to helium burning, then to carbon and neon.

By 1964, the role of neutrinos in producing added pressure in the dense cores of more massive stars was discovered and incorporated into the models. John Cox and Edwin Salpeter also examined the evolution of stars where electron degeneracy pressure was important. A similar calculation for stars 4 to 8 times the mass of the sun done by David Arnett in 1969 showed that if the carbon burning cycle was triggered in a core that was degenerate, the entire star would blow up in a 'Carbon Detonation Supernova'. Whether anything was left behind other than an expanding cloud of gas seemed to depended very critically on the density of the star's core before the detonation, and just how much pressure the neutrinos escaping from the star's core produced in the overlaying matter. Depending on the core's density and mass, what would be left behind the star after this explosion would be: nothing, a white dwarf, or possibly a neutron star.

Since the 1960's, computer models have become more sophisticated. Periodic revisions have been made in the number of nuclear reactions that are considered, as well as updates in the reaction rates and energy yields based on more exact theoretical calculations supplemented by experimental results. The detailed role of convective mixing in transporting energy from place to place within the star and changing the composition of the star is also being studied, as are the roles of rotation and mass loss. As the models become more refined, they are used to an ever-increasing degree in explaining the observed details of known stars. Some stars show an overabundance of certain elements over others that cannot be entirely explained by temperature effects alone. This suggests that convective mixing seems to be the culprit, wherein the elements in deeper layers in the star are mixed with the visible surface layers. Then again, for the peculiar A-type stars, convection may be suppressed by strong magnetic fields that have been measured on the surfaces of these stars, so that atomic diffusion driven by radiation pressure may be a more important factor.

A related area of study concerns the evolution of binary stars. The presence of a nearby star can alter the evolution of both stars, especially if matter is being pulled from one companion and dumped onto the other. The gravitational stresses that result inside a star with a close companion can alter convection patterns and mix enriched hydrogen gas with hydrogen depleted material in the core, so that one star, essentially, gets to re-live its youthful, hydrogen burning phase all over again as though it had just been born. The final stages in the evolution of stars are also of great theoretical interest. Exactly how do planetary nebulae form? How are neutron stars and black holes produced from supernova explosions? Do all supernovae produce identifiable remnants? Although we are tantalisingly close to answering these questions and can do so in general terms, the details are still a bit vague.

I have spoken about mathematical models for stars, but I have not really described for you what I mean by this terminology. How do you reduce a pinpoint of light in the sky into a collection of equations, and what would these equations look like? The basic equations defining the structure and evolution of a star have been known for nearly a century. They describe what determines whether a star is stable, or subject to gravitational collapse. They describe how energy is transported from the core of the star to its surface, and how the density and temperature of the gas varies from the core to the surface. This theoretical model must also describe how much energy is liberated by the various possible fusion reactions occurring in each gram of matter in the core. When we express all these relationships and interdependencies in symbolic form, we get the 'equations of stellar structure'.But these equations are not enough because you also have to specify how the pressure inside a star, which supports it against gravitational collapse, is dependent on the values for other physical quantities like a star's chemical composition, temperature, and density, which may, in turn, change from place to place inside the star. The amount of energy released in the thermonuclear fires in the star's core, also depend on these quantities as does the stellar opacity. The equation linking the pressure to the other variables is called the 'Equation of State' by the astronomical cognoscenti, and its form can change as the star evolves or as you dissect the star and examine various layers within it. The pressure due to light radiation and high temperature gas is usually expressed by, For high gas densities near 10^5 grams/cc, we also have to include electron degeneracy pressure, caused when electrons are squeezed together into a small volume. The opacity of a star determines how transparent it will be to its own emitted light radiation. Since radiation pressure is in many cases the most important internal support for a star, its accurate specification is crucial. Depending on the kind of interaction involved between matter and the light streaming out from the star's deep interior, the mathematical description of the transparency of the star's matter takes-on a variety of different forms. The sum total of these will determine how opaque the star is at a particular point in its interior, and how much radiation pressure will result. To write down all the different forms of the matter-radiation interaction that contribute to a star's opacity would easily fill a book of this size!

Although gravity is the ultimate source of energy for heating a star's interior, it is the nuclear reactions that provide the energy from which the star's internal pressure is ultimately derived. A complicated network of interdependent equations is required to account for the energy released by fusion reactions and how they change the internal element composition of a star. These describe how rapidly one element is converted into another by fusion or radioactive decay, and shows how the rate of energy release depends on the local temperature and density of the star.

To assemble these equations, one must first write down all the important pathways by which the conversion from one element to another occurs, and the energy released at each step. For example, when the cores of stars more massive than the sun reach temperatures exceeding 100 million degrees, the so-called Triple Alpha reaction becomes important in supplying the thermal pressure needed to prevent further gravitational collapse. In this fusion reaction, two helium nuclei fuse into a single beryllium nucleus; then, after an additional helium nucleus fuses with the beryllium, one obtains a single carbon nucleus as nuclear 'ash'. The reaction also produces a considerable amount of energy.

At still higher temperatures appropriate to pre-supernova conditions where temperatures exceed 5 billion degrees, one encounters reactions that convert carbon into oxygen, oxygen into magnesium and silicon, and finally silicon into iron. All these reactions are very temperature sensitive. For instance, in Triple Alpha fusion, the reactions produce 10 times more energy at 105 million degrees than at 100 million degrees! Where does a star get the high energies and temperatures to allow these reactions to proceed? The answer is from the gravitational collapse of the core of the star under its own weight. Just as a rock gains speed and kinetic energy as it falls to the ground unsupported, the matter inside the core of a star, if unsupported by a counter-balancing pressure, will continue its fall towards the stellar core. In so doing, it gains kinetic energy that appears as an increase in temperature of the gas.

The change in the chemical composition of a star as it 'burns' one element and leaves behind another as a nuclear 'ash' can be represented by yet another set of equations. Modern nuclear reaction networks such as those used to study the last years of a star about to become a supernova, incorporate over 250 nuclear species and their isotopes, along with their highly interdependent equations of interconversion. Having considered the interior of the star and what goes into describing its inner workings, what of its outer layers?

How does a star look to a distant observer? All you see through the eyepiece of the most powerful telescope is the radiation emitted by the surface of the star. The interior is completely hidden from view. Not only that, but the light produced in the star's dense core requires millions of years to reach its surface, before it can start its journey to earth. There are models available for predicting the strengths and shapes of the atomic spectral lines emitted by the surface gases, but these models depend on the temperature, density, composition and surface gravity of the star.

You can obtain predictions for these quantities at a particular instant in the life of a star using your stellar evolution model. These 'stellar atmosphere' models are very complicated; to merely write down the necessary equations would fill up several books this size. The most sophisticated model now in routine use is the one developed by Robert Kurutz at the Centre for Astrophysics in Cambridge, and his co-workers. His model contains 1,760,000 spectral lines for elements between hydrogen and nickel, and computes the expected spectrum shape and line intensities for most kinds of stars commonly studied in detail.

In addition to high temperature plasmas of charged atoms, stars are known to contain magnetic fields. A detailed study of the sun reveals a strong surface field of about 1 gauss, and sunspots where the fields are thousands of times stronger, along with a periodic 22-year cycle of magnetic polarity reversal, better known as the Sunspot Cycle. Other phenomena related to stellar magnetic fields include prominences, flares and coronal holes. Magnetic fields have been detected on nearly 100 stars, mostly of the peculiar A-type, which have surface fields 100 to 30,000 times stronger than the sun's. Sunspot cycles have also been observed on a number of nearby stars. Thanks to the rapid influx of data from satellite observations of the sun, and long-term studies from ground-based earth observatories, the detailed description of the role of magnetic fields in our sun has evolved rapidly from crude 'back of the envelope' calculations to highly sophisticated theoretical models. Presumably, the physics of the magnetic fields on more distant stars can also be described by this same theory, or simple modifications of it.

Solar Dynamo Theory provides a mathematical framework for understanding…..

…….***and next month the conclusion.***

Deep Space 1 (DS1) news

from Bill Wheaton

The ion drive on Deep Space 1 started Tuesday (after refusing to stay on properly at first, 10 days earlier -- probably due to contamination shorting its high-voltage accelerating grids), and has been working well ever since.

Great joy at JPL.

Acceleration is about 0.00002 gravities, which (if I have it right) works out to 2085.2 sec to do the standard 1/4 mile drag race, hitting a sizzling 0.86 miles per hour at the end. (Onlookers at the National Ion Drive Drag Races traditionally break for lunch between start and finish.)

Lest I sound scornful, it also works out to about 5.5 km/sec in a year (although DS1 only has enough Xe fuel aboard to run about half that long). The Cassini mission to Saturn was launched on a $400 M Titan IV because of its huge (? 5,500 kgm if I recall) launch mass, much of which is rocket propellant needed to get it into orbit around Saturn. It is in such applications that even the first-generation DS1 ion drive promises a revolution, especially when combined with the gravity-assist technique that has been developed to a fine art in the last decade.

Cheers to all --

Bill W.

I received the following information as an eMail from Raymond and thought it might be of interest to all of you ASSAguys and gals out there.
Chris.

Satellite tracking

http://liftoff.msfc.nasa.gov/realtime/jtrack/

Have a look at NASA's J-TRACK 3D java applet (go to the URL above, and look for the J-TRACK 3D link at the lower right of the page).

The applet takes awhile to load, but it is amazing - allowing you to track ANY satellite (as well as other orbiting bodies like the shuttle, MIR and the first chunk of the International Space Station) in real time as it orbits the earth. You can zoom in/out, rotate the planet, and get quite detailed info on every body (though most of the military satellites have minimal info :-)

A message to our Descendants

I received the following from a regular contributor to the ACC-List of which I am a subscriber. . . . .Chris.

I thought the readers of this list might like to learn about the KEO Project:

(http://www.keo.org/).

To quote from SpaceViews:

The KEO project is a French effort to preserve a piece of our heritage for distant generations.

The spacecraft, so named because "K", "E", "O" are the most common phonemes in Earth's major languages, would fly in a high Earth orbit for 50,000 years starting in 2001, carrying written greetings from ordinary people along with biological samples and a comprehensive library of human knowledge. The Web site has more information about the project and a form for users to submit their own greetings to be carried on the spacecraft.

I urge everyone who reads this letter to check this site out. It is really a fantastic project that makes one think about our species' place in the grand scheme of time and space, and really forces you to take a hard look at the past and future of humanity.

Alex Michael Bonnici

Puzzle Corner
Build Some Constellations

How many constellations can you make out of the letters in this grid?

T	N	R	M	L	U
U	E	Y	A	R	X
P	I	R	C	O	G
B	T	L	E	N	A
S	A	S	U	I	I
E	M	E	C	A	S

TARGET: 51 Constellation Names

Bonus: Which constellations were used as the basis for the grid?

YEAR-END STAR (?) PARTY

12th December, the very last lap of 1998 dawned cloudy - so what else is new when planning to do any sort of stargazing. What bliss, the clouds lifted by noon, and we were all ready to make the trek out to "Uncle Tom's Cabin" where the stars are brighter, and there is still a faint trace of oxygen in the air.

After negotiating a road that a sturdy 4X4 would be proud of, we arrived to the tang of smouldering braai-fires, a very inviting-looking pool, bird-song and shady trees.

Soon our numbers swelled (some faces were missing - *where were you !!*) and the games began. Tom brandished a rather large jar which contained the most delicious cherries - cherries like nature NEVER made them .... these delectable morsels were bobbing in an alcohol brew that would fell an ox. Needless to say, after many of those plump, succulent - or should I say lethal - fruits, we were seeing the most amazing UFOs.

The braai's were laden, food cooked, and many a strange tale told.

Eventually sated with good food, even better cherries and excellent conversation, we said our "good-byes" and negotiated the "road" back to the rat race.

Tom, I am sure that I speak for all who were present, in thanking you for opening your home to us once again - the rag-tag bunch from "Battle Star Gautengia"

Lu Penberthy

Variable of the Month:

R,S,T and TY Coronae Australis

On request of your Editor and as a special Christmas bonus, I am offering no less than four for the price of one.

These are Orion Nebula type variables and vary rapidly, so that the observer need never feel bored. They are in a field which is extremely easy to identify. Not only is there a bright globular cluster (marked 6723) but also a prominent double star (marked 66 68). The stars vary so rapidly that they can be observed profitably every night.

The time of observation should be reported to the nearest minute, or 0.001 day.

Girsh Pulik of the Johannesburg Centre has done a periodigram analysis of thousands of observations by myself and others of the light variations and perhaps he can be persuaded to let CANOPUS readers have a discussion of his results.

The bad news is that the field will be in conjunction with the sun early in January so you will have to wait until March for the field to be observable in the morning sky. But then our January and February skies are hardly conducive to consistent variable star observing.

Enjoy these interesting stars.

Danie Overbeek

185437 a+b (d)
185537 a+b

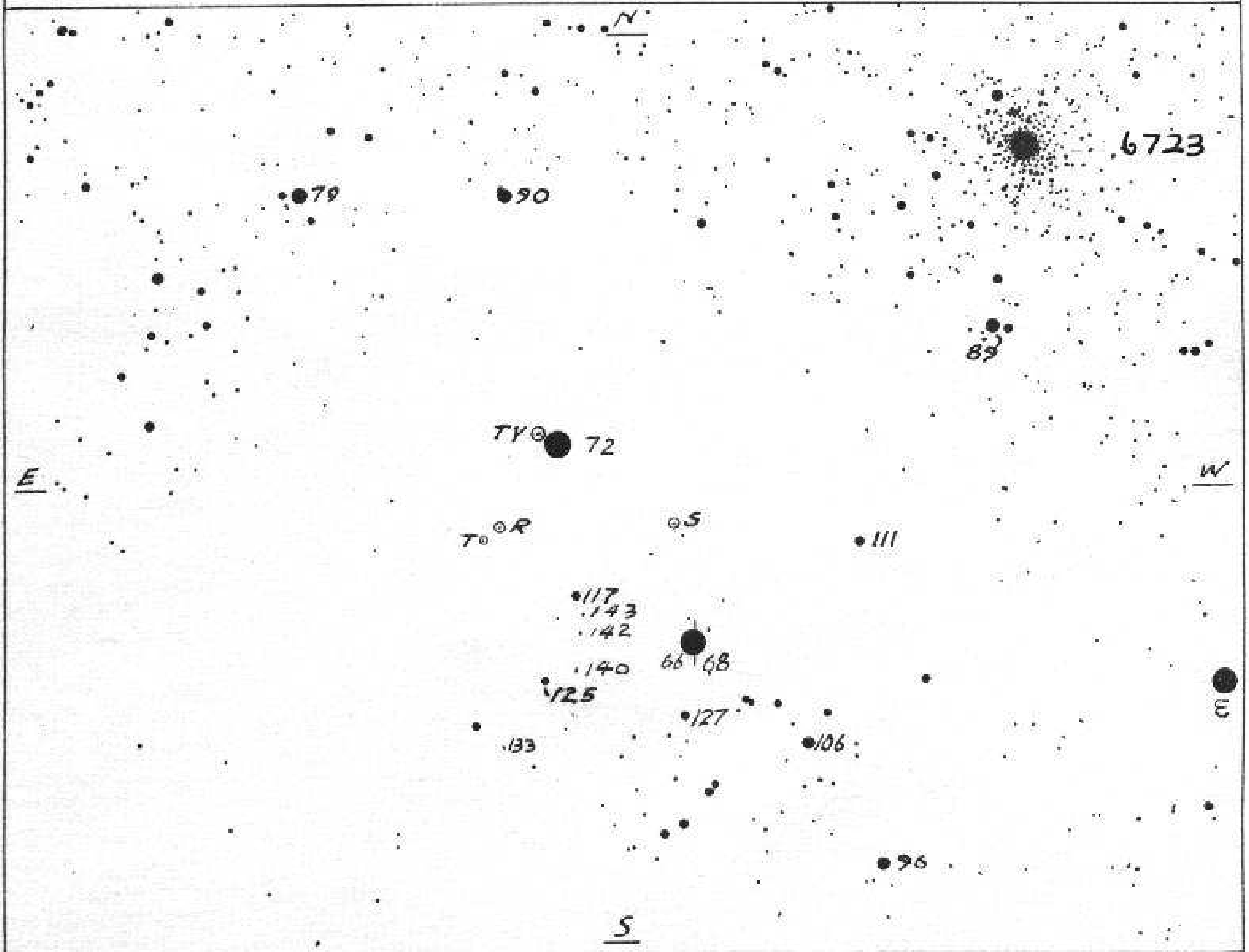
30' Scale.

R, S, T and TY Coronae Australis

These variables are Orion type.

Note:- TY and R are both involved in bright nebulosity which is also variable. TY is north following a bright star - both in the nebulosity.

185437a	S CrA	(1900)	18h 54m 16s	-37° 05'.4	Period	days.
Spec. G5.		(2000)	19 01 18	-36 57.4	Magn.	10.8 - 12.5.
185437b	TY CrA.	(1900)	18h 54m 56s	-36° 0.'9	Period	days
Spec B2.		(2000)	19 01 40	-36 53.1	Magn.	8.7 - 12.4
185537a	R CrA.	(1900)	18h 55m 08s	-37° 05'.6	Period	days.
Spec Gpe.		(2000)	19 01 54	-36 57.6	Magn.	10.0 - 13.6.
185537b	T CrA	(1900)	18h 55m 15s	-37° 06'.4	Period	days.
Spec. F0.		(2000)	19 01 59	-36 58.4	Magn.	11.7 - 13.5.



Mags From R.A.S.-N.Z.

A.A.V.S.O (d) Chart.

Rev. Mar. 1, 1961.

Traced by R.A.S. from Harvard photo. Approved by H.C.O. 1951.

In the Sky this month

January 1999

dd hh	
2 03	**FULL MOON**
3 21	Earth at Perihelion
5 08	Venus 1.8 S of Neptune
5 16	Regulus 0.2 S of Moon Occn.
8 23	Mars 4.4 N of Spica
9 14	LAST QUARTER
9 20	Mars 2.7 S of Moon
11 11	Moon at apogee
13 19	Venus 0.0 S of Uranus
16 17	Mercury 4.6 S of Moon
17 16	NEW MOON
18 01	Neptune 1.7 S of Moon
18 20	Uranus 1.8 S of Moon
19 08	Venus 2.2 S of Moon
21 23	Jupiter 1.8 N of Moon
22 08	Neptune in conj. with Sun
24 06	Saturn 2.6 N of Moon
24 19	FIRST QUARTER
26 22	Moon at perigee
27 07	Aldebaran 0.4 S of Moon Occn
27 07	Mercury 2.3 S of Neptune
31 16	**FULL MOON** Eclipse

February 1999

dd hh	
2 01	Regulus 0.4 S of Moon Occn.
2 02	Uranus in conj. with Sun
2 18	Mercury 1.5 S of Uranus
4 05	Mercury in superior conjn.
7 04	Mars 3.1 S of Moon
8 08	Moon at apogee
8 12	LAST QUARTER
14 11	Neptune 1.7 S of Moon
15 07	Uranus 1.7 S of Moon
16 06	NEW MOON Eclipse
17 01	Mercury 0.2 N of Moon Occn.
18 06	Venus 1.8 N of Moon
18 15	Jupiter 2.3 N of Moon
20 12	Moon at perigee
20 14	Saturn 2.7 N of Moon
23 03	FIRST QUARTER
23 12	Aldebaran 0.4 S of Moon Occn
23 21	Venus 0.2 N of Jupiter
26 19	Mercury greatest brilliancy

Brian Fraser

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