CANOPUS

The Astronomical Society of Southern Africa

Johannesburg Centre

Monthly Newsletter for February 1999

Contents:

The Sir Herbert Baker Library, 18a Gill Street, Observatory, Johannesburg

P.O.Box 93145, Yeoville, 2143

Editorial

February is with us once again - and Orion is well set for evening viewing. The Great Nebula in the sword of Orion is always magnificent and if you have the right equipment, the Horsehead Nebula is yours to capture, either on film or electronically.

NEAR had a near-miss and is due to re-attempt orbit insertion around Eros, sometime around the end of December or early January next year…in space exploration time and timing is always a key factor, as of course are limitations imposed by the amount of available fuel.

Brian has supplied us with the Sky happenings for February and March and we have the final episode of Eben van Zyl's Relativity presentation. Bill Wheaton has given us, as always, an excellent article. This month he writes on the Wide Field InfraRed Explorer (WIRE), and Danie revisits an old friend - UW Cen - which has been behaving somewhat strangely over the last little while.

Another appeal for articles - we published an excellent article a few months back on some deep sky objects, together with the applicable star charts. These were quite well received and we would like to do some more of these articles, and of course from the same authors (*hint…hint*).

We also have another letter to the Editors - this is a 100% increase to the previous total…Wow!

We say a hearty ***Thank You*** to Committee Member Wolf Lange who has agreed to fill the post as Centre Secretary for the balance of the year.

The Editors

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Committee of the Johannesburg Centre of the ASSA for 1998/1999

Chairman	Constant Volschenk	972-6038
Vice Chairman	Evan Dembsky	680-9304
Secretary	Wolf Lange	849-6020
Treasurer	Greg Corbett	453-0220
Librarian	Raymond Barbour	452-7728
Curator of Instruments	Frans van Nieuwkerk	609-8158
Viewing Officer	Constant Volschenk	972-6038
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Editor(s) of CANOPUS	Chris Penberthy	793-7480
	Raymond and Lori Barbour	452-7728

Our Web Address is **www.aqua.co.za/assa_jhb.htm**
Send e-mail to **assa_jhb@aqua.co.za**

Notice of Meeting

The **February** meeting of the Johannesburg Centre of the Astronomical Society, will be held at the Wits University in Lecture Hall P115, on Wednesday 10th February 1999 at 8:00 p.m. We will meet at the Wits Planetarium Parking lot at 19:30 and walk up to the Lecture Hall together.

Topic:

The Physics Magic Show
by
Tony Voorvelt.

Future Meetings

Feb 10th	Computers and Astronomy	Tony Hilton
Mar 10th	To be advised.	
May 12th	Innes Dome (negotiating)	Tony Voorveld
Jun 9th	History of the Observatory	Constant Volschenk
Jul 14th	AGM at Planetarium	

Dark Sky Viewing

On the Saturday nearest New Moon at Tom Budge's Farm in the Magaliesberg.
Actual dates will be published in later issues of this magazine.

New Members

We would like to welcome the following new Members to the Johannesburg Centre:

Neil Lindsay	Lynette Rens	Cynthia Reynolds
Alan Williams	Paul Silver	David Dickson

…..and a Special Thanks

to all those members who sent donations to the centre this year.

Apprentice Astronomer's Course

We intend starting a course for Apprentice Astronomers fairly soon. If you are interested in attending, or know of someone who is interested in attending, or would like to lecture on the course, please contact Maureen Chitters or Chris Penberthy. The course is aimed at teaching the basics of Astronomy to any who wish to learn, and will probably be held in the Planetarium.

Telescope Driving Course

Constant will be running another Telescope Driving Course for those wishing to learn to drive the Papadopoulis telescope. The dates are still to be finalised and be published as soon as available.

ASSA Symposium

The Cape Town Centre of the ASSA are hosting the ASSA Conference in March 1999. If you require further information or are interested in attending this event, please contact Brian Fraser at fraserb@intekom.co.za

Southern African Astronomical Handbooks

IMPORTANT - Any persons wanting to get a copy of the 1999 Southern African Astronomical Handbook must please get in contact with Constant Volschenk at the Planetarium (011) 716-3199. Constant will need your call fairly soon so as to be able to put in an order with the ASSA Parent body.

Letters to the Editors

31st December 1998

Dear Editors,

ONCE IN A BLUE MOON

In 'THE SKY THIS MONTH' for January 1999, FULL MOON will occur on 02 January at 03hrs and again on 31 January at 16hrs.

According to 'CALENDRICAL CALCULATIONS' by Dershowitz and Reingold:
'For obscure reasons, when two full moons occur within one Gregorian calendar month, every 2-3 years, the second is termed a 'blue moon'.

I wonder whether anyone can shed any (moon)light on the reason for this.

Incidentally, full moon on the 31st Jan will be associated with a lunar eclipse so the moon will be rather more reddish-brown than blue.

Patrick Moore in 'GUIDE TO THE MOON' describes blue moons of a different type, not subject to particular calendar dates, but as being due to dust particles in the upper atmosphere caused by giant forest fires. These are very rare and were observed in 1940, 1944 and 1950.

Yours faithfully
Richard Overy

Thanks for your letter Richard. We'll pass the buck by asking if there are any of our members out there who may be able to answer this interesting question. We will publish any replies received.

The Editors.

Relativity (part III)

by Eben van Zyl

Derivation of the Lorentz Transformation

This is the transformation which is needed to convert a reading ***x***' in the K' system of coordinates to an ***x*** value in the K system, if K' moves with a speed of v relative to the K system. According to classical Galileian / Newtonian mechanics: ***x' = x - vt***.
We are considering motion only along the ***x*** axis. ***y***' and *z*' remain the same as ***y*** and *z*, respectively.

A light signal along the positive ***x*** axis (to the right) of frame K is transformed according to the equation **x = ct, or x - ct = 0** **(1)**

Relative to K' the transformation is **x' - ct' = 0** **(2)**
Space-time points (called events) which satisfy (1) must also satisfy (2).

i.e. $\left(x^{'} - ct^{'}\right) = \lambda(x - ct)$ where λ is a constant **(3)**

In the negative direction $\left(x^{'} + ct^{'}\right)\mu(x + ct)$ where μ is a constant **(4)**

Add (4) to (3) $\therefore 2x^{'} = \lambda x + \mu x - \lambda ct + \mu ct$

$$= x(\lambda + \mu) - ct(\lambda - \mu)$$

$$\therefore x^{'} = x\frac{(\lambda + \mu)}{2} - ct\frac{(\lambda - \mu)}{2}$$

i.e. $x^{'} = ax - bct$ **(5 i)**

where $a = \dfrac{(\lambda + \mu)}{2}$ and $b = \dfrac{(\lambda - \mu)}{2}$ **.**

Equation (3) $x^{'} - ct^{'} = \lambda x - \lambda ct$

Equation (4) $x^{'} + ct^{'} = \mu x + \mu ct$

Subtract (4) from (3) $\therefore -2ct = \lambda x - \mu x - \lambda ct - \mu ct$

So that $-2ct = x(\lambda - \mu) - ct(\lambda - \mu)$

i.e. $ct = \dfrac{x(\lambda - \mu)}{-2} - \dfrac{-dt(\lambda + \mu)}{-2}$

..So that $ct = -bx + act$ **(5 ii)**

The problem now is to find the values of ***a*** and ***b.*** For the origin of **K', x' = 0**
x' = ax - bct. (Equation **(5 i)**), becomes **ax - bct = 0.**

$$\therefore x = \frac{bc}{a}t = vt \qquad \textbf{(6)}$$

and $b = \dfrac{av}{c}$ **or** $v = \dfrac{bc}{a}$ **,** **and** $bc = av$ **.**

v is the relative velocity of the two systems of co-ordinates.

The Principle of Relativity states: Relative to K the length of a unit measuring rod at rest to K', must be exactly the same as the length of the rod relative to K' of a unit measuring rod at rest to K.

Insert a particular value of t (time of K), e.g. **t = 0**,

Then (5 i) becomes **x' = ax - bc(0)**,

So that **x' = ax**

If **x'** increases by 1 unit (infinitesimally small) **ax = 1** so that $x = \frac{1}{a}$ **(7)**

Relative to K' where **t' = 0** , eliminating t from equations **(5 i)** and **(5 ii)** we get: **bct = ax - x'** and **act = ct' + bx .**

Thus $t = \frac{ax}{bc} - \frac{x'}{bc}$ and $act = c(0) + bx$ so that $t = \frac{bx}{ac}$.

$$\therefore \frac{ax}{bc} - \frac{x'}{bc} = \frac{bx}{ac} \quad \text{so that.....} \quad \frac{x'}{bc} = \frac{ax}{bc} - \frac{bx}{ac} .$$

But $bc = av$ and $b = \frac{av}{c}$ from **(6)** $\therefore \frac{x'}{av} = \frac{ax}{av} - \frac{av}{c} \bullet \frac{x}{ac}$

$$\therefore x' = \frac{ax}{av} \bullet \frac{av}{} - \frac{av}{c} \bullet \frac{av}{} \bullet \frac{x}{ac}$$

$$\text{ie} \quad x' = ax - \frac{av^2 x}{c^2}$$

$$\text{so that} \quad x' = a\left(1 - \frac{v^2}{c^2}\right)x .$$

Thus points on the x-axis separated by distance 1 relative to K will be represented by the distance

x' = a (1 - v^2 / c^2)1 and this must be equal to $\frac{1}{a}$ (from **(7)**)

$\therefore a\left(1 - v^2/c^2\right) = \frac{1}{a}$. Therefore $a^2 = \frac{1}{\left(1 - v^2/c^2\right)}$ **(8)**

Equations **(6)** and **(8)** determine the values of **a and b .** Insert these values of **a** and **b** in equation **(5 i) :** $x' = ax - bct$

$$\therefore x' = \frac{1}{\sqrt{1 - v^2/c^2}} - \frac{av}{c} \bullet \frac{ct}{}$$

$$\therefore x' = \frac{x}{\sqrt{1 - v^2/c^2}} - \frac{1}{\sqrt{1 - v^2/c^2}} \bullet \frac{vt}{}$$

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

The Lorentz transformation for events on the x-axis.

The time t' can be derived from: $t' = \frac{t - vx/c^2}{\sqrt{1 - v^2/c^2}}$

It equals the classical transformation divided by $\sqrt{1 - v^2/c^2}$

GENERAL RELATIVITY

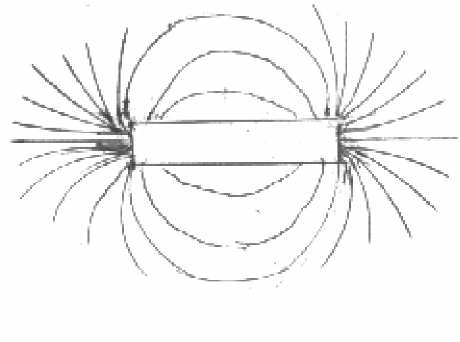
Every motion is relative to reference frames or systems of co-ordinates. In the Special Theory of Relativity, we deal only with displacement of co-ordinate systems in straight lines from the original system. Einstein worded the General Principal of Relativity as follows:

"All bodies of reference are equivalent for the description of natural phenomena, whatever may be their state of motion."

If the motion of a train carriage is changed into non-uniform motion, e.g., by powerful application of the brakes, the occupant of the carriage will also experience a corresponding jerk of push forwards. The Galileian/Newtonian law will not hold for non-uniform motion of the carriage.

According to Newton an apple falls to the ground and the Moon stays in its orbit because they are attracted to the Earth. This action at a distance, through empty space cannot be explained without the intervention of a pervading medium.

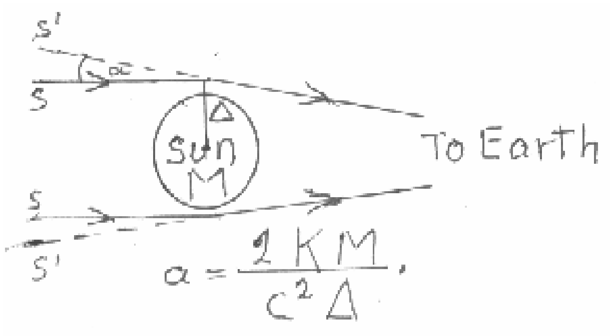
A magnet attracts iron because a magnetic field exists around the magnet and this field acts on iron forming a beautiful pattern of iron filings. With the aid of this field, electro-magnetic phenomena can be theoretically represented more satisfactorily than without it, applying particularly to the transmission of electromagnetic waves.



The Magnetic Field

Gravitation must be regarded in an analogous manner. The Earth (and other bodies) must produce a field which gets weaker inversely proportionally to the square of the distance. All bodies are subject to this field, not only iron.

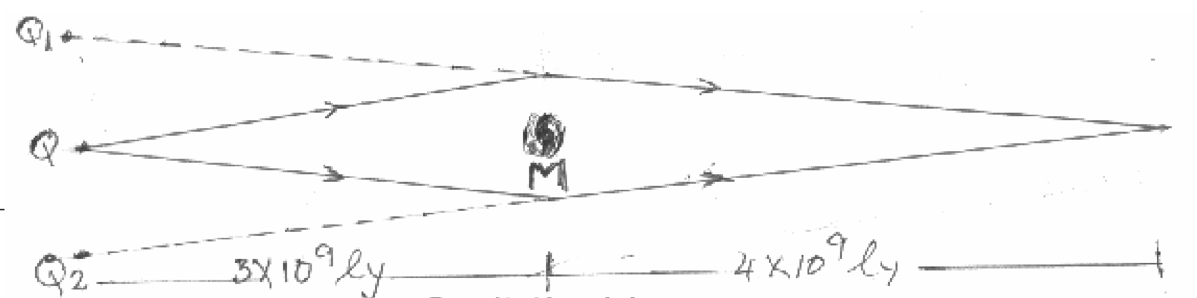
A body moving in a gravitational field experiences acceleration or retardation according to its direction of motion. So too Einstein postulated, that light is propagated curvilinearly in a gravitational field. He calculated from his theory by how much light would be deflected by the Sun, for example. the first opportunity to test this was the total eclipse of 29 May 1919. Photographs showed that stars in the same general direction as the Sun seemed to be deflected outwards from the Sun. This could only happen because the rays of light from the stars were bent by the Sun's strong gravitational field. The average amounts of the deflections of seven stars were:



Light is bent by gravitation

	Observed	Calculated
Right Ascension	20"	18"
Declination	31"	26"

Not only would light be deflected by the Sun, but the light from distant bodies, lying exactly on the line of sight of massive bodies between them and the Earth, would undergo bending, the massive body acting as a gravitational lens.

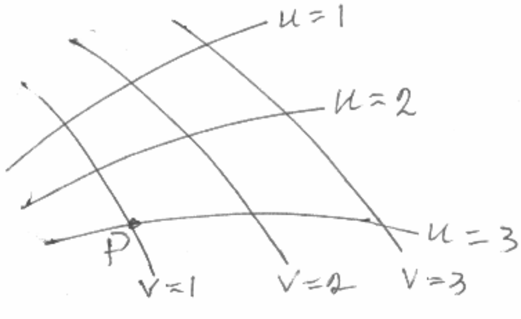


Gravitational Lens

The massive body M, a galaxy or group of galaxies, not necessarily visible, situated at a distance of 4 milliard light years, forms two images Q1 and Q2 of the Quasar Q. Einstein also showed that the image of the distant object could be deformed into a ring. Such an Einstein ring has been observed in the case of the Quasar MG 1131 +04 56 in the constellation Leo, as well as in other cases.

The General Theory of Relativity compels us to adopt new ideas about the space-time continuium, which cannot be Euclidean, but is curved in three dimensions and has time as the fourth dimension.

Einstein made use of Gaussian co-ordinates - a system of arbitrary curves. Neither the u-curves, nor the v-curves ever intersect each other. (vide iron filings around a magnet).



Gaussian Co-ordinates

From this Einstein stated the Principle of Relativity as follows:

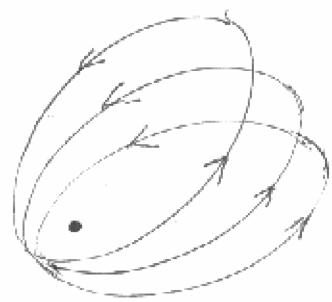
"All Gaussian co-ordinate systems are essentially equivalent for the formation of the general laws of nature".

Moving clocks and measuring rods must therefore be affected by a gravitational field, which, together with matter, must satisfy the law of conservation of energy and impulse; energy and matter, being the two fundamental concepts of nature. That matter and energy are equivalent, were shown by Einstein when he derived the equation $\mathbf{E = mc^2}$, in which **E** is the energy in ergs, **m** the inertial mass in grams and **c** is the speed of light in centimetres per second. If 4 grams of solar, or stellar, matter are therefore converted into energy, the amount of energy liberated will be 2573×10^{16} ergs. This is enough energy to completely vaporise, in one second, a dam of ice-cold water 35 metres in diameter and 1 metre deep. (0.7% of 4 grams is converted).

The energy released by the first atomic bomb corresponded exactly to the amount calculated from Einstein's formula.

Hans Bethe and Carl von Weizsäcker proposed in 1938 (before the first atomic bomb was exploded in 1945), that the Sun's energy is derived from the transmutation of hydrogen into helium according to Einstein's formula.

According to Newtonian mechanics, the elliptical orbits of planets maintain their orientations relative to the fixed stars. But the stars are not fixed; nothing is at rest. Therefore Einstein calculated that the planetary orbits must rotate forwards. The amounts are immeasurably small, except in the case of Mercury, where the observed amount of 43" per century corresponds exactly to the amount Einstein calculated. This was hailed as the first proof of General Relativity.


Rotating orbits

Einstein also showed that the general theory of relativity demands that the spectral lines of stars must undergo a small amount of redshift on account of the effects of the star's strong gravitational fields which lengthen the wavelengths of the emitted light. When the gravity gets concentrated enough, the gravitational field can get so strong that the escape velocity reaches the velocity of light. In this case, no radiation can escape from the centre of gravity, thus forming a GRAVITATIONAL VORTEX, commonly known as a Black Hole.

Karl Schwarzchild calculated that the radius of the EVENT HORISON in the case of a body of mass equal to the Sun would be only 2 kilometres.

Einstein/Weyl/Lorentz: The Principle of Relativity ***Einstein:*** The Theory of Relativity ***Gibilisco:*** Understanding Einstein's Theories of Relativity. ***P G W Davies***: Space and Time in the modern Universe ***A Eddington:*** The Nature of the Physical World.

Variable of the Month:
UW Cen re-revisited.

This interesting variable featured in both the 1998 May and 1998 July issues of Canopus.

It is necessary to add an important footnote to the UW Cen story. Members will recall that in 1997 June, the American amateur Tom Cragg visited the Johannesburg Centre following an AAVSO meeting in Sion, Switzerland. Back in 1990, Tom reported a brightening of UW Cen at a time when nobody else saw the star. Some of us were skeptical and Tom's observation was discounted as "one of those things".

A number of months later, UW Cen brightened to about magnitude 9.5, stayed bright for some years and then faded again. This brings us to the description in the 1998 May Canopus, where I said that it was at minimum and invisible. Lo and behold, the VSNet, an active Japanese organisation, announced last month that UW Cen had brightened to mag 12.6 during November, fading to invisibility within a few weeks. I missed seeing it due to bad weather and visit to Australia but should have seen it on at least one night. Berto Monard of Pretoria did in fact observe it during its outburst and remarked that something funny is going on.

So Tom's 1990 observation was probably a good one and it all goes to show that we cannot have too many amateurs watching a given star. I sometimes get the impression that amateurs tend not to observe, thinking: "What's the use, the regulars are all watching it".

Nothing can be further from the truth so go out there, observe UW Cen and help the astrophysicists to unravel its mystery.

Danie Overbeek.

JPL and NASA News

Bill Wheaton, IPAC

1999 February

WIRE Launch Approaches

Last month in the quick survey I gave of a busy period, I included a few sentences about WIRE, the Wide Field IR Explorer. This month I want to return to my habit of trying to give a more thorough discussion, and talk about WIRE in some detail. WIRE is a good example of the NASA Small Explorer Program (SMEX) ideal: a mission narrowly focused on a question of great current scientific interest.

When we look at galaxies in the local universe, we see, at the coarsest level:

- elliptical galaxies, which consist of a smooth distribution of trillions of old stars, with almost no gas and dust, and hence no new stars being formed;
- spiral galaxies, which, in their disk and arm regions, are full of gas and dust and evidently forming stars at a fairly rapid rate; and
- *starburst galaxies*, which are extremely dusty and gassy systems, in which stars are forming very rapidly.

Because starburst galaxies contain so much dust and gas, visible and ultraviolet light from the main energy-emitting, star-formation regions is heavily absorbed, to be re-reradiated mainly in the infrared. Thus starburst galaxies were first clearly identified as a class by IRAS, the Infrared Astronomical Satellite, which first mapped the sky in the 12, 25, 60, and 100 µ; bands in 1983-1984. Classic examples are M82, an irregular-looking companion of M81, and the large dusty spiral NGC 253, both of which are only about 10 million light years away (M lt-y; hence seen, as usual, as they were 10,000,000 y ago, the *look-back* time); and also the spectacular highly-disturbed system Arp 220, at well over 100 M lt-y distance. Evidently, the ellipticals used up their store of gas long ago, whereas for typical spirals, it is estimated that the observed gas will last for several 10^9 years (Gy) at the current estimated rates of star formation, up to as much as 10 Gy in some cases. For starburst galaxies, by contrast, star formation is proceeding so rapidly that the observed store of gas will be exhausted in less than 1 Gy, so such galaxies must be transient, short-lived phenomena.

In the more distant, older, universe, a key mystery is the way in which galaxies formed, and the role of star formation in the process. It is highly suggestive to suppose that the nearly gas-free elliptical galaxies we now observe are the remnants of ancient starburst galaxies, which used all their gas during the early history of the Universe. The possibility that the stars formed first, and then collapsed into galaxies, seems ruled out because the time for an extended cloud of stars to collapse into a galaxy is estimated by calculation to be *very* long, much longer than the maximum reasonable estimates of the age of the Universe. The possibility that the gas collapsed first, and then led to star formation after the gross structure of the galaxies was set, is alive and well; as is the intermediate possibility, that smaller clumps of gas first formed smaller galaxies, in which stars formed early, and that these small galaxies then collided and aggregated to form the largest galaxies we see today. Until recently, the most distant galaxies that could be observed (excluding QSO's) were at redshifts z of less than about 1, corresponding to distances of 5-10 G lt-y (depending somewhat on the cosmological model), and ages of half the age of the Universe, now very roughly estimated as 15 Gy. With the advent of the two Deep Field exposures, north and south, by the Hubble Space Telescope (HST), the twin 10 m Keck telescopes, and the new ESO Very Large Telescope (VLT) that is just coming into operation in Chile, galaxies are being imaged in the visible and near infrared (eg, 2µ;) at z's of 5 and more, very shortly (maybe 1-2 Gy) after the Big Bang. However, all these observations are hampered by the fact that, being in the optical or near-infrared, the enormous absorption typical of starburst regions, and the large red shifts due to the cosmic expansion combine to greatly reduce the available signal. The number of distant galaxies actually observed is severely limited by the small field of view that can be observed so intensively.

The mission of WIRE is to study starbursts in the distant Universe, from *z* of 0.5 to a about 3, in galaxies and protogalaxies. Because such starbursts are enormously luminous in the infrared, they can be observed at great distances by even quite a small telescope. The observation strategy is to conduct three distinct surveys, at successively greater depth, studying the number of sources found versus brightness, and also the color evolution of sources with look-back time, or age:

1. The moderate-depth survey will occupy about 60% or WIRE's time, with 15-75 min exposures over each of some 50 survey "areas", each about 1.5°; X 1.5°; in size.
2. The deep survey will obtain a large (2000 galaxy) sample at the largest look-back time. about 30% of WIRES's time will be devoted to it, with exposures of several hours in each field. The number of sources observed will imply the rate of evolution, as a rapid increase in starbursts with look-back will be reflected in a larger number of detected sources (see tables below).
3. The ultra-deep survey, to which 10% of the time is allocated. will take exposures of 24 hours or more in a small number of fields to constrain the IR background, and study the number of sources by observing the "lumpiness" of the background due to unresolved, confused sources. The results of this survey should yield the fraction of the luminosity of the Universe which is due to starbursts beyond $z = 0.5$.

The reddest detected sources will be selected for intensive follow-up study with HST and ground-based telescopes, such as the Kecks, to determine their spectra, obtain precise *z*, distances, and other properties.
What these surveys will actually see depends considerably on the way in which galaxies evolved with time since the Big Bang:
The 30 cm WIRE telescope operates at 12μ;

Projected WIRE Sample Size

No Evolution Scenario

Survey	Sky Coverage	25 micron flux limit (5 sigma)	# of sources
Moderate Depth	170 sq deg	0.69 mJy	30,000
Deep	8.3 sq deg	0.25 mJy	5,000
Ultra-deep	0.5 sq deg	0.17 mJy	500

Moderate Density Evolution Scenario

Survey	Sky Coverage	25 micron flux limit (5 sigma)	# of sources
Moderate Depth	830 sq deg	1.5 mJy	70,000
Deep	42 sq deg	0.56 mJy	14,000
Ultra-deep	1 sq deg	0.34 mJy	700

and 25µ, and has two 128X128 pixel arsenic-doped silicon infrared detector arrays cooled by solid hydrogen to less than 7° K. Its spatial resolution will be 20 arc-sec at 12µ; and 23 arc-sec at 25µ;. It is expected that its objectives, including the observation of tens of thousands of starburst galaxies, can be fulfilled in only 4 months. Launch is still scheduled for 26 February, 1999, on an Orbital Sciences *Pegasus* air-launched rocket. Dr. Perry Hacking is the P.I., with colleagues at IPAC, JPL, Cornell, and NASA Goddard Space Flight Center. Full details may be found at

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

HOW TO BUILD A STAR
(Part III)

Solar Dynamo Theory provides a mathematical framework for understanding how sunspots form, how periodic polarity reversals occur, and to what they depend on. One of the basic equations describing this process is, During a sunspot cycle, the entire magnetic field of the sun changes its shape, beginning with a field that looks like that of a familiar bar magnet, but changing to one that looks more like a donut shape along the sun's equatorial zone. This equation describes how the stellar magnetic field changes its shape from a polar geometry, B_p , into a toroidal shape, B_u : The basic process of the sun's 22-year field reversal. When solved for a particular stellar case, the equation shows how the stellar magnetic field evolves, and predicts, among other things, the duration of the sunspot cycle and the latitude distribution of the spots on the star's surface. The quantity G is called the 'turbulent eddy diffusivity' while R represents the radius of the region producing the field. The value of G depends on how rapidly magnetic fields can be transported from one place on the sun's surface to another. The faster this occurs, the shorter will be the sunspot cycle. Amazingly, this theory also works well in explaining why the polarity of the earth's magnetic field reverses every 250,000 years! The same equations are used, only the values for G and R change to reflect earth's smaller size and the conductivity of its iron core.

Most known stars rotate, some barely at all, while others, such as the so-called 'emission-line B-type stars', spin fast enough to deform their shapes into a distinctly oval shape. In particularly extreme cases, not only is the star deformed, but it spins-off matter along its equator where the centrifugal force wins over gravity and launches streamers of hot gas into space. Stellar rotation can produce a whole host of effects including sunspot cycles, surface deformation and convection. To include the rotation of a star into its mathematical description, we have to re-write all of the equations in terms of a rotating coordinate system. Since the shape is no longer a perfect sphere, instead of the temperature, density and composition only depending on the distance from the star's center, they now also depend on stellar latitude and longitude angles and are represented by a set of mathematical functions called Spherical Harmonic Legendre Polynomials. The affect of stellar rotation on the structure and evolution of stars is so complicated to describe mathematically, that only with the advent of fast computers have actual, realistic, calculations been attempted.

In addition to the slow, million-year long changes that stars experience during the course of their evolution, any amateur astronomer will tell you that some stars, usually the red ones, undergo visible changes in brightness within a few days or weeks. Stars vary in brightness in this way because they are passing through an unstable period towards the end of their lives. This phenomenon does not involve the expansion and contraction of the star's entire body from core to surface, but only the outer layers nearest the stellar surface. When the layers expand, the star's surface cools slightly and the star dims in brightness. When the layers collapse, they heat up slightly and the star brightens. Stellar variability can be described, mathematically, once a particular stellar model has been computed giving the initial dimensions of the unstable layers, their temperatures and compositions. A set of equations are then used to calculate the amplitude of the oscillation and its period, the result is an equation that looks like this,

Stellar winds appear to be a common feature of many types of stars throughout their lives, especially for the bloated red supergiants such as Betelgeuse which looses 1.4 solar masses of material every million years. Since at this rate, Betelgeuse will lose its entire remaining mass in about 20 million years, it must be well on its way to some major change in its life, perhaps a supernova explosion. One of the equations used to describe this outflow of matter from the surface of a star, including the effects of magnetic fields and rotation is,

Stellar winds can be detected around other stars by the affect that they have on the star's spectrum. Unusually broadened spectral lines from key elements, or other peculiarities in the profiles of these lines can indicate the presence of hot, ionized gas being ejected from a star. If the stellar winds are cool and dense enough, dust grains can condense out of the gas like raindrops. Although the surface of a star is usually very hot, exceeding 2,500 K in most cases, at a sufficiently great distance from the star, temperatures within the outflowing matter will be cool enough for carbon, or silicon atoms to stick together forming dust grains. This process of condensation can be described by equations that follow the growth of dust grains, and describe what observers on earth will see as they look at a star with such a dusty envelope surrounding it. For some stars like the infrared source IRC+10216, carbon dust grains are condensing in the atmosphere of this star in such numbers that the star itself is optically invisible. All that one can observe is the infrared emission from the heated dust grains which now form a dense cocoon around the star.

All of these equations, when combined together in a computer program, and after extensive de-bugging, can be used to create theoretical models of objects that run through their evolution, lose mass through stellar winds, evolve to become white dwarfs or neutron stars, and otherwise look surprisingly like the stars we see in the night sky. In theory, it would be nice to have a single program that could evolve a star from a collapsing gas cloud to, say, its eventual demise as a white dwarf or supernova; a program that would follow detailed changes in surface magnetic fields and solar wind output. In practice, however, this is not necessary or even desirable. If you are studying the collapse of a star's dense core prior to the supernova phase, the presence of absence of spots on the star's surface is not likely to make much of a difference physically or observationally. You might, however, be interested in whether or not the star was rotating, or how the convection patterns occurring at a particular location within the star are influencing the chemical composition of the core region. Both of these make a measurable difference in the properties of the left-over remnant, or in the chemical composition of the gas ejected into interstellar space.

A single computer program attempting to follow a star as it evolves from birth to supernova, yet giving detailed predictions for surface magnetic fields and spot distributions would have to follow the minute to minute changes in these fields while handling the million-year changes due to its evolution. It would also have to correctly keep up with the microsecond to microsecond changes in stellar structure during the supernova detonation itself. Even at a temporal resolution of one minute, there will be 10 trillion of these timesteps during the full life of such a star posing a daunting computational and bookkeeping problem. The solution? Theoreticians tailor their programs for studying the physics of interest, not the entire evolutionary process. If you want to study the supernova, begin the model with a 'realistic' composition provided to you by a stellar evolution model. Ignore stellar winds and surface magnetic fields. Once you have run your computer models spanning the last milliseconds of a supernova's life, you can patch them into the results from other models by arguing that the starting conditions you began your computations with, are compatible to the conditions predicted from the evolution models spanning 100 million years at thousand-year intervals. Like a giant patchwork quilt, astronomers use many interwoven, and interdependent, theories to assemble a complete view of a star's life; a view that no single one of the theories can describe completely.

One issue that all mathematical prognosticians must face, is one that may well thwart any practical attempt to construct stellar models of arbitrarily high predictive power. It is in the very nature of the mathematical approach that it will never lead to a perfect match between observation and theory for all length scales and time intervals. The reason? It's related to why meteorologists will never be able to tell you that, for example, five months from today, at 3:35 PM there will be a rain shower over the town of Adams, Massachusetts which will last 1 hour and 45 minutes. To make a prediction that specific, it is very likely that meteorologists will need to measure the state of the earth's atmosphere today, within every cubic inch over the entire globe, throughout its entire 100 kilometer thickness. In addition to the literally astronomical data storage requirements, the computer will not even be allowed to round-off any of the intermediate numbers it computes, and it will have to complete the calculation before the target hour passes.

Mathematicians tell us that nearly all the equations we create to represent nature are inherently unstable for use in forecasting. They are not unstable because they are incomplete, though that certainly contributes to faulty predictions, they are unstable because the data we feed them always are incomplete. When you construct a mathematical representation of a physical system, you begin by selecting the quantities for the variables in the model at a particular starting time. You start the stellar evolution calculation with, for example, a surface temperature of 6,000 K, a total stellar mass of 2.000 times the mass of the sun, and a composition approximated by treating hydrogen and helium separately, lumping all the elements heavier than helium together into one number, and that the star is of the same composition through out. The equations then tell you how each of the parameters change with each time step you evolve the model into the future, or past. The only problem is that the values that the variables take on at the end of the computation can be very sensitive to their values when you started the calculation. For the weather problem, it has been jokingly said that to know the weather pattern on one spot on the earth a few years into the future will depend on how vigorously a butterfly was stirring up the atmosphere a thousand miles away last year! For stellar evolution calculations, fortunatly,it appears that what you wind up with as a stellar model is not too sensitive to where you start out, provided you only want to know a star's size, luminosity, surface composition and temperature. Our curse, that we can never study the interior of a distant star or photograph its surface and surroundings, becomes our blessing since from our vantage point on earth that which we want to know about a star and can measure, can be summed up in a short list of numbers. A few million years difference in age between two stars like our sun, amounts to an observational difference between them that is, largely, not measurable in terms of temperature, luminosity or spectral features.

So where does this put the classical goal of science as a means of predicting and accurately portraying natural phenomena? For astronomy, it says that there are limits to our knowledge about the physical world. Within those limits we can hope to learn a great deal about the stars and the distant galaxies, but none of this knowledge will be certain. This will probably come as a bitter pill for many non-scientists as they may still founder on the wishful dreams of obtaining absolute knowledge, untarnished truths, and some scheme for distinguishing clearly between right and wrong answers. In science, we are accustomed to laws that may be overturned by the very next observation, theories that may be incomplete, or data that may not only be uncertain, but even wrong and misleading. This is not the arena that so many people might imagine science to be. Scientists do search for objective truths, but those truths are not written in capital letters and inscribed in stone. It is not that scientists have to change their methodology so that Truths can be revealed, it is that society has to learn that absolute truths about the physical world probably do not exist. As Jacob Brownowski states so poignantly in his essay 'Knowledge or Certainty'

"...Science is a very human form of knowledge. We are always at the brink of the known, we always feel forward for what is to be hoped. Every judgement in science stands on the edge of error, and is personal. Science is a tribute to what we can know although we are fallible..."

Constellation Search

The following paragraph contains at least 36 constellations… rearrange the letters to find which ones they are:

Standing beneath such striking celestial delights enhances our appreciation of creation. Our observations open strange realms and universes too vast for our minds and imagination to fathom. Sights we can only marvel at further increase our realisation of our own striking insignificance. Looking at the complexity of the cosmos adds to the spell that binds us to the mysteries of the heavens. Via our exploration we become aware of the underlying order within the chaos.

To make it easier here is a grid of the letters used in the paragraph and the solution

	# Used in Paragraph	# Used in solution		# Used in Paragraph	# Used in solution
A	*32*	*32*	**B**	*4*	*3*
C	*13*	*13*	**D**	*10*	*8*
E	*42*	*22*	**F**	*9*	*1*
G	*10*	*7*	**H**	*18*	*3*
I	*33*	*20*	**J**	*0*	*0*
K	*3*	*0*	**L**	*13*	*11*
M	*9*	*8*	**N**	*33*	*20*
O	*37*	*18*	**P**	*6*	*5*
Q	*0*	*0*	**R**	*26*	*24*
S	*30*	*20*	**T**	*35*	*8*
U	*11*	*11*	**V**	*6*	*5*
W	*5*	*0*	**X**	*2*	*2*
Y	*4*	*4*	**Z**	*0*	*0*

In the Sky this Month

February 1999

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

March 1999

dd hh		dd hh	
1 09	Regulus 0.3 S of Moon Occn.	18 10	Mars stationary
2 07	FULL MOON	18 11	Jupiter 2.7 N of Moon
3 07	Mercury greatest elong. E(18)	19 19	Mercury in inferior conjn.
7 02	Mars 3.2 S of Moon	20 00	Moon at perigee
8 04	Moon at apogee	20 01	Venus 5.2 N of Moon
9 22	Mercury stationary	20 03	Saturn 2.8 N of Moon
10 09	LAST QUARTER	20 21	Venus 2.6 N of Saturn
13 23	Neptune 1.5 S of Moon	21 02	Equinox
14 19	Uranus 1.4 S of Moon	22 18	Aldebaran 0.5 S of Moon Occn.
14 23	Pluto stationary	24 10	FIRST QUARTER
17 18	NEW MOON	28 16	Regulus 0.3 S of Moon Occn.
17 20	Mercury 7.0 N of Moon	31 23	FULL MOON

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