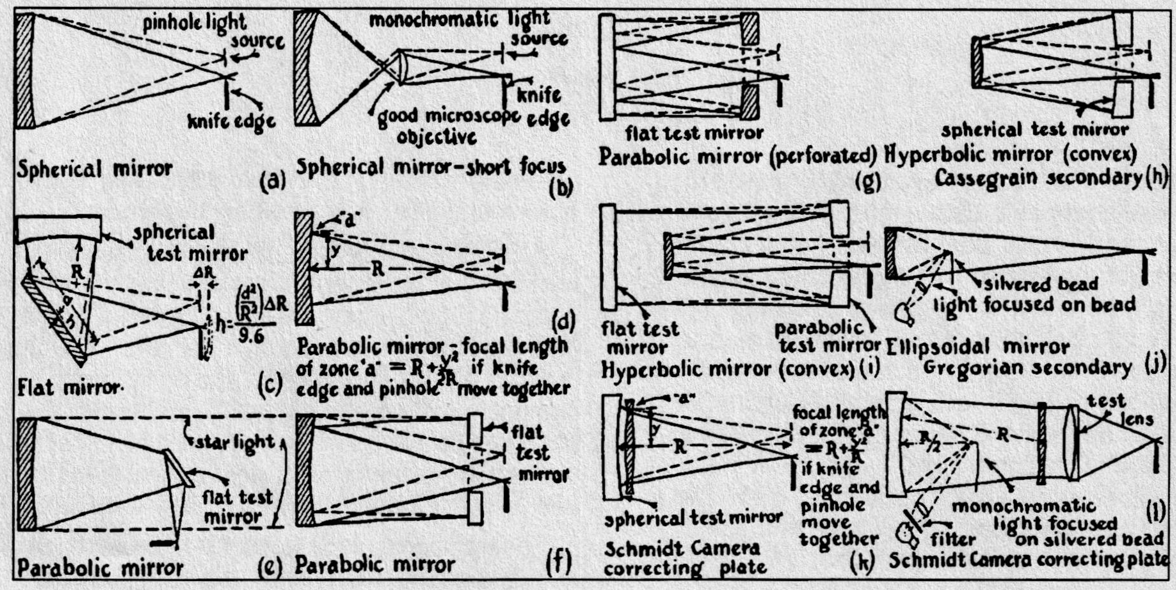
REFLECTIONS



REFLECTIONS

November 1992

Arrangements for Foucault testing of a variety of optical surfaces. Taken from John Strong's 1938 book "Procedures in Experimental Physics"

Kurt Hillig
Editor

University Lowbrow Astronomers

The University Lowbrow Astronomers is a club of astronomy enthusiasts which meets on the third Friday of each month in the University of Michigan's Detroit Observatory at the corner of Observatory and Ann Streets in Ann Arbor. Meetings begin at 7:30 PM and are open to the public. For further information, call Stuart Cohen at 665-0131.

This Month:

November 20 – Meeting at the **Detroit Observatory** in **Ann Arbor (7:30 PM)**. Dr. John Clarke of the Space Physics Research Laboratory at the University of Michigan will talk on "What's Really Being Done With Hubble?", focusing on his work in planetary atmospheres.

November 21 – Public Open House (from sunset until we freeze) at the **Peach Mountain Observatory** on North Territorial Road, 1.1 miles west of Dexter-Pinkney Road. It's getting chilly out there, but this means dry, haze-free skies and no mosquitos (unfortunately, also cloudy skies most of the time). Comet Swift-Tuttle should be visible in the early evening; along with Venus, Saturn and Uranus.

November 28 – Public Open House (at sunset) at the **Peach Mountain Observatory** on North Territorial Road. Just the thing to cure those too-much-turkey blues. Mars rises about 2:00 AM...

Next Month:

December 1 – Computer Subgroup Meeting (7:30 PM) (a Tuesday night this time). At the last meeting we forgot to choose a place for this one. Come to the November 20 club meeting to find out, or call Roget Tanner at 981-0134.

December 18 – Meeting at the **Detroit Observatory** in **Ann Arbor**. On the agenda: get in the Christmas spirit with a slide show on some of the prettiest celestial objects you'll ever see, including the red giant Nasum (α Rudolphus).

Arizona Astronomy Camp

The Steward Observatory Astronomy Camps for Adults and Teens for the coming winter, spring and summer (1993) have been scheduled. The dates are:

Advanced Adult Camp	February 18–21
Beginning Adult Camp	April 23–25
Beginning Teen Camp	June7–14
Advanced Teen Camp	June 18–25

The Astronomy Camps are run by Steward Observatory (Univ. of Arizona) as a non-profit educational outreach project. Attendees use the 40", 60", and 61" research telescopes of the Mt Lemmon and Mt Bigelow Observatories operated by NASA and Steward. A 16" Schmidt camera and many portable telescopes are also available.

Activities include observing, astrophotography with film and CCDs, lectures, demonstrations and discussions. Tours of research and engineering facilities, such as the spin-casting facilities of the Steward Observatory Mirror Lab, are also conducted. Teen Camps (ages 13 – 17) include four nights of observing, the activities of the Adult Camps plus tours of Kitt Peak, science demonstrations, lectures (space program, archaeoastronomy etc.) and other activities.

To receive more information about the Camps, contact Don McCarthy (602/621-4079) or Jeff Regester (602/621-6535); or write to them at the Steward Observatory, University of Arizona, Tucson AZ, 85721.

An Introduction to Atomic Spectroscopy

Kurt W. Hillig II
Dept. of Chemistry
University of Michigan

At the open house on May 2, I was asked by several of our guests just what astronomers saw with their optical and radio telescopes, and why a chemist was interested in astronomy. This got me started thinking about spectroscopy – since that's how both astronomers and chemists figure out what they're looking at. Since I've spent most of the last fifteen years working in microwave molecular spectroscopy, I thought I might write up something for the newsletter. The first article in this series tried to answer the question "where does light come from?" – i.e. the mechanisms for producing electromagnetic radiation. This article will address *atomic spectroscopy* – how atoms produce or absorb light, and what we can learn from this.

Atomic Spectroscopy in Astronomy

Free atoms occur in the universe only in certain special environments – in deep space, and in stars. This is because free atoms are usually quite chemically reactive. (The "rare" or "noble" gases – Helium, Neon, Argon, Krypton, Xenon and Radon – are always found as free atoms due their chemical inertness, except in the laboratory where some "exotic" compounds of some of these have been made.) The binding energy between the atoms in molecules is typically comparable to the energy of an ultraviolet photon, or to the kinetic energy of a molecule at a temperature around 2000 - 3000 K.

In deep space there's lots of UV radiation around (a molecule may encounter a UV photon every few seconds), so it's easy for a molecule to get knocked apart. On the other hand, the gas density is so low that a free atom may drift for decades before encountering another atom, so the probability of molecule formation is low. There's actually a fair bit of atomic oxygen a hundred miles or so above the surface of the earth too, as the sun provides plenty of UV and the density is still pretty low - in fact this is a major corrosion problem for LEO (low earth orbit) hardware like the Shuttle.

Stars, of course, are much more dense than deep space (remember the "teaspoonful weighs a ton" comparisons?) but they're also mighty hot. Of course there's plenty of UV, X-rays etc. inside most stars too, but it's the high-energy collisions that knock apart molecules before they can form.

Brown dwarfs, of course, don't count because they're too cold, so they should have a fair molecular component to them – think of Jupiter, but maybe ten or fifteen times larger. Likewise dense molecular clouds are seen where the gas density is high enough that the UV gets absorbed at the edges and never makes it to the center. They're still a hard vacuum by laboratory standards, but a lab-grade vacuum a few light-years across would be totally opaque.

So, atomic spectra can give us information about environments interesting to astronomers, cosmologists and planetary scientists: stars, interstellar space and the edges of atmospheres. Lets see how this works....

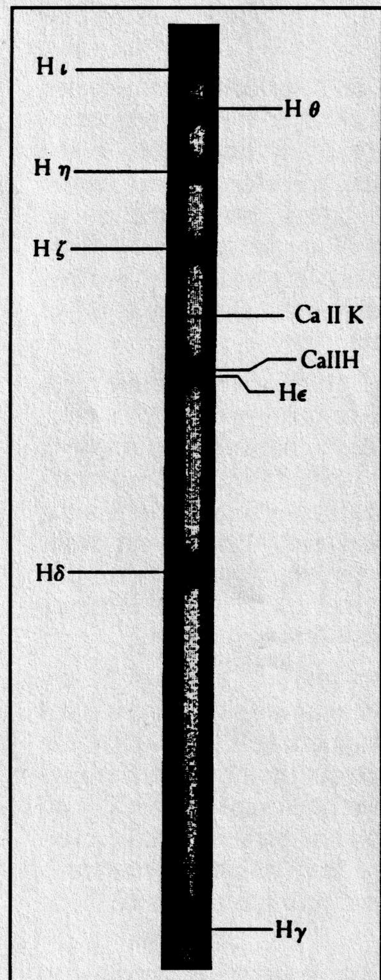
<u>KISS - Keep It Simple, Stupid</u> We start with hydrogen. Hydrogen is a wonderful material for many reasons: 1) about 99% of the universe is hydrogen – it's by far the most abundant element around; 2) it's simple – a hydrogen atom consists of only one electron and one proton; 3) it's understandable – the mathematical description of the hydrogen atom can be solved analytically; 4) it has spectral features over a wide range of wavelength; 5) mixtures between 4% and 74% in air are explosive (I like loud booms, OK?).

The traditional place to start is to pretend that electrons and protons are "featureless" particles – i.e. that they have charge and mass, but no size or other significant properties. With this simplification, one can solve the equations describing the hydrogen atom exactly. What is found is what you all know: a hydrogen atom has a proton at its center (like the sun in the solar system), and an electron "somewhere out there" around it. I deliberately do not use the word "orbit" to describe its motion, because that's not a good description of where it moves – you should think of it as a fuzzy cloud around the proton.

Now this fuzzy cloud of an electron can take on a variety of shapes – but only certain specific ones, and each one has a specific energy. There are integer numbers which appear in the mathematical functions which describe these shapes (and their energies), and we use these as indices to specify the energy levels; these are the *Quantum Numbers.*

<u>Number Theory</u> The first quantum number for the hydrogen atom is called, oddly enough, the "Principal" quantum number – N. This number basically tells you how far (on average) the electron is from the proton in the atom. And for hydrogen (and it's approximately true for other atoms) the energy of the electron is inversely proportional to the square of this number. (By convention, we define zero energy to be with the proton and an electron infinitely far apart. Since energy is given off when they combine to form a hydrogen atom, the atom has a negative energy. Don't let it bother you – the location of the zero point is arbitrary, and this is just a sliding scale. We define it that way because it makes the math easier.)

Let's be specific: The lowest energy state of a hydrogen atom has $N=1$, and its energy is –13.6 eV; the next higher state has $N=2$ and its energy is 1/4 of $N=1$, or –3.4 eV; the $N=3$ state has an energy of 13.6 / 9, or –1.5 eV etc. Now since transitions which absorb or emit light can only occur between these levels, you can see that there will be several series of transitions, at energies which fall into regular patterns; these are the Lyman, Balmer, Paschen, Brackett and Pfund series for transitions from upper levels to N=1, 2, 3, 4, and 5 respectively.

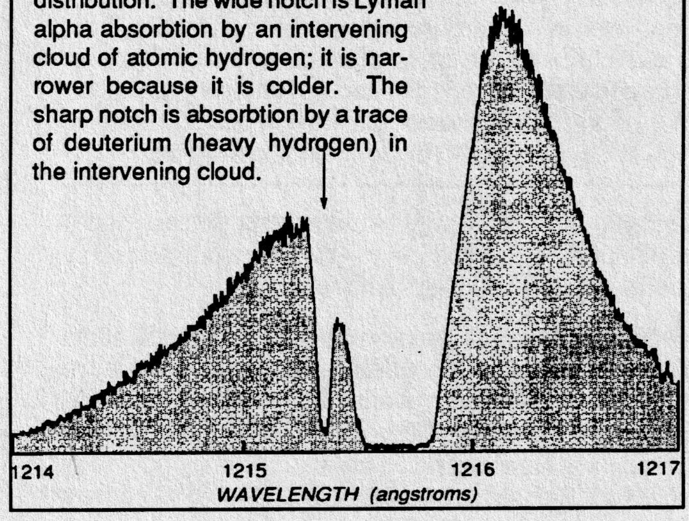


A portion of the spectrum of Vega, showing some of the Balmer series lines along with some atomic emission lines from singly-ionized calcium.

The lowest-energy Lyman line from $N=2$ to $N=1$ (with energy 13.6 – 3.4 = 10.2 eV) has a wavelength of 1216 Å, deep in the ultraviolet, while most of the Balmer series is seen at visible wavelengths. The Paschen, Brackett and higher series all lie at longer wavelengths, from the infrared on into radio frequencies. The well-known "Hα" line at 6563 Å wavelength, also known as the Fraunhofer C line, is the first member of the Balmer series.

Hot Stuff Revisited It's a whole lot easier to see a bright spot against a dark background than a dark spot against a light background. (Of course, most of the sky is dark, which really helps a lot!) One major consequence is that astronomers spend most of their time looking for emission signals (bright spots) rather than absorbtion signals (dark spots). And, as I discussed back in May, bright things are often hot things.

A portion of the spectrum of Capella as seen by the Hubble Space Telescope. The shaded band is the Lyman alpha emission, Doppler broadened by the star's rotation and the high thermal velocity distribution. The wide notch is Lyman alpha absorbtion by an intervening cloud of atomic hydrogen; it is narrower because it is colder. The sharp notch is absorbtion by a trace of deuterium (heavy hydrogen) in the intervening cloud.



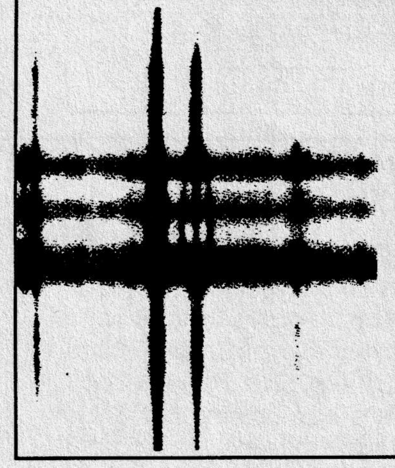
As was discussed in last month's *Reflections*, the relative strengths of the hydrogen lines form the basis for the OBAFGKM stellar classification scheme. For the hottest (O) stars, the hydrogen lines are weak because they're so hot the the electrons never spend much time associated with any one proton. The cooler B-A-F-G stars have stronger lines because they're hot enough to excite the electrons to high N values without kicking them right out of the atoms (the sun looks very impressive when you look in Lyman α light). The cold K and M stars can't excite the high N levels, so again they're weak H-line emitters.

What this means is that we can use the relative intensities of the high-N and low-N lines as a kind of thermometer to measure the temperatures of stars. This makes a nice calibration check to compare with the temperature derived from their broad-band blackbody spectra (i.e. their color).

Back to Basics Along with the principal quantum number to tell how far away the electron is from the nucleus, there's a second quantum number (the "magnetic" or "orbital angular momentum" quantum number, which can vary between $-N$ and $+N$) which describes the "shape" of the fuzzy electron cloud. In bigger atoms, interactions between the electrons can make states of different l values to have slightly different energies (in really big atoms, of course, this gets carried to perverse lengths). This leads to a "splitting" of the lines we discussed above.

As we move from light to heavy atoms, the nuclear charge increases, pulling the electrons in more tightly. But the number of electrons also rises, and this increases the repulsion between the electrons. It's the separation into different orbital angular momentum levels that allows the electrons to stay as far apart as possible within an atom. The result is that every atom has its own unique set of energy levels, and the atomic spectra are the fingerprint that we can use to tell them apart.

Now there's a good reason why our second quantum number is called "magnetic". One of the nifty features of the splittings it causes is that in many cases they are sensitive to the strength of an applied magnetic field (the Zeeman effect, after the physicist who first noticed it). Some of these lines have turned out to be very useful in studying the relationship between sunspots and the sun's magnetic field; they've also been used to measure and even map the fields at the surface of distant stars!

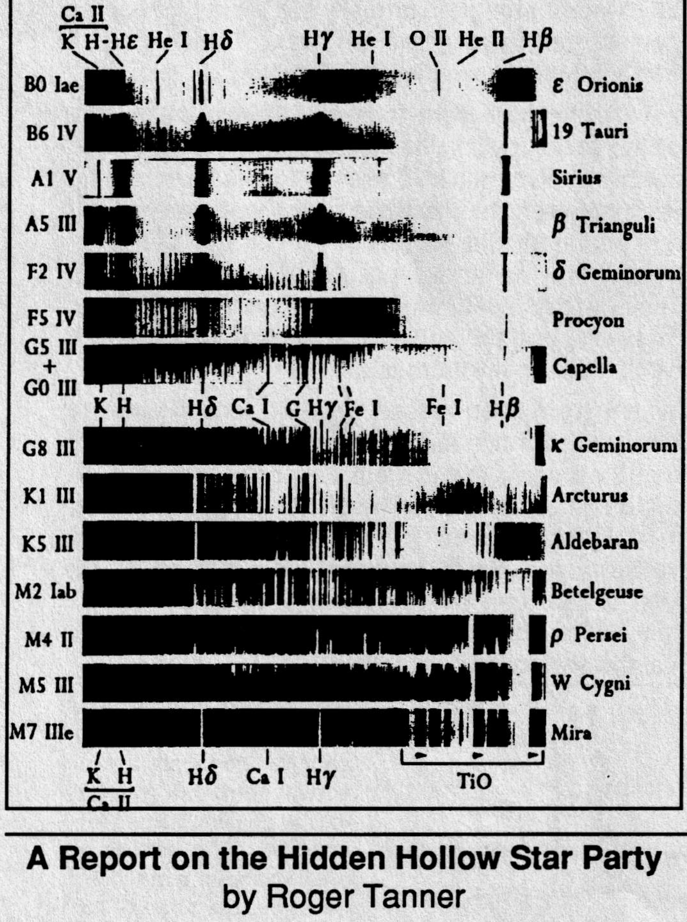


A scanning spectrogram across the width of a sunspot (the horizontal axis is wavelength, the vertical axis is position across the sunspot). The splitting of the line shows a magnetic field near the edge of the sunspot of about 1500 gauss – 3000 times the Earth's magnetic field. Other stars have shown fields as large as 50,000 gauss, attainable in the laboratory only with superconducting magnets.

How do You Pronounce "Unionized" Since in larger atoms all of the electrons repel each other, the removal of one electron (which can be accomplished by a UV photon or by a collision with another fast-moving atom) will change the interactions and shift the energy levels. Thus the spectrum of an ion is distinguishable from that of its parent neutral atom.

One small side note: Physicists commonly refer to a neutral (that's "un-ionized", not "union-ized") atom by its chemical symbol, for example "Fe" for iron (pronounced "eff ee"). Ions are denoted by a superscript number (with a + or – sign) following the symbol, denoting the charge of the ion. So an atom of iron with three electrons missing has a charge of +3, and is written as Fe^{+3} ("eff ee plus three"), or sometimes as Fe^{3+}. Astronomers, on the other hand, refer to the neutral atom by putting a roman numeral "I" after its symbol , e.g. "C I" ("see one") for neutral carbon. And if a chemist like me says "Oh three" it's really confusing, since I could mean ozone (a molecule with three oxygen atoms – O_3), triply-ionized oxygen (O^{+3}) or doubly-ionized oxygen (O III). All clear?

A series of stellar spectra showing spectral classes B0 through M7. For the cool M stars, some molecular emission bands from titanium monoxide can be seen. The hydrogen (Balmer) lines are strongest in the A-type stars.



Now ultraviolet light or X-rays, or collisions between extremely fast-moving atoms can strip many electrons off a nucleus – something that's pretty hard to do in the laboratory. In super-hot stars, in stellar coronas (which may reach several million degrees), and in "hot spots" around pulsars, highly ionized atoms such as Fe XIII have been observed; some cosmic rays are believed to be fully-ionized atoms (i.e. bare nuclei, with no electrons at all!) of elements as heavy as uranium.

It'll Make Your Head Spin There are still a few more quantum numbers we need to completely describe atoms. But, unlike the previous two these don't tell you anything about where the electrons are. Instead, they tell you which way the electrons and nucleus are spinning. Just like the earth and sun both spin on their axes, electrons and many (but not all) nuclei spin. What makes spin tricky here is that spin comes in units not of 1 but of 1/2 (times Planck's constant *h*, but we usually leave that out).

Now an electron is charged, and with a spin of 1/2 the charge is rotating. And just like a current circulating in a coil or wire, this creates a small magnetic field – the electron is also a magnet, with a north and south pole!. Protons too are spin-1/2 particles, so in a hydrogen atom we've got an additional splitting – the proton and electron spins can be parallel or antiparallel. (This is quantum mechanics – you're not allowed to put them at right angles. Sorry, those are the rules.)

Like any pair of magnets, when you line them up nose to tail they attract, but lined up head to head they repel. So these two states have slightly different energies; specifically 1420 MHz corresponding to a wavelength of 21 cm. And those of you who know about radio astronomy may recognize this number. The 21 cm line has been used since the early days of radio astronomy to look at the distribution of hydrogen in the universe. And, since it's a very sharp line, it's easy to measure velocities accurately with it from small Doppler shifts (in fact it's such a sharp line that you need a very high-quality receiver to pick it up!).

One other use of the 21 cm line is that many people in the SETI business feel that it's the natural and obvious wavelength to use if you want to send a signal to a (hopefully existent) alien culture around a distant star, and many of the SETI searches to date have been centered on this line. Unfortunately, we haven't noticed anyone calling yet, but then we're only just now starting to have receivers sensitive enough to have a good chance of finding anything.

A Report on the Hidden Hollow Star Party

by Roger Tanner

The Hidden Hollow Star Party was held September 25 and 26 at the Hidden Hollow Nature Reserve. The major attractions were the 31" f7 telescope and the talks given by several prominent amateur astronomers such as Richard Berry, Jack Newton, Steve Edberg, Don Parker, Tippy D'Auria and others. They were also holding the Great Lakes Region Astronomical League meeting. As is typical of most big star parties there were door prizes, and a featured speaker – David Levy – talking about pleasures and perils of comet hunting (surprise).

Hidden Hollow is situated on the top of a large hill about 15 miles south west of Mansfield in central Ohio. The trip only took 3.5 hours, which means it is closer than Astrofest. The talks started Friday afternoon at 1:00 with Richard Berry and Jack Newton talking about CCD imaging and its capabilities. Richard talked about the Lynxx PC camera and how it is the best camera for planetary imaging because of its ability to down load images quickly. Evidently the secret to the super planetary images he showed is to take several hundred picture and only save the ones where you catch the moments of good seeing. He showed a stunning mosaic of about 30 images which covered the crescent moon taken during a period of steady seeing. The mosaic was put together with a Windows photo manipulation program called PhotoStyler.

Jack Newton showed the deep sky images of faint planetary nebula and galaxies he has taken with the SBIG ST-6. He would show a fantastic long exposure picture (1+ hr) taken with his cold camera and a 25" f5 Newtonian telescope. He would then show the same object taken with the ST-6 using tricolor CCD imaging, which was a composite of a red, green, and blue filtered images. The cumulative exposure was 5 minutes for red, 10 for green and blue. The images were much deeper and had more detail in the CCD image but were 20% of the field of the 35mm frame. He had several images of spiral galaxies with the young blue stars in the arm, the older red stars in the nucleus and little red H II regions sprinkled in the arms, rather incredible to say the least. Jack is also using PhotoStyler to merge his three monochrome images into one color one. He also showed a picture of Maffei 1, a galaxy which is so faint it was only successfully photographed with the Palomar 200" in the 60's. Jack says he can get >22 magnitude stars in 10 minutes with his 25" scope. This shows stars and objects which are below the Palomar Sky Survey. His pictures, both electronic and on film were a treat. Don Parker did not make it because he was still putting his house in Coral Gables back together after the hurricane, but Richard showed several of his incredible images of Jupiter.

Tippy D'Auria gave his talk "A New Way to Measure Astronomical Distances" which involves scaling the Universe down so that the basic measure of distance is one square of a roll of toilet paper. He rolls the paper out to illustrate the distances between various objects like the Sun and the planets. When he gets to the Oort Cloud he starts ringing the crowd with several rolls. A very graphic demonstration of the vast differences in distances.

Friday night was very good for observing with very little light from Mansfield. Tom Ryan and I looked at some nebulae with an O III filter which really brought them out. We looked at the Veil but couldn't find the second and third part. Some astronomers from Canada who were standing by found it by panning around. We were looking only about a degree too far north.

I didn't get to look through the 31" because the lines were always long. The 31" is housed in a round block building with a aluminum dome. The long focal length, 17.5 feet means the eyepiece is a long way up in the air. They have an electric scissors lift platform to buzz you up to the eyepiece, which is why the line to look through it moved rather slowly. The mirror was ground by the club members. Tom Ryan grew up near here and was exposed to astronomy and telescope making through this club. They also had a mirror making demonstration Saturday morning which I missed (sleeping).

I tried to take some CCD images but got terrible results because my secondary dewed up. Peter Schmitka was there with his 18" Dob with a heated secondary. He had no problems with dew. He was also selling his ball telescopes which are like a AstroScan except they are 14" f5 and are very nicely finished.

Saturday morning the Flea market and commercial displays were pretty busy. I found a couple of guys selling a heavy weight aluminized Mylar bag to cover your scope and bought one. This is a definite necessity for the Texas Star Party, as the sun down there delaminated several spots on my secondary cell - other people have had dark colored plastic parts on their scope melt in the midday sun! Saturday afternoon Stephen Edberg gave a excellent overview talk on the prospects and plans for solar system exploration. Stephen works for NASA at JPL and gave his personal views on what the possibilities are for various planned and possible space missions. At the end of his talk he discussed the present political situation in Washington and how it affected the planning. In conclusion he mentioned the story about Vice President Quale asking after a space policy planning meeting "What planet is the Space Telescope going to anyway?". Seemed to sum it up rather well...

Saturday grew cloudy and Richard and Jack repeated their CCD talk to a full meeting room, (OK, so it was cloudy). The dinner (if you paid for the meals) was a "burn it yourself steak fry". Actually it was an excellent piece of meat and came with all of the trimmings. Many of the optimists stayed up to 11 or so before finally giving up to the clouds. They had about 350 people show up, but there was never any crowding. I will be back.

The Poop on P/Swift–Tuttle

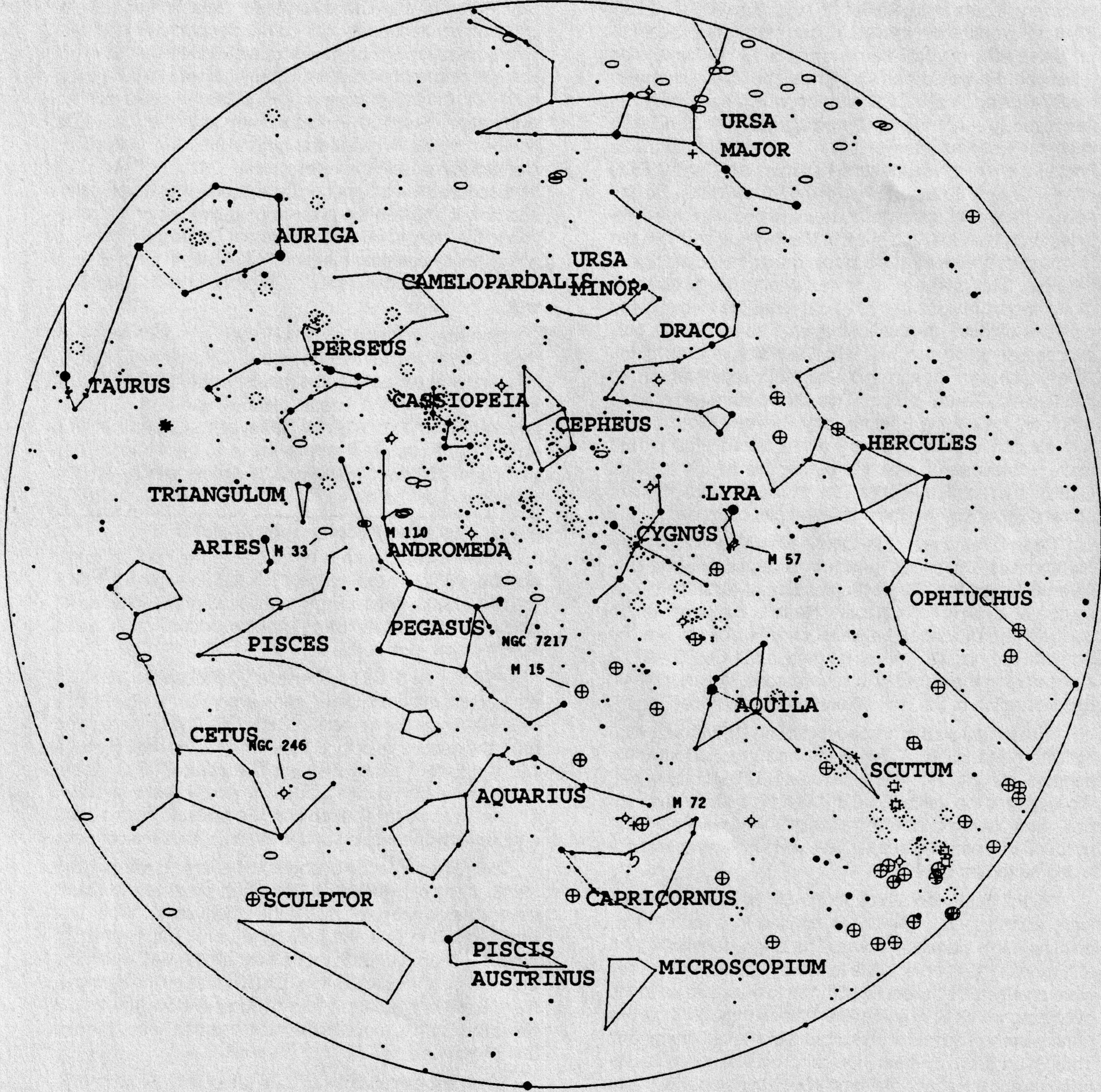
There's been quite a bit of talk in the popular press about a prediction that comet P/Swift-Tuttle has a 1 in 400 (or 1 in 10,000, depending on who's reporting) chance of hitting the earth the next time it comes around in 2126. Let's take a closer look at this...

P/S-T (the "P" is for "Periodic") is the parent comet of the Perseid meteor shower, seen every year as the Earth's orbit intersects the comet's. Since P/S-T has a retrograde orbit, the relative velocity of the earth and the meteors is 60 - 65 Km/s, very fast by meteoric standards. If P/S-T were to hit the earth at this speed, it would leave a crater estimated as 30 miles deep and 150 miles across – but it's doubtful anyone would survive to see it, thus the concern.

P/S-T has a period of about 134 years. It was spotted earlier this year, though it had been predicted to return several years ago (based on rather spotty data). When first reported to the IAU, the preliminary orbit put it within 14 days of hitting the earth on its next orbit – well within the uncertainty of the calculation. If it did cross on the right day, there's still only about a four-minute window (the time it takes the Earth to move its diameter in orbit), hence the one in 400 number.

The best calculations to date (as of Nov. 6) have P/S-T missing the Earth by 0.4 au. Still, observations for at least another year will be needed to pin down its exact path.

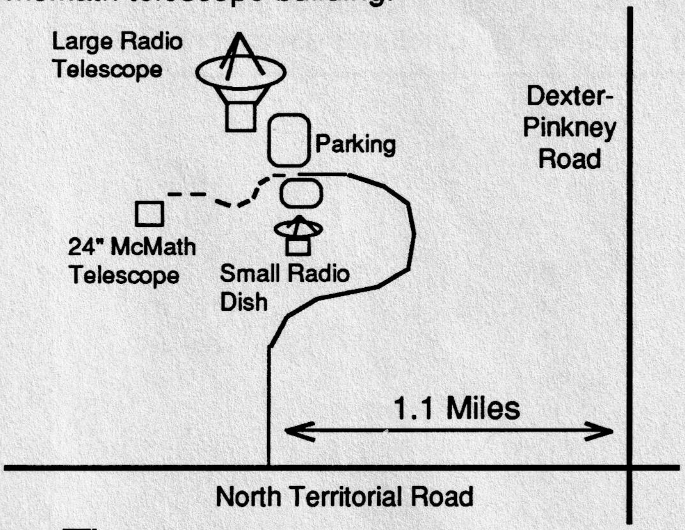
Star Chart for November 20, 1992 8:00 PM EST Ann Arbor, MI



☞ Places:

The Detroit Observatory is in Ann Arbor, at the corner of Observatory and Ann Streets, across from the old University of Michigan hospital and between the Alice Lloyd and Couzens dormitories. The Detroit Observatory is an historic building which houses a 19th century 12-inch refractor and a 6-inch transit telescope.

The Peach Mountain Observatory is the home of the University of Michigan's 20-meter radio telescope, and the McMath 24-inch telescope maintained and used by the Lowbrows. The observatory is located northwest of Dexter; the entrance is on North Territorial Road, 1.1 miles west of Dexter-Pinkney Road. A small maize and blue sign marks the gate. Follow the gravel road one mile to a parking area near the radio telescopes. Walk along the path southwest (between the two fenced-in areas) about 300 feet to reach the McMath telescope building.



☞ Times:

The monthly meetings are held on the third Friday of each month at 7:30 PM at the Detroit Observatory. During the summer months, and when weather permits, a club observing session at Peach Mountain will follow the meeting.

Public Open House / Star Parties are held on the Saturdays before and after each new moon at the Peach Mountain Observatory. Star Parties are cancelled if the sky is cloudy at sunset – call 426-2363 to check on the status. Many members bring their telescopes; visitors are welcome to do likewise. Peach Mountain is home to millions of hungry mosquitos – bring insect repellant, and wear warm clothes, as it gets cold at night!

☞ Dues:

Membership dues in the Lowbrow Astronomers are $20 per year for individuals or families, and $12 per year for students. This entitles you to use the 24" McMath telescope (after some training). Dues can be paid to the club treasurer, Ron Avers, at a meeting or by mail at this address:

9394 Anne
Pinckney, MI 48169-8912

☞ Magazines:

Members of the Lowbrow Astronomers can get a discount on these magazine subscriptions:

Sky and Telescope: $20/yr
Astronomy: $16/yr
Odyssey: $10/yr

For more information, contact the treasurer.

❐ Sky Map:

The sky map in this issue of *REFLECTIONS* was produced by Doug Nelle using *Deep Space 3D.*

✎ Newsletter Contributions:

Members (and non-members) are encouraged to write about any astronomy-related area in which they are interested. Please call the newsletter editor (Kurt Hillig, 663-8699) to discuss length, format, etc. Announcements and articles are due 14 days before each monthly meeting. Contributions should be mailed to Kurt Hillig, 1718 Longshore Dr., Ann Arbor, MI 48105.

☎ Telephone Numbers:

President:	Stuart Cohen	665-0131
Vice Pres:	Doug Nelle	996-8784
	Paul Etzler	426-2244
	Fred Schebor	426-2363
	Tom Ryan	662-4188
Treasurer:	Ron Avers	426-0375
Observatory:	D. C. Moons	254-9439
Newsletter:	Kurt Hillig	663-8699
Membership:	Steve Musko	426-4547

Peach Mountain Keyholder:

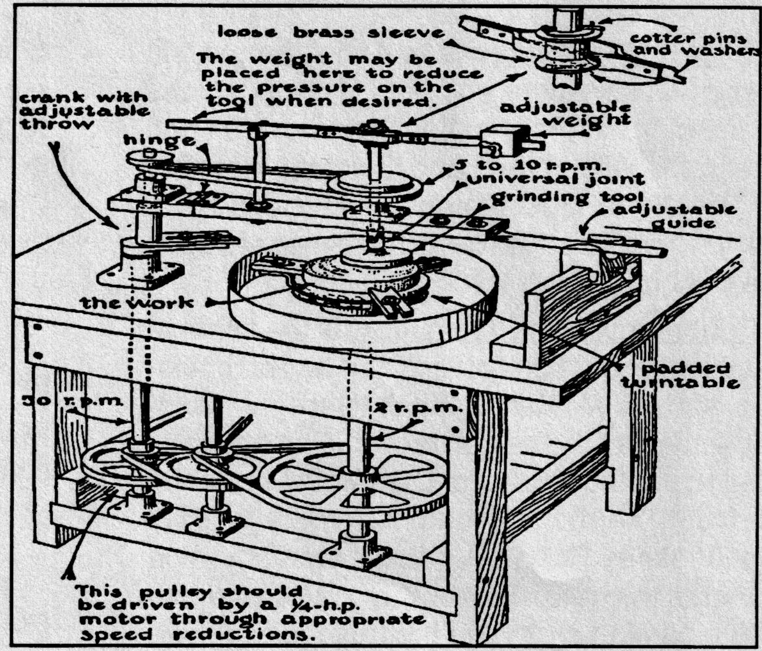
Fred Schebor 426-2363

Monthly Meeting:

Dr. John Clarke
of the
Space Physics
Research Lab
on
What's Really
Being Done With
Hubble?

November 20, 1992 7:30 PM

At the
Detroit Observatory in
Ann Arbor



A modified Draper machine for the grinding of large mirrors and lenses. Taken from the book "Procedures in Experimental Physics" by John Strong, Prentice-Hall, 1938 (reprinted by Lindsay Publications, 1986)

University Lowbrow Astronomers
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