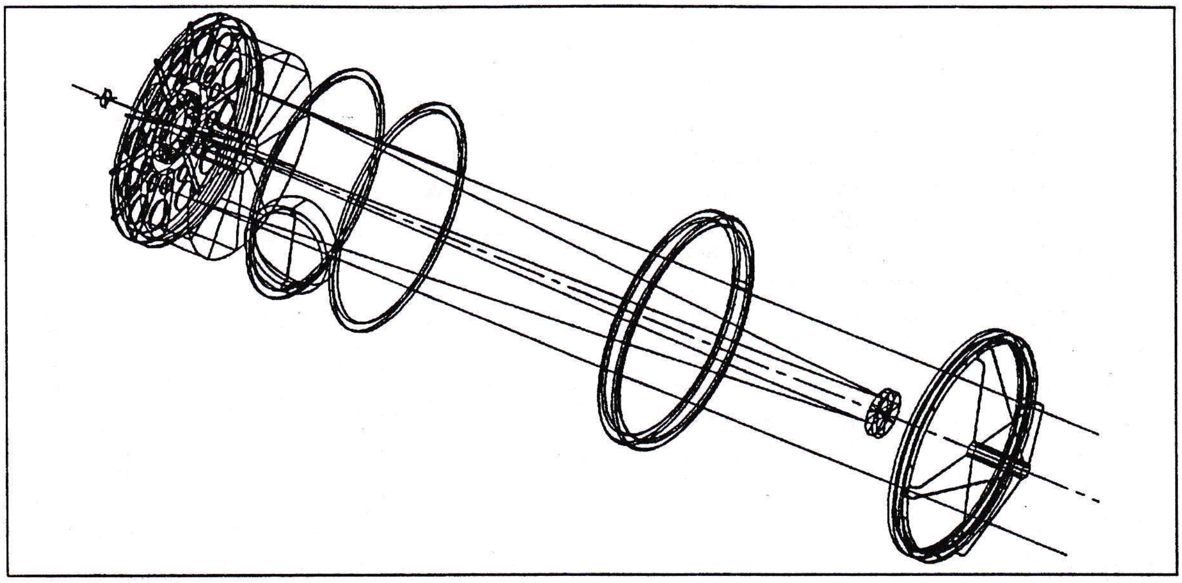
REFLECTIONS



REFLECTIONS

May 1992

A CAD model of the optical tube of the McMath 24" Cassegrain telescope at Peach Mountain, MI. Produced by Tom Ryan of the Lowbrow Astronomers.

Kurt Hillig
Editor

# University Lowbrow Astronomers

The University Lowbrow Astronomers is a club of astronomy entnusiasts 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:

**May 14 - Auction** at **KMS Fusion** in **Ann Arbor**. The KMS going-out-of-business sale, with lots of optical and test equipment, computers, furniture, etc. on the block.

**May 15 - Meeting** at the **Detroit Observatory** in **Ann Arbor**. Dr. Kenneth Gibbs of the Enrico Fermi Institute at the University of Chicago will talk on the Chicago Air Shower Array (CASA). The CASA is an instrument for studying cosmic ray interactions in the atmosphere.

**May 30 - Public Open House** at the **Peach Mountain Observatory**, on North Territorial Road1.1 miles west of Dexter-Pinkney Road, if the skies are clear.

## Next Month:

**June 1 - Computer Subgroup Meeting** at **Kurt Hillig's** house (a Monday). The computer subgroup will explore the Zemax optical design package, play with the shareware program Skyglobe, and continue discussion on the details of the digital setting circles for the 24" telescope.

**June 4 - Star Party** at the **Ardis Elementary School.** See the letter from Ron Avers inside, and come help out!

**June 6 - Public Open House** at the **Peach Mountain Observatory.** It's possible that the 24" scope will be up and running for this. If not, we'll shoot for the 27th.

**June 19 - Meeting** at the **Detroit Observatory**

**June 27 - Public Open House** at the **Peach Mountain Observatory**, if the skies are clear at sunset.

### A Message From the Editor

For the next year, I have the responsibility for getting *REFLECTIONS* out on time every month, and in the past two weeks I've come to realize that it's a big job. To make this work, I need your help. What can you do? Two things:

1) Write something! You all have an interest in astronomy, and this interest takes many forms – it's quite likely that you're a local expert on something that others would find fascinating, and writing about it is a great way to to share your knowledge and to reinforce your own understanding. If you're not too sure of your writing skills, I can help (I am the editor, after all!). I'll accept almost any legible hard-copy format, or text or MS Word files on 3-1/2" disks (Mac preferred, but I can handle DOS format.

2) Get it to me on time! The newsletter should be mailed 8 days before each meeting, and it takes about a week to put together – the deadline for each issue is 14 days prior to the meeting that month.

### KMS Auction

The KMS auction will be an all-day affair on May 14, with the preview on the 13th. Among other items to be sold is a set of 16" full-thickness Pyrex mirror blanks. Those who would like to see the catalog or want to arrange some "group bids" can meet at Kurt Hillig's house (1718 Longshore Dr., Ann Arbor; 663-8699) on Wednesday, May 13 at 8 PM. This could be a great opportunity if the bidding stays sane.

# Astronomy and Spectroscopy. Part I: Light Production

by Kurt W. Hillig
Department of Chemistry
University of Michigan

At the open house on May 2, I was asked by several of the 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'd write this up for the newsletter.

A caution: numbers, where I use them, are from my head and not from reference books – I may be off by one or two orders of magnitude in spots! (This comes from being having deadline to meet and no references handy.)

Lets start at the beginning....

### Where Does Light Come From?

There are three basic mechanisms for the production of electromagnetic radiation – i.e. light. They are: quantized emission from diffuse nuclear, atomic or molecular sources; thermal emission from high-density matter; and bremsstrahlung from high-energy electrons in a magnetic field. We'll take them in that order.

Quantum Mechanics in a Nutshell Quantum mechanics (QM) is the mathematics of small things – molecules, atoms, nuclei, etc. – and, in particular, small *low density* things (more about that in a minute). It was developed around the turn of this century to explain a number of atomic and molecular phenomena which seemed to violate the principles of classical physics. The most important consequences of QM to astronomy are twofold: 1) the energy of a microscopic system can only take on certain discrete values, and 2) there is an uncertainty in the value of the energy which is inversely proportional to the time the system spends in that particular state (this is one aspect of Heisenberg's uncertainty principle). In the discussion below, I will often refer only to atoms for brevity; however all of this applies to molecules and nuclei as well.

What makes QM useful to astronomers is that when an atom, molecule, etc. jumps from one energy state to another, it often does so by emitting (or absorbing) electromagnetic radiation, and the energy of the radiation (proportional to its frequency ) equals the difference in energy between the two states. This gives rise to *line spectra*, which are characterised by sharp, discrete features; the wavelength (or frequency) of each features is a unique signature of the entity which produced it. One can find dark line spectra when light from a continuous source is selectively absorbed by something in front of it. For example the well-known Fraunhofer lines in the solar spectrum rise from absorbtion by atoms in the solar atmosphere. On the other hand, bright-line spectra, such as the "nebulium" lines (later found to be doubly-ionized oxygen) seen in planetary nebulae, arise when an atom or molecule in an "excited" state decays to a lower energy state.

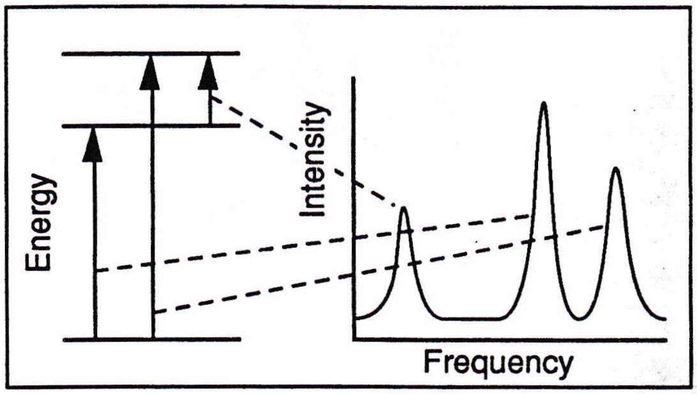



Figure 1: Three energy levels, three transitions, and the resulting spectrum

There is a connection between pressure (or density) and line spectra, which comes through the uncertainty principle. If you consider an isolated atom, as in the interstellar medium, it very rarely encounters anything - the *mean free path* may be millions of kilometers, and the mean time between collisions can be many years. Such an atom can change state only through radiation, and the average time it takes to do this is called the *radiative lifetime*. The radiative lifetime is inversely proportional to the *line strength* of the transition; weak lines have long lifetimes. Through the uncertainty principal, this means that the energies of the states are very precisely determined, and the *natural linewidth* of the transition is very narrow. As the atoms get packed more tightly, they collide more frequently – in air at room temperature the mean free path is about $10^{-7}$ meters, and collisions occur every $10^{-10}$ seconds or so. Since transitions between energy levels can occur through collisions, the average lifetimes of the states get shorter as the density rises, and uncertainty in the energies gets larger. Since the lines we observe are superpositions of many, many lines from all of the atoms in the gas, the result is a *pressure broadening* of the lines.

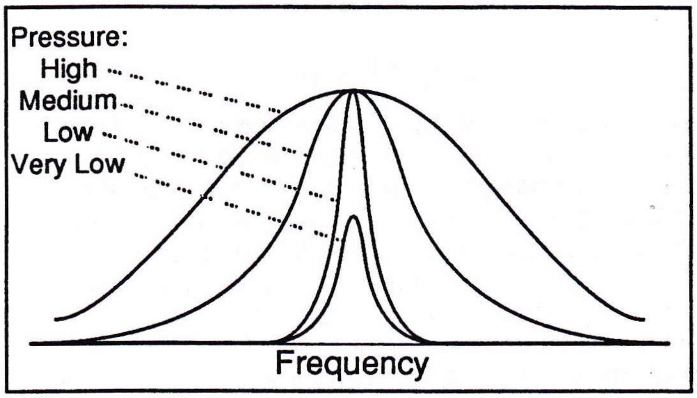



Figure 2: A pressure-broadened line at four pressures. At the lowest pressure, Doppler broadening dominates the lineshape.

The intensity of a line arises from three main factors: the line strength, which is characteristic of the free, unperturbed system; the total number of atoms in the field of view; and their temperature. Pressure also enters in, in that a very narrow line might be missed – especially a narrow absorbtion line – simply by being washed out by the background, while a broad line can more easily be seen; spectroscopists use both peak intensity and integrated intensity (peak height x linewidth) depending on the system under study.

Temperature is important in understanding line spectra, as it defines the number of atoms (out of a large population) in the two states between which transitions are observed. An atom in a low energy state can absorb a photon of light and jump to an excited state; an atom in an excited state can likewise jump to a lower state and emit a photon. In a large collection of atoms, the overall intensity of absorbtion or emission will depend on the ratio of the populations of the two states. If both have the same population, absorbtion and emission will be equal and cancel each other out; if the upper state is empty, then absorbtion will be strong. However, atoms can be excited by collision as well as radiation. In a hot gas, the atoms are moving quickly and the collision energies are high, producing a *thermal population* in the excited states and weakening the absorbtion; on the other hand, transitions from excited states to still higher states can sometimes be seen in a hot gas while thay would be unobservable in a cold gas.

There is one final contribution which is important in astronomy (and spectroscopy) – the Doppler effect. This occurs in two ways. The "train whistle" analogy which we're all sick of by now points out that the motion of an observer with respect to an object will shift the apparent frequency of a spectral line, and the magnitude of the shift is proportional to the relative velocity. However, consider a stationary hot gas compared with a stationary cold gas. Temperature is largely a measure of the average kinetic energy of the atoms, so the atoms in a hot gas move faster than those in a cold one. Considering the component of velocity along our line of sight toward the gas, the velocities in the hot sample have a wider distribution than in the cold gas. The line spectrum we observe will be smeared out by the superposition of the individual lines of all of the atoms with all of their different Doppler shifts, giving rise to a temperature-dependent *Doppler broadening*. At microwave frequencies and temperatures around 250K (coincidentally, very similar conditions to my thesis research...) the Doppler and pressure-broadening efects are about equal at a pressure of $10^{-6}$ Torr ($10^{-9}$ atm; $10^{-4}$ pascal). At lower pressures or higher temperatures the Doppler effect dominates and vice versa.

Scientists who study planetary atmospheres can make good use of the various contributions to linewidth and intensity to remotely measure temperature, pressure and wind velocity; the linewidth of an atmospheric line tells you the pressure (since it's usually large compared to the Doppler width), the Doppler shift (not the width!) gives a velocity measurement, and the line intensity provides a temperature measurement. Similar measurements can be made of stellar atmospheres, or of interstellar clouds.

Hot Stuff In a diffuse gas, spectra are characterized by lines, but as the density increases, the lines get broader. By the time one gets to the density found at the surface of a star, or in a cold grain of interstellar dust, the lines have broadened to the point where they can not be resolved; the result is a *continuum* or *black body* spectrum. In this case, the spectrum looks like a broad curve rather than a set of discrete lines, and the shape and height of the curve is related to the temperature. The frequency of the peak of the emission curve and the total radiated output rise as the temperature increases.

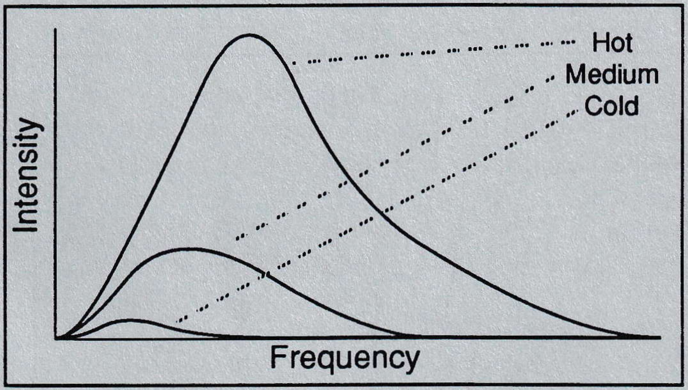



Figure 3: Black body radiation at three source tempeatures. As the source becomes hotter, the frequency of the emission peak gets higher.

The famous 2.73 K (that's two degrees above absolute zero) background radiation of deep space has its peak in the microwave region - it's a black body because it was produced very early in the life of the universe, when the average density was much higher than it is now. (Researchers with the COBE satellite experiment have raised quite a stir with the recent discovery of temperature variations of a few millinoths of a degree in the background, suggesting large-scale structure in the early universe – but that's another story.) On the other hand there are stars with surface temperatures around 100,000 K, and their black body curves peak in the soft X-ray region. The sun's radiation peaks in the green – right where the human eye is most sensitive – while IRAS (the InfraRed Astronomical Satellite) found dusty accretion disks around several nearby stars from their strong infrared emission, having temperatures of a few hundred degrees.

Thermal emission provides a useful method for measuring the temperatures of remote objects, and stars and galaxies also provide distant broad-band light sources with which to probe the absorbtion lines in stellar atmospheres and interstellar clouds.

A Magnetic Personality The last source of radiation is the most exotic (at least, if you consider Quantum Mechanics to be quotidian then it's exotic). It's known to astronomers as *bremsstrahlung* (it's the German word for "braking radiation"), or to spectroscopists as synchrotron radiation. When a charged particle undergoes an acceleration, it emits radiation; this is how radio transmitters work. When a very high energy electron moves through a strong magnetic field, its path curves and it emits light.

In the national synchrotron laboratories at Brookhaven or Stanford or near the surface of a neutron star – where the magnetic field can be large – or in interstellar space where the field is small but electrons can move at very high velocities, the acceleration can be high enough to push this radiation into the ultraviolet and even X-ray region. Bremsstrahlung produces a broad-band emission, although it's generally not as broad as thermal emission, but it's distinguishing feature is that it is polarized (the E-field vector of the radiation lies in the plane of the path of the electron). This makes it a good diagnostic tool for exploring magnetic fields around stars and in interstellar space.

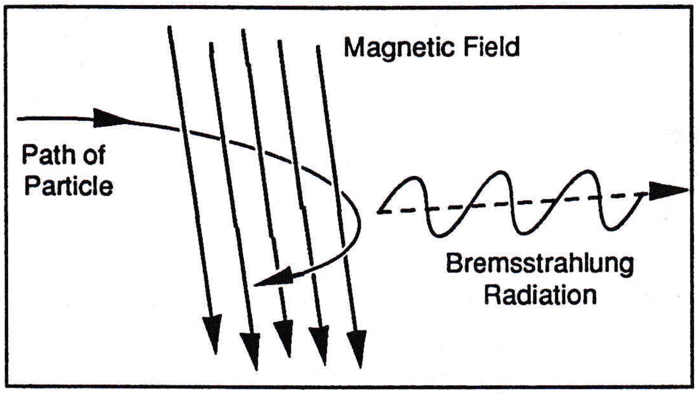



Figure 4: As a high-velocity charged particle is accelerated by a magnetic field, it emits plane-polarized radiation.

What I've Said To recap, there are three main ways in which light can be produced: by quantum state emission from a diffuse gas (as in a fluorescent lamp or a planetary nebula); by thermal emission from a dense material (like the surace of a star, or grains of dust in a dark nebula); and by synchrotron radiation, when relativistic electrons follow a curved path in a magnetic field. Each of these has a unique spectral signature that can provide a wealth of information about the source.

Of course, there are interactions and mixtures among these, and spectra aren't always (in fact are almost never) simple. For example, a jet from a quasar which hits the interstellar medium can heat it to a tremendous temperature; yet the emission will have a strong line component because the gas is still very diffuse even though very hot. Or consider Earth's atmosphere: To us it looks blue – a color associated with very hot stars – yet radio and infrared astronomers work in the daytime, and they see the sky as a very cold object (around 60 K). This is because the blue color doesn't come from emission at all, but rather from the scattering of sunlight. For the same reason, Jupiter is bright, and it's optical spectrum looks a lot like the sun's, but that's because we're seeing reflected light; the tops of Jupiter's clouds are not at 5000 K.

The Teaser Next time, I'll discuss atomic spectra in more detail, and try to give some insight into the kinds of astronomical information one can learn from them. After that, I'll discuss molecular spectra – primarily in the infrared and microwave – and again try to explain just what they tell us.

### Help Needed with a Third-Grade Class Star Party

From Ron Avers:

I have been asked to put on a Solar System show for three third-grade classes from Ardis Elementary School in Ypsilanti. They have been studting the solar system in class, and would really appreciate viewing the Moon and Jupiter through "real" telescopes. This has already been rescheduled twice due to bad weather.

There will be 60+ students, their teachers, and some parents and other family members – about 100 are expected altogether. I would greatly appreciate some help from anyone with any kind of telescope or binoculars to help provide more viewing time of more objects and features, and to help answer the multitude of questions which can arise at a Star Party of this size.

The teachers have not expressed an interest in deep-sky objects. They would like to stay on subjects connected to the solar system, or beginner-level observing, i.e. simple explanations of what they are seeing.

When: Friday, June 5 – cancelled if completely overcast, but if it's partly cloudy it's on.
- 8:00 Presentation on Jupiter
- 8:30 Set up scopes, start viewing the Moon
- 9:00 Jupiter, Moon, Mercury?, Mizar?, etc.

Where: Ardis Elementary School, 2100 Ellsworth Road
Out in the middle of the school yard – possibly several hundred feet from electricity – to get away from the street lights near the school building.

If you need more information or directions, call Ron at 769-9623 (work) or 426-0375 (home).

### Another Note from the Editor

We can save on the cost of newsletter mailing by using UM campus mail for those of you who have a campus mail address. If you're affiliated with the University, please contact the membership director (Steve Musko) to have your campus mail address added to the database.

### Did You Know?

Earth's moon has a mass of $7.35\times10^{22}$ kg. If it takes 4 gallons of milk to produce a pound of cheese (ignoring, for the time being, the exact type of cheese – we assume that all cheeses are more or less the same, that raw milk is nominally 4% milkfat and solids, and that the average cheese has a density of 1.2 g/cc) – and assuming that the average cow produces milk at 38% of the rate of a champion cow (the world record milk production from a single cow is about 8000 gallons per year), and given that the area of Argentina is $2.8\times10^{8}$ hectares (at an average density of one cow per hectare per year), then if all of the cows on the pampas were dedicated solely to cheese production it would take 50 times the current age of the universe (no, I'm NOT going to debate the value of the Hubble constant) to produce enough green cheese (well, after $7.6\times10^{11}$ years, you'd be green too) to make one moon.

They may be small compared to a galaxy, but planets (is the moon a planet?) are still pretty big.

# Subgroup and Officer's Reports

## Computers In Astronomy Subgroup

The Computer subgroup met on May 1 at Tom Ryan's house: six members were in attendance. The main topic for the evening was refining the design for installing digital setting circles on the 24" telescope. Steve Musko presented a preliminary layout for the computer electronics, based on a PC/XT donated to the project by the U. of M. Space Physics Dept. After much discussion of maximum count rates, telescope slewing rates, necessary gear ratios, etc. it was concluded that the best mechanical design had the RA optical encoder driven by the RA worm gear shaft. This requires only a 9:1 gear ratio, as opposed to a 6580:1 ratio which would be needed if the encoder were driven off the RA axis. With a 1000 pulse per revolution encoder, this will give 5 pulses per arc second in RA.

The meeting devolved into non-computer-related topics as we took a tour of Tom's latest acquisition - a set of 16" bench-test optics. This led to a discussion of optics and telescope design, which in turn made the topic of next month's meeting obvious: Computer-Aided Optical Design. Tom has a very sophisticated CAD program for optics, which he will demonstrate at the next meeting, and which he is willing to aid club members with for use in designing new telescopes and other hardware.

### Next Meeting

The next meeting of the Computers in Astronomy subgroup will be on Monday, June 1 at 7:30 PM, at Kurt Hillig's house at 1718 Longshore Drive in Ann Arbor. Call him at 663-8699 (home) or 747-2867 (work) if you need directions. All interested people are invited to attend. As always, interesting new software or hardware is also welcome; please call first to make arrangements. On the Agenda: Tom Ryan will demonstrate the ZeMax optical design system, which looks like a really slick (for $1500 it better be) package. The shareware program Skyglobe (DOS only!) will be on display. It looks pretty nice, and it's free – bring a floppy if you'd like a copy.

## Membership Survey Report

In the month before the April Elections, Ron Avers managed to contact 33 of the 64 club members by telephone – if you weren't called, please check with the new membership director (Steve Musko) and make sure he's got your correct phone number. The purpose of the survey was two-fold: to solicit nominations for officers, and to find out what the club members want for and from the club.

As for the first purpose: see the "Important Numbers" section on the last page to find out who the new officers are!

There were several ideas proposed for activities and meeting topics:

1) Light Pollution – Dean Freese would like others to join him and the club in making the local communities more aware of (and responsive to) this issue. His suggestion: join the International Dark Sky Association, get their slide presentation, get out and start educating developers, builders, city councils, zoning boards, etc.

2) Astronomy Magazine Directory – Several people asked why we're not listed in Astronomy's index of clubs. Let's make sure we're not left out next year!

3) Open Houses – many suggestions:
   - A) Prepare handouts for visitors describing some of the things they might see, with enough "gee-whiz" to be inspiring...
   - B) Publicize more widely – for example at the UM Planetarium shows, on WUOM, etc. – and to a more distributed audience (Jackson, Lansing, etc.).
   - C) Provide coffee and snacks.
   - D) Define a telephone contact for information and/or an on/off status report.
   - E) Prepare a brochure on the history of the McMath 24" telescope, and one on the Lowbrows.

4) Meetings: Get rid of the tables and arrange the chairs in a U, so we can all fit and see each other.

5) Suggested Meeting topics:
   - A) Individual interests – a good way for new and old members to get to know one another is to invite everyone to give a brief presentation on their astronomical interests: photography, telescope building, optical design, planetary observing, comet hunting, photometry, .... What projects are people working on? Who needs help? Who's willing to help?
   - B) The UM radio telescope / Radio Astronomy – What is its history ? What is it used for? What has it discovered? How does it work? Can we take a tour?
   - C) The history of the UM Astronomy department (by Rudi Lindner). The people, the scopes, its connections with the rest of the astronomical community.
   - D) UM research in astronomy - see if some of the students in the department (or faculty!) could come talk about their work.
   - E) Astronomy basics: How to buy a telescope, and how to figure out what kind of telescope you need (possibly by a sales rep or dealer?).
   - F) Hands-on lessons / workshops at PM, such as: telescope operation – cleaning, setup, alignment, and testing; observing tips and techniques; learning the constellations; binocular astrononomy; how to run the McMath 24" scope (we should to write a new manual / checklist).
   - G) Astronomical / educational films and videos.
   - H) What have we forgotten? Let one of the VP's know!

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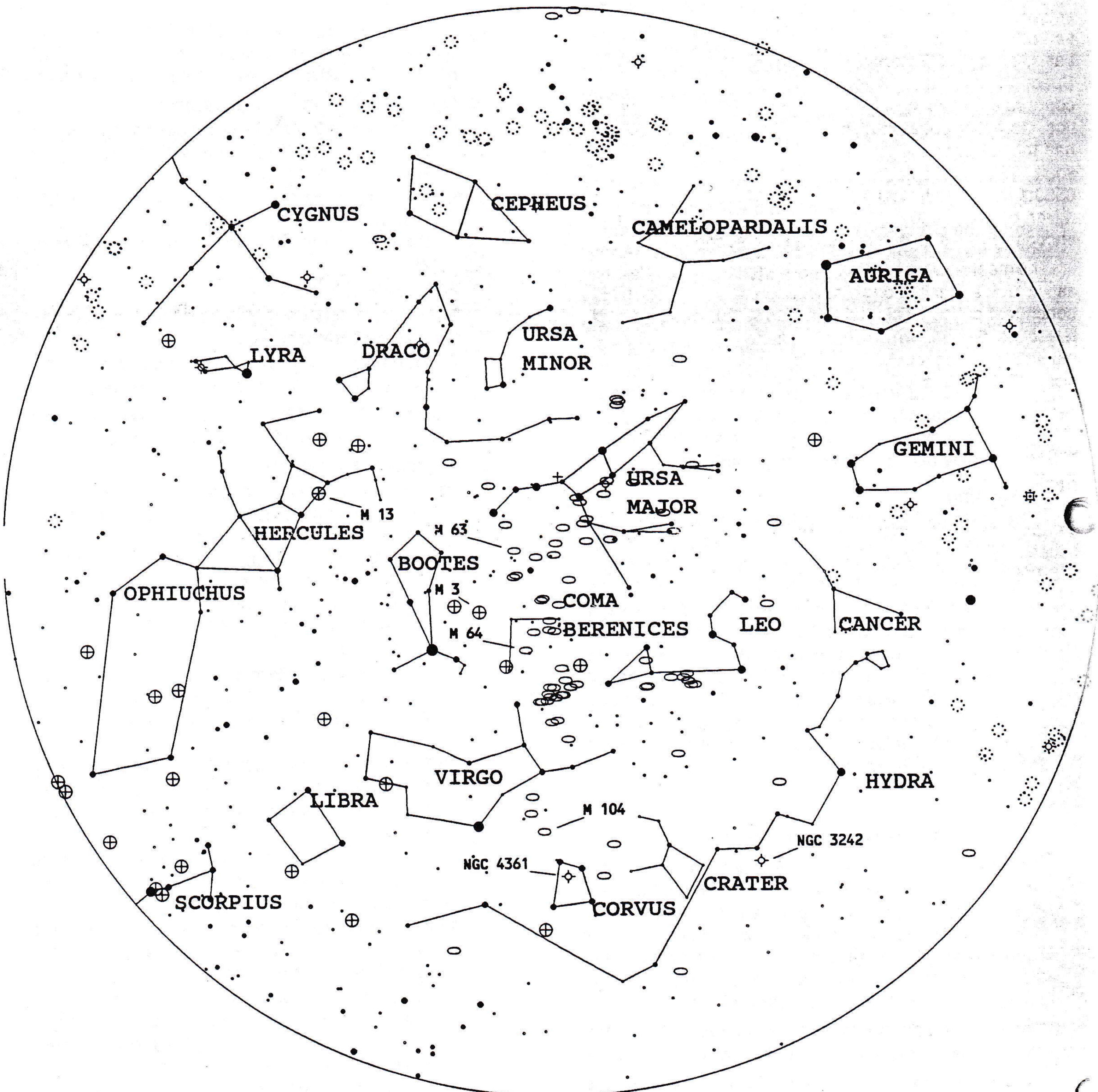
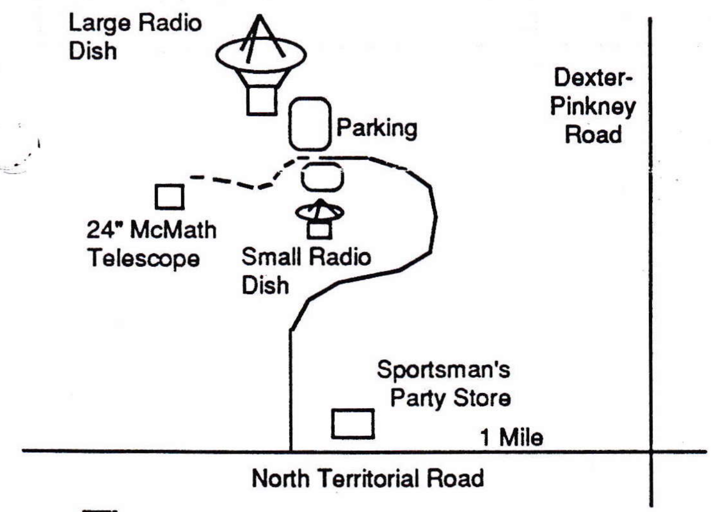


## ☞ Places:

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 two radio telescopes and the McMath 24-inch optical telescope maintained and used by the Lowbrows. The observatory is located northwest of Dexter; the entrance is on North Territorial Road, 9.5 miles west of US23, 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 (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 AnneSt.
Pinkney, MI 48169

## ☞ Magazines:

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

Sky and Telescope: $18/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 Kurt Hillig, using the Voyager program on a Macintosh IIcx.

## ✎ 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 | 123-4567 |

**Peach Mountain Keyholder:**

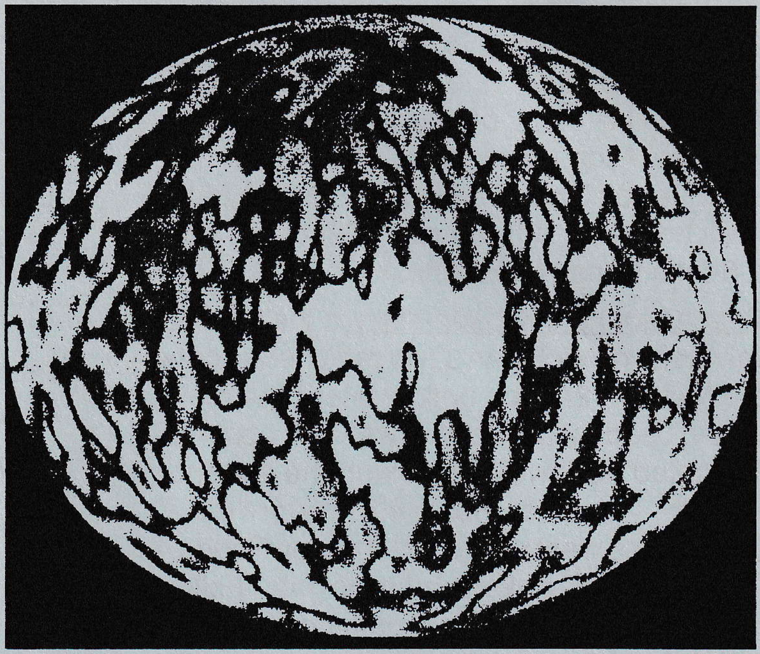
Fred Schebor 426-2363

# Monthly Meeting:

Dr. Kenneth Gibbs
of the
Enrico Fermi Institute
at the
University of Chicago
on the
Chicago Air Shower
Array

May 17, 1992 at 7:30 PM

At the
Detroit Observatory in
Ann Arbor



A microwave map of the sky, produced by the Cosmic Background Explorer (COBE) satellite, showing the variation in the temperature of the 2.73 K cosmic black-body background. The intensity scale represents a temperature range of only 0.00003 K. NASA photo.

University Lowbrow Astronomers
840 Starwick
Ann Arbor, MI 48105