2003

Students: Slavko Bogdanov, Jonathan Devor, Deborah Freedman, Andy Friedman, Ryan Hickox.
Examiners: Dimitar Sasselov (DS), Alex Dalgarno (AD), Steven Murray (SM), Tom Dame (TD).
Slavko:

- How do you measure the radius of a star? (AD)
- If you look at a 100 year old supernova, what do you see in terms of its spectrum? (SM)
- What are the masses of: (a) the Galaxy (total) (b) the stars in the Galaxy (total) (c) gas in the Galaxy (neutral, ionized, molecular, dust) (d) How do you determine each of these masses (6 methods...rough one, but Slavko nailed it!)(TD)

Jonathan:

- What is the maximum magnitude change when two identical stars eclipse one another? [2.5log(2) = 0.75] (DS)
- Describe the evolution of a 1 solar mass star. (Started talking about White Dwarfs) Why is degenerate nuclear burning a runaway progess? [Equation of State is independent of temperature](SM)
- What are the main phases of the gas in the Interstellar Medium, and their temperatures, densities, etc...? [HII, molecular, atomic](BN)

Andy:

- If you have a 10 x 10 pixel CCD array, and a diffuse source (blob shaped) that takes up a total of 25 pixels, with an intensity of $I = 0.3\frac{K}{pixel-sec}$, and a noise over the whole CCD of $1\frac{K}{pixel-sec}$, how many seconds do you have to integrate to detect the source? [To reach a $SNR = 3$ (i.e. a 3σ detection), you need to integrate for 17.2s] (i.e:
  $SIGNAL = 25pix \times 0.3\frac{K}{pix-s} \times T[s]$, and
  $NOISE = \sqrt{25pix \times 0.3\frac{K}{pix-s} \times T[s] + 100pix \times 1\frac{K}{pix-s} \times T[s]}$
  This gives $T = 17.3s$ for $SIGNAL/NOISE = 3$. You get $T = 16s$ if you ignore the variance from the source.] (TD)

- What is an HII region? What is a planetary nebula? Derive an expression for the size of an HII region. [Stromgren Sphere: Radius occurs when #recombinations/s = ionizion photons above Lyman limit/s] Why can you see background galaxies through an HII region?(DS)

- Describe the atmospheres of the inner terrestrial planets, i.e. Mars, Venus, Earth. What are their compositions? What are their histories? What are the surface temperatures of those planets? (BN)

Deborah:

- Draw the rotation curve of the Milky Way. Explain its shape. What does the curve tell you about the distribution of dark matter.(DS)

- What supports a White Dwarf from collapsing? [electron degeneracy pressure] Where exactly does this pressure come from - what quantum mechanical principles are at work? [Uncertainty Principle + Pauli Exclusion Principle](AD)

- What is the Crab Nebula? How much energy is it emitting? Where does the energy come from? [Neutron star spin energy] What is synchrotron radiation? (SM)

Ryan:

- How do you measure the mass of the Sun? [knowing distance, period, estimate using circular orbit, Newton's Laws] (SM)

- You would like to observe a source with RA 20h, dec -10 deg. Our current sidereal time is 16h, and latitude is 42 N. (a) What time would be best to observe the source? [current time + 20 hours] (b) Where on the sky should you look? [180 deg, elev. 38 deg] (TD)

- Name one of the colloquium speakers and discuss the research and why it is interesting (DS)

Students: Xavier Koenig, Kamson Lai, Shinae Park, Julie Nantais, Christopher Pilman.
Examiners: Ramesh Narayan (RN), Matias Zaldarriaga (MZ), James Moran (JM), Patrick Thaddeus (PT).
Xavier:

- What is the angular resolution of an optical telescope? Why can't we achieve this in actuality? What is the seeing limit caused by? (10cm sized fluctuations in Earth's atmosphere give 1 arcsec angular diffration at telescope)? (RN)

- How do you calculate the equilibrium temperature of the Earth's surface from the energy it receives from the Sun and the energy it emits as a black body at temperature Tsurf? What is the effect that makes the Earth warmer at its surface than this? Where in the atmosphere is the Earth at the equilibrium temperature that you calculate for no atmosphere? (Stratosphere?). (PT)

- Describe the HR diagram. What parameters are plotted on the axes, and what parameters of stars determine their position on the plot (Mass, Luminosity, Teff) ? What processes generate the energy of stars on the Main Sequence? How do stars evolve on the HR diagram? (MZ)

  (Additional question to all students: work out the Sidereal time right now).

Kamson:

- How does sound speed depend on density ? What is the mechanism behind the 21cm line? (PT) What is the degeneracy of the 21 cm line (MZ)

- What is the surface temperature of the moon? Estimate the emitted to reflected flux from the moon in the radio.(JM)

- Name the first 10 elements on the periodic table? How are they created? Will the sun ever make Carbon? What do low mass stars do when they leave the Main Sequence? (RN)

Shinae:

- Describe the structure of the Hydrogen atom. (RN)

- How do you measure the mass of a galaxy cluster? (MZ)

- Tell me about O stars in globular clusters? (PT)

Julie:

- What is the resolution limit of a telescope? [$\theta diff = 1.22\lambda/D$]. Where does that λ/D dependence come from? Derive it from the Heisenberg uncertainty principle. [$\Delta p \Delta x = h$, Δx= diameter of telescope, $\Delta p = p_{tot} sin(\theta) \approx (h\nu\theta/c)$] What is the typical angular resolution of a radio telescope? (JM)

- Tell me about globular clusters? [Densely packed, very old collections of millions of stars] What is their typical mass? (10^6 solar masses. What's their typical radius? [$10pc$]. How do we know they are old? [Main Sequence turnoff at low Temp. on Color Magnitude Diagram] What keeps them from collapsing? [Orbital velocities, angular momentum of binaries]. What are some typical orbital velocities? Derive on the board using a circular orbit, $M = 10^6$ solar masses, $R = 10pc$ [$10km/s$]. Are the orbits really circular? [Heck no!]. How does that change the answer? [It doesn't...Virial Theorem gives $v^2 \approx GM/R$ just like a circular orbit!] (RN)

- What is gravitational lensing? Derive on the board a formula for the deflection angle of a Newtonian billiard ball passing by the sun. Then, let the ball be a photon travelling at the speed of light c. [The mass cancels out in the derivation]. Did we really get the right answer using Newtonian gravity and billiard balls instead of GR and photons? [It's within a factor of 2](MZ)

Christopher:

- ? ()
- ? ()
- ? ()

2002

Students: Brant Robertson, Yosi Gelfand, Richard Cho, Dan Marrone, Mark Hartman.
Examiners: Bob Noyes (BN), Avi Loeb (AL), Lars Hernquist (LH), Pat Thaddeus (No Show).
Brant:

- How do you determine the luminosity of the Sun? (BN)
- How can we measure the core temperature of the Sun? Did solar neutrino experiments give the expected numbers? (AL)
- What is the green house effect? Why are Venus and Mars substantially different than the Earth? What happened to water on Mars? How does the mass of a planet affect its atmosphere? (LH)
- How does the spectrum of the Sun compare to that of Sirius B? Why do spectral lines vary from star to star? An A star, for example, has very strong Balmer lines. What about the specturm of cooler stars? (BN)
- What is the cosmological principle? Why is homogeneous not equal to isotropic? How can we tell that the universe is not centered around us? [Avi: "You weren't expected to answer that question. I just wanted to see you sweat."] (AL)
- What is the velocity distribution of gas molecules in the air? Of stars in a cluster? What is the evaporation time of a cluster? (LH)

Yosi:

- How do you measure the mass of the Sun? (BN)
- Why doesn't the Earth burn hydrogen? How massive does a star need to be to burn hydrogen? How much smaller is the Earth than this limit? (AL)
- Draw HR diagram of disk stars. How do you get the age of a cluster? [Answered inadvertently]. How do stars evolve on the HR diagram? (LH)
- What does the width of a spectral line tell you? What are the physical processes that broaden spectral lines? (BN)
- How do we detect neutral hydrogen? Is most mass neutral or ionized? (AL)

- How are extrasolar planets detected? What do these extrasolar planets look like? Do they fit into the current model of solar system formation? (LH)

Richard:

- Why does the Sun shine? (BN)
- How do we get planets around the Sun? (AL)
- What does it mean for a black hole to be black? Calculate the Swartzschild radius of a black hole. How would you detect a black hole observationally? (LH)
- What is limb darkening? (BN)
- What evidence do we have for existence of the big bang? (AL)
- What happens to comets as they approach the Sun? Why are there two kinds of tails? (LH)

Dan:

- Given Energy/reaction, M, and L of the Sun, how would you estimate its main sequence lifetime? (BN) Do it on the board. (AL)
- Where did the Sun come from? How was the solar system formed? Is the Sun a typical star in our galaxy? (AL)
- You have a low mass object orbiting a pointlike, much higher mass object. What kind of orbits are possible? What physical properties are conserved in these orbits? Suppose the higher mass object was very extended (past the orbit of the lower mass object). What do the orbits look like? (LH)
- How is the atmosphere of a star stratified by pressure? How does pressure scale height depend on T of the star? Write down the equation of hydrostatic equilibrium. (BN)
- Why do we say the cosmological principle applies to the Universe? What is this length scale? (AL)

- Tell me about Cepheids. Why are they variable? (LH)

Mark:

- Describe the structure of the Sun. Why is there a convective envelope? (BN)
- How does the lifetime of the Sun compare to the age of the Universe? How old was the Universe when the Sun was formed? (AL)
- How do we determine the age of the solar system? How does radioactive dating work? How would you infer the bombardment rate of the Earth by planetesimals in early solar system? [Look at cratering rate or new and far side of moon.] How do you measure the age of different parts of the moon? (LH)
- What is a Stromgren sphere? How big is it? How does this size depend on the temperature of the central star? (BN)
- How did structure form in the Universe? When did this structure form? (AL)
- How was the Milky Way created? Where is the dark matter located? Why does it have a different distribution than luminous matter? Where did the gas energy go during the collapse? (LH)

Students: Vit Hradecky, James Battat, Maryam Modjaz, Jenny Greene, David Smith.
Examiners: Irwin Shapiro (IS), Robert Kirshner (RK), Dimitar Sasselov (DS), George Rybicki (GR).
Vit:

- How do tidal forces arise, dependence on mass, distance, etc. (IS)
- What is the age of the Earth, stars, the Universe, and how are they measured? (RK)
- Draw the rotation curve of the Galaxy. Why is it not Keplerian at large r? Why solid body rotation at low r? (DS)
- Explain the origin of seasons on Earth (short question). (GR)

James:

- Why can we expect the Sun to shine rather than detonate tomorrow (self-regulating: as core temperature increases, radius increases which decreases the temperature). Show and explain key parts of HR diagram of solar evolution. When it reaches the white dwarf stage, why doesn't the Sun collapse (electron degeneracy pressure)? (RK)

- How long (within a factor of 5 in years) will it take for the constellations to change appreciably (proper motion of a constellation star is 1 arcsec/year, distance to them is 10 pc)? (DS)

- Describe accretion disks. (gas cloud collapses, conservation of angular momentum leads to increased spin rate, cloud flattens to form disk -why?- and friction between particles in disk cause energy loss and accretion onto host object). (GR)

- Why isn't there a lunar eclipse every month (orbital plane of moon around earth does not coincide with ecliptic)? Why are there ever lunar eclipses (when moon lies on or near the line of nodes. The line of nodes is the line of intersection between the ecliptic and the moon's orbital plane around the earth)? (IS)

Maryam:

- How does the velocity of the shockwave depend on the temperature of the surrounding gas? (v is proportional to square root of T since $1/2mv^2 = NkT$) (GR)

- What is the distance to the Galactic Center? How does one know it? What is the most convincing method? (He wanted to hear parallax measurements with VLBI) (IS)

- Tell me the name of one of the colloquium speakers, the content of their talk and why it's important. (RK)

- Tell me about 3 ways to detect extrasolar system planets. (radial velocity shifts, astrometric, unconventionally: intelligent life, conventionally: e.g. transits) (DS)

Jenny:

- What are HII regions? Explain this apparent paradox - There is a foreground HII region where most of the light from the central star is absorbed, yet we can detect a distant galaxy through the HII region in the V band. (Answer: The peak flux from the star is in the UV, that is being completely absorbed by the HII region. However, optical photons are free to pass through (they don't ionize hydrogen). (DS)
- Black holes - what are they, and what evidence do we have that they exist in the Universe? (GR)
- Why would we send a probe to Pluto? (RK)
- Hard to say exactly what the question was here - What is the cosmological constant? Why did Einstein think he needed it for a static universe (matter)? Why can't we see the effects of it locally? (IS)

Dave:

- What is dark matter? How do we know it exists? (RK)
- What is the r-process? What elements are made this way? (DS)
- What is the CMB? Where did it come from? (He wanted to know about the power spectrum.) (GR)
- What is Olber's paradox? (IS)

2001

Students: Craig Heinke, Alceste Bonanos, Scott Schnee.
Examiners: John Huchra (JH), Krzysztof Stanek (KS), Alyssa Goodman (AG), Josh Grindlay (JG).
Craig:

- What are Apollo objects? (JH)
- What is a planetary nebula, and how could you find its temperature and density? (long) (JG)
- What would be the number of leaves on that tree in June? (An order-of-magnitude estimation/ methodology problem.) (KS)

- How do we get the distance to the Virgo cluster? (JH)
- Bolometric corrections: what are they? (JG)

Alceste:

- What are the relative frequency of partial solar and lunar eclipses? (long) (KS)
- What is dynamical friction? Where is it important? (long) (JH)
- Write down the terms in the Drake equation, and fill in those that are somewhat known. (AG)
- Describe the galaxy, its component parts. (KS)
- What are the major cosmological principles? Describe. (JH)
- How does accretion onto a white dwarf differ in luminosity from that onto a neutron star? (JG)

Scott:

- Draw the H-R diagram of a 4 Gyr-old globular cluster. (long) (AG)
- GRB 990123 was observed at 9th magnitude, at z=1.6. What would be the magnitude if it was 1 kpc away? (Ignore relativistic corrections.) (KS)
- Discuss spiral density waves. (JG)
- If I turned Jupiter into a black hole, what would its radius be? (AG)
- There's a major galaxy cluster directly overhead now in Raleigh-Durham. How would I figure out what's overhead there right now? (Use sidereal time for RA, latitude for Dec.) (JH)

2000

Students: Greg Ball, Steven Furlanetto, Peter Sollins, Ming Sun, Mike Westover.
Examiners: John Huchra (JH), Martin White (MW), Jim Moran (JM), Ramesh Narayan (RN).
Greg:

- How do you determine the temperatures and radii of the stars of an eclipsing binary? (light curve shape, depth of dips is proportional to the fourth power of the temperature difference) (MW)
- What are Apollo objects and how many are known? (asteroid size bodies crossing Earth's orbit, about 100 known) (JH)
- What's the formula for the Schwarzschild radius of a black hole? Calculate R_s for the sun. Calculate the "density" given by this radius. What density would you get for something the mass of the earth? What mass black hole might be found in an AGN (10^8 solar masses) and what density would be obtained for that (1 g/cm^3) (RN)
- Compare the parts of the radio brightness of the moon due to its internal temperature and the reflected radio waves from the sun. Guess the temperature of the moon (use same equilibrium condition as for earth, is a bit cooler 250K due to having no greenhouse effect). What's the appropriate form of the blackbody spectrum (Rayleigh-Jeans)? Calculate the various contributions. (JM)

Steve:

- Explain the basics of special relativity: Lorentz contraction, time dilation, relativistic mass, and the Doppler effect. (RN)
- Explain the differences between stellar evolution of high and low mass stars (including location on the HR diagram, different fusion cycles, and end states) (MW)
- Is the year 2000 a leap year? Why are there leap-seconds? Why is the earth's rotation slowing down? (JM)
- What are the three effects that interstellar dust can have on radiation as it propagates to us? (He was after extinction, scattering, and polarization) (JH)

Peter:

- What is the Hubble constant? Why is it important? Name three methods of measuring it (distance ladder, lensing, CMB anisotropies) (JH)

- Talk about dark matter (rotation curves of spiral galaxies). What mass distribution would one need in order to get a flat rotation curve? (RN)
- As the CMB is redshifted by the expansion of the universe the individual photons lose energy. Where does it go? (nowhere; the universe is not symmetric under time translation so it needn't conserve energy) (MW)
- Why can radio astronomers get such better spatial resolution than optical astronomers? What is the difference in seeing at radio wavelengths and optical wavelengths?

Mike:

- How would you measure the distance to the sun using observations of the transit of Venus from Tahiti? (observations from two different latitudes give two tracks on the surface of the sun, so you get the size of the sun) (JM)
- Describe the cosmological principle, the perfect cosmological principle, and the anthropic principle. (JH)
- What is the energy source of stars? (fusion) Given that 10% of the hydrogen in the sun is burned over its lifetime, what fraction of the rest energy of that hydrogen is used? (RN)
- If you had a box in space filled with atmospheric air, with a helium balloon inside it, and the box was accelerated, what direction would the balloon move inside the box? (in the direction of the acceleration) (MW)

Ming:

- How can you measure the radius of a nearby star? (RN)
- State the possible observations to rule out the Big Bang. (MW)
- What methods are used to search for extrasolar planets? (JM)
- What is the sidereal time of Mt. Hopkins at the noon of June 21 (to first order)?

1999

Students: Dan Harvey, Johnathan Jenkins, Robin McGary, Aaron Sokasian, Aaron Tustin.
Examiners: Alyssa Goodman (AG), George Rybicki (GR), Lars Hernquist (LH), Shadia Habbal (SH).
Johnathan:

- Write down the virial theorem. Apply it to a gas cloud in equilibrium. What does it look like more generally, out of equilibrium? (AG)
- What happens to electrons moving in a magnetic field when the field lines converge (non-relativistic electrons, magnetic mirror). What is adiabatic invariance? (He claimed this was in Shu, Alyssa didn't believe him) (LH)
- Explain the aurorae. (SH)
- How do we measure the mass of galaxies dynamically? What measurements would you make for a spiral galaxy? (GR)

Robin:

- Describe the "Butterfly diagram" (solar sunspots) (SH)
- What is the size of the moon in arcminutes? What is the resolution of a 1000ft radio telescope in neutral H? Could you resolve the moon? What is the best resolution of VLBI? (10s of micro arcsec!) (AG)
- Describe the Hubble Law (draw diagrams of magnitude as a function of z, etc.) What is going on currently at the CfA? (Kirshner and what he thinks) What does grey dust have to do with it? (he didn't make me answer this one). (LH) At the end GR asked us casually if we knew the current sidereal time.

Aaron:

- What property is the same for all stars on the main sequence? What process generates the energy in stars? How does this process depend on the central temperature? What keeps the stars in the lower left hand corner of the diagram from collapsing? (GR)

- Name three observations that confirm General Relativity. (bending of light during solar eclipse, gravitational lensing, gravitational redshift) (LH)

- What are comets? How many tails does a comet have? Why do comets have tails? What did studies of cometary tails tell us about the solar wind? (SH)

- What is the frequency of binary stars in the galaxy? (40%) Why do binaries form (easier to conserve angular momentum in a collapsing cloud)? Do most clouds collapse directly to a star, or is there an intermediate stage? (forms a disk first) How could Jupiter have been formed from the disk (she wanted me to say that the major mode of instability in a disk is a bulge, which becomes Jupiter) (AG)

- If you can measure the spectrum of a star, how can you estimate its mass (find its location on Main sequence etc.) Then, what can you say about the luminosity? In reality, what is the main source of error in the magnitude estimate, and how do you correct for it (measure the color, which gives you the amount of intervening dust, which tells you the extinction)?

1998

Students: Hannah Jang-Condell, Pinaki Chatterjee, Vincent Fish, Kenneth Rines, Xiaohu Wang.
Examiners: Jane Luu (JL), Bill Press (BP), George Rybicki (GR), Robert Kirshner (RK)
Hannah:

- Where does the 21 cm line of hydrogen come from? What is the time scale for this process (10^6 years) How can it occur if it has such a long decay time? (rarified clouds) (JL)

- What is a single line spectroscopic binary? What can we determine about this binary? What more information can we get from a double line binary? (BP)

- Clusters of galaxies, virial theorem and dark matter (GR)

- Expansion of the universe. How do you measure the density of the universe (umm...) How does it compare to the critical density and what does it indicate about the universe? (open universe) (RK)

1997

Students: Saurabh Jha, Ann Bragg, Dave Charbonneau, Andisheh Mahdavi
Examiners: George Field (GF), John Huchra (JH), Ramesh Narayan (RN)
Saurabh:

- What is the Crab nebula? (SNR...) If you could make one measurement to tell that there's synchrotron emission, what would it be? (polarization) What do you think is the chemical composition of the filaments you see in the Crab? (metal enriched) (GF)

- What are the Apollo objects? How many are there? (JH)

- How do we measure the mass of the Galaxy? If the rotation curve is flat, how does mass scale with radius? (RN)

1996

Students: Peter Bloser, Ann Esin, Betsy Barton, David Heyrovsky.
Examiners: Alyssa Goodman (AG), George Field (GF), Ramesh Narayan (RN).
Betsy:

- Describe the HR Diagram. What determines where a star is on it? How do we measure luminosity and effective temperature? (RN)

- How do we measure the radius of a star? What might cause the luminosity of a star to change? Describe the significance of the solar system and planets in the development of astronomy. What is the scientific importance of the planets (element abundances etc) How old is life on earth? (3 billion years) (GF)

- What is a black hole? What is the radius? Where do we find them? (This led to a few AGN questions...their mass and luminosity) (RN)

- Describe the different scales of the missing mass problem? (How much mass is missing on each of the scales, how do we know etc.) (AG)

- How big is a (certain) molecular cloud? How many solar mass stars can you make from it?

Ann:

- How to make a rough estimate of the critical density ρ_{crit}? (Assume $E_{TOT} = 0$ condition: for a shell of matter $E_{POT} = E_{KIN}$, and one has then ρ in terms of H_o) (AG)
- How important is quantum mechanics in astronomy? (my answer: important, e.g. spectroscopy: line intensity, forbidden lines etc, that seemed enough) (GF)
- Where would one observe Lyman α line? (HII regions, e.g.) (RN)
- What is the difference between elliptical and spiral galaxies? Lead to a discussion of Population I and II stars, how to tell which is which, which population is the Sun, etc. (RN)
- Why are the orbits of the solar system planets almost confined to a plane? (formation of planets from an accretion disk) (AG)

David:

- What is Lyman alpha radiation, where do we observe it? What is Hα? (RN)
- What is an AU, a parsec, parallax? (GF)
- What is the resolution of a 5m optical telescope and a 100m radiotelescope? (AG)
- Nucleosynthesis of light elements- primordial and stellar (deuterium) (RN)
- Equivalence principle in general relativity. How does it explain bending of light? Can we observe bending of light? (gravitational lenses) What are observations of lensing good for? (dark matter detection) (GF)
- What is the solar neutrino puzzle? How could it be explained? (neutrino oscillations) (AG)

Peter:

- How do you find the mass of the sun? (RN)
- What is radar? How is it used to study the solar system? What evidence is there for non-Newtonian behavior in the solar system? (Mercury) (GF)
- Give an overview of the Milky Way. (AG)
- Describe the physics of white dwarfs, derive relations between parameters on board (RN)
- Describe binary stars-how to find masses, orbital parameters, x-ray binaries (GF)
- How do we try to measure H_o, what systematic errors could occur? (AG)

1995

Students: Ray Jayawardhana, Aaron Romanowsky.
Examiners: R. Kirshner (RK), Al Cameron (AC), Chris Kochanek (CK)
Anonymous:

- What keeps the Sun from collapsing? (hydrostatic equilibrium, pressure vs. gravity) (CK)
- Tell me about the Milky Way. (spiral arms- how do you know they are there, rotation curve) (RK)
- How old is the Earth? (rocks, Moon rocks, meteorites, led into star formation, molecular clouds) (AC)
- What are some mechanisms that generate radio waves? (synchrotron-where do you get it?, molecules) Receivers (single dish vs. interferometers, resolution) (CK)

Aaron:

- What is a white dwarf? How do we know white dwarfs exist? How do we measure radii of white dwarfs? (RK)

- What types of binary systems are there? (close, wide...) What are the orbital characteristics (elliptical, circular: close binaries tend to circularize) (AC)

- What is Hubble's Law? What is the age of the Universe (upper bound)? How is critical density related to Ho? Describe development of structure formation, how voids develop naturally from underdense regions etc. How can we know the initial density perturbations? (COBE) What was the magnitude of these perturbations? (CK)

- Describe the distance ladder. Questions about Cepheids etc. Use of supernovae as standard candles (what type? how do we know if they make good standard candles?-redshifts correlate with brightness) (RK)

Ray:

- How is Jupiter different from Earth? What are the most abundant elements on Jupiter? How do the chemical compositions of Jupiter and Sun compare? Internal structure of Jupiter etc. (AC)

- How can you use the LMC to weigh the outer galaxy? Radial vs. proper motions, angular resolutions, use of archival plates etc. (CK)

- If neutrinos had a non-zero mass, how would that affect astronomy? Solar neutrino problem, dark matter problem, baryon to photon ratio, 3 types of neutrinos etc. (RK)

- Life on Earth: Where was life a billion years ago? When did life move from the oceans to the land? What effect does the Moon have on life on Earth? (tides, stabilizes Earth's tilt). Why wasn't there life on land a billion years ago? etc etc. (AC)

1994

Students: Rohan Mahadevan, Zoltan Haiman, Lorraine Allen.
Examiners: Avi Loeb (AL), Alyssa Goodman (AG), Josh Grindlay (JG), Noyes (N).
Rohan:

- How do neutron stars form? (type 1, type 2)

- Where do we find molecular clouds in the galaxy? What's the size, width, mass, M/L ratio?
- How fast are SNR shocks? What do they do to the ISM?
- What are quasars?
- What is the seeing limit from earth?
- How would you calculate how long the sun would live? What is the ratio of energy given out by a supernova explosion to the total lifetime of the sun? ($10^{53}/10^{51}$ or 100 times) Where does the energy come from in a supernova explosion?
- How does the gas in clusters cool? (Bremsstrahlung)
- How do you calculate the strength of the ISM B-field in a region of no electrons? (Zeeman splitting)

Zoltan:

- Why are stars in equilibrium? Why stable equilibrium? (AL)
- Estimate speed of expanding mass shell in SNR explosion. Estimate total energy released. (AG)
- Interstellar medium. What ionizes HII regions? What ionizes dense parts where OB stars can't ionize? (cosmic rays) (AG)
- Quasars, 20 sec overview. Estimate luminosity from mass accretion onto black hole. (JG)
- Why can't we see center of Milky Way? Is there analogy on Earth? (Rayleigh scattering) (JG)
- Resolution of radio telescopes. Effected by seeing or not? (AG)

Lorraine:

- What are cosmic rays. How are cosmic rays trapped in the galaxy?
- What are HII regions? How are HI clouds heated (cosmic rays)

- Model for AGN; how do you estimate the energy released from one?
- How are elliptical galaxies believed to have formed (vs spiral)
- Why haven't clusters of galaxies (or was it globular clusters?) collapsed into disks? (cooling time > Hubble time)
- What's the magnitude of the anisotropy in the CMB?
- What's VLBI?
- Questions about resolution; the seeing limit (why?) (because of the size of the atmosphere layers)
- How are luminosity and mass related (for stars)-got into HR diagrams; what are high mass and low mass stars?
- What's Chandrasekhar's limit?
- What's electron degeneracy pressure; white dwarfs.
- Tons of questions on supernovae: what are they, estimate such things like how fast is the shock wave and material propagating out; how much energy is released; how would you estimate how long before the shock wave slows to 10km/s; what fraction of released energy is visible photons.
- How do you derive (by Newtonian arguments) the critical density?
- Estimate the Sun's internal temperature.
- Clusters of galaxies- how estimate temp of the x-ray gas (Bremsstrahlung)
- What's at the Milky Way's nucleus?
- What's a quasar?
- Interstellar B-field. How do you measure it?
- Polarization of light (dust grains and by B-field, synchrotron radiation)

1993

Students: Eric Woods, Norm Grogin
Examiners: Thielemann (FT), George Rybicki (GR), Hartmann (H). Anonymous:

- Describe the creation of the universe (Big Bang, Baryon genesis, recombination, CMB created...) (FT)
- How big is the Milky Way? Show the path of white dwarfs on the H-R diagram. What is the basic criterion for nuclear fusion (or something like that-kinetic energy overcomes electrostatic repulsion.) (GR)

Eric:

- What provides pressure in ordinary stars? (FT)
- What is an HII region? What sort of star would you expect to find there? (H)
- What is gravitational redshift? (FT)

Norm:

- What is the Milky Way? (Follow-ups about composition, size, age, etc.) (GR)
- Discuss the H-R diagram. (FT)
- Discuss T-Tauri systems. (H)

1992

Students: Min Yan, Diego Mardones, Q. Zhang, Louis Kalikow?, Martin Krockenberger.
Examiners: George Field (GF), F. Thieleman (FT), P. Thaddeus (PT)
Min:

- How many kinds of supernovae are there in the universe? (Type I,II) (TF)
- Why are molecular clouds important in astronomy? (star formation) (PT)

- What is the mass and size of Galactic molecular cloud? (Giant) (PT)

Diego:

- Why do stars need nuclear reactions in order to be in equilibrium? (FT)
- Where does the 3K background come from? Why is it important? Main characteristics. (PT)
- Describe the evidence for dark matter on local, galactic, and clusters of galaxies scales. (PT)
- Special characteristics of elliptical galaxies. (GF)

Anonymous:

- What is the reaction involved in the Davis Solar Neutrino experiment? (I said some sort of beta-decay, and he bought it.) Followed up with where in nature are neutrinos trapped. (FT)
- Talk about binaries. (semi-detached Algol, cataclysmic, detached, contact...) (FT)
- Describe the various celestial coordinate systems. (He wanted to know 'fixed' angles [RA, Dec] and elevation, hour angle and how to get from one to the other. Led into detailed discussion of wobbling of Earth's axis, nodal precession. YUCK!) (GF)
- Discuss the rungs of the extragalactic distance ladder. (PT)

Q. Zhang:

- What kind of stars evolve to iron-producing stage? What happens after that? Describe binding energy curve. (FT)
- What are H and He abundances after Big Bang? How are heavy elements formed? What are 'r' and 's' processes? (FT)
- Describe distance ladder. How to measure distance from close stars to quasars. (PT)

- How to measure the mass of a galaxy? What are different types of galaxies? What type is our galaxy? How to observe the spiral arms in our galaxy? Can you "see" the center of our galaxy? (GF)

Louis:

- Tell me about the sun. (GF)
- Suppose you turn on an O-star in a cloud of hydrogen gas. Explain what happens next in the cloud. (PT)
- Explain the various stages of stellar burning. (FT)
- What information can we get from spectral lines (e.g. from their width etc.) n1/n2=g1/g2 exp(-(E1-E2)/kT). (GF)

Martin:

- What is a quasar? (Redshift, luminosity, in elliptical galaxies, black hole in center.) (GF)
- Cosmic rays; what are they? Where do they come from? What are their energy cutoffs and why are they of these energies? (Answer: Low, 100 MeV→ Magnetopause of solar system blocks below these energies. High: 10^{20} eV→ Scattering by CMB, over long distances.) (PT)
- How do the pulsations in Cepheids work? Would it work if the opacity would be Kramer's opacity? Age of globular clusters–how do we know? (FT)
- Tell me about recent discoveries in Cosmology...(Molecular clouds at z=2.2, general cosmology) (GF)

1991

Students: Dan G.,
Examiners: Birkinshaw (B), G. Field (GF), A. Dalgarno (AD), P. Thaddeus (PT)
Dan:

- If you had 2 billion dollars to build a gamma-ray observatory, where would you put it and what would you see? (choke) What are the different types of AGN? (B)

- What are possible snags in use of Cepheids as distance indicators? What are the parameters determining the period of a Cepheid? (GF)
- Discuss the compostion of the inner planets (atmospheres, etc. reasons for differences). Compare to gas giants. Why are they different? (AD)
- (group) Each person give one "rung" on the distance ladder. (PT)
- Why would there not be any comets if the rest of the ... did not exist? How are comets knocked in from the Oort cloud?
- List half a dozen (two each) sources of magnetic fields. (B)
- Give methods of measuring magnetic fields (one each). (GF)

1990

Students: Brian Schmidt, Dan Reisenfeld.
Examiners: Birkinshaw (B), F. Thieleman (FT), John Raymond (JR), R. Kirshner (RK).
Brian:

- What are quasars? Optically or observationally, how do we identify them as such? What are the background radiation fields other than microwave and what are their sources? (B)
- What keeps stars from contracting? What are the three types of pressure in stars? What elements are formed in Big Bang and why? (FT)
- What are the differences between PNs and HIIs. Pick your favorite binary and tell me about it. (JR)
- Neutrinos in stars: detections and use of determining the goings-on inside of stars. What are the observational evidences of black holes? (RK)

Dan:

- Degeneracy pressure: what is it? Where does it come from? Is there an analogous mass limit to Chandrasekhar for neutron stars? Why is there more uncertainty for neutron star mass limits than white dwarf mass limits? (FT)

- Energy transport convective stability/instability; describe. (FT)
- Why is it dark at night? (Answer: Olber's Paradox) What is resolution of paradox? (B- mean questions)
- What is sidereal time right now? (yeah, right) (B)
- Describe HII regions (size, temperature, where they are, energy source, radiation processes) (JR)
- Describe the solar cycle (flares, sunspots, magnetic fields). What is the relation between flares and magnetic fields? (JR)
- The obligatory planet question: Why is the Earth's core hot? (radioactive decay) How are radioactive isotopes formed? (he had to get SN in somehow....) (RK)
- Explain the meaning of the Hubble constant. What are problems with its determination? How do we measure distances to galaxies? (RK)
- Comments: Relax...as B. said, " We make you squirm and then pass everybody."

Anonymous:

- How do we know the galaxy rotates? (measure radial velocities as function of angle,... distance for a given angle and use Oort's formula) (RK)
- What's the microwave background? (JR)
- What are spiral density waves? What drives..... (JR)
- What are cosmic rays? (B)
- What is a maser? What kinds of masers... (B)
- How do you know the ages of globular clusters? (FT)
- How are elements formed in the Big Bang, i.e. He, Li (FT)

1989

Students: JJW, Sean Carroll
Examiners: Mark Birkinshaw (MB), Steve Kent (SK), Willie Benz (WB), Al Cameron (AC).
JJW:

- What is the Jeans instability? Write relevant equations on board (unhappy face!) (MB)
- What is gravitational lensing? Describe it; discuss relevance to astronomy. (MB)
- Supernovae; difference between Type I and Type II. (SK)
- Describe time evolution of eccentric orbits of binary stars; describe instabilities. (sweating face) (WB)
- What is the primary composition of the inner planets? How are their magnetic fields produced? (AC)

Sean:

- What is the missing mass problem? Is the dynamical mass in galaxy clusters enough to close the universe? (no) (SK)
- Describe the structure of earth's atmosphere. Why is the ozone layer thin? Why does CO2 absorb in a broad band rather than sharp lines? (pressure broadening) (AC)
- If you took an X-ray telescope and pointed it at the sky, hwat would you see? (X-ray binaries, SNRs, Seyfert galaxies, intergalactic matter at centers of galaxy clusters) (MB)
- What's the difference between stars and thermonuclear bombs? (gravity) What keeps stars in equilibrium? Why do pulsating stars not settle down or pulsate wildly out of control? (opacity changes) (WB)
- When we look at distant stars, how do we know how to correct for interstellar absorption? (SK)

Anonymous:

- Lagrangian points: where are they? which are stable/unstable equilibrium points? describe how they work in binary systems (detached, semidetached, etc.) (MB)
- Line broadening mechanisms (for emission lines). What can line profile tell about the source? (WB)
- Age of solar system, and methods for determining this. (AC)
- UBV diagram: Where is main sequence? How do stars move under interstellar reddening? if metallicity is lowered? (SK)
- How do supernovae come about? Steps, and source of energy? How do novae come about? (SK)

1988

Students: Adrienne Cool, Lawrence Chernin.
Examiners: Alan Lightman (AL), Mark Birkinshaw (MB), F. Thielemann (FT), Steve Kent (SK).
Adrienne:

- What are the basic parameters describing the sun? (R, L, M) He might have asked about central temperature too, I can't quite recall. (AL)
- What is Cygnus A? (MB)
- In what form does most of the Sun's luminosity ...? If photons could escape as easily as neutrinos, what could we say about the evolution of the Sun? (FT)
- You are going to attend a lecture entitled 'the missing mass'. What do you expect you will hear about? (He wanted the various missing mass problems) (SK)
- What is M/L in various of these situations? (I didn't know.) (SK)
- What are the parameters describing a black hole? (Got mass, missed spin.) (AL)

Lawrence:

- Describe the parameters of the universe and their values, and what's known about them: Ho, qo, Λ, Ω. (AL)
- Describe binding energy curve. (FT)
- Draw a rotation curve, what shape curve should be, present data, missing mass. (MB)