



CONFIDENTIAL

Date: January 5, 2011

To: Astronomy Department Faculty

Re: Edited Transcript of Dec. 17, 2010 (noon-4:30 p.m.), Planning Meeting of
Astronomy Department Faculty

Attendees: Alcock, Berger, Charbonneau, Dalgarno, Eisenstein, Finkbeiner, Hernquist,
Goodman, Grindlay, Kirshner, Lee, Moran, Sasselov, Shapiro, Soderberg, Stubbs

Absent: Kovac, Loeb, Narayan, Thaddeus

Agenda

a. Introduction

b. Discussion of white papers in six groups (see attached list, p. 20)

Cosmology
Exosolar planets
Astrochemistry
Facilities and Centers
Appointments
Miscellaneous

c. General discussion

JM Goal of meeting is to try to gain a perspective of the research objectives of the Department. These will have to be merged in some context with the Strategic Plan of the CfA. One endpoint may be the plan we develop for new hires. This is the first year in quite a while during which we have not had a search under way. Generally have one search/year. Optimistic scenario would be to continue at this rate. Not clear how this would change the net size of the Department.

BK What is FAS planning?

JM Nothing written down. Bloxham says that intention is to cut size of FAS faculty from about 730 to 670. This would erase gains of last decade. The Astronomy Department size has stayed constant at about 20 for the past decade.

DS Try to go through WP discussion quickly.

DE Need to talk about some big topics not covered by WPs.

JM Charles, please talk about SAO Visiting Committee overlap.

CA New quasi parallel approach. SAO VC Feb. 15-16, Harvard Feb. 17-18. Opportunity for overlap. Chair of Harvard VC, Ewine van Dishoeck, will sit in on SAO VC on Feb. 16. Chair of SAO VC, David Spergel, will sit in on Harvard VC on Feb. 17 morning.

We have a CfA Strategic Plan (2007). Not too old, but pre-Decadal Report, pre-Harvard financial reversal. Will organize about three broad meetings of CfA people to consider adjustments to Strategic Plan. Some of the suggestions received in the WPs, for example, with respect to the MMIT, will require buy-in from broader CfA as well as UA partners. Changing MMT from general to transient instrument is not trivial, and it will take time to develop consensus and a plan. May only be able to decide on process by February.

Stubbs: Cosmology

- CS Considerable amount of cosmological investigations underway, but efforts are carried out under separate PIs and are not coherent. Compare with organization of ITC and Physics Department Center for the Study of Fundamental Laws. Maybe we should tie together our various efforts in cosmology to improve visibility to graduate students, to give opportunity for interaction. How would such a program relate to theory and programs in Physics Department? Relate to big picture issues before us: How will infrastructure evolve to support data-intensive activities; what is the connection to rapid time-domain measurements in both hemispheres; how will we deal with opportunities in 21 cm cosmology?
- We have invested a faculty position in CMB polarization measurements. Kovac says if we want to be serious, we need more people, as at other universities. Critical to understanding inflation, which is on par with understanding dark matter and dark energy.
- DE What big projects are we going to invest in? SN cosmology program has gone incredibly well here. It has a critical mass. Other areas are scattered. Use our own facilities or national facilities?
- AG Wavelength structure of CfA Divisions doesn't make sense. Is that going to change? Would a cosmology group be part of a new structure?
- CS Face same challenges in Physics Departmental programs and cross-cutting initiatives of various kinds. Think carefully about these structures. Also, Decadal Survey does matter. We should follow its recommendations. For example, what would we propose for the \$10-100M initiatives? Position ourselves as leaders.
- CA Propose important scientific initiatives; don't propose only for money.
- DC 21 cm efforts: which ones will get going first? What is our current investment?
- JM See WP scheduled for later discussion. In 1995, we became partners in the MWA. Thirteen signature institutions including (in the US): MIT, Haystack Observatory, SAO, and Harvard. Nine members of MWA board (four from US from each of its institutions; Brissenden and Moran currently represent SAO and Harvard). It's being built (late and over budget) but will take data in two years. 512 tiles of 16 dipoles each in Western Australia. 80-300 MHz for 21 cm line, $z = 6-17$. Our interest is the EOR experiment. Good also as transient machine because of its wide (30°) field of view. Compare ALMA $30''$. Good for dynamic imaging of Sun. One setback: Greenhill decided not to be involved. We are co-Is on new NSF proposal.
- DC Who will lead EOR?
- JM The EOR group is headed by Jackie Hewitt at MIT, and Angelica de Oliveira Costa and Daniel Mitchell are SAO members of the group. There's a large theoretical effort here, also.
- DE In three or four years, there will be attempts to use the same technique at redshifts at 1-3 to map large-scale structure. The next step from, say 10^7 to 10^9 galaxy surveys, maybe best done in the radio, not optical. This is a high-risk, high-reward situation. MWA may be a learning element. This could be the future for large-scale structure, and CfA could have leadership role in both theory and observation. Neutral about MWA. Point is that

this could be a steppingstone to a big paradigm shift in how large-scale structure projects are done. Train is beginning to leave the station....

- CA HERA, successor of PAPER and MWA, got strong endorsement in Decadal Survey. NSF will take seriously. Initiative between PAPER and MWA is with the latter but not necessary to continue that way. We have greater depth and breadth technically here to bring to bear on the problem if we so desire.

Charbonneau: Exoplanets

- DC Success story. CfA the best place in the US for study of exoplanets in terms of detection and characterizations. Was not true a decade ago. It's a very exciting time: First transiting habitable planet will probably be announced in next year, based on current progress. Kepler working well. Radiative velocity follow-up working well. Special time in the field. Biosignatures big and exciting goal. Along the way, we learn about physical structure of planets. CfA is heavily invested on both SAO and Harvard sides. Derived prominence but not having had to pay, e.g., Kepler: More Kepler staff at CfA than anyplace else, except for Ames. Kepler is \$600M project. MEarth survey, \$2.5M, expanding to Chile in next year. Harps North is a spectrograph to follow up Kepler detections. It will be next, on Italian 4 m in La Palma. Plans for first-generation instrument on GMT, GCLEF. Came close on satellite proposal, final five on SMEX proposal on TESS (PI is Ricker at MIT but Dave Latham was key player). Being repropose for larger-budget cap program. We must make sure we retain prominence as we move into era of looking for life on other planets. GMT will not image planets like Earth. It will do great thing with radio velocity and spectral follow-up. We're devoting resources to spectroscopy (Harps North, GMT, Kepler follow-up). But neither Charbonneau nor Sasselov do spectroscopy. Dave Latham is real leader here, a central figure. He has acted like a faculty member. What about when he retires? Life may be discovered by other groups, Harvard and CfA should do that! Others could claim credit because of collaborations, but we're doing the work.

JM Could an SAO appointment be critical?

DC Yes, on either side would be good, but shouldn't defer if SAO delayed.

JG How close can we get with Magellan? Do we have to wait until GMT? What will happen in ten years, here and elsewhere?

BK Paul Butler and Steve Shectman have built and are using radial spectrograph for Magellan. We could ask to use it.

DC Kepler's stars are too far and in northern hemisphere. As GMT is built, will free up time for 8m telescopes for exosolar planets. Europeans are taking this approach with Expresso for one of 8m VLT telescopes, which will be powerful. Can do things with 8 m and with GMT.

CA Will not be able to operate Magellan telescopes in same way when the GMT is built. Significant changes necessary. Advantages to dedicated programs.

DC Harps is a single-pixel instrument on 3.6 m telescope. Used every night and has cleaned up.

Sasselov

- DS WPs highly correlated with DC's. First, why should our department (and CfA) pursue Earths from the ground as well?; second, about origins program. For the first, I have the same recommendations as Charbonneau. More staffing, i.e., FTE in observational spectroscopy-related work (both for medium-resolution spectroscopy and for precise radial velocities). GMT and spectrograph (in phase A now at CfA) is a good idea. Models are coming to the point where they can't tell much more unless feedback from multiwavelength spectroscopic observations. So need a bigger telescope, simply a matter

of photons. Harps North will tell about interiors of small planets but bigger telescope needed for Dave's projects. CfA is already designing GCLEF (a super Harps instrument for GMT). Harps North is a steppingstone.

2nd paper (Origins of life initiative): How can our department benefit in looking for life on other planets? Extraordinary intellectual opportunity here at Harvard (chemists, biologists, etc.). Current provost has been very supportive (\$5M in last three years). High-risk endeavor. Reminiscent of cosmology in 1960s, which was risky, but it was certain that with bigger systems, one could probe farther. Given the complexity of biological systems, it is not clear how far we can go. Biochemistry, planetary chemistry for exosolar planets are all highly uncertain. One of our Harvard team members got a Nobel Prize last year. Use as an opportunity for more hires. Missing link: Reviving FTE search with EPS department: someone who does chemistry, link to people in molecular biology and chemistry. Right now, link is maintained by Dan Schrag and Andy Knoll, but they are busy and very senior. Need now to keep this going (junior faculty), half with Astronomy, half with EPS.

- EB Do we have people who do both aspects of the spectroscopy?
- DC Jacob Bean, a prize fellow here, is an example of someone who developed a precise relative velocity spectral instrument himself on VLT. Also used low-res spectrograph for transmission spectrum (see article in *Nature* two weeks ago).
- DS Harps North (not just a clone of Harps) – development of second laser calibration system (Astro-comb, by Szentgyorgyi, Walsworth, Phillips).
- BK What about the theory side, e.g., Sara Seager and Adam Burrows? Do we need theoretical astrochemists to work on planetary atmospheres?
- DS Former students Eliza Miller-Ricci and Sara Seager are doing exactly this. Long-term, ten years, need better observational capability. Right now, against the wall. Theory needs observations for guidance. What can we do uniquely that no one else is planning?
- DC Observationally driven. Some have devoted energy to imaging planets and spectroscopy with TPF. In reality, will not happen for 20 years. Other recommendations of Decadal Survey related to temporal signatures could open up funding. Given TPF is not going to happen, how should we look for life in next decade?
- AG Astrochemistry: People who used to do ISM now do chemical structure of disks. Very relevant for planets. Ted Berger, Karin Oberg good people. U. Virginia forming astrochemistry of universe center. How to use ALMA?
- CA Lot of young talent is going into this area. Would get good candidates if we had search. This past year, the two top candidates in CfA fellowships were in exosolar planets. Expect strong pool.
- CS Science here is tremendously exciting. I salute my colleagues for their extraordinary progress. We need to keep strength in this area. BUT: Department has maintained its size, but hiring has been on the Harvard side while retirements have been on the SAO side. From FAS perspective, Harvard has been putting in more. Need to make compelling case. Our Harvard faculty has grown while University wants to shrink staff. Winning arguments may have to do with undergraduate education.
- JM Hires have been disappointing or difficult with interdisciplinary searches with Physics, EPS. Haven't worked out well. Failed search in EPS. Physics back and forth with choices, etc. Is there an advantage to a Divisional search? Not sure there are still Divisional slots.
- DS EPS is interested in joint searches. John Shaw talks to Jeremy often and feels we could get joint slot in addition to other basic needs.
- AG Xiao-Li Meng in Statistics feels the same way about getting shared appointment in astrostatistics.

- DE On the Harvard Side, we have a few slots; opportunity pool is better on the SAO side. How to get people hired who would win faculty positions at other top institutions? Could get 20 go-getters over next decade.
- CA Demographics suggest significant retirements on SAO side: Open search for three positions a year ago was successful (hired Murray Clay, Andrews, and Kaspar). Wants to conduct searches in groups of about three. If we don't get creamed in 2012 budget, next fall, will do that, including ones open to higher-level positions.
- DC US citizenship a limitation. And are SAO benefits competitive?
- DE CfA strategic plan must confront this. Approximately 60 total SAO Federal staff. Small changes in policy could have big impact.
- CA SAO Federal positions (as opposed to Trust positions) are reserved for US citizens; carry equivalent of tenure. Compensation is a little lower than Harvard, but competitive with top 20 institutions (e.g., UCal!). Not competitive with Princeton, Caltech.
- JM Startup funds are not in the SAO culture. Startups for recent Harvard faculty are impressive.
- CA SAO entering fundraising campaign. One goal is to remedy this discrepancy over time sale of seven to ten years. SAO positions have significant benefits: Don't need summer salaries, don't need to teach.
- DS Teaching responsibilities for Harvard: I never took sabbatical. We don't have staffing to cover courses (e.g., Astro 201a), especially with regard to increasing number of students who want to do exoplanets. May be saturated with students soon.
- DC Yes. I took four new students this year.

Dalgarno: Astrochemistry

- AD Breadth of subject makes it hard to cover. Pat Thaddeus and I will retire by 2012 from Harvard (not Smithsonian). Pat will complete the survey of carbon monoxide, then extend it to HCN. HCN is a diagnostic of higher-density regions. He will not be replaceable. He discovered negative ions, as suggested here in a theoretical paper 25 years ago. Pat has been so successful because he combines lab work with observations and some theory. SAO lab now led by Mike McCarthy. Measure high microwave frequencies to high precision in lab of molecules of astrophysical interest. Sometimes astronomical detections come first. SAO plans to build a higher-resolution lab spectrometer. Lots of astrochemistry activity also at Harvard. It is enormously strengthened by SAO component. Gary Melnick proposes to continue observations at other telescopes of molecular oxygen and other molecules in various regions of the galaxy. Regarding astrochemistry of exoplanets: unrecognized work here on solar planets. I have a new paper on the escape of helium from Mars in the *Journal of Geophysical Research*. I regret that exoplanets have come too late for me!
- JM What about McCarthy lab?
- CA McCarthy lab is healthy and will move to 60 Garden Street. Pat has worked closely with Tom Dame - 3 kpc arm. Mike McCarthy runs the lab where negative ions were discovered and then found with Green Bank telescope. Sustained long-term vision and research goals of this group are paying off.
- AD Pat has connections everywhere, so he can get someone to do the astronomical observations.
- JM New radio instruments, EVLA, SMA, ALMA, cover such wide bandwidths with fantastic resolution that you can observe hundreds of lines at once in the ISM and certain stars.
- AG Center for Chemistry of the Universe: \$25M/5 years. UVA + NRAO collaboration. Down to final competition of two proposals. This center will try to corner the market in

astrochemistry. Interested in Oberg and McCarthy from CfA and Herbst. UVA has promised to support center internally.

AD This center is trying to hire my postdoc to do calculations of reaction rates in gase phase and on surfaces.

Lee: Solid-State Astrochemistry

JL Wrote WP based on conversations with Pat, Alex, Hossein Sadeghpour, and Mike McCarthy. We have good potential for being leaders in condensed matter, from x-ray to radio. But current groups are sophisticated but isolated from one another. Need a forum to bring together radio, infrared, x-ray. We have a lot of things in place, but progress is not cohesive. New missions and telescopes JWST, ALMA. Lot of interest at SEAS, Physics, EPS, and externally. I get calls offering experimental time. Strong interest outside astronomy community. Can experimental efforts be brought together, under umbrella like ITAMP?

AG NSF Chemistry Division doesn't like astronomy, according to Brooks Pate.

CA True for physics, also.

JL Physics focused on atomic physics, nanoparticles. Maybe NSF would fund multidisciplinary research. Center for Nanoscience at Harvard – has phenomenal facilities for this type of work but not much interaction. We should bring multidisciplinary people here for talks (as does ITC). Lots of applications to microbiology and geology. Also, international interest. Can we do a proposal for a Center? Does the Department want to go this wide?

CA Example of ITC comes up repeatedly: cohesive group, young people, transformative, etc.

AG/DS This could be done in CfA Divisions, but they are mostly aligned by wavelength.

JG Future of ITAMP? Reconstitute ITAMP to meet needs of Lee?

AD Way to go is to write an independent proposal. Difficult to get support within astronomy. Will be challenging to renew ITAMP. Have one more year of a 20-year run. Will write proposal. Unless we replace Kate Kirby externally, we don't have a chance of renewal. NSF will read this as no institutional interest on our part.

DS Subject of chemistry is a recurrent topic in exosolar planets. The obvious strength in Department and SAO should be toward problems of exosolar planets.

JL Want to be able to have funds for interdisciplinary conferences

AG European labs strong and so much work is done there. Problem with SAO not being able to hire non-US citizens..

CA Hiring a non-US citizen is not a small matter, especially for young, but has happened, e.g., Gaspar Bakos. Hold Trust post until his naturalization comes through. Alexyi Vikhlinin being sought after in Europe. Try to keep him until naturalization comes through.

IS Dual citizenship? Could hold in SAO Trust positions people who commit to become citizens. Five-year process.

DC Lucky with Gaspar; he was loyal. Had offers.

CA Very high percentage of Trust scientists are foreign. Just lost Maxim Markevitch.

JM Numerous mentions of Centers. Have any Centers been formed since the beginning of the financial crisis? Is this era over?

CS I called Jeremy about building a "thing" having to do with observational cosmology. Should we call it an initiative, enterprise, collaboration, endeavor, center, or what? Reply (after consultation with Smith): You're allowed to propose a Program in Cosmology (no funding). Centers have money, programs don't. Center for Quantum Physics has recently been formed. It was a piece of Lukin's retention. It helped to be a multischool initiative. We'd benefit from establishing an entity, i.e., a program; students would

- benefit, better visibility. Reasons not all about money. Very successful low-budget program in microbiology.
- CA Money is hard to come by, but let's not focus only on that. We'll be competitive for NSF and NASA dollars.
- DE Lots of seed money and postdocs available. Department would be foolish to lock up money in specific centers or programs. Keep money fluid. Have a lack of planning and coordination. Size of CfA makes that hard, and Divisional structure divides us. We need planning on a micro level – a few faculty and SAO people getting together and deciding to do something. We need to decide what to do, make a plan for five years, and not only worry about Bloxham's blessing. We need active planning done in a wise manner. Writing a proposal is the easy part; we know how to propose.

Kirshner: GMT

- BK GMT idea grew out of the great success of building the Magellan telescopes. Began studies six years ago. Set up entity to build the GMT. Tackling big risk of casting and polishing first mirror. Consortium consists of Harvard, SAO, UA, Carnegie Observatories, U. Texas and Texas A&M, U. Chicago, Australia, and South Korea. Board members from CfA are Alcock (SAO), Kirshner (Harvard), and McClintock (SAO). Site to be near Magellan on Las Campanas. Will do design up to critical design review over next two years. Second mirror going forward. Instruments being studied at CfA: NIRMOS (Fabricant) and GCLEF (Szentgyorgyi, Eschelle spectrograph). Of five studies, we have two, and three will be selected. Partners putting up real money (Australia \$70M, Korea \$74M, others \$56M, or \$200M so far toward \$700M). Need Harvard to agree to contribute 10%, or \$70M (early on, committed \$2.7M+). Need to have GMT called out on capital campaign. Don't need all money at once, but need assurance it's coming. This is an uphill struggle. Emphasis at Harvard being given to current needs (e.g., dorm renovation), not 20-year future.
- IS Where is rest of money coming from?
- CA Money coming from aspirations of the partners. Harvard, SAO, Texas, Texas A&M, and U. Chicago, all at 10%, would be enough.
- BK I think the problem will be oversubscription. Decadal Review has put GMT on its list and asked NSF to decide soon about its support. NSF may contribute a 25% share of the project (construction and operation). \$700M construction costs; will also have to have an operations budget and money for next-generation instruments.
- CA Other partners are looking to what Harvard is doing. Harvard's standing back is slowing whole process.
- BK NSF asked to make decision between GMT and TMT in next year. I expect they will do this promptly, which is not to our advantage.
- CA NSF expected to commit \$15M over next four years (MREFC) but with no binding commitment to construction costs of either project. Doesn't make sense, and will do more harm than good. NSF responds to proposals, cannot commit to support construction at this stage.
- CA SAO is committed to the GMT, with or without Harvard. Is not yet a budget line item. Request to start last year declined. New request for 2012. Normally would have heard back from OMB by now.
- CS Clear action item for VC: We hope next provost is a scientist, and VC should make him/her sympathetic to GMT.
- BK Not going to do better than current provost. Strong scientific case can be made to NSF. Being in the south is good (ALMA, LSST). Lower cost and risk, according to Decadal Survey. Project has staff and funds to do engineering. Have about two years to really get funding pinned down. On Jan. 24, Drew Faust will visit CfA re: GMT.

- CA Give her a 2-3 page document in advance. We will schedule the agenda for the Faust meeting.
- DE Need to be very clear in telling her why this is a necessary step for the Department. What exists now is not competitive and won't be in five to ten years. Harvard and CfA are major destinations now for all sorts of junior people but will not be as compelling if don't have something larger than a 6.5 m. Now competing with Keck 10 m. Not good situation and will only get worse.
- BK Recall what John Huchra said about the status here when he arrived in the mid-1970s. Not even a working spectrometer on 60" telescope. Compare with today. We have limited but very good instruments. GMT is important for long-term strategy of University.
- CS Would a favorable view by Harvard president affect NSF's view?
- BK Yes, would help financial credibility of project.
- CS What is project's response to Decadal Survey budget estimate?
- BK Decadal survey challenged the cost estimate, but some things were counted twice. It also said the schedule is too optimistic, so the required funding will be \$1.1B. TMT, \$1.8B stretching to 2026. Andrea Gilbert, a Harvard undergraduate, was part of Aerospace budget team. Principal objection was in fabricating the mirrors. Need to phrase the question to Harvard as a percentage share (10%), not a dollar amount. Need another way to pay for operations. NSF won't act fast enough to pay for construction and will have to pay a disproportionate part of operations. Not what NSF likes to do.
- DC What happens if the GMT is not part of the capital campaign? Other avenues?
- CA The main focuses of the capital campaign are current use giving, endowed chairs, undergraduate support, and renovating undergraduate housing (\$100K per room). Donors like to fund these things. Harvard needs to do these things anyway. Then other money is freed up for projects like the GMT.
- BK Sometimes lightning strikes: Donors can appear out of nowhere. Long shot.
- DC Any other way? Sell Agassiz station? Sell nights on telescope?
- DS Hard to name 10% of a facility after a donor. Last week, a planet named after a country, Qatar 1b. Drew Faust asked me about a Harvard 1b.
- CA To zeroth order, most donations come from Harvard alumni. Harvard knows all about them. We are forbidden to contact alumni. But we have a route via SAO and Carnegie, which are open to joint fundraising, which provides a different route to Harvard alumni. Patty Stonesifer, chair of SI Regents, is on a first name with Bill Gates (she ran Gates Foundation). Bill Gates doesn't care about astronomy; he gave money to LSST because of personal connection (Simeone?). The upcoming meeting with Faust was facilitated by Provost Hyman. Bloxham is supportive. We are going to get a hearing.
- DS Must be able to answer question if this project will benefit anyone else at Harvard?
- DC Planetary science usually a separate department in other universities. Astronomy is small department.
- JG Strongest argument: Real path to evidence for life – that involves other departments
- CA Don't know Drew Faust's interests. She's a Civil War historian. She is generally wary of high costs of scientific projects. It really is about the money. We may want to discuss with her John Quincy Adams's handwritten report of the first visiting committee; fall from prominence when Hale went to California; clawing our way back up over the past 25 years. This may resonate with her. Design principle is similar to those used on Magellan, which came in under budget! But price of steel is going up, so costs can inflate.
- BK To see how far we have come, recall Dennis Overbye's comment in *Lonely Hearts of the Cosmos* to the effect that in the 1970s, Harvard had fallen from the top ranks of astronomy programs. Good students still went there because of the Harvard name but

- faculty was mediocre. Written in 1990. We have done so much better since then. Observational optical astronomy at Harvard has come a long way due to MMT, redshift survey, Magellan. Very good people come. No dead wood on faculty. Department in receivership in 1970s.
- JM Is GMT funding available to support design effort at optimal rate?
- BK Yes. It will cost \$55M and be finished in two years. One potential delay would be a shoot-out with TMT at the NSF. That would divert our engineers.
- IS What about the Keck 10 m telescope in terms of budget and time?
- CA Keck 1 was late and cost more (trouble with mirrors). Keck 2 was pretty good.
- IS Why has GMT mirror testing gone so slowly?
- BK Progress slow lately. Technical problems with first mirror.
- CA Test apparatus had to be redesigned. Completion of polishing of mirror is scheduled for 2011.
- DE Talked to Jim Burge, primary optical guy at Arizona. Says that TMT polishing is even harder. He thinks he has figured out how to do this.
- CS Large aperture telescopes reach full fruition when married to adaptive optics systems. We are the mercy of our partners in this pivotal area. We have to make decision at CfA level about whether to get involved in what I consider a critical but challenging aspect of the project, the adaptive optics (AO) system. I'm apprehensive about this vulnerability.
- BK Non AO secondary will be installed first.
- CS I am concerned that we will be at a big disadvantage if we haven't planned for an AO system. If we were not going to do this, I recommend we just clone Magellan.
- DE Pasadena (Carnegie) folks not interesting in pushing AO for GMT. We've languished vis-à-vis TMT, which has competitive advantage.
- BK GMT has just hired an AO engineer. Getting work done.
- DE Worried that in an NSF shoot-out, TMT will pull out a 200-page AO design document, and we will have only a conceptual pamphlet. I really worry about our being at a competitive disadvantage.
- DS I agree with Chris on the need for AO. Limited resources in our Department. I suggest supporting GMT instrument development from Department. AO is responsibility of whole consortium.
- CA If money is the rate limiting step, we may want to have GMT first light without an AO system. Shaves \$100-150M off construction costs. No one wants to do this. Do what you can now, then in about 2020, get major equipment funds from NSF for AO. NSF may be interested in paying for this kind of technical work.
- CS Operations costs will soon be able to be covered from NSF/MREFC. NSF getting more interested in lifecycle cost of facilities.

Break

Berger: MMT

- EB Study of transients is one of the main projects in coming decade. How to support this, going forward from Pan-STARRS to LSST era? Spectroscopy is important. Could focus efforts on MMT. MMT has (1) two weaknesses: too many instruments, too many secondaries, and (2) no imaging capabilities since megacam shifted to south. How to simplify? Fix imaging capability: fairly modest cost (\$100K). A quick fix. Long range: simplify instruments: flexible and capable for time-domain astronomy; dark time imaging spectrographs. Two instruments proposed: Binospec (optical) and MMIRS (infrared) on Magellan. Need clone for MMT. Revision of mode of operating. Make time-domain astronomy a first priority. Discussions needed with CfA and Arizona.

- DE Not only for LSST but for near-term (Binospec a game changer for MMT). I think Arizona will be well disposed. Arizona may not like queue observing.
- IS Should we start time scale for queue observing ASAP?
- EB Queue scheduling already 50%.
- CA Binospec estimated to be at CfA in late 2013. Built to be shipped back and forth between Magellan and MMT. Alarmed at this possibility. \$4M for second copy.
- DE Build a copy of MMIRS – path of least resistance. What will we need to be competitive in 2018? We're behind the curve on instrument development for MMT.
- EB Need two instruments with single secondary, not ten instruments with three different secondaries.
- BK As LBT comes online, Arizona will go along with this.
- DE If we were drilling masks on 6–12 hr time scale, could accommodate transients with other programs. Big advantage of Binospec (at CfA) is that we can process data and support telescopes with TDC. Support people through calibration.
- CA TDC is working now. Pipeline for Megacam delayed, not of great concern. It sounds like we could bring about a second copy of MMIRS: consult Warren Brown, Dan Fabricant.
- DE Encouraged by discussions with Brown.
- EB Want packages to be simpler.
- CS Crazy out-of-box idea: Building an instrument that's very late called Pisco (Stark's project), 4-band imager. Getting photometric redshifts now with workarounds on other telescopes. So Pisco on Magellan not needed. But Pisco could be attached to a small telescope such as 3.5 m at Apache Point, same f number. Chicago may want out of 3.5 m collaboration. Disadvantage: Would divide efforts among SW telescopes. Could be a good opportunity. Could buy in to 3.5 m consortium or trade observing time for instrument availability. Need about \$150–200K/year.
- CA Put Pisco on MMT?
- CS Designed for f/10; other telescopes are more agile.
- AS Princeton has access to 3.5 m. Highly attractive for SN work. Princeton kicks in a few postdocs.
- DE \$100K for 1/16 share of operations. Relative cheap; could buy three shares.
- CS Could buy Chicago time share. Near-term opportunity during PS-1 era.
- BK But Pisco is not done yet.
- DE PS1 for two more years: Are we interested in re-upping as part of consortium in PS-1 or PS-2 (ready in two years)?
- CA And what does re-upping mean? They haven't named a price.
- BK We're using PS-1 well compared with everyone else. Just when we're good at it, we should exploit it.
- CA Need science plan. Significant amount of solar system objects will be found by end of two years.
- AS How about a center for time-domain studies?
- CS LSST is coming. We should be part of it in areas that we find interesting. Need to continue Pan-STARRS. Not a coherent enterprise at CfA now, but we have time to change this. We have opportunity to be center of time-domain activity. Could be equivalent of Sloan.
- AG We have a center for time series analysis at Harvard, but we don't participate. Why?
- CA Not sure. Area of application is in solar system work. Faculty are working on transients, but they have their own techniques. We need to get organized for LSST, but science from LSST is years away. Problematic for grad students' time frames.
- DE Spectroscopic connection to Pan-STARRS/LSST also important. Third area of opportunity: static sky. But no extended object photometry available. Need 100 Tb disks.

Major question about going forward with PS-2: Is collaboration serious about working on extended objects?

- CA How interesting, really. Pan-STARRS's image quality not that good.
 BK Better than Sloan.
 DE Optics will be better on PS-2. It will not be great until sited on Mauna Kea.
 CA Two issues. (1) Site. (2) Dan Fabricant thinks they screwed up optics on PS-1 and are destined to do it again on PS-2. Also don't have permission from Mauna Kea.
 DE Given six years on PS, lots of opportunity for galaxy evolution projects.
 EB Pan-STARRS had to be done in-house. Need to utilize outside expertise. We're doing a lot of that. We're working with images, not just photometry.

Grindlay: Magellan

- JG Time-domain astronomy becoming very important. DASCH finding hundreds of transients. Have pressing needs for spectroscopy to follow up. Want to make Magellan synoptic with LSST, e.g., in same hemisphere. Do rapid-response queue observing with Magellan. Natural role for Department (recall that Magellan funded by HCO) to consider how to use our share. Suggest 50% of our time and perhaps all Magellan time be devoted to transients and spectroscopy in the era of LSST. Still a role for imaging and near-IR. Could be running within 3-5 years. In north, could use MMT and Pan-STARRS. Need to switch to queue observing mode. Sometimes need onsite observing, but for rapid access, queue observing is better. Optimize schedule for conditions as well as TOs. Make that transition at Magellan.
- Data issues: large storage and databases critical concerns. Massive imaging data sets: DASCH will ultimately be 1 petabyte, already have 100 TB of data. Have signed on with Odyssey in a major way with 100 TB of storage. Need to think about how we will approach time-domain astronomy in a global way. I talked with James Cuff about future of HPRC (see note at end of transcript) in FAS. Harvard's effort is expanding. Faculty user supplies hardware, FAS supplies expertise. Great deal. Make it long-term.
- AG Many efforts are under way at Harvard beyond FAS. Gus Muench is funded partially by Virtual Observatory. Need to find ten test users at CfA to make an archive for data not placed elsewhere. Sharing capability enables data to survive long-term. In collaboration with ADS, make data-literature interconnection work. Where can data sets survive so that, e.g., they'll still work as links in papers? First project with Barry King's Institute for Social Sciences. Where would hardware go? Need robust maintainable system. Could use SI Herndon site. Start with 100 GB individual data sets, not huge sets. Pepi Fabbiano promoting CfA VO. Gus is involved in this.
- JG LSST is not the only instrument opening floodgates to time-domain astronomy and demanding large data storage. Science is irresistible. There will be competition between the Explorer program and TESS. We can play a major role if we're set up for spectroscopy; this is a requirement to get fundamental science.
- IS What fraction of time on Magellan now devoted to spectroscopy?
 BK Most of Magellan time is devoted to spectroscopy. Expect a hostile reception from Science Advisory Committee if want to focus telescope to a specific program. People want to do their own projects. [Many of BK's comments about the culture of the optical community have been omitted.]
- EB Green Bank program works because we are able to exchange fixed nights for target of opportunity access.
- BK Carnegie resists queue observing. Note that the Observatory does not pay for observers to execute queue observing. They want people to go to the site. They resisted the high-speed data link. This link will make observing (technical capabilities and data transport) much better.

- CA A new discussion is coming. We will not be able to support Magellan and MMT in the old way in the era of new telescopes.
- CS NOAO is interested in talking to us about using for LSST follow-up on Magellan.
- DE Swap for Gemini time, so we could use for TO.
- JM Mention DASCH?
- JG There's a potential donor for DASCH. Project is going very well. Have lots of volunteers. Could start scanning in a couple months (x10 current scanning rate). If funds don't come through, we'll go back to NSF.

Soderberg: Radio Astronomy

- AS We are a strong contender at long wavelengths (i.e., radio). Do we want to continue to be strong – the future? I think the answer is yes. Everyone here probably will use EVLA (2012) and ALMA (2013–14) to some extent. In the same ways that Pan-STARRS paves the way toward LSST, the EVLA prepares us for ALMA. If we want to be ready for the data flow from EVLA and ALMA, we must begin to prepare now.
- The ALMA project promises to provide fully processed data (eventually). Anyone who sits on their committees knows that this is not going to happen any time soon. We need to put in resources now in terms of staffing, computer hardware, etc. Ramp up now with EVLA data so we can hit the ground running when ALMA data start flowing. Not clear what to do now. We have a Jansky fellow as a liaison to NRAO.
- AG I am on ALMA advisory committee and confirm what you said. Will be call for early observing proposals in February 2010. Recurrent NRAO phrase is “underpromise and overdeliver.” Idea that a person unfamiliar with interferometry will be able to press a button and get images is insane. Right now, ALMA archive doesn't work. NRAO has asked me to develop 3D tools for the community (e.g., with NSF CDI proposal). NRAO not equipped to handle huge data cubes, let alone time-varying cubes. Computation, statistical, visual tools wanting. I am putting my efforts into more abstract visualization. Worried that NRAO doesn't have funds and resources to do ALMA analysis thoroughly. Perhaps Harvard could participate in an NSF fund matching program to develop tools.
- DE Need to be careful. We could easily get bogged down trying to build a pipeline.
- AG No, we need to concentrate on science extraction tools.
- AS Archive will eventually work. CASA making progress.
- AG CASA written in Python. Lots of statistical packages also use Python.
- AS Could run CASA on Odyssey if it were parallelized.
- AG SAO runs the RTDC, which employs two people, Shoshana Rosenthal and Alice Argon.
- CA At least on the SAO side, we'll clean up in the early years of ALMA because of the SMA expertise.
- EB NRAO really lagging on data processing/analysis.
- AG The initial hardware for ALMA seems to work; doesn't have fundamental imaging flaws like Pan-STARRS.
- AG ALMA will work for the people who know how to use the data.
- AS CfA has such a strong group. We should be able to handle ALMA data ourselves.
- AG Line between what NRAO and what user will supply is moving (the wrong way!).
- AS Need people here who will liaise with NRAO to keep us tightly in the loop.
- DE New people, or natural transformation of SMA staff?
- CA May learn more from Fred Lo, director of NRAO, who is on SAO VC. May not be getting level of support from NRAO that he wishes.
- AG Scott Ransom, NRAO considering outside funding to support time-domain processing.
- JM MWA shows how constrained NRAO is. Opportunity for us to take lead in ALMA.
- JM I already spoke about the opportunities with the MWA during the cosmology discussion. People should also consult the WP I put online this morning.

- CS Daniel cited the interest in exploring 21-cm hydrogen at $z = 1-2$ (500–700 MHz). Can the MWA do this?
- JM No, its upper frequency limit is 300 MHz. Need a new instrument. ATA array is in desperate financial shape. Stuck at 42 elements, wants at least 256. It could be a platform for the mid-frequency SKA. It runs from 500 MHz to 10 GHz and could work on $z = 1-2$ hydrogen, given enough sensitivity. An alliance with them could be very fruitful.
- AG I agree.

Hernquist: ITC and High-Performance Research Computing

- LH Let me comment on Avi's WP. Bottom line is that ITC funded firmly only for another two years. Need continued support, ideally by endowment to continue indefinitely. Reasons are very clear. ITC supports a large number of valuable activities: forums, seminars, postdocs, outside visitors, grad students.
- JM We all agree that ITC has been highly successful.
- LH Okay, then goal is to find support.
- JM Efforts to work with development office have been rebuffed. The de facto situation is that 100% of ITC funding comes from HCO, which could go on indefinitely.
- CA ITC leveraging its resources. Gets people with external fellowships, then extends them. Very good value for money. But as Jim said, the support is basically out of HCO endowment in two pieces: regular HCO budget and dean's strategic payout (dean can spend strategic payout only for items in accord with terms of endowment). Only guaranteed for another two years, but we can choose to continue HCO support. Bloxham doesn't want to tie hands of future deans by making indefinite commitments. He has agreed to guarantee postdoc offers that extend beyond the two-year ITC horizon.
- BK So this seems to be substantially under our control.
- CA Yes, substantially.
- BK Call for new endowment is somewhat disingenuous. We have an endowment, the HCO endowment.
- CA Better to have specific endowment for ITC. Would be a logical thing to do. If the right donor comes around, it would take \$20M for an annual yield of \$1M.
- DE Computation sounds like a 21st-century topic, so maybe a donor could be found outside pool interested in building telescopes.
- JM Is HCO endowment growing at all through new contributions?
- CA Not sure, but it's not very much.
- DC It is delightful to see how successful the ITC has been. Students and postdocs thrive there.
- LH Also help observers.
- DC Wish the rest of the organization were as well organized.
- CA Don't have to copy everything that ITC does to achieve the results we want. We must make good environment for all of CfA. One difficult decision I had to make was to demolish an office for the ITC common area.
- DE The ITC, like the Department, is very much a cooperative entity, based on collegiality. Hope that planetary group can follow this model, as with extragalactic optical group. Need to create very strong mentoring environments in groups led by faculty and SAO scientists.
- CS I was not able to get any support for a new center in physics because the deans are completely oriented toward getting current use funds. ITC is a roaring intellectual success. Tremendous value. Would put ITC on top of any prioritization.

One more thing. FAS research computing has been transformational. Bloxham and visiting committee need to hear that. Nothing with this impact has happened since my arrival. Need to resoundingly pound on this issue.

[Many respond “hear, hear.”]

EB Any way to generally expand visiting program at CfA? Transient community needs this.

CA Model is very useful. Need to see how much it would cost.

JM Let’s focus on high-performance computing. A crucial issue.

LH I think everyone recognizes the great importance of high-performance computing to simulations, theory, and observations. Odyssey now housed at 1 Summer Street, Boston. FAS recently signed on to be part of a consortium with BU, MIT, and UMass to develop a new center in Holyoke. Odyssey and its descendent will be moved to that site. Now have 10K cores, 1.5 petabytes of storage. We need to think about our requirements for accessing this new environment. Need our own technical support as a liaison to center. Need an upgrade path for hardware. Harvard’s current policy is to pay for site infrastructure while faculty supply hardware (contracts, startup, etc.). Center would maintain equipment.

JG Good deal since hardware boxes are cheap.

LH I need as much hardware as possible, so “low cost” of cores is a relative term. Hard to find support mechanisms at this level from NSF and other agencies. Hence, I have a big problem.

JM FAS paid for part of Odyssey, along with your funds. Will it pay for the next generation?

LH Not clear yet.

JM Are you still getting enough access to the Odyssey cluster?

LH Yes, for the time being. However, I may have to turn to the NSF supercomputer centers to take care of my needs. I don’t see a path here at the current time. Others with my level of need for processing and storage will face this problem eventually.

DE There is a big gap between CF support of desktops and the HP facility, which is an aggressive setup of Beowulf style clusters. If you want to do intermediate-scale things, you have to bring your own technical expertise.

AG For everyone’s background, let me recap the history of this problem. In 2000, Lars and I approached Irwin about the need for a large facility. Letter sent to Knowles from us and 14 other faculty advocating a center for advanced scientific computing. Would do a lot of things we are talking about and bring in new people of broad intellectual interests. Knowles replied, asking how this was research, not infrastructure. He stepped down. I got onto the Task Force on Science and Technology set up by Summers and Hyman. They asked for Lars and me to turn this into a project. Lars chose to develop the ITC and I became director of the IIC. In the financial crisis, funds dried up. Kaxiras, the acting director of IIC at the time, went to Switzerland. That segued into the FAS supporting the HPRCC and Odyssey. Kaxiras lured back by Cherry Murray and has his own Institute for Advanced Computational Science in SEAS. Not widely available to other faculty. The University does not have a global plan for hardware or software. I am not sure, as with Lars, that FAS will take care of our problems.

LH I am not convinced that FAS will invest in the kinds of things Alyssa and I are talking about for simulation and data mining and data manipulation. IIC was an initiative rather than an institute that would spawn ideas that the departments would pick up.

DE The way to leverage the HPRCC investment is to hire our own technical people to take advantage of it.

CA That type of technical support group typically works better on the SAO side. CfA agreement is to share telescopes, which doesn’t extend to HPRC. SAO people not using Odyssey independently. Note that SAO/SI has a parallel effort. SI owns a fabulous facility in Herndon, VA, and it does the same type of infrastructure support as FAS. SI

- does buy equipment. This is one area in which institutional boundaries matter more, i.e., SI has broader objectives than serving SAO as does FAS with the Astronomy Department.
- IS Note that CfA agreement involves only HCO and SAO facilities.
- CA We should scope out Daniel's suggestion of intermediate support and see if it can work.
- LH Sevendra has been our own technical liaison with the HPRCC, but he is leaving. The University's policy on HPRC is very ad hoc. At Princeton, decisions made by a faculty committee. Here, decisions made by administrators. Odyssey users should have input.
- AG Bloxham very knowledgeable and sympathetic. Unfortunately, the now-defunct HUSEC put the damper on interdepartmental initiatives.
- IS Since Bloxham's heart is in the right place, why isn't there faculty input into the HPRCC?
- CA Don't know, but those who might contribute have gotten tired of politics and slow pace of progress.
- AG One-off deals like retention packages seem to be the only way to get a University response.
- James Cuff, director of the HPRCC, is very supportive, e.g., sharing Sevendra. We need to come up with a plan that involves SAO and propose it to Cuff and then Bloxham. Try to meet our needs and not solve the computing problem at the University level.
- CA We didn't push for faculty oversight before because ad hoc oversight was going in the direction we want. In the first few years, most of Odyssey's cycles went to Lars's group. Beware of what you ask for (faculty oversight). However, the early era is over, the faculty broadly uses Odyssey. Need to reconsider oversight.
- DF Odyssey very useful for Pan-STARRS so far.
- DE If we are serious about large-scale synoptic studies with Pan-STARRS, we need to bring all the data here and process it on our cluster. We have not confronted imaging. Problems are going to get bigger and bigger.
- AG In my world of star formation, 90% of potential users cannot access Odyssey. Need to figure this out.
- DE If we buy a Pan-STARRS cluster, we can let anyone use it.
- AG Would HPRCC open such a cluster to SAO users?
- CA Would have to work that out.
- IS Pan-STARRS can be a Trojan horse for the whole place!
- JM This all seems like a big looming crisis.
- CA Infrastructure support is a very valuable base to start with.
- DE Yes, but we need expertise to decide what equipment to buy.
- JM Is old ITC cluster gone?
- LH Yes. Only Odyssey is available, except for the IBM Blue Gene used by Ramesh's group.
- CA Remember Joy Sircar organized the acquisition of the Blue Gene. We just provide space and electricity. Blue Gene just showed up!

Hernquist: Faculty Appointments in Theory

- LH Since I came here, we've made 13 appointments, roughly 1 per year. Nine are still here. Of those nine, only one is a hard-core theoretician (Finkbeiner). Twenty percent of faculty are theoreticians. Half of graduate students are working in theory. This is a serious disparity. Ramesh, Avi, and I are saturated. Turn students away. Dearth of faculty for student committees. Last year, the theory search ended up with appointment of Daniel (who is no longer considered a hard-core theoretician!). We did not identify other strong senior people. Need to hire junior faculty.
- EB Any particular area of theory?

- LH I think Avi and Ramesh would agree with me that we need the best people, regardless of their current theoretical interests. Go for best. Can't control evolution of students' interests. Charbonneau and Huchra started off wanting to be theoreticians.
- CA Old Caltech model: Many are called, but few are chosen (for theory). Don't advocate this.
- DS Need more theoreticians just to cover breadth of field. I mentioned in my WP the need for a theorist in exosolar planetary atmospheres.
- IS Go with best young theorists who will follow excitement.
- JM Thirty years ago, faculty was half theoreticians.
- LH Depends on how you count. Now certainly below a quarter.
- AS SAO can help. Just appointed Ruth Murray Clay, and she already has a student, Becky Dawson.
- JG Agree that theorist should be top priority.
- LH I think any search should be wide open to find the best person. If a theorist is truly outstanding, then we go for that person. Don't want to hire a theoretician who isn't top notch.

Goodman: Faculty Appointment in Astrostatistics

- AG Have joint astrostatistics group at CfA. Main focus is in HEA. Hogg's colloquium yesterday an example of extreme astrostatistics. Need to deal with large data sets and figure out how they interrelate. Function of time, wavelength, etc. Multidimensional planes. The human genome project is on 690 Mbytes, which is rather insignificant compared with Pan-STARRS, etc. In life sciences, there are bioinformaticians who are trained differently from bench biologists. Typical physicist knows more about statistics than typical biologist, but we need specialists, too. Brandon Kelly and Kaisey Mandel here at CfA doing interesting stuff. Xiao-Li Meng, head of Statistics Department, wants to hire joint person, statistics and astronomy. UC Davis, University College London, others targeting this specialty. Looking 8–10 years, this is where the action will be. Letter written by SAO people for formal recognition of statistics group.
- JM Want a house statistician?
- AG Don't want service people. Need real collaborator who will innovate.
- BK Look at our age list of faculty and plan for future. Greatly diminished by loss of Huchra.
- DE Big hole in faculty is galaxy evolution at $z > 1$. Current faculty concentrated on transients or resolved stellar population. Need to get ready to exploit LSST and JWST. None of WPs so far address this.
- CA Little discussion of ALMA and the "virtual" project, WFIRST. I will circulate NAS report on WFIRST [commissioned because overruns on JWST may preclude start on WFIRST].
- JM How should we proceed on appointments? In the past at the junior level, we usually decided to hire the best person.
- DF Think the right hire in statistics would be valuable.
- JG Also need experimentalist.
- CA Going to be more openings on SAO side than Harvard. Expect to go out for three positions next year.
- LH What about Doyle Chair, which is restricted to cosmology?
- JM Could try to fill chair, but finances are not clear.
- IS Unless every faculty member has a restricted endowed chair, it is hard to use the Doyle Chair as a bargaining chip. The dean ultimately controls the size of the faculty.
- JM Doyle Chair must be filled externally (to tenured faculty), which may carry weight.

Soderberg: Mentoring

- AS Students want mentoring program beyond research advisors. Concerns about gender issue. Need to train faculty. Students select second advisor. ITC has this for postdocs.
- BK Why do students need mentor beyond research advisor?
- AS GSAS makes these assignments for women GS.
- EB Would make tighter connection between students and faculty.
- DF What happened to our student-faculty lunch program? It was very useful.
- JM Casualty of FAS financial reversal and the FAS focus on food. Maybe we should reinstate these lunches.
- IS Lunches were very good for personal interaction.
- EB JC also helps. Faculty should also show up for JC.
- JM Mentoring idea deserves study by CAS.

Wrapup: What are the next steps?

- BK Disparate issues. Cannot just bundle up.
- JM HPRC crucial.
- BK Don't ask too much of VC. VC reports to board of overseers. The VC is mainly used to see if a department is going off the rails.
- DE Let's summarize ten or so themes, e.g., transients, ITC, GMT.
- JM I will try to summarize themes, and we will meet again.
- CA Need to explain NRC report on ranking of graduate programs. Don't want to be caught flat-footed.
- JM Alyssa, will you do an analysis of this report?
- AG No, I go on observations. Our graduate student recruitment proves our excellence.
- CA Must have common purpose with SAO. I will plan two to three meetings in January to discuss CfA strategic plan.
- JM Should we emphasize the formation of ad hoc groups of Harvard and SAO people?
- DE Must subvert effect of Division structure when it comes to sciences collaboration.

A note on acronyms: I have used *HPRC* for "high-performance research computing" and *HPRCC* for the entity High-Performance Research Computing Center. The correct name seems to be FAS Sciences Division Research Computing Group. For more information, go to www.rc.fas.harvard.edu.

21 White Papers (in order of discussion)

- I. **Cosmology**
 - Observational Cosmology; Christopher Stubbs
 - CMB at CfA: Opportunities for Harvard; John Kovac

- II. **Exosolar Planets**
 - The Fast Track to Finding an Inhabited Exoplanet; David Charbonneau
 - Why Should Our Department (and CfA) Pursue Earths ($\sim 1 M_E$, $1 R_E$) from the Ground as Well?; D. Sasselov
 - Harvard Origins of Life Initiative: Its Relevance to our Department; D. Sasselov

- III. **Astrochemistry**
 - Opportunities in Molecular Astrophysics and Use of the 1.2-m Telescope as a Teaching Tool; Patrick Thaddeus
 - Astrochemistry; Alex Dalgarno*
 - Astrochemistry; Michael McCarthy (requested by Alex Dalgarno)
 - Opportunities in Astrochemistry; Gary J. Melnick (requested by Alex Dalgarno)
 - Astrochemistry: The Value of the SMA; Eric Keto (requested by Alex Dalgarno and Jim Moran)*
 - Astrochemistry: The Rise of Complexity; J.C. Lee

- IV. **Facilities and Centers**
 - The GMT: A Project Whose Time Has Come; Bob Kirshner
 - MMT Instrumentation and Policies for Time-Domain Astronomy; E. Berger, A. Soderberg, C. Stubbs, and R. Kirshner
 - Reconfiguring Magellan (and MMT) for TDA Spectroscopy; Josh Grindlay
 - The Future of Radio Astronomy at the CfA; Alicia Soderberg*
 - The Murchison Widefield Array (MWA); Jim Moran*
 - ITC Future Directions; Avi Loeb
 - High-Performance Computing; Lars Hernquist

- V. **Appointments**
 - Need for New Faculty Appointments in Theory; Lars Hernquist
 - Why the Harvard Astronomy and Statistics Departments Should Hire at Least One New (Joint) Faculty Member in Astroinformatics; Alyssa Goodman

- VI. **Miscellaneous**
 - Improving Graduate Student Support; Alicia Soderberg and Avi Loeb

**These WPs arrived on 12/17 or later.*