

# COSMOLOGY: THE GAME

Astronomy 160b, spring 2007

**Introduction.** The idea behind this exercise is to simulate the process of scientific discovery in cosmology, as it might take place over the next few years. We have put together some theories of the Universe which are consistent with what is known today, but go considerably beyond current knowledge. Your task is to uncover these imaginary secrets of the universe, through the process described below. We will end the game when you have discovered the explanation for the problems of Dark Matter and Dark Energy. At the end, all participants will write a brief description of the solution, and a nomination for the most important discovery along the way — the scientist(s) who carried out the project with the most votes will receive an appropriate simulation of the Nobel Prize. Note that the rules and projects described below are guidelines, not restrictions — if during the session there's something you want to try to do that isn't incorporated into the flow of things as described, just say so, and we'll work out an appropriate modification on the spot.

**Sequence of Play.** At the start of the game, everyone will be assigned a role — as a junior or senior scientist of one of several competing scientific institutions, or as a member of a review committee. This initial assignment isn't really important, since the roles will change (see below). Each “cycle” of the game then goes like this:

- 1) Each institution decides on a project to propose, and a funding request. The senior scientist presents the case for this project to the review committee. The review committee can ask questions of the proposers — such questions should be answered by the junior scientist.
- 2) The review committee decides which project(s) to approve. They can provide full or partial funding of any of the proposals, up to a limit of four “units” of funding each cycle — any funded proposal must be given at least one unit, or more. Funding must be expended, and cannot be stored up. As described below, most projects cost more than one unit, and some must extend over more than one cycle before completion.
- 3) The review committee reports the results of their deliberations. Each member of the committee must report the disposition of one of the proposals.
- 4) The instructor will announce the scientific results of the successful projects, and any other relevant events that should be taken into account.
- 5) All junior scientists are promoted to senior scientists; all senior scientists are promoted to the review board; all review board members retire, and are reborn as junior scientists — thus everyone will go through all the available roles.
- 6) Another cycle is carried out with the new roles.

Open Yale courses

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## Potential Projects

You can propose to do anything you can think of. To help guide your ideas, some possible projects are listed below, but if you want to do something else, that's fine too, provided you can convince the review committee that it is worthwhile. For each of the projects below, we provide a brief description of the kinds of science that can be obtained, the total cost in funding units (the committee can allocate 4 per cycle), the delay between the initial funding provided and when the science will be carried out, and the risk that something will go wrong and project will not be accomplished. Note that for projects funded in multiple years, at least one funding unit must be allocated in each successive year or the project is cancelled and you have to start over again. However, successive peer review committees are *not* bound by the decisions of their predecessors, and can cancel ongoing projects if desired.

- JDEM/SNAP (4 units, 1 cycle delay, high risk). This is a space telescope with a large field of view specifically designed to obtain observations of Type Ia supernovae out to  $z = 2$ . If additional funding is available, it could also carry out useful observations of large scale structure.
- LSST (3 or 4 units, no delay, moderate risk). This is a ground-based repeated all-sky survey. It can provide detailed studies of supernovae with  $z < 0.5$ , studies of the large scale structure, and studies of solar system and galactic objects. The latter includes observations of microlensing events caused by MACHOs which may be contributing to the Dark Matter. Note that with 3 units of funding, one can only carry out *one* of these kinds of studies — with 4 units you get all three, or two with special emphasis on one of them.
- New Generation Space Telescope (5 units, 2 cycles delay, high risk). Provides many of the capabilities of SNAP, LSST, and enhances the abilities of general ground-based observers.
- Giant Segmented Mirror Telescope (2 or 3 units, 1 cycle delay, low risk). A new ground-based telescope for general use, greatly enhances the abilities of general ground-based observers. 2 units of funding are required simply to build the telescope, an additional unit of funding is required to actually carry out science with the telescope.
- WIMP Detectors (3 units, no delay, moderate risk). This project involves construction of a device that might be able to detect the large flow of WIMPs that would be passing through the Earth if WIMPs are indeed the Dark Matter. The project would also attempt to determine the nature of any WIMPs detected.
- Gravitational Wave Detectors. There are two versions of this, a ground based project called LIGO (2 units, no delay, moderate risk) and a space based project called LISA (4 units, 1 cycle delay, high risk). In both cases they can provide information on the distribution of black holes throughout the Universe, and detailed tests of General Relativity, including possible constraints on Theories of Everything involving Dark Energy etc. Obviously the space-based version is likely to produce

more detailed results.

- High Energy Observatories e.g. Constellation-X (3 units, 1 cycle delay, high risk). These space missions study celestial X-rays and gamma-rays. Such observations can uncover information about the evolution of structure by observing galaxy clusters and supermassive black holes, study the distribution of black holes throughout the universe, and possibly uncover hitherto unknown new kinds of objects and radiation,
- Microwave/Radio Observatories. Microwave and radio observatories can be placed either on the ground (1 unit, no delay, low risk), in balloons (2 units, no delay, moderate risk) or in space (3 units, 1 cycle delay, high risk). In all cases one can obtain information on the Cosmic Microwave Background, and also on other celestial objects. The higher cost missions are more specialized to the CMB, and provide much more detailed information.
- Particle Physics Supercolliders (4 units, no delay, moderate risk). Supercolliders provide information about basic physics, and may constrain or discover interesting WIMP candidates.
- General Astronomical Observing (1 or more units, no delay, no risk). This category supports many individual observing projects using already existing telescopes and instrumentation. You can specify subject matter, or leave it to the scientific community to decide what is the most promising. You can also specify the extent to which “risky” non-mainstream science should be supported. Each unit of funding increases the level of discovery.
- Astrophysical Theory (1 or more units, no delay, no risk). This category supports theoretical study of astrophysics, including simulations of the growth of structure, the nature of supernova explosions, studies of celestial dynamics (the motions of astronomical objects) curves, and detailed studies of the formation and evolution of stars and galaxies. You can specify a topic to be studied, or leave it to the scientific community to decide the most promising directions. All such work is more-or-less “risky”, so that distinction doesn’t have to be made.
- Fundamental Physics Theory (1 or more units, no delay, no risk). This category supports fundamental studies of physical theories, including string theory and particle physics.
- Follow-up Work (1 or more units, no delay, no risk). Most projects benefit from continued effort to pull out more detailed results that could be obtained at first.
- Anything else you can think of. If you describe it to us, we’ll give you a cost etc, and we’ll see what turns up.