SUMMARY OF THE CONFERENCE

James E. Gunn
Hale Observatories
California Institute of Technology

There has been presented at this conference a bewildering variety of problems for the Space Telescope, so many and so broad in scope that it is clear that the instrument in its lifetime will not be used for all of them, however able it may be to solve them and however interesting they may be.

There are several conclusions to be drawn from this state of affairs, and I wish mostly in this summary to discuss the conference in the light of those conclusions.

First, it is clear that it would be criminal to use ST for problems that can be solved from the ground, even if their solution using ground-based techniques is laborious in the extreme. I have made a list, almost certainly woefully incomplete, of problems that can probably only be attacked by ST or its like. They come mostly from the conference, and I will occasionally use my privilege of having the last word to chide my colleagues for leaving out a few important things.

In the solar system, high resolution UV spectroscopy with the HRS will allow study of atmospheric chemistry in all (but most interestingly in the outer) planets. Jupiter in particular promises a gold mine. The resolution of ST is, as we have heard, sufficient for rather detailed meteorological studies on Venus and Jupiter. The very large amounts of time required to do this problem justice may be difficult to obtain; but it would seem to me that at some point in the life of the mission some protracted study should be undertaken.

ST will not resolve the nuclei of comets, but monochromatic imagery and UV spectroscopy of the nuclear region will almost certainly yield improved understanding of the physical processes in these primitive bodies.

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The understanding of the interstellar medium seems to be in a state of continuous evolution; in many respects, the HRS on ST will have the final word on several interesting problems. Copernicus has resolution which is tantalizingly close to enough, but ST will be able to resolve blends and indeed resolve the expected motions within single clouds. The aperture and resolution will allow the study of very much larger volumes of space; UV spectroscopy of stars behind moderately dense molecular clouds will yield direct probes of molecular chemistry and provide several tests of molecular formation and destruction dynamics.

IUE has already opened up a fascinating new topic which ST will be able to extend beautifully: the study of the far gaseous halo of the Galaxy, and, indeed, other galaxies. Detailed absorption line spectra of Magellanic Cloud stars and bright QSOs will elucidate the physical conditions in the halo and almost certainly answer the question of whether such structures cause the absorption line spectra of quasars.

Little attention was given to problems of star formation, which brings me to a suite of problems for ST for which few counterparts exist in ground-based asstronomy. One might call them "voyeur"-problems. In the solar system, one can observe phenomena with imaging devices and see rapid changes. In galactic astronomy, the size scales and velocities and the span of human life and attention is such that, except for rapid photometric variation of essentially point sources, one observes an essentially static universe. There are, of course, exceptions - changes in nova and supernova shells and reflection nebulae are seen, and binary motion is seen - but ST will, in two areas, enormously enlarge this list. In the Taurus dark cloud, 100 pc away, stars are forming; the resolution of moderately enhanced ST pictures at this distance will resolve about 5 A.U., corresponding to dynamical times of a few years for one solar mass objects. One may be able to see matter falling into and/or flowing out of protostars and may see preplanetary disks. The other case of "motion watching" which will be of enourmous interest is the Crab Nebula, in which ground-based data whet the appetite, which ten times the resolution may or may not slake, but will be certain to be interesting.

One of the most active areas of extragalactic research at present is the study of stellar populations, a game played with considerable difficulty from the ground because of limitations in limiting magnitude, and, but also more importantly, confusion. One will reach with ST through Baade's window in the bulge of the Galaxy to well below turnoff, yielding an answer to the crucial question (in one instance, at least) of what the formation mass function is in an elliptical-like population. In M31, one will be able to reach almost to the turnoff in the oldest stellar population, and explicit removal of the bright stars will allow very

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much better study of the faint population than will ever be possible from the ground. The very faint main sequence will be reachable in globular clusters and to a lesser extent in the dwarf spheroidals. There will be an enormous amount of data where now there is essentially none toward answering the questions concerning the kinds of stars that form under widely differing physical and chemical conditions in the universe, and how the formation mechanisms affect and are affected by the dynamics and morphology of the present system. It is worth being reminded that we live in a universe ninety percent of whose mass we are aware of only because it gravitates, but whose nature is entirely unknown. It is not clear that it has anything whatsoever to do with star formation, but it would be nice to know.

Stars per se also received short shrift in these proceedings, and it is interesting to note that a number of spectroscopic binaries can be resolved using ST which are close enough that complete dynamical parallaxes can be obtained using both velocity and separation information. The cosmic distance scale, which ST has long been supposed to determine accurately, can, perhaps, start very close to home.

Star formation, the interstellar medium, and gravitation together make galaxies, and it is in the high resolution study of their component parts that ST will make significant advances.

For the evolution of galaxies, it is the high resolution and the near-infrared imaging capabilities of ST which will be valuable. Counts from the ground already reach to the 24th magnitude, and ST will extend that by a couple of magnitudes, but the exciting possibility delivered by ST is the study of the morphology of external systems to the largest distances to which they are detectable. The accompaning photographs are simulations of wide field camera images of 1000 sec exposure on an Sc I and a barred spiral. The resolution and noise characteristics are based on the expected performance of the instrument, a night sky of 23^m per square arcseconds in the visual, and a passband which remains at 4500 Å in the galaxy rest frame and is 20% wide. The Sc I is seen at simulated redshift of 0.078, 0.180, and 0.50; the barred spiral at 0.051, 0.12, and 0.27. The last picture of the set is of the barred spiral at a redshift of 1.0, as imaged with the Planetary Camera with modest image enhancement (resolution enhanced by a factor of 1.4) with 8000 seconds of data (four 2000 sec exposures).

It is apparent that one can study structure in galaxies to very large distances indeed; the study of the evolution of galaxies reduces to the (still difficult) problem of selection: Who are whose precursors?

The exciting prospect of using supernovae as distance indicators has been rather exhaustively discussed here; even if (as seems likely) the spectroscopic task imposed by the Baade-Wesselink

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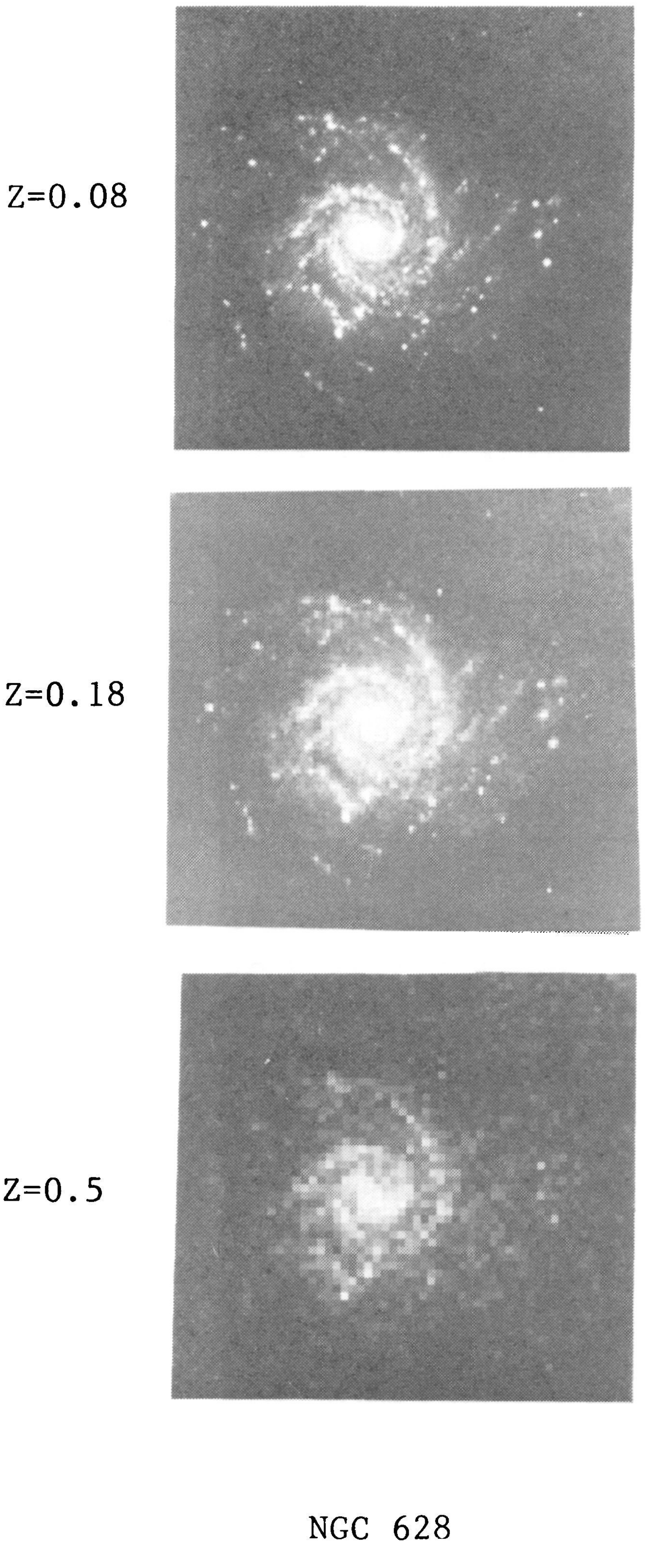

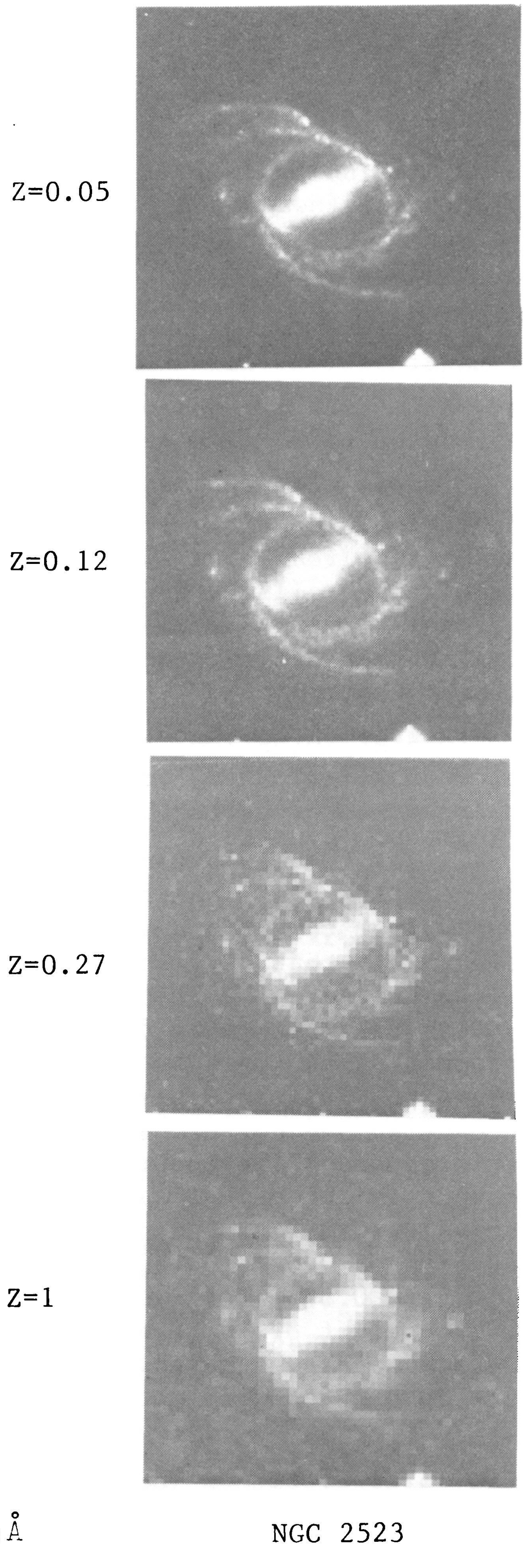

Figure 1. Simulations of WF/PC images of the galaxies NGC 628 and 2523 observed at different redshifts. A world model having $q_o = 0$ is assumed. The image is what would be observed at wavelength $\lambda = 4500(1+Z)$ Å The simulations for all images except NGC 2523 (Z=1) are 1000 sec exposures in the WFC mode. That of NGC2523(Z=1) is a Planetary Camera image which is a composite of 4x2000-sec exposures.

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technique is beyond the capabilities of ST, purely photometric techniques appear very promising.

What ST will say about the quasar problem is not clear; we have heard a very carefully considered suite of problems concerning absorption lines which ST can address; to some extent this is almost certainly a problem concerning galaxies and/or the intergalactic medium, not QSOs themselves. The question of the association of quasars with galaxies can certainly be elucidated with ST, especially if the small-angle scattering properties of the optics are as good as they might be. To me the most exciting prospect for the QSO problem attackable with ST will come from the study of relatively nearby active systems where QSO-like things are going on on a much smaller scale. Systems like M87, 4278, 1068, are near enough that much can be learned about the dynamics and inflow of matter into whatever engine powers the nonthermal activity.

The problem of the distance scale is one about which so much has been written and said in connection with ST that it needs no comment. Suffice it to say that it is evident from the controversy still surrounding the problem that it has not been solved from the ground, and that the faint limit and high angular resolution of ST render it an incomparable tool for its solution - not that it will be easy even with ST.

The classical cosmological problem - i.e., discovering which Friedman model is the "correct" one for the universe - is, of course, just an extension of the distance scale problem, and with ST even some of the distance scale techniques can be adopted for its solution. The classical tests using galaxies can be applied in a unique way with ST, because the sizes of the galaxies at large redshifts can be resolved, and there is hope that those classical tests may yet yield a global value of the deceleration parameter which can be compared with what we hope by then will be a quite well-determined value for the density parameter from studies of nearby systems. ST's ability to study galaxies at very large distances will make it an invaluable cosmogonic tool for the study of the origin of structure in the universe, which is, perhaps, as interesting as the global questions.

The questions raised here will hopefully not be all the interesting ones when ST flies, and whether they are or not, the most exciting results will certainly be serendipitous.

This conference has dealt little with ground-based preparation for ST, and it is worth considering a little. The awesome pressures on ST can be alleviated somewhat by good homework before and during the mission. Technology, some of it directly related to ST, has made ground-based telescopes potentially enormously more powerful than they were even a couple of years ago. We recently completed a small, low-resolution CCD spectrograph and camera for use at the prime focus of the 200-inch telescope, which has a 30% total effective throughput; a galaxy spectrum of one hour's exposure and a five-minute exposure of the cluster are shown. The redshift is 0.53 and the visual magnitude 21.8. A fifteen-minute exposure of the spectrum would easily have yielded the redshift. It is to be fervently hoped that these magnificent detectors will be produced and made available for ground-based use; the gulf separating "ordinary" astronomy on the ground and some of the capabilities of ST will, I think, be narrowed enough to significantly sharpen the effort for ST itself.

The last point I wish to discuss is a sociological/political one. Whatever problems for ST remain elusive at present, the set of more-or-less obvious ones is so large that ST cannot work on them all. Who gets to do them? Hopefully not the proposer with the earliest postmark, but that is an obvious solution. The community needs desperately to invent a mechanism to make efficient, fair use of ST in a way which will involve all capable interested parties. Problem-oriented teams are one possibility, and there may be others; it is clear that some approach must be worked out before the telescope flies.

It looks as if it will finally happen, this magnificent machine, and I would like to extend my personal thanks and, I trust, the thanks of the whole community, to those in the community who have worked for years to make it happen, and to those at NASA Headquarters and Goddard and Marshall, and at ESA who are making it happen, and perhaps especially to Lyman Spitzer whose vision it was to begin with.

Figure 2. The cluster 160131+4254 observed with the Hale 5-meter telescope using a camera employing a 500x500 CCD developed by Texas Instruments as part of the development program for Space Telescope. The exposure was 5 minutes in a band 1000 wide centered at 6500

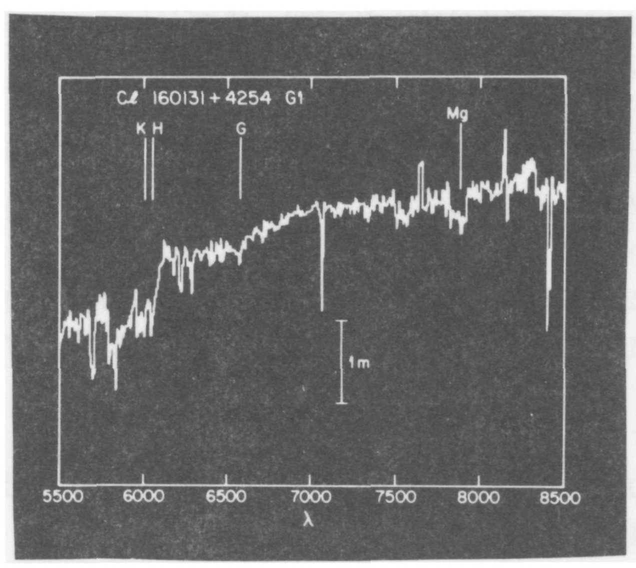

Figure 3. The spectrum of the brightest member in the distant cluster 160131+4254 taken with the CCD camera in its spectrographic mode. The exposure was 4000 sec. The r magnitude of the galaxy is 21.8, its redshift is 0.53.

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