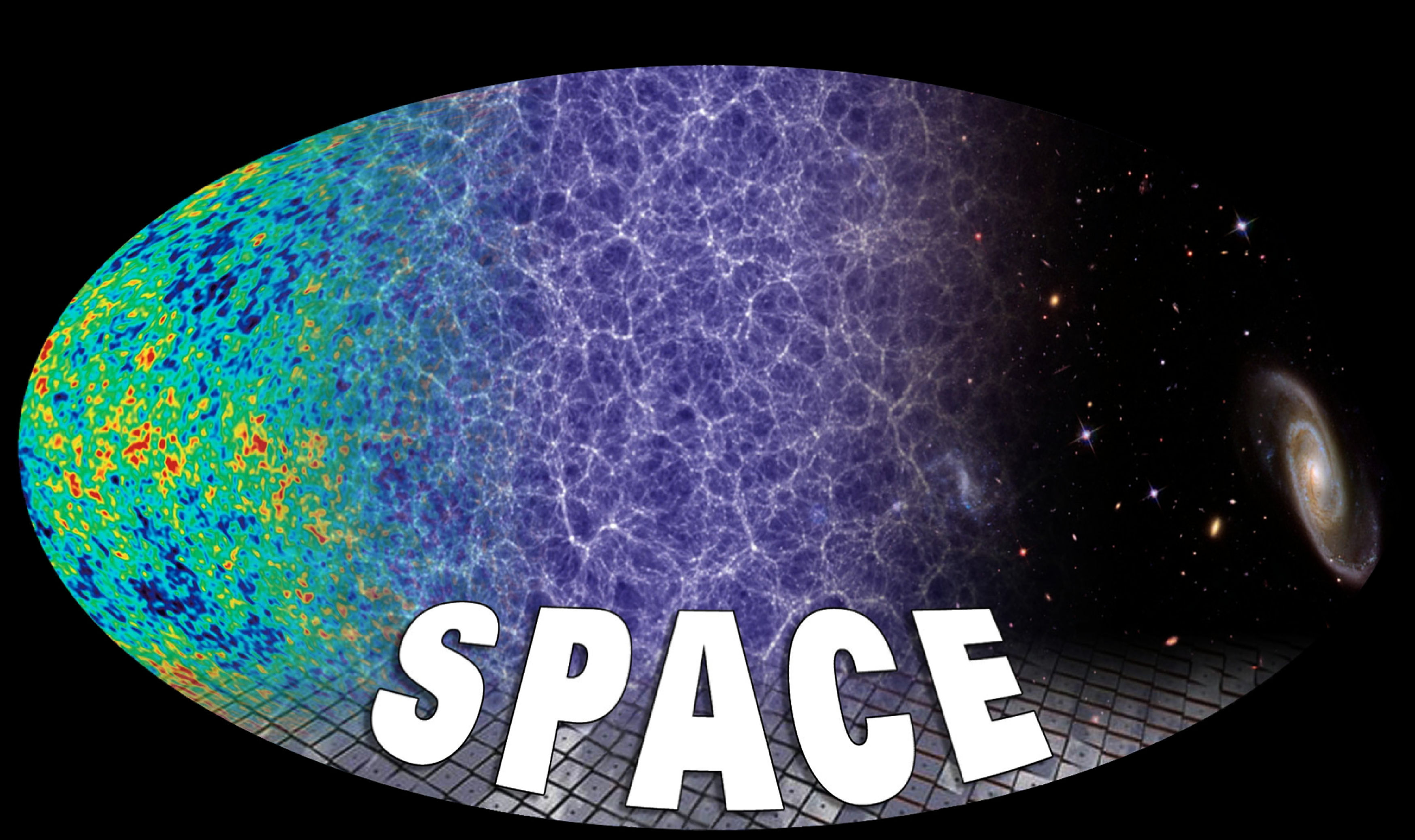


The SPectroscopic All- sky Cosmic Explorer

M. Robberto (STScI), A. Cimatti (INAF, Bologna) & SPACE Science Team*

What is SPACE

The SPectroscopic All-sky Cosmic Explorer (*SPACE*) is a joint ESA-NASA class-M mission proposed in response to the last ESA Call for the Cosmic Vision 2015-2025 planning cycle.

SPACE will produce the largest three-dimensional evolutionary map of the Universe over the past 10 billion years by taking near-IR spectra at R=400 of more than 0.5×10^9 galaxies down to AB~23 over the 3π sr of sky unobscured by the Galaxy. *SPACE* will precisely locate (Δz~0.001) each galaxy and observe **baryonic acoustic oscillation (BAO)** patterns in the Universe between 5 to 10 billion years ago. Using the scales in the spatial power spectra as "standard rulers" to measure the equation of state and rate of change of dark energy, *SPACE* will improve the figure of merit for knowledge of dark energy by more than an order of magnitude. The same dataset will simultaneously allow an accurate assessment of the evolution of **structure formation** over the last 10 billion years, providing a complementary method to discriminate between theories of dark energy and theories of modified gravity proposed to explain the acceleration of the universe. The spectroscopic catalogue of more than a half billion galaxies out to redshift z≈2 will be used for a wide range of investigations into the formation, evolution, and interaction of **galaxies in the Universe**.

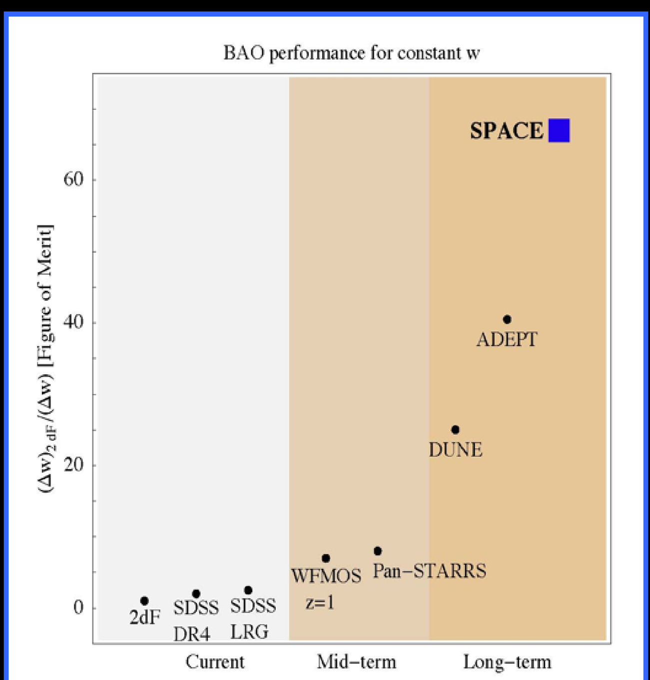
SPACE Science

Owing to the depth, redshift range, volume coverage and quality of its spectra, *SPACE* will obtain:

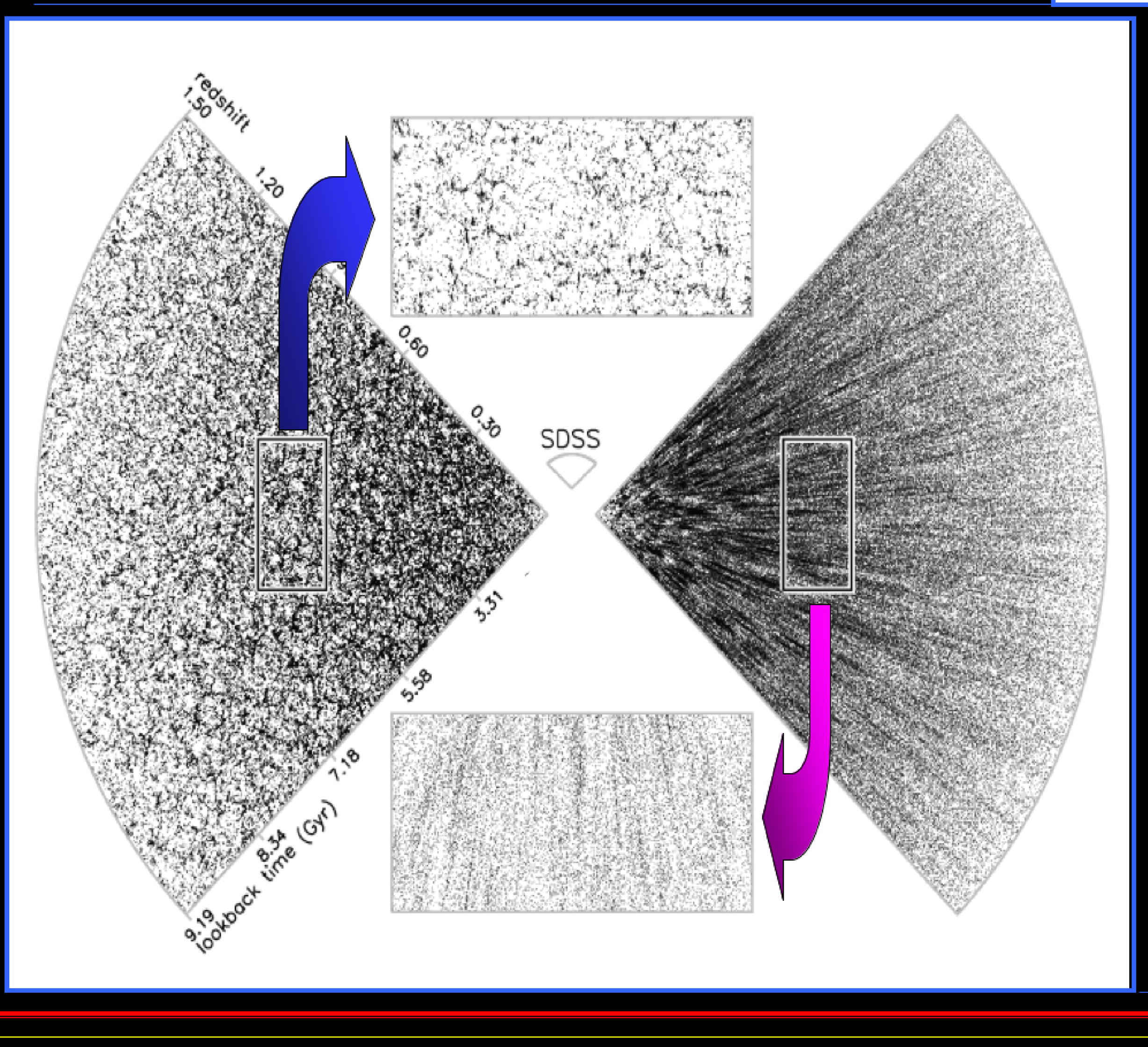
- ✓ The first direct measurement of the form and distribution of primordial density fluctuations generated in the rapid expansion (**inflation**) just a tiny fraction of a second after the Big Bang.
- ✓ The definitive measurement of the **power spectrum of density fluctuations** and its turnover, a key prediction of Big Bang cosmology, set when the Universe was 27,000 years old.
- ✓ The highest precision measurement of **baryonic acoustic oscillations** imprinted when matter and radiation decoupled 380,000 years after the Big Bang.
- ✓ The most accurate **inventory of baryons, neutrinos, cold dark matter and dark energy**.
- ✓ The tightest constraints on the nature of the **dark energy and gravity**, by measuring the evolution of the cosmic expansion rate and the growth rate of cosmic large-scale structure.
- ✓ The complete characterisation of the **large scale distribution of galaxies** to break the degeneracy between different theories of galaxy formation.
- ✓ The intensity, spectral shape and origin of the faint **near-IR cosmic background**.
- ✓ The galaxy and AGN content, formation and evolution in the **Universe up to z < 10**
- ✓ Constraints on the **coolest stellar objects in the Milky** Way and on the Initial Mass Function

Why SPACE

No presently conceived ground-based or space facility can approach the observational power needed to accomplish *SPACE*'s core science goals. *SPACE* spectra will directly provide distances a factor of 10 more accurate than photometric redshifts (photo-z) and -insensitive to the degeneracy of spectral energy distributions. Unlike other missions that need extensive ground-based imaging and spectroscopic redshift surveys to calibrate their photometric redshifts, *SPACE* is "self sufficient", without any need for complementary data from the ground or space to achieve its main scientific goals. Indeed, *SPACE* will enhance the scientific return of other missions, providing redshifts for several millions of objects too faint to be measured from the ground.



The BAO performance of several surveys normalized to the 2dF. The figure of merit is as defined by the Dark Energy Task Force.

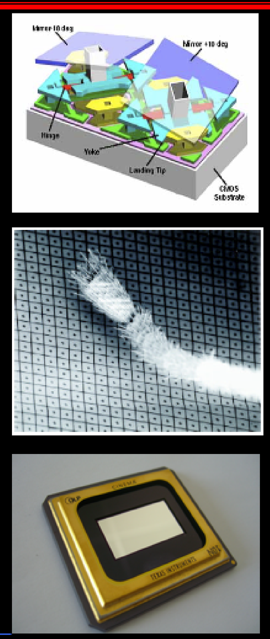


A "cone" of the Universe as it would be seen by an observer located at the center of the figure. Each dot is a galaxy selected from the "Millennium Simulation" (Springel et al. 2005) with H(AB)<23, z<1.5 and random sampling rate of 1/3. The top and bottom rectangles show regions extracted from the left and right cones, respectively. The left cone and the top rectangle show the use of spectroscopic redshifts. The right panel (and bottom rectangle) show how the information is completely lost in the case of photo-z, even with a very optimistic σ_z=0.02(1+z) (e.g. Abdalla et al. 2007). The small cone at the top shows the volume covered by the SDSS

How SPACE works

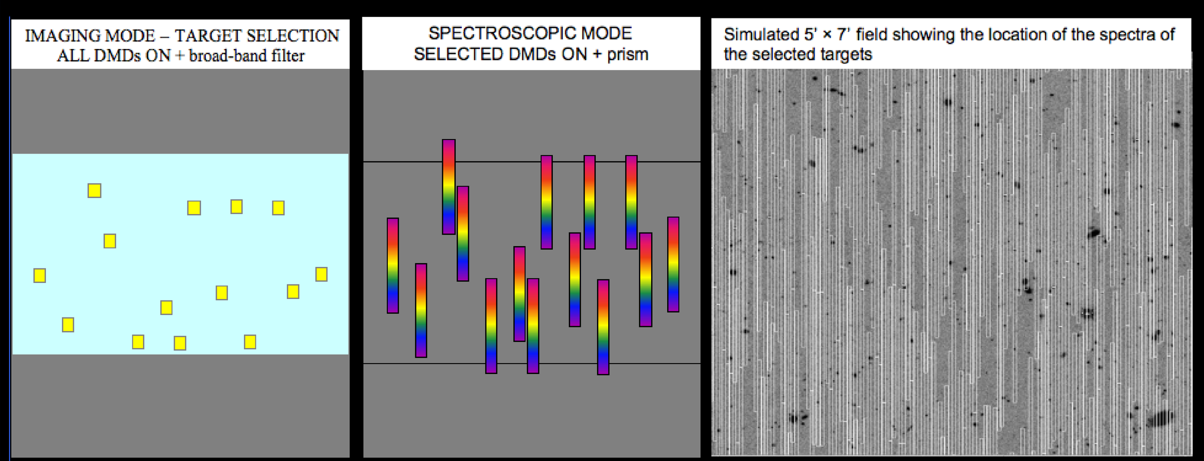
SPACE performs multi-slit near-IR spectroscopy in outer space, exploiting the sky background 500 times lower than from the Earth. The use of multi-slits rather than unmasked (slitless) spectroscopy gives *SPACE* the ultimate advantage, as it allows us to fully exploit the low celestial background for sensitivity, extended spectral range, and clean separation of source spectra.

SPACE generates slits using the latest generation of Digital Micromirror Devices (DMDs), the leading technology in digital imaging (e.g. DLP projectors). Our proposed designs uses 4 chip with a total of 8.8 million randomly addressable optical switches. Depending on the DMD configuration, *SPACE* can perform imaging, slitless and slit spectroscopy (our main observing mode), and even integral field spectroscopy using Hadamard transforms. All these observing modes are possible without adding complexity, weight or cost to the basic hardware needed for the core science program.



Top: typical substructure of a Texas Instrument DMD; Center: DMD array with an ant leg for size reference; Bottom) Packaged 2048x1080 DMD.

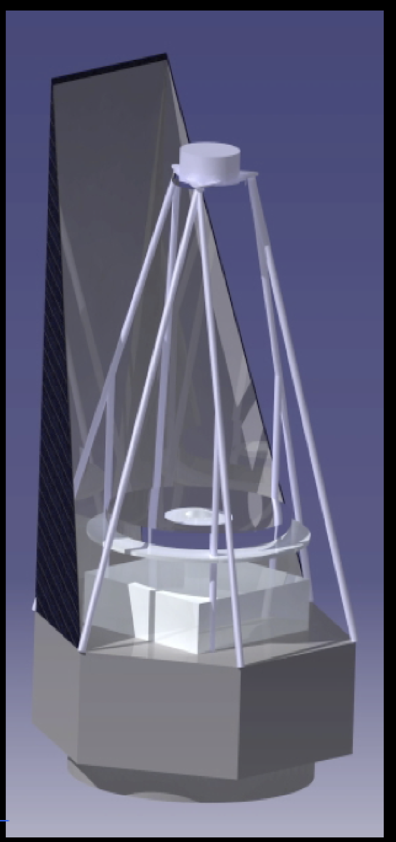
Sketch of the observing strategy. Left: a field projected on the DMDs (all-on) is reimaged on the detector. The light blue color indicates the zodiacal background, the gray color the detector dark current. Center: all DMDs are turned off except those on the targets, prism is inserted. Right: simulation using the baseline SPACE parameters.



SPACE facts

SPACE INSTRUMENT PERFORMANCE	
Total field of view	*51' x 27' (0.4 sq. degree)*
Nr. and type of DMDs	*4 TI-CINEMA chip (2048x1050)*
Total nr. of mirrors	*8.8 million*
Mirror field of view	*0.75" x 0.75"*
Number of spectra	*~6,000 simultaneous*
Detector Pixel size	*0.375" x 0.375"*
Dispersing element	*Prism R~400; 0.8-1.8µm*
Imaging filters	*z, J, H, narrow band*
Detector	*HgCdTe 0.4-1.8µm, 2k x 2k*
Nr. of detectors	*16 (4 mosaics of 2x2 chips)*
Detector Temperature	*~145K*
QE	*>75% average*
Readout noise	*5e-/multiple read*
Observing modes	*Wide field imaging, slit, slitless and integral field spectroscopy (Hadamard)*

SPACE MISSION SUMMARY	
Telescope diameter	*1.5m*
Optical configuration	*Ritchey-Chrétien*
Wavelength range	*0.6-1.8 µm*
Optical quality	*Diffraction limited λ>0.65µm*
Pointing stability	*0.1" rms/ 30min*
Overall mass	*1486 kg*
Data rate	*1.5Mbit/s*
Orbit/Launcher	*L2/Soyuz*
Launch date	*Mid 2017*
Mission Duration	*5 years*
Partners	*ESA-NASA-European Agencies*



SPACE launch configuration

SPACE Mission

1) SPACE All-sky (Galaxy limited) survey

In 30 months *SPACE* will image 70% of the sky in the H-band to a limiting magnitude AB≈23. For each 0.4 square degree field *SPACE* will automatically extract an unbiased, stellar mass selected sample of galaxies and take **spectra of every third galaxy** to a limiting magnitude AB=23 in the range 0.8–1.8µm (targeting up to z~2.5), with resolving power R ($\lambda/\Delta\lambda$≈ 400), continuous spectral coverage and absence of sky-lines residuals. This *SPACE All-Sky Survey* will be the dataset for BAO analysis, the measurement of structure development, and the study of individual objects.

2) SPACE Deep Field

For 4 moths *SPACE* will target a smaller 10 deg^2 area, performing a **deep spectroscopic survey of ~2 million galaxies** over to AB=26 and 2<z<10. This *SPACE Deep Survey* will discover an **enormous number of primordial galaxies** at very high redshifts, assembling samples from as far back as 500 million years after the Big Bang. It will reveal a large number of Ly a emission galaxies, star forming galaxies, rare examples of passively evolving galaxies at the earliest epochs, and the earliest QSOs. It will address the formation and early evolution of galaxies from the epoch of "first light." Its wide field of view (0.4 square degrees) is ideal discover objects that will be studied in detail by the James Webb Space Telescope (JWST) and its successors.

3) SPACE GalacticPlane Survey

Thanks to its great versatility, SPACE can perform integral field spectroscopy with coded masks. Exploiting this capability, SPACE will

perform in 2 months an integral field survey of a 1 degree strip centered on the galactic plane between ±60° of galactic longitude. Reaching AB~20, SPACE will go deeper in 3-d spectroscopy that SPITZER/GLIMPSE and GAIA.

4) SPACE Open Time

Approximately 40% (2 years) of the planned 5yr mission duration will be made available to the scientific community for GO programs.

*** SPACE Science Team:** **Austria:** W. Zeilinger (U.Wien); **France:** E. Daddi (CEA Saclay,), **M. Lehnert**, F. Hammer (Meudon), O. Le Fevre, J.-P. Kneib, J.-G. Cuby, L. Tresse, R. Grange, B. Milliard, M. Saisse (LAM); **Germany:** S. White, **G. Kauffmann**, B. Ciardi, G. De Lucia, J. Blaizot (MPA Garching), F. Bertoldi (U. Bonn), E. Schinnerer, **A. Martinez-Sansigre**, F. Walter, J. Kurk, J. Steinacker (MPIA Heidelberg): **International:** P. Rosati, P. Padovani (ESO); D. Macchetto (ESA); **Italy:** A. Ferrara (SISSA), A. Franceschini (U. Padova), A. Renzini (INAF OAPD), S. Cristiani, M. Magliocchetti, E. Pian, F. Pasian, A. Zacchei (INAF OATS), G. Zamorani, M. Mignoli, L. Pozzetti, C. Gruppioni, A. Comastri (INAF OABO), N. Mandolesi, R. C.Butler, C. Burigana, L. Nicastro, F. Finelli, L. Valenziano, G. Morgante, L. Stringhetti, F. Villa, F. Cuttaia, E. Palazzi, A. De Rosa, A. Gruppuso, A. Bulgarelli, F. Gianotti, M. Trifoglio, F. Paresce (INAF IASFBO), **L. Guzzo**, F. Zerbi, E. Molinari, P. Spanó (INAF Milano), **R. Salvaterra** (U. Milano), M. Bersanelli (U. Milano), D. Maccagni, B. Garilli, M. Scodeggio, D. Bottini, P. Franzetti (INAF IASFMI), T. Oliva (Arcetri, TNG); **Netherlands:** M. Franx, H. Roettgering, M. Kriek (U. Leiden); **Romania:** L. Popa (U. Bucharest); **Spain:** R. Rebolo, M. Zapatero Osorio, M. Balcells (IAC), A. Perez Garrido, A. Díaz Sánchez, I. Villó Pérez (UPCT, U. Politecnica de Cartagena); **Switzerland:** H. Shea (École Polytechnique Lausanne); **United Kingdom:** C. Frenk, **C. Baugh**, I. Smail, S. Cole, R. Bower, T. Shanks, M. Ward (U. Durham , Inst. Comp. Cosmology), R. Content, R. Sharples, S. Morris (U. Durham, Centre for Advanced Instrumentation), J. Silk (U. Oxford), J. Dunlop, R. McLure, M. Cirasuolo (ROE), R. Kennicutt (IoA, Cambridge), M. Jarvis (U. Hertfordshire); **USA:** **Y. Wang** (U. Oklahoma), X. Fan (U. Arizona), P. Madau (UCSC), **M. Stiavelli** , **I. N. Reid**, M. Postman, R. White, S. Casertano, S. Beckwith (STScI), J. Gardner, M. Clampin, R. Kimble (GSFC), A. Szalay, R. Wyse (JHU), A. Shapley (Princeton), N. Wright (UCLA), M. Strauss (Princeton), M. Urry (Yale), A. Burgasser (MIT), J. Rayner (Hawaii), B. Mobasher (UC Riverside), M. Di Capua (UMD), L. Hillenbrand (Caltech), M. Meyer (Steward).