ESO-USM-MPE Workshop on

Multiwavelength Mapping of Galaxy Formation and Evolution

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Co-organized with the Universitäts-Sternwarte-München and the Max-Planck-Institut für Extraterrestrische Physik, this workshop was held in Venice, Italy, from October 13 through 16, 2003. The venue, on the premises of the *Venice International University* on the island of S. Servolo, proved ideal for hosting the 173 participants for the four full days of the meeting.

The workshop was meant to expand over a broader range of issues compared to the ESO-USM workshop on *The Mass of Galaxies at Low and High Redshift* that was held in 2001 in the same place. Much indeed has occurred in the meantime, worth reporting and discussing. An impressive set of facilities, in space and on the ground, are now used to map galaxy populations in all relevant windows, from X-rays to radio wavelengths, from the local universe to the highest possible redshifts, from pencil-beam probes to wide scale surveys. The primary goal of the meeting was to document these observational efforts while trying to answer the current main questions on galaxy formation and evolution:

- When did star and galaxy formation begin?
- What kind of sources have been responsible for the re-ionization of the universe?
- How has the overall star formation evolved with time?
- What is the interplay between galaxy and AGN formation and evolution?
- What has been the relative role of thermonuclear vs. accretion power in the global energetics of the universe?
- How did the mass assembly of galaxies proceed with cosmic time?
- When did the morphological differentiation of galaxies take place?
- At what pace have these processes proceeded as a function of the LSS environment?

Following cosmic time, presentations and discussions proceeded from high to low redshift, starting on the first day with an exciting review of the WMAP major results by Licia Verde. The most intriguing result was, of course, the very high redshift of re-ionization advocated by the WMAP team. As then emphasized by Piero Madau and Andrea Ferrara, the observed luminosity density of the ionizing radiation (from either galaxies or AGN) does not seem to increase fast enough with redshift, leaving open the first two questions above, and highly speculative our description of the universe between $z \sim 6.6$ and ~1000.

The search and characterization of the highest redshift galaxies was the next major topic. Quite successful has been the narrow-band filter technique to find Ly-α emitters, especially with the Suprime Camera on Subaru (Yoshiaki Taniguchi, Len Cowie), with several objects at $z \sim 5.7$ and $z \sim 6.6$ having been identified thanks to Ly-α passing through OH-free spectral windows. Promising results from the dropout technique were also reported, using ACS multicolour data from public GOODS (Matt Lehnert) and ACS/GTO data (Garth Illingworth). While we still know very little about the galaxy population beyond redshift ~ 5, these studies demonstrate that observing strategies exist to make rapid progress.

Mostly focused on AGNs, a full session was dedicated to X-ray observations, also in combination with optical and sub-mm observations. The space density of both obscured and unobscured AGNs appears to peak at the fairly low redshift $z \sim 0.7$, and then declines steadily at higher redshifts (Günther Hasinger), thus exhibiting a quite different behaviour compared to the cosmic star formation history, which reaches a maximum at z ~ 2 and then stays nearly constant, as several speakers reported (e.g., David Elbaz, Mauro Giavalisco, Chuck Steidel).

With much of the star formation being

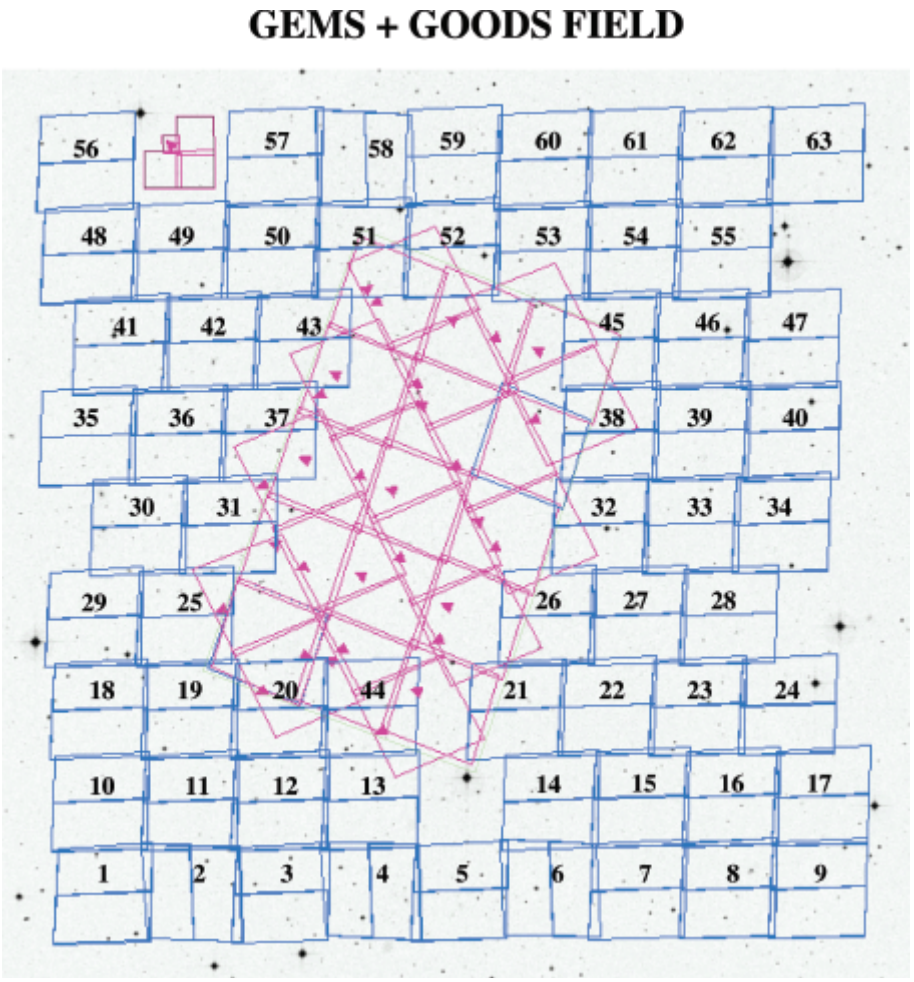


Figure 1: The mosaics of the GEMS (blue) and GOODS (magenta) individual ACS exposures in the CDF-S field (courtesy of Hans-Walter Rix). ACS data are publicly available.

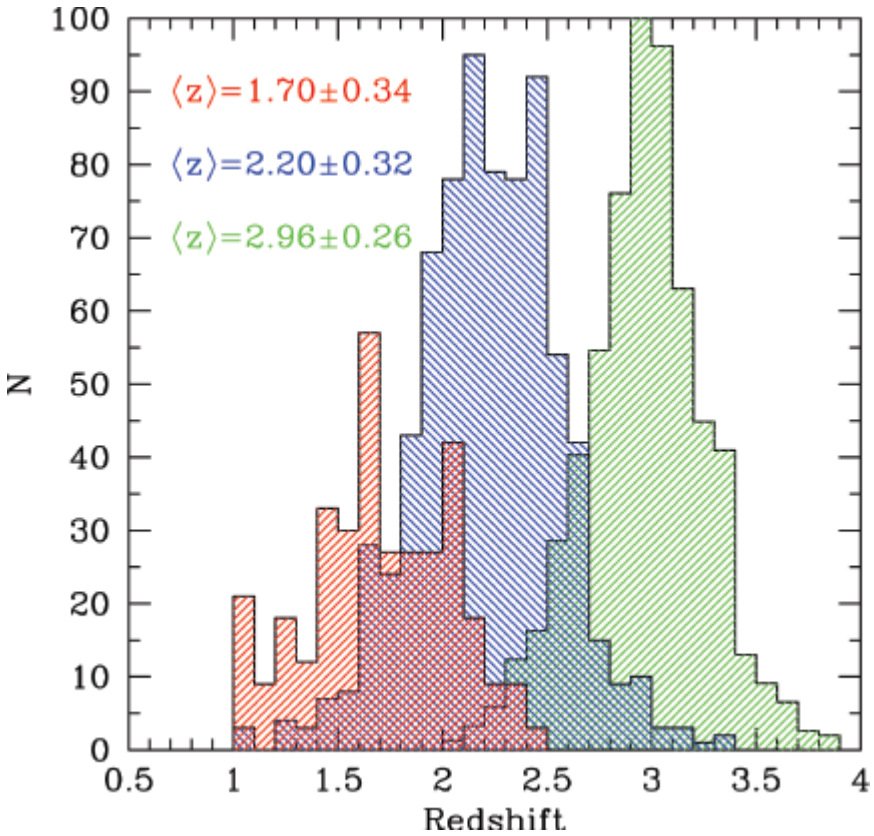


Figure 2: The redshift distribution of 2-colour selected high redshift galaxies observed at Keck with LRIS-Blue and LRIS-Red (courtesy of Chuck Steidel).

hidden by dust in the optical and near-IR, we can learn a lot from mm and sub-mm observations of high redshift galaxies. So, while waiting for ALMA, reports of SCUBA, MAMBO, SIMBA and IRAM observations (respectively by Ian Smail, Frank Bertoldi, Tommy Wiklind, and Reinhard Genzel) were followed with much interest. In particular, Reinhard reported the IRAM measurement of the very high mass of a z=2.8 galaxy via the CO linewidth, showing that the sub-mm can do much more besides offering a better measure of the star formation rate. As SCUBA angular resolution is too coarse, in a fully multifrequency approach Scott Chapman used high-resolution observations in the radio to identify the likely optical counterparts of a sizable sample of SCUBA sources, then obtained their redshifts using optical emission lines. The objects lie at a median redshift 2.4, and with a space density over 1000 times higher than in the local universe they contribute significantly to the global star formation rate at their epoch.

The central part of the workshop was occupied by multifrequency surveys. The status, first results, and perspectives of GOODS were reported by Mark Dickinson, Mauro Giavalisco, Stefano Cristiani, and others. With the ACS data fully acquired, reduced, and publicly released along with the VLT/ISAAC near-IR coverage of about 1/3 of the GOODS-South field, astronomers are eagerly waiting for all the promised complementary data to become available. Besides completing the near-IR coverage, this includes especially the SIRTF mid-IR coverage now to be completed in 2004, along with the FORS2 and VIMOS spectroscopy. While the GOODS database is still largely incomplete, important scientific results are nevertheless being produced with what is already in hand. In particular, a robust estimate of the UV luminosity density and of the space density of Lyman-break galaxies (LBG) all the way to $z \sim 6$ was presented (Giavalisco), along with the evolution of their size (Ferguson), while combining *Chandra* X-ray and ACS observations it has been possible to estimate the space density of high-z QSOs in the GOODS fields (Cristiani).

The Combo17 project, along with its HST/ACS "GEMS" extension (see Fig. 1) was presented by Hans-Walter Rix and Eric Bell. Some 30,000 photometric redshifts from 17 intermediate and broad bands led to an estimate of the evolution of the red-sequence (or early type) galaxies all the way to $z \sim 1$, with their colour change being consistent with passive evolution.

However, their luminosity density at $z \sim 1$ falls short by a factor 2–3 with respect to a pure luminosity evolution (PLE) model, with the missing galaxies being the faint ones, rather than the bright ones, as one may have expected. ACS images confirm that the vast majority of red-sequence galaxies are morphologically early type (i.e., Sersic index $n \geq 2$).

Chuck Steidel reported how he was able to "*colonize*" the so-called "redshift desert" ($1.5 \leq z \leq 2.5$) using LRIS-Blue at the Keck telescope, hence sampling the rest-frame UV of star-forming galaxies selected by a two-colour criterion, similar to the one first used for LBGs at $z \sim 3$. Fig. 2 shows the wealth of galaxies that can be seen in the desert once a UV-blue sensitive spectrograph is used, as indeed required to detect the interstellar absorption lines over the UV continuum of star-forming galaxies (see an example in Fig. 3).

Compared to surveys of UV/optically selected galaxies, the observation of galaxies selected in the near-IR (such as in the FIRES, MUNICS, GDDS and the K20 projects) offers a somewhat different, complementary view of the distant universe. Ultradeep near-IR observations over the HDF-S have revealed a population of galaxies with photo-$z \sim 3$ which only marginally overlaps with LBGs, nearly doubling the estimated stellar mass at this redshift (Ivo Labbé). The growth with cosmic time of the stellar mass density was one of the central themes of the conference, along with the number density evolution of very massive stars. Both the K20 and the GDDS spectroscopic surveys (Andrea Cimatti, Emanuele Daddi, Adriano Fontana, Hsiao-wen Chen) appears to indicate that much more many massive galaxies were already in place at $z \geq 1.5$ than so far predicted by semi-analytical models. Yet, while their number density appears to be in better agreement with a PLE model, they are in fact starburst galaxies much different from the galaxy population in the model itself. On the other hand, the discrepancy with respect to semi-analytical models seems less severe in the MUNICS photo-z survey (Niv Drory), which is ~ 0.5 magnitude shallower in K but extends over 20 times larger area. In the end, everybody agreed that cosmic variance may go some way towards accounting for apparent discrepancies between different surveys, along with different selection effects.

The formation and evolution of early-type galaxies remains a key issue that was widely discussed at the meeting, using both the low-redshift and high-redshift evidence (e.g., Emanuele Daddi, Daniel Thomas, Nobuo Arimoto, Mariangela Bernardi, Guinevere Kauffmann, Roberto de Propris, Scott Trager) with the prevailing opinion favouring a very early formation epoch ($z \geq 2$–3) for the bulk of stars in these galaxies, with rather small dependence on the environment.

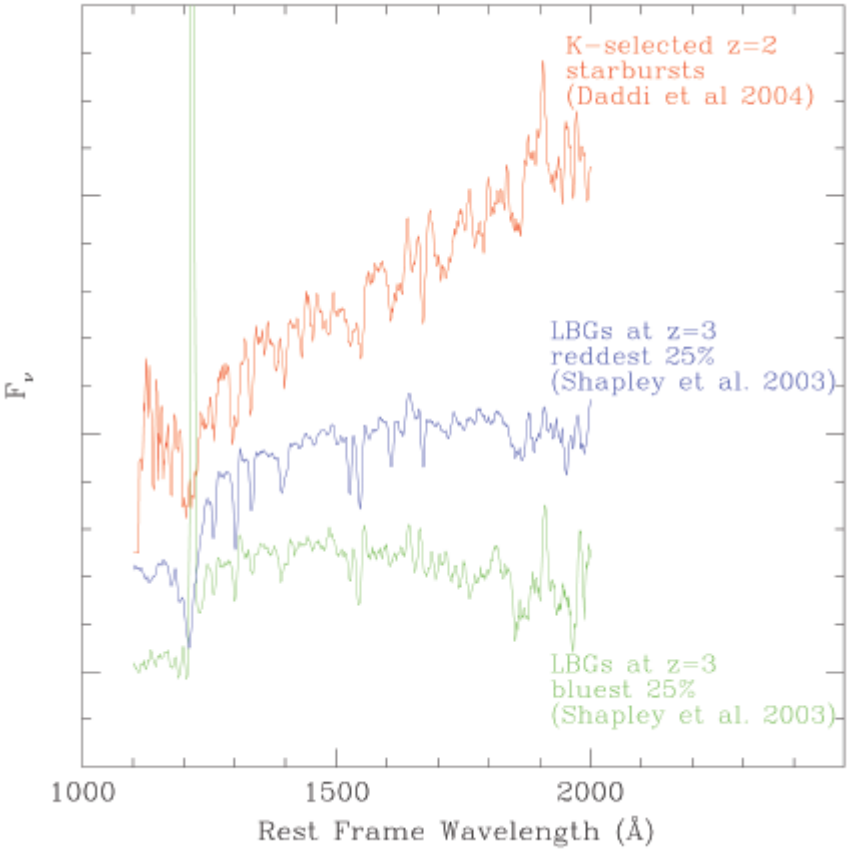


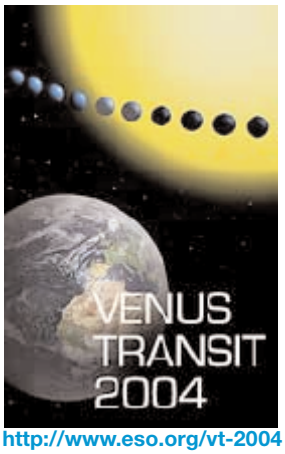
Figure 3: VLT/FORS2 coadded spectra of starburst galaxies with $1.7 \leq z \leq 2.3$ from the K20 sample (courtesy of Emanuele Daddi), are compared to the coadded spectra of the 25 bluest and 25 reddest classical z= 3 Lyman-break galaxies.

While the meeting was mostly dedicated to observations, hence dominated by observers, a few theorists also attended and made lively contributions to it (Avishai Dekel, Cedric Lacey, Rachel Somerville, Simon White). Rachel, in particular, presented efforts in tuning model parameters trying to push the assembly of massive galaxies towards earlier epochs.

Imaging/spectroscopic surveys that have just started were also illustrated, showing early results from the VLT VIMOS Deep Survey (VVDS, Olivier Le Fèvre), the Keck DEEP/DEEP2 survey (David Koo, Jeffrey Newman), and GALEX (Chris Martin, Mike Rich). For other major surveys that are about to start, motivations, plans, and expectations were also illustrated, including SWIRE on SIRTF (Alberto Franceschini, Seb Oliver), the near-IR Ultra Deep Survey which is part of UKIDSS (Omar Almaini) and the COSMOS 2-square degree ACS survey (Nick Scoville). Given its convenient equatorial/10^h location, COSMOS is attracting virtually every major facility on the ground and in space with the goal of providing a full multiwavelength, public dataset, thus promising astronomers the means they need to cope with cosmic variance while mapping galaxy and LSS evolution all the way to at least $z \sim 3$.

All in all, during the four days of the meeting 66 oral and over 100 poster contributions were presented, and I apologize for the many I could not mention in this cursory summary. Much of the success of the meeting was also due to the 30-minute long discussions at the end of each session, and to the colloquial atmosphere favoured by the city and by the daily vaporetto trips to and from the island.

The VT-2004 Educational Programme - A Unique Opportunity



http://www.eso.org/vt-2004

On June 8, 2004, Venus passes in front of the Sun as seen from the Earth. This very rare event (the last one was in 1882 and no living person has ever seen one!) lasts about 6 hours and will be visible from most of Europe, Africa and Asia. It will most certainly generate unprecedented attention from the media and the public, not just in these areas, but all over the world.

The VT-2004 project is launched in this connection and aims at transforming public curiosity into knowledge and interest in science through a broad set of actions. It is managed by the European Southern Observatory (ESO) and the European Association for Astronomy Education (EAAE), together with the Institut de Mécanique Céleste et de Calcul des éphémérides (IMCCE) and the Observatoire de Paris in France, as well as the Astronomical Institute of the Academy of Sciences of the Czech Republic. The programme is supported by the European Commission in the frame of the European Science Week 2004. It starts officially on January 1, 2004, but provisional information is already available at the dedicated website (www.eso.org/vt-2004/). When ready, it will provide access to a wealth of related information in many (European) languages about many different aspects (scientific, technical, historical etc.) of this event.

The VT-2004 project invites active participation of all interested individuals (including teachers, students, amateur astronomers, etc.) and educational institutions (planetariums, public observatories, science centres, etc.). It will provide comprehensive information about the related - scientific, technical, social and historical - aspects. It encourages and will coordinate real-time measurements of the transit, thus publically re-enacting the determination of one of the most fundamental astronomical parameters, the distance from the Earth to the Sun. It also explains the relation of this event to the search for extra-solar planets by the transit method, the only one which, in the near future, might be able to discover Earth-size planets.

The VT-2004 project promotes international collaboration throughout a large part of the world, by observing the same rare celestial event, debating it via the web and adding local observational contributions to a large, common database. Real-time feed-back via the web and the media will ensure that this will become a very special public event. A large, international network of educational institutions that will be actively involved in the Venus Transit event is being established (see the website).