

Starbursts – from 30 Doradus to Lyman Break Galaxies: Conference Summary

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“Starbursts” are intense episodes of star formation in which the surface density of star formation ranges up to 10,000 times that in normal galaxies. They are important features of early galaxy evolution. Many of the distant, high-redshift galaxies we are able to detect are in a starbursting phase, often apparently provoked by a violent gravitational interaction with another galaxy. Nearby analogues to the large-scale starbursts at high redshifts are rare, although more modest events are often found in dwarf galaxies. These can be studied in much greater detail than the distant cases and have been found to exhibit common traits, such as the presence of compact, high-luminosity star clusters (often referred to as “super star clusters”).

This conference aimed at bringing together scientists (observers, theorists, and modelers) studying starbursts on the full range of scales, from small, localised starbursts such as seen in the 30 Doradus region in the Large Magellanic Cloud, through relatively nearby galaxy-wide starbursts and interactions such as observed in, e.g., M82 and the Antennae galaxies, to their high-redshift counterparts, in particular the “Lyman break galaxies.”

The breadth of the conference topic generated immense interest. The conference proved far more popular than space availability allowed for, once again showing that the starburst community is very much alive and kicking! With more than 190 participants, 71 oral presentations and some 100 poster papers, most of the networking and surely some of the most interesting scientific discussions happened off-line in the corridors, during the lunch breaks or even at the sumptuous conference dinner hosted by the University of Cambridge’s ancient Queens’ College.

Five days of a densely packed programme proved to be like drinking from a fire hose; yet it also generated a highly satisfactory and stimulating environment. We hope that new collaborations have found roots at this meeting, and that it will be remembered as a watershed conference, bringing together experts from a wide variety of backgrounds. Summarising the meeting’s key scientific output is therefore no mean feat...

Let us be bold and first consider the question as to the importance of starburst events to astrophysics as a whole. If we did not know that major starbursts existed, would we have difficulties explaining the key properties of the Universe? The answer to this simple yet profound question must be a resounding “yes,” we believe. Almost certainly, the ubiquitous, dense super star clusters originated under spe-

cial starburst-like conditions, involving massive gas flows, very high ambient pressure, and – as a consequence – the presence of dense, shocked material. Similarly, massive starbursts appear mandatory to generate the very high stellar densities found in large spiral bulges and elliptical galaxies,

Another line of argument has to do with the mass deposition in stars over cosmic time. There is evidence that some 50 per cent of all stars in local galaxies at the present epoch may have been generated in (luminous) infrared galaxies, which we now know are among the major contributors to starbursts at intermediate and high redshifts.

Finally, it appears that in order to explain a number of observables, such as the chemical enrichment of the intergalactic and intercluster medium, the well-defined mass-metallicity relation in galaxies, the absence of super-supermassive black holes, and even cosmic reionisation, one needs to invoke large-scale galactic winds (“superwinds”), akin to the archetype discovered in the 1960’s in the nearby galaxy M82.

One of the key lessons of the conference was that in order to make progress in studying these problems we require a “pan-spectral” approach, combining observations taken over as large a wavelength range as possible with key theoretical advances. This is particularly important because many starbursts are enshrouded in dust clouds that are optically thick at shorter wavelengths. A long wavelength baseline is needed to overcome the distortions caused by extinction and to derive the basic properties of the stellar populations (ages, chemical abundances, and star-formation rates). In most cases, this implies sampling the spectral energy distribution from the ultraviolet to the far-infrared. However, for the youngest embedded starbursts even infrared radiation is strongly absorbed by dust, and we must turn to the millimetre and radio domains. Rapid progress is already being made on both ends of the spectrum, as illustrated by the most recent results from both GALEX in the ultraviolet and the Spitzer Space Telescope (SST) in the mid-infrared.

The size and complexity of typical starburst environments push the instrumental resolution required to the limit, even for nearby objects. While the future looks brilliant for high-resolution astronomy at infrared to radio wavelengths, with long baseline radio interferometry being upgraded in both North America and Europe, the powerful ALMA observatory now under construction for the millimetre domain, the James Webb Space Telescope on the horizon in the mid-infrared, and ground-based adaptive optics at shorter in-

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INSTITUTE OF ASTRONOMY
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KEYNOTE
SPEAKERS:

Tim Heckman (USA)
Jay Gallagher (USA)
Almudena Alonso-Herrero (USA)
Bruce Elmegreen (USA)
Mark McCaughrean (Germany)
Ian Bennell (UK)
Jürgen Knödlseder (France)
Claus Leitherer (USA)
Daniela Calzetti (USA)
Nils Bergvall (Sweden)
Paul van der Werf (Netherlands)
Neil Trentham (UK)
Jim Ulvestad (USA)
François Schweizer (USA)
Richard de Grijs (UK)
Françoise Combes (France)
Chris Mihos (USA)
Rob Kennicutt (USA)
Bob Abraham (Canada)
Joe Silk (UK)
Natascha Förster-Schreiber (Netherlands)
Roberto Terlevich (Mexico)
David Elbaz (France)
Nick Scoville (USA)
Clive Tadhunter (UK)
Rosa González Delgado (Spain)
Daniel Schaerer (Switzerland)
Johan Fynbo (Denmark)
Max Pettini (UK)
Bob O'Connell (USA)

SOC:

Richard de Grijs (Chair)
Cathie Clarko
Françoise Combes
Uta Fritze-von Alvensleben
Rosa González Delgado
Claus Leitherer
Max Pettini
Evan Skillman
Roberto Terlevich
Paul van der Werf

<http://www.astr.cam.ac.uk/meetings/starburst2004>
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frared wavelengths, it is bleak for the crucial optical and ultraviolet domain.

The *Hubble Space Telescope (HST)* has been the high-resolution UV-optical mainstay for more than a decade now. It has contributed immensely to the development and rapid progress in this field, as witnessed by the fact that well over two-thirds of the talks at the conference employed HST observations. Yet *HST*'s future is in doubt due to recent decisions taken by NASA, much to the dismay of this community. It is urgent to maintain, or even improve, high-resolution capability in space shortward of the near-infrared passbands. If no action is taken soon, our community will lose one of its most valuable assets on a time-scale of only a few years. The recent loss of STIS has already greatly diminished our UV spectroscopic capability, while *HST*'s gyros (used for attitude control) are not expected to last more than a few years. A robotic repair mission is currently under design, but many are sceptical that this will be realised rapidly enough to avert disaster for our community.

A major theme of the conference was “scaleability,” i.e. the question as to whether or not we can scale up our detailed knowledge of local star-forming systems to those seen at large cosmological distances, and to more extreme environments. Star formation occurs in three broad amplitude ranges: “quiescent” star formation, such as we know and love it in our own Galaxy and nearby normal systems; elevated or “enthusiastic” star formation such as found in, e.g., blue compact dwarf galaxies; and extreme or “psychopathic” starbursts mostly found in distant systems.

The evidence that, to first order, we can indeed scale star-formation physics across these ranges is fortunately good. This implies that we require only modest (rather than fundamental) adjustments to the star-formation framework. The premier example here is the tight relation, over some 6 decades, between the star-formation activity per unit area and the local gas surface density (known as the Schmidt-Kennicutt law). Starburst properties, in addition, appear to be continuous across a range of amplitudes – and redshifts – suggesting a galaxy classification sequence similar to the Hubble tuning fork, but now from M82-like starbursts via ultraluminous infrared galaxies (ULIRGs), to the recently discovered SCUBA galaxies, as well as from Lyman Break Galaxies through luminous compact blue galaxies, perhaps down to dwarf ellipticals. It appears that the frequency of starbursts was larger at high redshifts (although of similar duration as in the local Universe), yet there does not appear to be a strong transition (or step function) in frequency, again supporting the scaleability argument.

More and more evidence, predominantly observational, points to an almost universal initial mass function for stars, at least at the high-mass end, on scales from (super) star clusters to galaxies as a whole. A great deal of attention is being focussed on the handful of situations (e.g., star clusters in M82 and the Antennae galaxies) where there may be a deficiency of low-mass stars with respect to the universal initial mass function. This result is an important aspect of scaleability, especially since the massive stars are the dominant source of feedback in the star-formation process. This is currently one of the most active fields in the starburst community,

Data on star-forming galaxies are now pouring in from our large telescopes and especially from the deep extragalac-

tic surveys being made at all UV through infrared wavelengths. This will help resolve many of the issues raised at the conference. However, there are also critical questions in areas that may not be receiving the attention they deserve, such as: how does feedback operate in young starbursts and regulate processes like quenching, saturation and outflows? In particular regarding the latter, the largest effects of starbursts are related to galactic superwinds, but there are numerous uncertainties regarding their underlying physics. Similarly, an important open question concerns the nature and impact of starburst triggers: for a given trigger, there is apparently a large variation in the resulting star-formation amplitude, which remains poorly understood as yet. A final important problem concerns the drivers and time-scales for dust shroud dissipation. All these areas will benefit from a combined observational/theoretical attack.

We are looking forward to the rapid progress that will be delivered by GALEX, SST, ALMA, and the large number of dedicated ground-based surveys by the time of the next major starburst conference.

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