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SUMMARY TALK

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RESUMEN

Esta contribución contiene la casi imposible tarea de resumir los múltiples y variados resultados presentados en esta Conferencia sobre *"Starburst Activity in Galaxies"*.

ABSTRACT

I present here my contribution to the almost impossible task of summarizing the deeply rich and varied presentations to the Conference *"Starburst Activity in Galaxies"*.

Key words: **GALAXIES: ACTIVITY — GALAXIES: INTERACTIONS — GALAXIES: STARBURST — STARS: FORMATION**

1. INTRODUCTION

We have been amazed during the week by a wealth of beautiful data obtained both from space and ground-base observations, and not only from the new observatories (EUV-Hopkins-*HST-ASCA-ISO* and Keck); we were also shown very impressive and sophisticated models of starbursts and their environment using pure hydrodynamics, or magneto-hydro, photoionization cluster synthesis. You name it, they included it in their codes. In the end, we could not but leave the conference with the positive impression of having learnt something about *"Starburst Activity in Galaxies"*.

2. TRIGGERING STARBURSTS

The key process seems to be `gas fueling`. We have seen evidence for enhanced star formation in *interacting galaxies* convincingly presented both in talks and in posters. We heard about scaling laws for star formation, and also how the presence of a bar can create powerful resonances and how the gas inside the inner one moves out and that inside the outer one moves in and a ring is created where the surface density reaches a critical value for star formation.

The efficiency of bars to form both nuclear and circumnuclear starbursts by central gas fueling was also indicated by simulations. A single bar with Inner Limblad Resonance in about a Kpc scale or two nested bars (~100 pc) seem to be the triggering mechanism in such a model, for star-forming activity in isolated galaxies. Rare cases of collissions between galaxies also produced starbursts in expanding rings, simulated by 3-D n-body/Smooth Particle Hydrodynamic models. There is ample evidence of ring star-bursting processes in galaxies. From the —first described some 30 years ago— Sersic-Pastoriza or hot-spot galaxies to some active galaxies like NGC 1068, or many more cases presented in poster papers.

Another process where large-scale shocks generated by the collision of gas clouds with masses of more than 10^6 $M_\odot$) was invoked to explain the apparent space-time structures of superassociations.

Star formation seems to be induced tidally in cluster galaxies, with observational evidence for a higher frequency in richer clusters. Tidally induced starbursts are also believed to be the case in luminous and ultraluminous IR galaxies; Genzel has summarized the studies presented on them.

An alternative scenario is proposed by this model in which a black hole binary formed by a merger triggers intense star formation in the central regions of a spiral, and depending on the mass ratio of the black holes, the gas will respond by forming circumnuclear or nuclear starbursts.

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As for the starburst phenomenon of H II galaxies, various types of evidence were presented. First, that star formation in these galaxies is **not** triggered by interaction with a luminous/massive galaxy, but that many H II galaxies show low mass H I companions perhaps capable of inducing the burst while non-bursting low surface brightness galaxies do not.

3. SUPERWINDS, SUPERBUBBLES, WASP-WAISTS AND JETS

Phenomena that are known to be linked to starbursts are superwinds, superbubbles, and jets, and several models were presented attempting to reproduce them and to understand their interplay with "violent"star formation activity.

Winds and bubbles at large scales as well as "wasp-waists" (stationary solutions that limit the gas to a small region near the rotation center of the galaxian plane) formed by the radial pressure of an accretion disk, were produced by models in which starbursts drive strong outflows. Simulations of superwinds could reproduce several phases like a hot halo in which soft X-rays are produced, optical emissions produced via shocks, and photoionization in which warm gas escapes into the intergalactic medium where optical filaments are produced; in low-mass galaxies, hot metal-enriched gas is likely to escape and even some molecular gas can be found participating in the outflow. As much mass can be found forming stars as flowing out.

Models were also presented in which, the stellar wind energy, controls gas properties, the conditions in which very compact clusters are formed, and winds and radiation provide the constrains. As stars evolve and red supergiant winds appear, they squeeze into even smaller spaces, very high densities grow and compact supernova remnants are produced. Regions that are very dusty are created. Exquisitely elaborated 2-D hydro models with adaptive mesh grids were presented that have been developed to study the physics and evolution of these compact remnants.

Models to reproduce the evolution of a compact star cluster, including magnetically driven winds that appear collimated in 1 Kpc scales were also presented.

And may be we know now the forming processes of low mass stars and how they self-regulate; and that an altogether different —but yet unknown— process is probably needed to form high mass stars.

4. KINEMATICS OF STARBURSTS

Fabry-Perot images were presented, showing them as powerful tools to segregate different kinematic stages of, and created by, nuclear starbursts: bipolar jets, bubbles, plumes, extensions, etc.

5. STAR-FORMING DWARFS

We were told how star-forming dwarfs are found, essentially from objective prism surveys, selecting the objects with UV excess and strong [O III] lines. Every form of environmental action on them was analysed, and we learnt that, for those that belong to clusters, environment seems not to affect their colours or metallicity, but only their excitation conditions. Those in clusters do not follow the Metallicity-Luminosity relation as the field ones follow. And, judging by the ratio $F(H\beta)/L_B$, the star formation rate at present is much lower than in the past, for those galaxies in voids or in low density media.

Evidence for and against galactic wind dominated evolution of dwarf irregulars was discussed, and the conclussion reached that moderate winds can be OK. This could explain simultaneouly the problem of the large ammount of Fe observed in the haloes of rich cluster of galaxies (comparable to the one seen in the cluster itself) and also the controversial low value of dY/dZ: the rate of He per unit metal produced, observed in H II galaxies. Still, if moderate winds provide a good agreement for $\Delta Y/\Delta O$, a good fit to the relation C/O vs. O/H obtained from *HST*-UV spectroscopy is provided by models without any wind. Of course, the conclusion was the need for more and better data.

All previous arguments are based on nearby objects. What is the behaviour at higher redshifts? We need to (and today we can) find out.

There is a consensus that dust destroys Lyα emission, and hence the explanation for the hitherto accepted correlation between Lyα/Hβ intensity ratio and metallicity in the sense that the lower the metallicity, the larger the chances of the star-forming dwarf to display Lyα in emission. This correlation has been broken, as we heard here, by new *HST*-UV high resolution spectra, from which it seems that the main culprit in destroying Lyα emission is not dust, but rather gas column density and narrow velocity field in the neutral and ionized gas regions. Present questions relevant to the neutral vs. ionized gas abundances will hopefully be solved in the near future with forthcoming *HST* observations.

6. STARBURST STELLAR POPULATION

We heard of very elaborate population synthesis methods using J, H, and K band spectroscopy. Still, the degeneracy age-metallicity and even a lack of luminosity class discrimination in certain cases, reminds us of the need for combining it with methods involving wider wavelength coverage. The impression, nevertheless, is that this problem will have been solved at the next starburst meeting.

From extreme UV spectra of starbursts, a new method comes based in the analysis of the λ1036 Å O VI doublet, that allows a good stellar population synthesis for O stars (combined with Si IV and C IV). When fully implemented, it will provide a powerful method for studying the stellar population of bursts at high redshifts.

New diagnostic diagrams are being developed specially for high redshift emission-line objects. With just EW([O II]) and EW(Hβ) it is possible to obtain a good discrimination between Seyfert and H II galaxies.

It is fascinating that we saw how the stellar component of very young clusters can be traced from our galaxy and 30 Dor to z over 3, when the Universe was less than 10% of its present age. Exciting also was the report of dynamical mass determination of superclusters in starburst galaxies through the velocity dispersion measured in absorption lines of the atmospheres of the stars. This will help to determine if low mass stars are formed in Starburst or if the IMF is top heavy.

What is still a bit worrying is that the observed Starburst broad-band colours are not well fitted by current synthesis models.

It is also interesting to ponder about the apparently discrepant results in determining star formation rates from Hα and from X-ray fluxes in the studied case of He 2–10. May be they trace different moments in the star formation history of galaxies, F(Hα) representing the present day one.

7. PHYSICAL PARAMETERS OF THE STAR-FORMING REGIONS

Regarding the chemical composition of H II regions we learnt that, for abundances higher than about 1/2 of the solar value, it cannot be accurately determined, unless we have large wavelength coverage in the optical region and appropriate detailed photoionization models are used to determine functional parameters. ISO will observe FIR emission lines that may solve this problem.

High dispersion long-slit *scanning spectroscopy* provides the mean to map nearby nebular physical parameters like extinction and electronic density and temperature.

And how exciting! the finding that a fair number of faint blue galaxies turned out to be compact narrow emission-line galaxies at redshifts from 0.1 to 0.7, and when observed with *HST* and Keck, their properties (velocity dispersion - luminosity relation, M_B vs. size, velocity dispersion vs. effective radius) closely resemble those of nearby H II galaxies; they are perhaps the progenitors of present day dwarf irregulars.

8. PHOTOIONIZATION MODELS

We learnt how photoionization models are built, and checked with good data for low-metallicity objects, for which electron temperatures can be accurately measured, so that they then can be applied to higher metallicity, low S/N data. I guess that soon, dust is going to be incorporated into these models.

A new way of modelling the emission line spectrum of AGNs, interpolating into a fixed grid of models was presented. The intensity of different lines depends on the geometry. We were also reminded that the broad line region spectrum of high redshift QSO have high metallicity, a combination of redshift and luminosity, perhaps?

9. EPILOGUE

I will not describe in detail the statistical studies that participants from the floor have made, only that they found (luckily enough) no correlation between the style and cloths worn by the speakers and the quality of the talks.

I tried to convey the flavours of the scientific contents of my alloted half of the talks. I hope I had succeded in doing that. What I cannot even begin to attempt —but anyone who has been to Mexico knows what I am talking about— is to describe the festive creative atmosphere during the whole Conference (and beyond) and the wonderfully warm hospitality by the organizers and by the colleagues, students and staff at INAOE.

On behalf of all the participants, Muchas Gracias.