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PROBING COSMOLOGICAL PARAMETERS WITH H II GALAXIES

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RESUMEN

Re-investigando el uso del diagrama de Hubble para medir la constante cosmológica (Λ) y la densidad de masa del Universo ($\Omega_{\rm M}$), hemos re-encontrado un importante efecto de "enfoque" en Λ para $z \sim 3$, que implica que la magnitud aparente de una candela estándar a $z = 2$–3, prácticamente no depende de Λ para $\Omega_{\rm M} > 0.2$ y que, eligiendo el intervalo de corrimientos al rojo de acuerdo con una estimación del valor de $\Omega_{\rm M}$, éste puede ser medido independientemente de Ω_Λ. Exploramos la evidencia que sugiere que galaxias con brotes extremos de formación estelar, (galaxias H II), pueden ser usadas como estimadores de distancia sobre un amplio intervalo de z. Hemos recopilado datos de la literatura de galaxias H II hasta $z \sim 3$, y encontramos una buena correlación (a pesar de efectos sistemáticos: edad, metalicidad, extinción, cinemática), entre sus luminosidades y dispersión de velocidades, confirmando así la correlación conocida para galaxias H II en el universo cercano.

ABSTRACT

Investigating the use of the Hubble diagram to measure the cosmological constant (Λ) and the mass density of the Universe ($\Omega_{\rm M}$), we found an important focusing effect in Λ for $z \sim 3$. This effect implies that the apparent magnitude of a standard candle at $z = 2$–3 has almost no dependence on Λ for $\Omega_{\rm M} > 0.2$ and that $\Omega_{\rm M}$ can be measured independently of Ω_Λ by targeting the z range according to an estimate of the value of $\Omega_{\rm M}$. We explore the evidence in support of the suggestion that extreme starburst galaxies (H II G) can be used as distance estimators up to high redshifts. We have compiled literature data of H II G up to $z \sim 3$ and found a good correlation (in spite of systematic effects such as age, extinction, kinematics, and metallicity) between their luminosity and velocity dispersion measured from their strong emission lines, thus confirming the correlation already known to exist for H II G in the nearby Universe.

Key Words: **COSMOLOGICAL PARAMETERS — GALAXIES: DISTANCES AND REDSHIFTS — H II REGIONS**

1. INTRODUCTION

Inconsistencies in recent results from distant supernova surveys have lead to a renewed exploration of cosmological models with cosmological constant Λ (Lineweaver 1998; White 1998). The use of supernovae to measure simultaneously Ω_M and Ω_Λ (the energy density of vacuum) was pioneered by Goobar & Perlmutter (1995), Perlmutter et al. (1998) and Riess et al. (1998) showed that type Ia SN at redshifts $0.1 < z < 1$ could strongly constrain the allowed range in these cosmological parameters.

We have shown (Melnick, Terlevich, & Terlevich 2000) that the strong *focusing* effect of Hubble diagrams with Λ (already mentioned by Refsdal, Stabell, & de Lange (1967)) allows to separate the effects of mass and vacuum density in the expansion, provided one can measure distances in the range $1 < z < 3$. This is shown in Figure 1, that plots the predicted luminosity distance (normalized to $\Omega_{\rm M} = 0.5$ and $\Omega_\Lambda = 0$) as a function of z for different combinations of cosmological parameters. For a given $\Omega_{\rm M}$, the world models of different Ω_Λ converge in a narrow redshift range and the degree of convergence increases with increasing mass density.

It is therefore desirable to explore distance estimators like the $L({\rm H}\beta)$–σ relation in H II galaxies (Melnick, Terlevich & Moles 1988: MTM) that can be potentially used from the local group of galaxies up to redshifts of cosmological interest with today's technology. We have used published data to show that the $L({\rm H}\beta)$–σ relation for local galaxies is also satisfied by emission line objects of redshifts up to $z \simeq 3$. We argued that strong emission line galaxies are very promising objects to be used for a global determination of the cosmological parameters $\Omega_{\rm M}$ and Ω_Λ.

Figure 2 shows the $L({\rm H}\beta)$–σ relation for the published samples; filled triangles: local galaxies from MTM; squares: data from Koo et al. (1995) and Guzmán et al. (1997); circles: high redshift objects from Pettini et al. (1998). No extinction corrections

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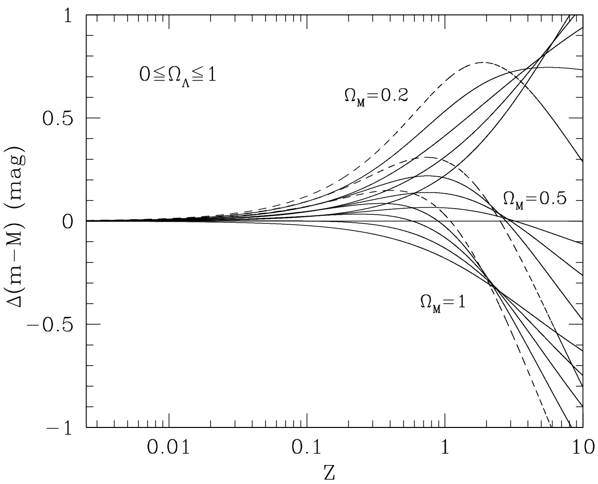

Fig. 1. Normalized distance modulus $\Delta(m-M) = (m-M)_{\Omega_{\rm M},\Omega_\Lambda} - (m-M)_{.5,0}$ as a function of redshift. For each value of $\Omega_{\rm M}$ as labeled in the Figure we plot a family of vacuum energy density $\Omega_\Lambda = 0$, 0.25, 0.5, 0.75, 1.0. For each family, the dashed line corresponds to $\Omega_\Lambda = 1$.

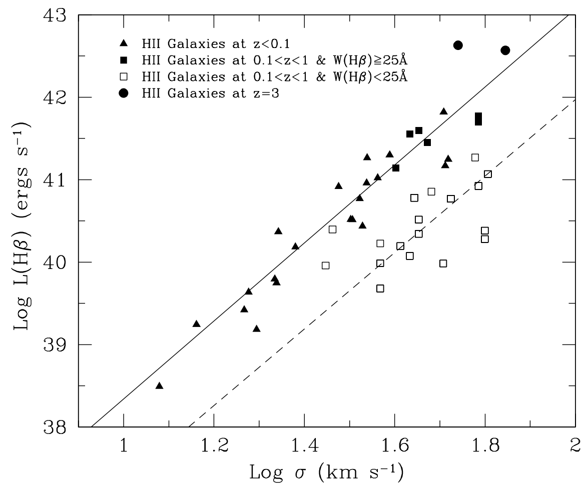

Fig. 2. The Luminosity-sigma correlation for H II galaxies at a wide range of redshifts. The solid line shows the Maximum-Likelihood fit to the young H II galaxies in the local Universe. The dashed line shows the predicted $L(\mathrm{H}\beta)$–σ relation for an evolved population of H II galaxies. The cosmology is $H_0 = 65$, $q_0 = 0$, $\Lambda = 0$.

have been applied. The most important systematic effects (age, extinction, kinematics, metallicity, and the very physics of the relation) have been discussed by Melnick et al. (2000).

Our strong conclusion is that using the redshift-magnitude diagram method $\Omega_{\rm M}$ can be measured independently of the value of Ω_Λ by targeting the z range according to an estimate of the value of $\Omega_{\rm M}$. In particular, for small $\Omega_{\rm M}$, the optimum redshift is $z \sim 3$ where already a significant sample of H II galaxies does exist (e.g. Pettini et al. 1998) Ω_Λ is best determined well away from the region where the focusing occurs, i.e., either $z < 1$ or $z > 5$.

Using the high efficiency IR spectrographs in the new generation 8–10m telescopes it will be possible to determine the Hβ line widths, luminosities, and equivalent widths of high z H II over a wide range of luminosities with high accuracy. This will allow for the first time using the distance estimator to probe the cosmological parameters out to unprecedented distances.

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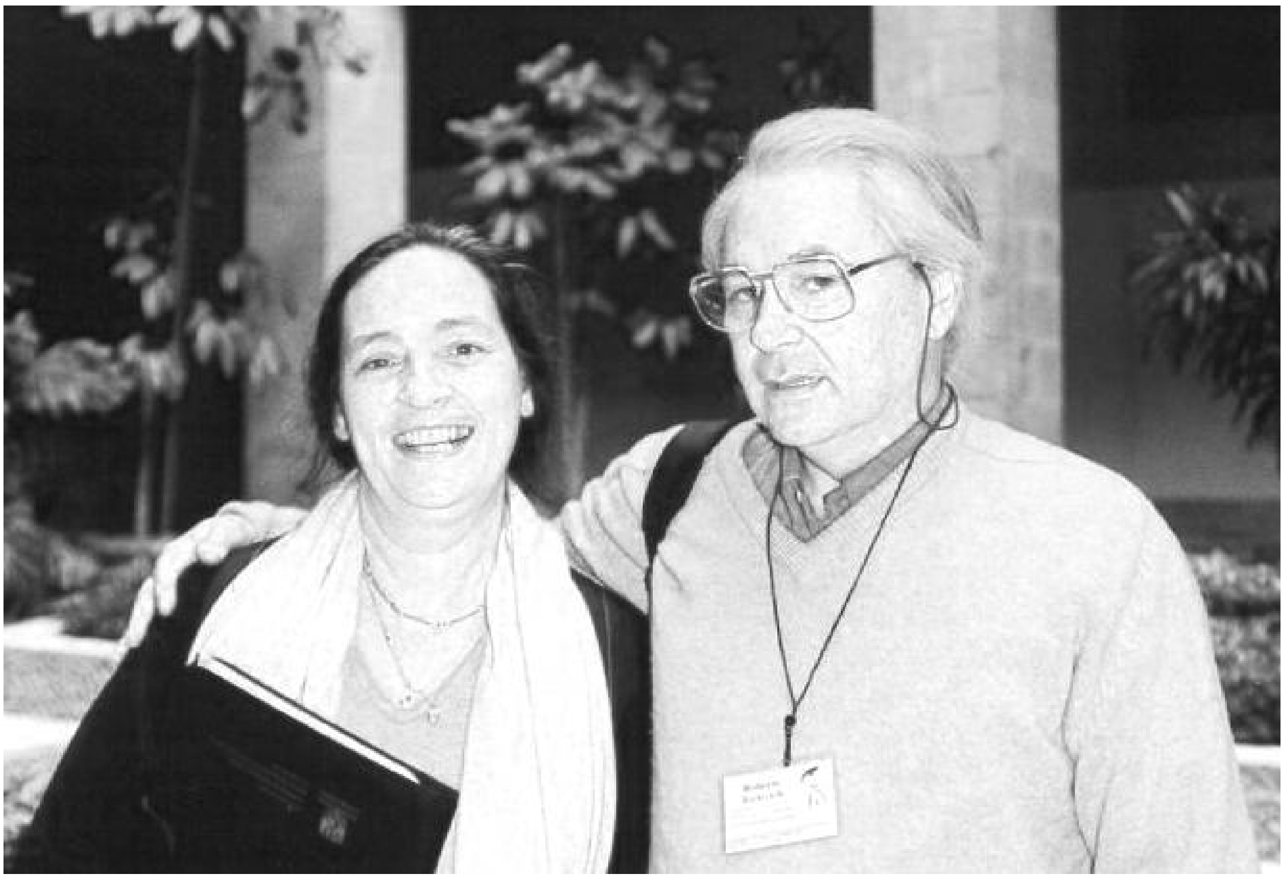

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