A determination of the local Hubble constant using Giant HII Regions and HII galaxies.

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The aim of this work

To determine the Hubble constant using the $L-\sigma$ relation as distance indicator, with the new calibration of the zero point, and analyzing the possible systematic effects associated with the method and the calibrators GHIIRs and HIIGs.

Introduction

HIIGs are compact and massive systems experiencing luminous bursts of star formation generated by the formation of young super stellar clusters (SSCs) with a high luminosity per unit mass and with properties similar, if not identical, to GHIIRs. The potential of GHIIRs as distance indicators was originally realized from the existence of a correlation between the GHIIR diameter and the parent galaxy luminosity [11, 10] see also [6]. A different approach was proposed by [7, 8], who found that the turbulent width of the nebular emission lines is correlated with the GHIIR diameters.

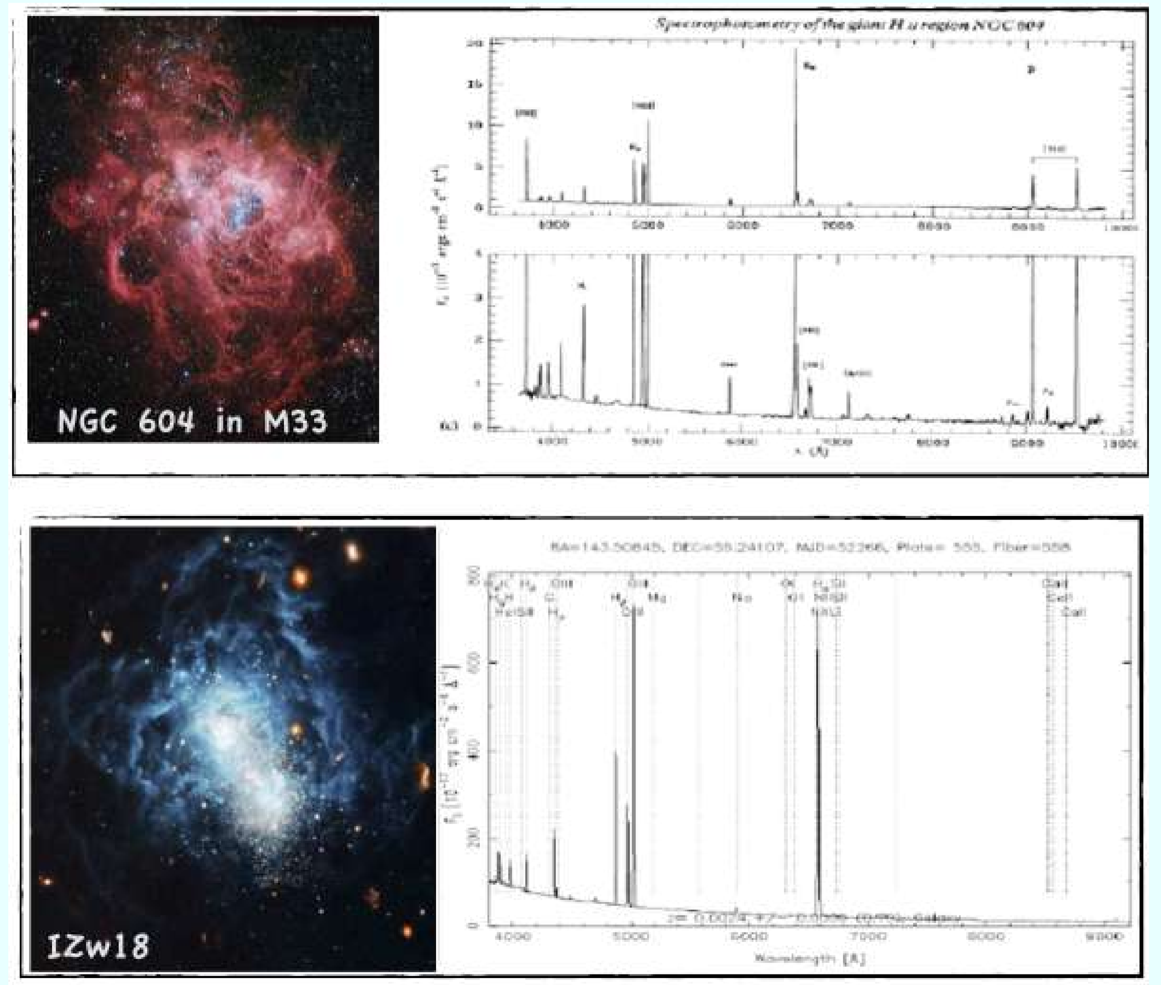

Figure 1: Spectra and images of H II region in M33 (NGC 604) and one HII galaxy (IZw18), the spectra were taken from Sloan Digital [4] and Sky Survey (SDSS), respectively. Credit for the images Hubble Space Telescope (HST).

In 1981, [12] found a tight correlation between the turbulent emission lines veloity dispersion and their integrated luminosity: the $L-\sigma$ relation. This correlation, valid for HIIGs and GHIIRs, links a distance dependent parameter, the integrated Hβ line luminosity, with a parameter that is independent of distance, the velocity dispersion of the ionized gas, therefore defining a redshift independent distance estimator.
The relationship between the integrated Hβ line luminosity and the velocity dispersion of the ionized gas of H II galaxies and giant H II regions represents an exciting standard candle that presently can be used up to redshifts $z \sim 4$. Locally it is used to obtain precise measurements of the Hubble constant by combining the slope of the relation obtained from nearby ($z \leq 0.2$) H II galaxies with the zero point determined from giant H II regions belonging to an 'anchor sample' of galaxies for which accurate redshift-independent distance moduli are available [2, 9]

About Me and the project

I am a postdoc at Instituto Nacional de Astrofísica, Óptica y Electrónica in México. My research interest includes Observational Cosmology, Star Formation and Super Stellar Clusters using spectroscopy data. Scan the code for more references or please feel free to contact me for more information. arenas@inaoep.mx

The determination of the Hubble constant: The data

The measurements that are required for the calibration are the following: 1) Narrow-band imaging or low-resolution spectroscopy with wide slits to obtain the integrated Hβ flux. 2) High-resolution spectroscopy to measure the velocity dispersion from the Hβ line profile. For local calibration, we present the results of the observations of 36 GHIIRs hosted by 13 nearby galaxies with redshift-independent distances.

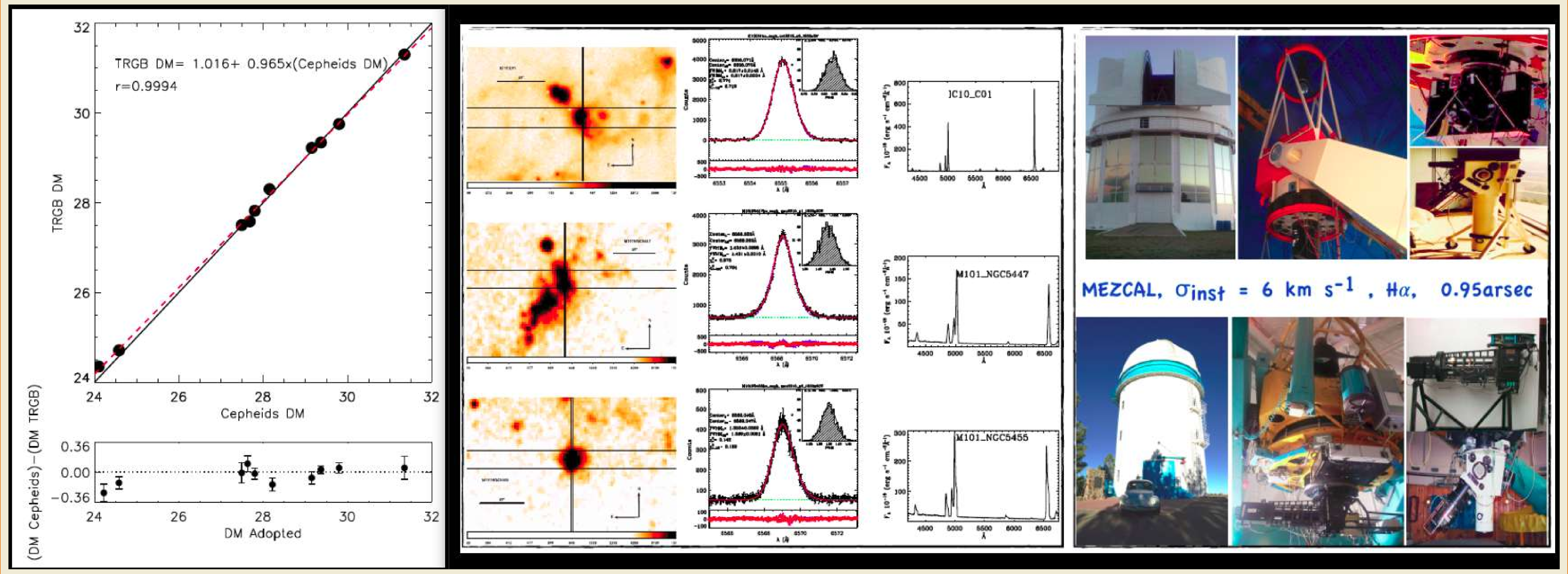

Figure 2: Comparison of the distance moduli for our anchor sample obtained using the TRGB or the Cepheids PL relation. High-resolution Hα profile and low spectra resolution for differents GHIIRs in the sample, OAGH and SPM observatories and instruments used in this work.

The determination of the Hubble constant: Methodology

The Hubble constant is determined as follows: first we fix the slope of the $L-\sigma$ relation using the velocity dispersions and luminosities of the HIIGs. The slope is independent of the actual value of H_0. The said slope is then used to determine the zero-point of the relation using our new data of GHIIRs.
To estimate the Hubble constant we use the slope (α) of the $L-\sigma$ relation of the HIIGs and our anchor sample to calibrate the zero point (Z_p) of the distance indicator as follows:

$$Z_p = \frac{\sum_{i=1}^{36} W_i(\log L_{\mathrm{GHR,i}} - \alpha \times \log \sigma_{\mathrm{GHR,i}})}{\sum_{i=1}^{36} W_i} \tag{1}$$

where $L_{GHR,i}$ is the Hβ luminosity of each GHIIR and $\sigma_{\mathrm{GHR,i}}$ the corresponding velocity dispersion. The statistical weights W_i are calculated as:

$$W_i^{-1} = \left(0.4343\frac{\delta L_{\mathrm{GHR,i}}}{L_{\mathrm{GHR,i}}}\right)^2 + \left(0.4343\alpha\frac{\delta\sigma_{\mathrm{GHR,i}}}{\sigma_{\mathrm{GHR,i}}}\right)^2 + (\delta\alpha)^2(\sigma_{\mathrm{GHR,i}} - <\sigma_{\mathrm{HIIG}}>)^2 \tag{2}$$

where $<\sigma_{\mathrm{HIIG}}>$ is the average velocity dispersion of the HIIGs that define the slope of the relation. Thus, the calibrated $L-\sigma$ relation or distance estimator is: $\log L(H\beta) = \alpha \log\sigma + Z_p$. To calculate the Hubble constant we minimise the function,

$$\chi^2(H_0) = \sum_{i=1}^{N}[W_i(\mu_i - \mu_{H_0,i})^2 - ln(W_i)] \tag{3}$$

where μ_i is the logarithmic distance modulus to each HIIG calculated using the distance indicator and the Hβ flux F(Hβ) as

$$\mu_i = 2.5[Z_p + \alpha \times \log\sigma_i - \log F_i(H\beta) - \log 4\pi] \tag{4}$$

and $\mu_{H_0,i}$ is the distance modulus calculated from the redshift using either the linear relation $D_L = zc/H_0$ or the full cosmological prescription with $\Omega_\Lambda = 0.71$.
The best value of H_0 is then obtained minimising χ^2 with statistical weights $W_i^{-1} = \delta\mu_i^2 + \delta\mu_{H_0,i}^2$ calculated as,

$$W_i^{-1} = 6.25[(\delta Z_p)^2 + \left(0.4343\frac{\delta F_i}{F_i}\right)^2 + \left(0.4343\alpha\frac{\delta\sigma_i}{\sigma_i}\right)^2 + (\delta\alpha)^2(\sigma_i - <\sigma>)^2] \tag{5}$$

The determination of the Hubble constant: Systematics

In particular, we explore alternative parametrizations that can not be easily included in the error scheme, as follows:
- Two samples: S1 with 107 galaxies or S2 with $z < 0.1$ and 92 galaxies;
- Two different sources for the Hβ photometry: [3] (Ch14) or SDSS;
- Two formulations for the luminosity distance for the HIIGs: $D_L = H_0/cz$ (LR) or full ΛCDM cosmology with $\Omega_\Lambda = 0.71$;
- For these three cases we use two different extinction laws: [1] (C00) or [5] (G03).
- Evolution corrections. We have included in the estimate of the evolution correction the contribution of an underlying older stellar population and of the differential extinction.

Main Results

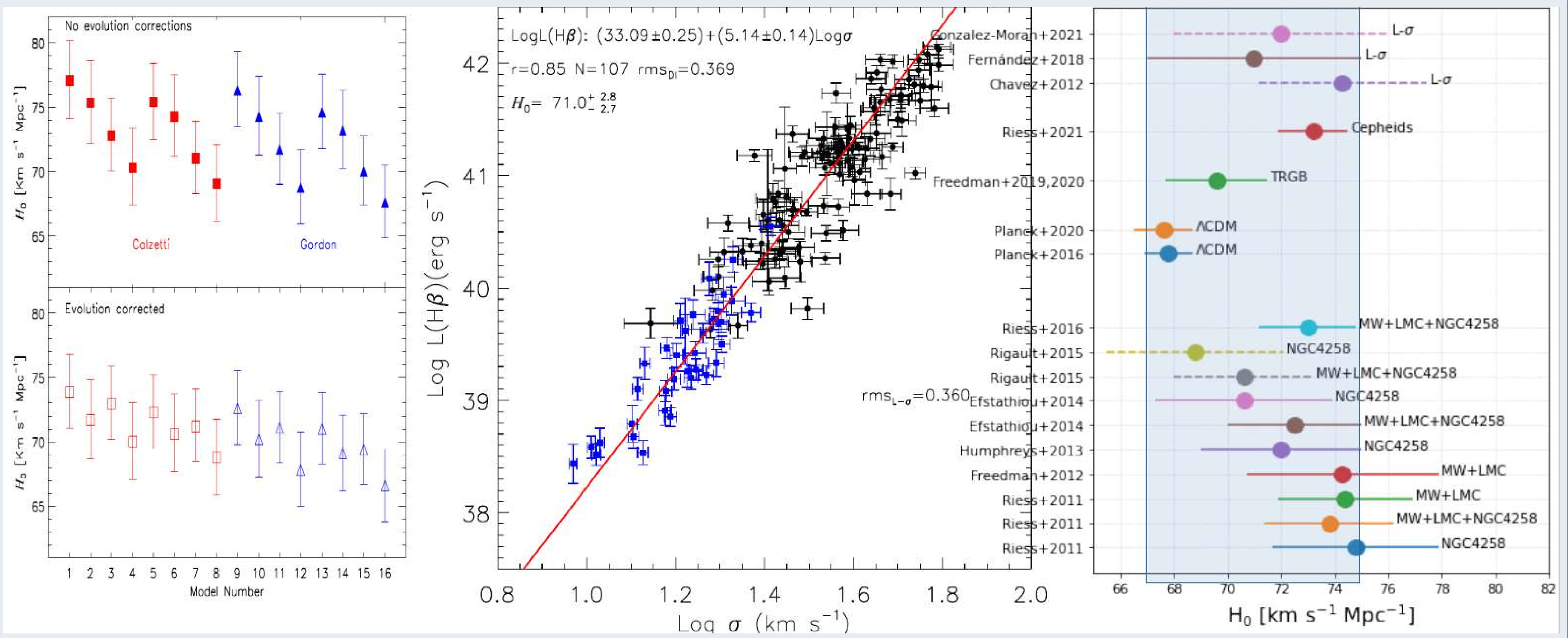

Figure 3: Left upper: Resulting H_0 without correcting the luminosities for evolution. Left Bottom: Same as the top panel, but using the fluxes corrected for evolution. As discussed in the text, the difference between models 1-8 (in red) and models 9-16 (in blue) is the adopted extinction law as indicated by the figure legends. Middle: The $L-\sigma$ relation for the [3] sample using the velocity dispersions in the original paper; the fluxes have been corrected using [5] extinction law. The solid line is the fit to the HIIGs points. The inset equation is the distance indicator where the slope is obtained from the fit to the HIIGs and the Zp determined following the procedure described in the text. Right: Our main result incorporating the evolution correction, is H_0=71.0 ± 3.5 km s^{-1} Mpc^{-1}(random+systematic) a value that is half way between the most recent determination from Planck and SNIa.

- We have used the $L-\sigma$ distance indicator to derive an independent local value of the Hubble parameter H_0. To this end we have combined new data for 36 GHIIRs in 13 galaxies of the 'anchor sample' that includes the megamaser galaxy NGC 4258, with the data for 107 HIIGs from [3].
- Using the SDSS photometry gives values of H_0 slightly lower than those calculated using the photometry of [3]. This is probably related to the fact that the small aperture of the SDSS spectroscopy underestimates the emission line fluxes in the nearest objects, that happen to be also the lowest luminosity ones. The result is a steeper slope in the $L-\sigma$ relation leading to a smaller value of H_0.
- Using the extinction law from [1] tends to produce values of H_0 slightly larger than when using the extinction law from [5] but with a systematic difference inside the H_0 errors. Given that Gordon extinction law is derived from the prototypical massive star forming region 30-Doradus, while Calzetti extinction law is derived from global properties of mostly massive star forming galaxies and therefore includes aspects related to the parent galaxy, we chose to use the former.

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