RevMexAA (Serie de Conferencias), **11**, 117–118 (2001)

THE CHEMICAL EVOLUTION OF DYNAMICALLY HOT GALAXIES

Michael G. Richer,
Instituto de Astronomía, Universidad Nacional Autónoma de México
Marshall L. McCall,
Dept. of Physics and Astronomy, York University, Toronto, Canada
Grażyna Stasińska
DAEC, Observatoire de Meudon, France

RESUMEN

Utilizamos las abundancias de oxígeno en las nebulosas planetarias de M32, los bulbos de M31 y la Vía Láctea, y las enanas esferoidales NGC 205, NGC 185, Fornax, y Sagittarius para investigar la evolución química de estas galaxias. Encontramos que las abundancias de oxígeno estan muy bien correlacionadas con las dispersiones de velocidades, lo que se explica naturalmente si el mecanismo controlando la evolución química es el balance entre la energía inyectada por supernovas y el potencial gravitacional. Adicionalmente, el cociente [O/Fe] está correlacionado con la dispersión de velocidades para M32 y el bulbo de la Vía Láctea, indicando que la escala de tiempo para formar la mayoría de las estrellas es más corta en bulbos y elípticas más masivas. Las enanas esferoidales no siguen esta relación y tienen cocientes [O/Fe] indicando que la mayoría de sus estrellas se formaron en una escala de tiempo corta. Finalmente, todas estas galaxias siguen la misma correlación entre la abundancia de oxígeno y la luminosidad, un resultado sorprendente dado las distintas historias de formación de estrellas que indican los cocientes [O/Fe].

ABSTRACT

We investigate the chemical properties of M32, the bulges of M31 and the Milky Way, and the dwarf spheroidal galaxies NGC 205, NGC 185, Sagittarius, and Fornax using oxygen abundances for their planetary nebulae. Our principal result is that the mean stellar oxygen abundances correlate very well with their mean velocity dispersions, implying that the balance between energy input from type II supernovae and the gravitational potential controls chemical evolution in bulges, ellipticals, and dwarf spheroidals. It appears that chemical evolution ceases once supernovae have injected sufficient energy that a galactic wind develops. All of the galaxies follow a single relation between oxygen abundance and luminosity, but the dwarf spheroidals have systematically higher [O/Fe] ratios than the other galaxies. Consequently, dynamically hot galaxies do not share a common star formation history nor need to a common chemical evolution, despite attaining similar mean stellar oxygen abundances when forming similar masses. The oxygen abundances support previous indications that stars in higher luminosity ellipticals and bulges were formed on a shorter time scale than their counterparts in less luminous systems.

Key Words: **GALAXIES: ELLIPTICALS, DWARF SPHEROIDALS, BULGES, OXYGEN ABUNDANCES, EVOLUTION**

All dynamically hot galaxies (DHGs: ellipticals, dwarf spheroidals, and bulges of spirals) follow a common Mg_2 index–velocity dispersion relation (Bender, Burstein, & Faber 1993). Since magnesium is a product of type II supernovae and since the velocity dispersion is related to the gravitational potential, the $Mg_2 - \sigma$

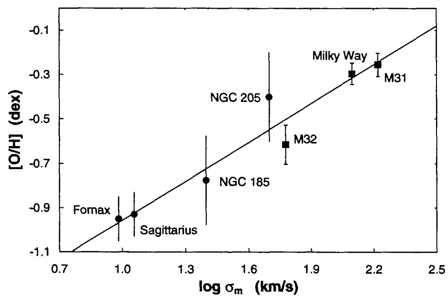

Fig. 1. The mean oxygen abundances in DHGs are well-correlated with their velocity dispersions. Such a relation arises naturally if galactic winds are the agent that terminates chemical evolution in DHGs.

relation has long been interpreted as evidence of galactic winds. The Mg_2 index is good for ranking galaxy metallicities, but of limited value for probing chemical evolution in DHGs. It is not calibrated in terms of an abundance, and its vulnerability to the age–metallicity degeneracy cannot normally be avoided (Worthey 1994). We have recently obtained oxygen abundances for bright planetary nebulae in several nearby DHGs: the elliptical M32, the bulge of M31, and the dwarf spheroidals NGC 205 and NGC 185. We augmented this sample with oxygen abundances from the literature for the planetary nebulae in the bulge of the Milky Way and the dwarf spheroidals Fornax and Sagittarius. In the bulge of the Milky Way, the mean oxygen abundances observed in stars and in planetary nebulae are identical (McWilliam & Rich 1994; Richer et al. 1998), a relation we presume holds in all DHGs.

We find that the mean oxygen abundances in DHGs correlate very well with their mean velocity dispersions, (Fig. 1). As first considered by Larson (1974), star formation entails the formation of supernovae, and, as star formation proceeds, these supernovae inject energy into the interstellar medium. If the rate of energy injection exceeds its losses, the internal energy of the interstellar medium will eventually exceed gravitational binding, at which point the interstellar medium will flow away in a galactic wind. A correlation between abundances and velocity dispersions is a natural outcome of this scenario, for the deeper gravitational wells of more massive galaxies allow star formation, and chemical enrichment, to advance further than in the shallower gravitational potentials of less massive galaxies. It is just such a correlation that we see in Fig. 1. Although the oxygen abundance only measures the energy input from type II supernovae, we can account for the energy contributed by type Ia supernovae using the observed [O/Fe] ratios. When we do so, the correlation in Fig. 1 improves.

We also find that, for M32 and the bulge of the Milky Way, the [O/Fe] ratio correlates with the velocity dispersion. The slope we find is in agreement with the slopes of the $[Mg/Fe] - \sigma$ relations found for bulges, ellipticals, and lenticular galaxies (Jablonka, Martin, & Arimoto 1996; Jørgensen 1997). All of these correlations imply that the time scale for star formation is shorter in more massive galaxies, a finding contrary to the expectation of Larson's (1974) model. Together with Fig. 1, this result implies that the storage of supernova energy is highly efficient. One advantage of a longer star formation time scale in less massive ellipticals is that it allows more time for dissipation, a possible explanation for their higher matter densities. Finally, all DHGs follow a single relation between oxygen abundance and luminosity. Considering the different [O/Fe] ratios of the different types of DHGs, this suggests that the star formation history has little influence upon the oxygen abundance eventually attained. This does not mean that all DHGs follow the same chemical evolution, for it still allows gas flow and consumption to assume different relative importances in the evolution of the different DHGs.

REFERENCES

Bender, R., Burstein, D., & Faber, S. M. 1993, ApJ 411, 153
Jablonka, P., Martin, P., & Arimoto, N. 1996, AJ, 112, 1415
Jørgensen, I. 1997, MNRAS, 288, 161
Larson, R. B. 1974, MNRAS, 169, 229
McWilliam, A., & Rich, R. M. 1994, ApJS, 91, 749
Richer, M. G., McCall, M. L., & Stasińska, G. 1998, A&A, 340, 67
Worthey, G. 1994, ApJS, 95, 107