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DARK MATTER AND THE CHEMICAL EVOLUTION OF IRREGULAR GALAXIES

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RESUMEN

Se presentan tres tipos de modelos de evolución química para galaxias irregulares: de caja cerrada con tasa de formación estelar continua, de caja cerrada con brotes de formación estelar, y con vientos galácticos ricos en oxígeno y tasa de formación estelar continua. Se discute la evolución química de dos galaxias irregulares, II Zw 33 y NGC 1560, y de una galaxia irregular "típica". La fracción de estrellas de baja masa requerida por nuestros modelos es mayor que la derivada para la vecindad solar, pero muy similar a la encontrada en cúmulos globulares. Para nuestra galaxia típica se necesita una fracción de masa del 40% en forma de objetos subestelares y masa oscura no bariónica dentro del radio de Holmberg, lo cual está de acuerdo con los resultados derivados de II Zw 33 y NGC 1560, para las que tenemos una estimación independiente de la fracción de masa en materia oscura no bariónica. Los modelos de caja cerrada explican mejor los valores observados de C/O, $\Delta Y/\Delta$O y Z/O que los modelos de vientos galácticos ricos en oxígeno.

ABSTRACT

We present three types of chemical evolution models for irregular galaxies: closed-box with continuous star formation rates (SFRs), closed-box with bursting SFRs, and O-rich outflow with continuous SFRs. We discuss the chemical evolution of the irregular galaxies NGC 1560 and II Zw 33, and a "typical" irregular galaxy. The fraction of low-mass stars needed by our models is larger than that derived for the solar vicinity, but similar to that found in globular clusters. For our typical irregular galaxy we need a mass fraction of about 40% in the form of substellar objects plus non baryonic dark matter inside the Holmberg radius, in good agreement with the results derived for NGC 1560 and II Zw 33 where we do have an independent estimate of the mass fraction in non baryonic dark matter. Closed-box models are better than O-rich outflow models in explaining the C/O and Z/O observed values for our typical irregular galaxy.

Key Words: **GALAXIES:ABUNDANCES — GALAXIES:EVOLUTION — GALAXIES: IRREGULAR — STARS: MASS FUNCTION**

1. INTRODUCTION

Carigi et al. (1995) concluded that an initial mass function, IMF, with a larger fraction of low-mass stars than in the solar vicinity, as well as the presence of a moderate O-rich outflow, were needed to match chemical evolution models results with a series of observational constraints provided by a "typical" irregular galaxy, that is a galaxy with the average properties of about a dozen well observed irregular galaxies. Carigi, Colín, & Peimbert (1999) produced a new set of models taking into account, mainly, the determination of the accurate IMFs for globular clusters derived from HST observations, and the determination of the amount of dark matter in several irregular and spiral galaxies.

We can define the gas mass fraction of a galaxy as, $\mu = M_{gas}/M_{total} = M_{gas}/(M_b + M_{nb})$, where M_b is the baryonic mass and M_{nb} is the non baryonic mass (we are defining as "M_{nb}" the matter that does not follow the stellar or gaseous mass distribution). M_b can be expressed as, $M_b = M_{gas} + M_{sub} + M_*$, where M_{sub} is the mass in substellar objects ($m < 0.1$, m is given in solar masses), M_* is the mass in stars in the $0.1 \leq m < 85$ range plus the mass in stellar remnants. It is possible to evaluate μ observationally from a direct determination of M_{gas} and a dynamical determination of M_{total}.

The general IMF used in this paper is given by $\mathrm{IMF} \propto \begin{cases} m^{-\alpha_1} & \text{if } 0.01 \leq m < 0.5\ , \\ m^{-2.2} & \text{if } 0.5 \leq m < 1.0\ , \\ m^{-2.7} & \text{if } 1.0 \leq m < 85\ \ . \end{cases}$

For the solar vicinity $\alpha_1 = 1.30$ (Kroupa, Tout, & Gilmore 1993; KTG). For a given α_1, a parameter r is introduced to quantify the reduction in the fraction of stars in the $0.5 \leq m < 85$ range relative to KTG IMF.

2. RESULTS AND DISCUSSION

Based on determinations of the mass function for the lower main sequence of the globular clusters NGC 6752 (Ferrano et al. 1997) and NGC 7099 (Piotto, Cool, & King 1997), we derived an average r for globular clusters, $r_{GC} = 1.85$, reflecting that the fraction of low-mass stars in globular clusters is significantly different (higher) than for the KTG IMF. This fact can be the result of an r that decreases with metallicity, or that the IMF in the solar neighborhood is not well known.

Dwarf irregular galaxies are dominated by non baryonic dark matter, but only for a pair of them (NGC 1560 and II Zw 33) both, the rotation curve and oxygen abundance in the interstellar medium are known. For NGC 1560 we have derived $M_{nb} = 49\%$ (Broeils 1992) from closed-box models with continuous SFR. Available chemical observational constraints (O abundance and μ) are not enough to discriminate the age model. Carigi & Bruzual (2001) combine chemical and spectral evolution models and find the best agreement with the observed B-V and U-B colors of NGC 1560 with an $r = 1.73$ 10-Gyr model.

For II Zw 33, assuming $M_{nb} = 0.0\%$ (Walter et al. 1997), closed-box models with continuous SFR imply $r > 2.5$. If we want to adopt a universal IMF at low metallicity of $r = 1.8$ for II Zw 33 (as implied by globular clusters and NGC 1560), the models will imply $28\% < M_{nb} < 37\%$, or the presence of a O-rich outflow to maintain $M_{nb} = 0$. The presence of a thick disk in II Zw 33 (Brinks 1998) does not favor strong outflows, but since O-rich outflows models predict C/O higher than those obtained by closed-box models, a C/O determination and a better determination of M_{nb} for II Zw 33 are needed to discriminate the models.

From the available observational constraints of NGC 1560 and II Zw 33 we can not unambiguously quantify the importance of O-rich outflows in the evolution of the dwarf irregular galaxies. To aid answer this relevant question, we also modeled the typical irregular galaxy, given its extra observational constraint, although we lack an estimation of its M_{nb}. The dark matter mass fraction implied by the models amounts to about 40%, part could be baryonic (substellar) and part non baryonic. For the typical irregular galaxy, if $r = r_{GC}$, M_{sub} is at least 26.6% and $M_{nb} = 13.6\%$ inside the Holmberg radius.

We find O-rich outflows not to be very important for the typical irregular galaxy because O-rich outflow models predict higher C/O and Z/O values than those observed. By comparing bursting SFR models with continuous SFR models of the same age the differences in the final abundance ratios are very small. The largest differences occur just after each burst: the C/O, $\Delta Y/\Delta$O, and Z/O values decrease, diminishing the differences of C/O and Z/O with the observed values but increasing the discrepancy of the $\Delta Y/\Delta$O from observed.

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