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The Relationship between Rotation and Magnetic Activity in Cold Dwarfs, as Seen in H-alpha Emission in Group-X Open Cluster Stars

Context: Starting with the seminal work by Skumanich 1972, studies have shown that low-mass, main-sequence stars ($\leq$ 1.2 $M_\odot$) lose angular momentum over time, leading to a decline in their magnetic activity. However, the details of this age-rotation-activity relationship remain poorly understood. The well-defined ages of open clusters make their stars invaluable targets for studies of the activity- rotation relation. Our study focuses on the open cluster Group-X (≈300 Myr old; Faherty et al. 2018, Tang et al. 2019, Messina et al. 2022, Newton et al. 2022, Olivares et al. 2023), providing a critical reference point between young stars and older clusters like the Hyades and Praesepe (≈700 Myr old), to better map the behavior of these stars during their first billion years of evolution.

Methods: From existing Group-X studies, we first constructed a cluster catalog that contains 356 low-mass stars. Next, we obtained optical spectra using the Hiltner 2.4m telescope at MDM Observatory, Arizona, and we obtained archival spectra from the LAMOST (Zhao et al. 2012) and SDSS (York et al. 2000) missions, for Group-X stars. All in all, we have spectra for 167 Group-X members. We measured the equivalent width (EW) of the Hα line and used it as an indicator of chromospheric magnetic activity (Cram & Mullan 1979, Stauffer & Hartmann 1985, Fan 2021). We compared these data against similar published measurements for members of the Hyades and Praesepe clusters, including new results for 250 Praesepe stars and 131 Hyads (Núñez et al. 2024). We converted EW to fractional Hα luminosity ($L_{\mathrm{H}\alpha}/L_{\mathrm{bol}}$) following the method in Núñez et al. 2024, and we analyzed the relationship of these activity values with the Rossby number (R_o = rotation period divided by the convective turnover time) data for the same stars, to characterize their magnetic activity as a function of rotation. For this latter analysis, we used light curves from the TESS (Ricker et al. 2015) and ZTF (Bellm et al. 2019) missions to obtain rotation periods for our Group-X members.

Results: We confirm that younger M dwarfs exhibit higher activity. Binary members show a similar $\mathrm{EW}_{\mathrm{H}\alpha}$ distribution to single members, consistent with observations by Núñez et al. (2024) in the Hyades and Praesepe. The relationship between $L_{\mathrm{H}\alpha}/L_{\mathrm{bol}}$ and R_o reveals a rapid power-law decay for slow-rotating stars (R_o $gtrsim$ 0.3) in Group-X, in agreement to similar studies (e.g., Stauffer et al. 1994, Stelzer et al. 2013, Newton et al. 2017, Núñez et al. 2024). Surprisingly, the regime of fast-rotating stars (R_o $lesssim$ 0.3) exhibits a shallow decline consistent with a power-law, contrary to the typical flat "saturated" relation found in the same studies.

Interpretation: These findings suggest that the shape of the saturation level (i.e., fast rotators) could depend on cluster age. The absence of a flat saturation level in Group-X, in contrast to that observed in older clusters, indicates a potentially significant evolution in the rotation-activity relationship between 300 and 700 million years. This period seems critical for the development of mechanisms regulating magnetic activity in low-mass stars, possibly including the onset of effects such as coronal centrifugal stripping observed in ultra-fast rotators (Jardine & Unruh 1999, Marsden et al. 2009, Núñez et al. 2024).

Conclusion: Group-X emerges as a crucial reference point for understanding the evolution of the rotation-activity relationship in low-mass stars, revealing a significant transitional phase in their early magnetic history and providing new insights into how the saturation mechanisms observed in young and older clusters develop.

Nivel de formación

Pregrado

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