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Transition of latitudinal differential rotation as a possible cause of weakened magnetic braking of solar-type stars

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The rotation of solar-type stars, including the Sun, is actively studied because it governs the stellar magnetic activity through the dynamo mechanism. Because magnetized stellar winds emanate from a corona of solar-type stars, they carry off not only the mass but also the angular momentum of a star. Then, solar-type stars generally spin down through this magnetic braking mechanism[1]. The formulation of spin-down of solar-type stars is investigated through numerical simulations and observations. Previous formulations of spin-down explain the basic observed trend of solar-type stars that are younger than the Sun[2]. However, there are still unsolved problems remained: Stars older than the Sun spin down considerably slower than the trend predicted from the a standard theoretical model[3]. This breakdown of the spin-down trend, called "weakened magnetic breaking", means that a regime change in the magnetic braking process occurs around the solar rotation period.

Recent observations using the asteroseismic method[4] and 3D MHD simulations[5] reveal that the differential rotation (DR), especially latitudinal differential rotation (LDR), is a typical feature of young solar-type stars and that this tendency is gradually reduced with stellar age. Incorporating these properties, we construct the phenomenological spin-down formulation[6], which considers an effect of LDR, to resolve the two problems mentioned above. Assuming the magnetic braking is regulated dominantly by the rotation rate in the low-latitude region, stars with the equator-fast DR (pole-fast DR) spin down more efficiently (inefficiently) than those with the rigid-body rotation (see Fig.1).The spin-down of the stars with solar mass and metallicity under our formulation reproduces the observed trend of both solar-type stars and the Sun, including weakened magnetic braking (see Fig.2). Our results indicate that latitudinal DR and its transition are essential factors that control the stellar spin down.

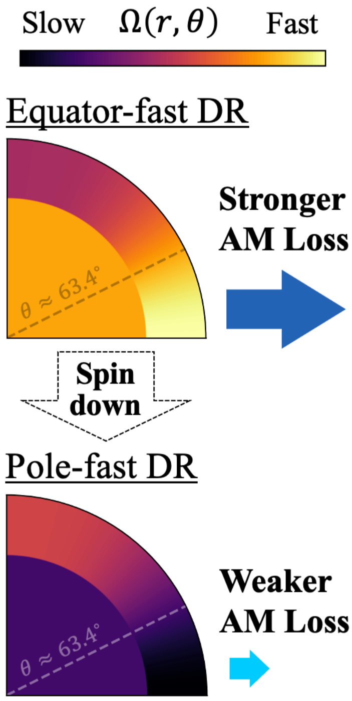

Figure 1. The schematic picture of the LDR effect on the stellar spin-down. The top horizontal color-bar indicates the stellar angular velocity, $\Omega(r,\theta)$, where r and θ denote the distance from the center and co-latitude, respectively. The upper and lower quarter sector represents a star with equator-fast DR and pole-fast DR, respectively. Under the assumption that the magnetic braking is regulated by the low-latitude rotation speed, AM is removed more strongly (weakly) under the equator-fast DR (pole-fast DR).

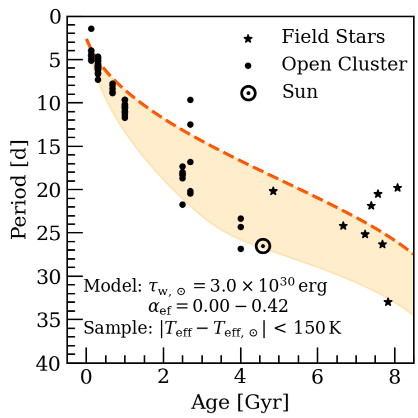

Figure 2. The spin-down of the stars with solar mass and metallicity considering LDR (orange shaded region). The abscissa and ordinate represent the stellar age and the stellar rotation period, respectively. The circles and stars represent the observational values obtained by open clusters and field stars, respectively. The orange dashed line is the case without LDR.

-References-
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