New theory helps explain and predict the activity of sun-like stars

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It is easier to determine the age of star clusters than individual "field stars." For example, cluster NGC 1783 shown here is under one and a half billion years old — which is very young for globular clusters. The work by Blackman and Owen might ultimately lead to a new approach to determine a star's age. Image taken with the Advanced Camera for Surveys (ACS) on board the NASA/ESA Hubble Space Telescope.

Researchers have developed a new conceptual framework for understanding how stars similar to our Sun evolve. Their framework helps explain how the rotation of stars, their emission of x-rays, and the intensity of their stellar winds vary with time. According to first author Eric Blackman, professor of physics and astronomy at the University of Rochester, the work could also "ultimately help to determine the age of stars more precisely than is currently possible."

In a paper published today in *Monthly Notices of the Royal Astronomical Society*, the researchers describe how they have corroborated known, observable data for the activity of Sun-like stars with fundamental astrophysics theory. By looking at the physics behind the speeding up or slowing down of a star's rotation, its x-ray activity, and magnetic field generation, Blackman says the research is a "first attempt to build a comprehensive model for the activity evolution of these stars".

Using our Sun as the calibration point, the model most accurately describes the likely behavior of the Sun in the past, and how it would be expected to behave in the future. But Blackman adds that there are many stars of similar mass and radius, and so the model is a good starting point for predictions for these stars.

"Our model shows that stars younger than our Sun can vary quite significantly in the intensity of their x-ray emission and mass loss," said Blackman. "But there is a convergence in the activity of the stars after a certain age, so you could say that our Sun is very typical for stars of its mass, radius, and its age. They get more predictable as they age."

"We're not yet at the point where we can accurately predict a star's precise age, because there are simplifying assumptions that go into the model," said Blackman. "But in principle, by extending the work to relax some of these assumptions we could predict the age of for a wide range of stars based on their x-ray luminosity."

At the moment, empirically determining the age of stars is most easily accomplished if a star is among a cluster of stars, from whose mutual properties astronomers can estimate the age. Blackman explains that its age can then be estimated "to an accuracy not better than a factor of 25% of its actual age, which is typically billions of years." The problem is worse for "field stars," alone in space such that the cluster method of dating cannot be used. For these stars, astronomers have turned to "gyrochronology" and "activity" aging - empirically aging the stars based the fact that older stars of known age rotate more slowly and have lower x-ray luminosities than younger stars.

"Over the past few decades astronomers have been able to empirically measure these trends in rotation and magnetic activity for stars like the Sun, but Eric and his collaborators are trying to devise a comprehensive theoretical interpretation," said Eric Mamajek, professor of physics and astronomy at the University of Rochester and one of the astronomers leading the development of empirical methods for determining a star's age. "Ultimately this should lead to improved constraints on the evolution of rotation and activity in Sun-like stars, and better constraints on how the magnetic properties of our Sun have changed over the course of its main sequence life."

And this is where the model developed by Blackman and his coauthor James E. Owen is important: it provides a physics explanation for how stellar rotation, activity, magnetic field, and mass loss all mutually evolve with age.

"Only by tackling the entire problem of how stellar rotation, x-ray activity, magnetic field and mass-loss mutually affect each other could we build a complete picture," said Owen, a NASA Hubble fellow at the Institute for Advanced Study, Princeton. "We find these processes to be strongly intertwined and the majority of previous approaches had only considered the evolution of one or two processes together, not the complete problem."

More information: Eric G. Blackman et al. Minimalist coupled evolution model for stellar X-ray activity, rotation, mass loss, and magnetic field, *Monthly Notices of the Royal Astronomical Society* (2016). DOI: 10.1093/mnras/stw369

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