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Evidence of Universal Heating Mechanism of Solar and Stellar Atmospheres

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The Sun and other Sun-like stars commonly host extremely hot outer atmospheres, including the corona with a temperature of over 1 million Kelvin and the chromosphere with a temperature of about 10,000 Kelvin. However, it is still unclear how these plasmas are heated and whether the heating mechanism is common to the Sun and other stars. It is widely believed that magnetic flux transports the energy upward from the solar/stellar surface and heats the plasma by dissipating energy in the atmosphere. The representative scenarios include the wave dissipation and nanoflare hypotheses.

The purpose of this study [1] is to explore the relationships between the solar and stellar heating mechanisms. To this end, we analyzed the Sun-as-a-star synoptic data over the past decade and derived the scaling relationships between the surface magnetic flux and irradiances of various spectral lines. Because each spectral line has its formation temperature, if we make scatter plots of magnetic flux and irradiances for different spectral lines, we may gain insights into heating mechanisms over a wade temperature range.

Figure 1 shows the double logarithmic scatter plots of irradiances vs. the total unsigned magnetic flux, in which the colored dots represent the solar data over the 10 years. In each panel, we fitted the solar data with a straight line to estimate the power-law relationship. The scaling laws are compared with the observational data of G-type main-sequence stars with the ages from 50 Myr to 4.5 Gyr. As a result, we found that the acquired scaling laws are strikingly replicated in Sun-like G-type stars. This indicates that the heating mechanism of the Sun and Sun-like stars are common throughout the wide temperature range from the corona to the chromosphere, regardless of the age and activity level.

It is also found that the power-law exponent decreases from above unity to below unity as the temperature decreases from the corona to the chromosphere. This indicates the possibility that the efficiency of the atmospheric heating varies over different temperature regimes.

References

[1] S. Toriumi & V. S. Airapetian, The Astrophysical Journal, **927**, 179 (2022)

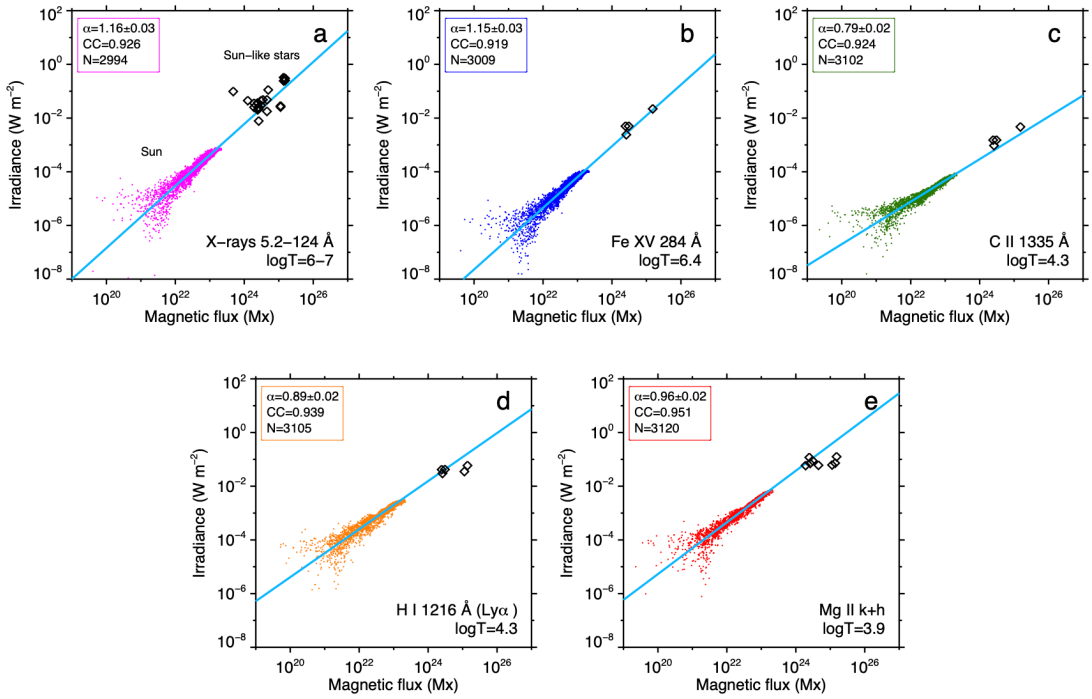

Figure 1. Comparison of the magnetic flux and irradiances of five different spectral lines for the Sun and Sun-like stars. In each panel, the straight line indicates the result of a linear fitting to the double logarithmic plot. The power-law index α, correlation coefficient CC, and data number N are provided at the top left.