SLEUTHING THE DYNAMO: HST/FOS OBSERVATIONS OF UV EMISSIONS OF SOLAR-TYPE STARS IN YOUNG CLUSTERS

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ABSTRACT HST/FOS spectra of young solar-type stars are providing new clues to the early evolution of subcoronal activity.

INTRODUCTION

The Hubble Space Telescope (HST) and its two main ultraviolet spectrographs (FOS & GHRS) have opened new frontiers in the solar-stellar connection. In particular, the sub-2000 Å FUV range harbors key emissions that arise in the $T \approx 10^5$ K subcoronal layers (e.g., Linsky, Brown, & Carpenter 1991). While the venerable International Ultraviolet Explorer has contributed greatly to the understanding of the puzzling hot outer atmospheres of cool stars (e.g., Jordan & Linsky 1987), its gaze has been confined to bright, mostly nearby, field stars. In contrast, the HST FOS is hundreds of times more sensitive, and its reach is correspondingly deeper. Here, we describe an FOS study of faint solar-type stars in young Galactic clusters. Our intent is to explore the early evolution of the spin catalyzed hydromagnetic “Dynamo”, and associated subcoronal activity.

THE SAMPLE

Table 1 lists the targets and FOS exposures. The stars are of similar spectral type (G0–G2) to the Sun, and are located in open clusters ranging in age from 1/8-th the Sun (Hyades) to about 1/80-th (Pleiades, α Persei).

Following target acquisition, a short (50–300 second) integration with grating G270H (2222–3301 Å) was obtained. It was followed by a deep (27.5–89 minute) observation of the 1150–1606 Å interval at 2 Å resolution with grating G130H. The fainter Pleiades and α Per stars each were recorded over three consecutive orbits in 1780-second segments. The brighter Hyads were done in single orbits, and a 15.5 minute exposure with G190H (1573–2330 Å) also was obtained.

The G270H spectra display sharp $h$ and $k$ emission components in the deep Mg II absorption trough, even at $\approx 3$ Å resolution. The G130H traces are dominated by diffuse sky-background emissions: H I λ1215 Lyα and O I λ1302. Weak stellar C IV λλ1548,50 emission is visible in each orbit on the active stars.
H II 314, HE 350, and HE 709, while Si IV \(\lambda\lambda 1393,1402\) and C II \(\lambda 1335\) are seen in the total observations. All of the G130H spectra – particularly of the Hyads – are affected by high levels of grating scattered light. Significantly, H II 314 \textit{flared} in C IV during the final of its three orbits (Ayres et al. 1994), while the two (fainter) \(\alpha\) Per stars also show signs of short-term variability.

<table>
<thead>
<tr>
<th>Targets</th>
<th>(&lt; V &gt;)</th>
<th>(&lt;\text{Sp. Typ.}&gt;)</th>
<th>Exposure Times(^a) (ksec)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(mag)</td>
<td></td>
<td>G130H</td>
</tr>
<tr>
<td><strong>Hyades</strong> ((d = 45\text{ pc}; \text{age} = 600\text{ Myr}))</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HD 25825, 26767, 27835, 28344, 28992</td>
<td>+8.0</td>
<td>G1±1 V</td>
<td>1.65</td>
</tr>
<tr>
<td><strong>Pleiades</strong> ((d = 130\text{ pc}; \text{age} = 70\text{ Myr}))</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>H II 314, 996, 1514</td>
<td>+10.5</td>
<td>G0 V</td>
<td>5.34</td>
</tr>
<tr>
<td><strong>(\alpha) Persei</strong> ((d = 170\text{ pc}; \text{age} = 50\text{ Myr}))</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HE 350, 709</td>
<td>+11.0</td>
<td>G0 V</td>
<td>5.34</td>
</tr>
</tbody>
</table>

\(^a\) BLUE Digicon; A-1 aperture.

**ANALYSIS**

The final observations of our program were taken only very recently (HE 709: 1993 October 2). Nevertheless, we wish to comment on two aspects relevant to the Workshop. Figure I correlates the HST/FOS C IV fluxes vs. ROSAT PSPC detections of the cluster stars (X-ray fluxes for the \(\alpha\) Perseids are not yet available; we assumed log \(L_X = 30 \pm 0.3\), the "saturation" level in the Pleiades). The points in the lefthand panel are from an extensive survey of field G–K dwarfs conducted during the ROSAT/IUE All Sky Survey (RIASS; Ayres et al. 1993). The power law connecting the F9–G2 RIASS stars has a slope of 2.0 (and is repeated in the HST panel). While the young cluster members lie at the upper bounds of X-ray and C IV emission among solar-type MS stars, already by Pleiades age there is a wide dispersion in activity among the ostensibly coeval stars. The dichotomy might be a relic of the pre-MS evolution of the stellar spins, or it might arise later through the action of coronally-regulated angular momentum loss (see, e.g., papers from Session 2 of the Workshop).

In that regard, the overt C IV fluctuations of the three hyperactive dwarfs of our sample are intriguing. In particular, persistent subcoronal variability might be a signature of flare-dominated heating in stars for which the magnetic flux production rate is saturated. One imagines that the hyperactive stellar surface is pervasively covered by compact arcades of magnetic flux ropes. Continual eruptions of new flux into the pre-existing structures lead to strong interactions and frequent explosive reconstructions. In analogy with large solar flare events, one expects substantial material fluxes in the form of Coronal Mass Ejections.
These in turn might fuel the magnetospheric braking that funnels the fast rotators at Pleiades and α Per age into the more modest spin distribution—and modest coronal activity—of Sun-like stars at Hyades age.

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REFERENCES