Hubble Science Briefing

Hubble Does Double-Duty Science:

Finding Planets and Characterizing Stellar Flares in an Old Stellar Population

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Setting the Stage
SWEEPS

• SWEEPS = Sagittarius Window Eclipsing Extrasolar Planet Search (Sahu et al. 2006)

• 7 day long stare of a field in the Galactic bulge, characterized by an old stellar population (about 10 billion years in age)

• 2 optical filters, V and I, and nearly continuous monitoring

• Sahu et al. found evidence for 16 extrasolar planets, with periods < 4.2 days

• follow-up epoch imaging of the same field 2 years later (Clarkson) to determine the space motions of stars
Motivation: why study stellar flares?

- understand details of the flare process in vastly different stellar environments: does the solar model provide a good explanation of what we’re seeing?
- how do flares affect stellar environment, particularly in young stars or stars with planets?
- break through “foreground fog” of flare stars when searching for cosmological transient (interesting?) sources

We have a very well-studied star at 1 AU, so why look any further?
Stellar Flares

- The Sun flares, and cool stars with magnetic fields flare.
- Flares occur as the result of the rearrangement of magnetic fields above the surface of a star.
- They are seen as a sudden increase in intensity; and the entire atmosphere of a star participates in the flare.
- Due to different physical processes at work, flares can be detected across the electro-magnetic spectrum (radio to gamma rays).
- Most flares are detected at optical and X-ray wavelengths.
What does a flare look like?

Screenshot of an animation depicting the initiation of a solar flare. Download animation of this image (third from top in article) at

http://www.nasa.gov/mission_pages/swift/bursts/monster_flare.html

[Note: these are large files]
How to Make a Flare

I. Find a star whose interior has energy transfer by convection below the surface
Find a young star (which is rotating rapidly because it is young), or alternatively, find a binary in which the two stars are tidally locked (orbital period = rotational period)
Find a star which has evidence of spots on the surface, indicating magnetic fields emerging and interacting.
The kinds of stars typically targeted for flare studies:
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- young stars
- active binaries
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- young stars
- active binaries
- red dwarfs
## Comparing large solar and stellar flares

<table>
<thead>
<tr>
<th>Source</th>
<th>Energy</th>
<th>Max. Duration</th>
<th>Intensity Increase (Visible)</th>
<th>Intensity Increase (X-ray)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sun</td>
<td>$10^{32}$ ergs</td>
<td>~5 hours</td>
<td>1.000270</td>
<td>6000</td>
</tr>
<tr>
<td>Young stars</td>
<td>$10^{36}$ ergs</td>
<td>~1 day</td>
<td>small</td>
<td>50</td>
</tr>
<tr>
<td>Single stars</td>
<td>$10^{35}$ ergs</td>
<td>several days</td>
<td>1000</td>
<td>500</td>
</tr>
<tr>
<td>Binary stars</td>
<td>$10^{38}$ ergs</td>
<td>~1 week</td>
<td>10</td>
<td>120</td>
</tr>
</tbody>
</table>
• the flare rate of stars declines with time, in concert with the decrease in the amount of magnetic fields the star can generate

• flaring at old age (several GY and beyond) can be seen from our Sun, and a few serendipitous measurements of stellar flares from single stars

• at ages of several billion years, tidally locked binaries can still produce flares

• the flare rate of old stars has not been systematically studied, due to the low expected flare rate
Flares, Eclipses, & the SWEEPS dataset

- eclipsing extrasolar planets produce a **DECREASE** in the light from the star
- flares from the star **INCREASE** the star’s intensity
- SWEEPS data were taken in ~5 minute exposures, alternating the two filters
- the long timescale (1 week) and dense temporal coverage (cadence of ~10 minutes) of the dataset makes it ideal to search for flares in an older stellar population
- SWEEPS became DRAFTS (Deep, Rapid Archival Flare Transient Search), an archival HST project
Finding Flares: we found flares on stars which show no underlying variations (top) and those which do (bottom)
What we found

• Out of 229,701 stars that could be searched, 105 showed flares (128 flares total; some stars flared multiple times).

• The flare energies and peak intensities are consistent with those seen in nearby active stars ($10^{33}$-$10^{35}$ ergs), and show a disconnect with solar flare behavior.

• Based on the star’s brightness, we saw modest flares in the brighter stars (flares increase of 10% or less in the star’s brightness) and larger flares in the fainter stars.

• A surprising fraction (85%) of flaring stars showed underlying variations, despite being a small component of the sample.

• This implies that the flaring rate is larger by a factor of 640 in the “variable” stars compared to the flat activity stars.
Additionally,

- the stars exhibiting regular variations had a tendency to have short periods (less than 3 days)
- this is likely a signature of fast rotation, and the variations are caused by starspots
- the fast rotation could be a signpost of youth, or pointing towards an active binary
What is the nature of the flaring stars?

- Their brightness and temperature are consistent with the old stellar population
- Their space motions look like the old stellar population
- They are likely not foreground young stars, but old binaries
- These binaries should have orbital periods equal to rotation periods, so can remain active for a long time
- These binaries must be much more common in the bulge than they are nearby
Impact on Planets

- the radiation of a flare can affect a planet’s atmosphere; only a small fraction of the high energy radiation can get to the planetary surface.

- a significant flux of ultraviolet wavelength light may be able to damage the ozone layer of a planet, depending on the composition of the atmosphere.

- most troublesome (and least quantifiable) is the ability of energetic particles to compress a planet’s magnetic field and expose the atmosphere to the radiation.

- this research shows that flares are a force to be reckoned with in old stars.
Conclusions

• We have searched for flares in an old stellar population

• These flares are similar to those on active stars in the solar neighborhood

• The number of these active binaries in the bulge is larger than in the solar neighborhood, by a factor of $> 20$

• Flares may pose a threat to planets around older stars, particularly planets around binaries (which we haven’t found yet)
Questions?