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Superflares and "Hot-Jupiters"

Eric P Rubenstein

Yale University Astronomy Dept., 260 Whitney Ave., New Haven, CT 06520-8101, USA

Abstract. Schaefer, King & Deliyannis (2000) reported the discovery of powerful stellar flares on single, solar-type stars. The outbursts on these F8-G8 stars were $10^2 - 10^7$ times more powerful than the largest solar flares. The observed properties are similar to the magnetic reconnection driven events of RS CVn binaries. Rubenstein & Schaefer (2000) suggested that superflares may be magnetic reconnection events mediated by the interaction between the magnetospheres of a close-in jovian planet and the star. Stars exhibiting superflares may therefore harbor detectable planets.

1. Introduction

Stellar flares with $10^2 - 10^7$ times more energy than the largest solar flare have been detected from 9 normal F and G main sequence stars (Schaefer 1989, Schaefer, King, & Deliyannis 2000). These superflares (SFs) have durations of hours to days and are visible from at least x-ray to optical frequencies. The absence of world-spanning aurorae in historical records and of anomalous extinctions in the geological record indicate that our Sun likely does not suffer superflares. There is a marked similarity between superflares and the large stellar flares produced by RS Canum Venaticorum binary systems; such flares are caused by magnetic reconnection events associated with the untangling of magnetic fields between the two stars. The superflare stars are certainly not of this class, although Rubenstein & Schaefer (2000) propose a similar flare mechanism. That is, superflares are caused by magnetic reconnection between fields of the primary star and a close-in Jovian planet. Thus, by only invoking 51 Peg-like planetary properties and RS CVn-like reconnection scenarios, we can explain the energies, durations, and spectra of superflares, as well as explain why our Sun does not have such events.

We are highly motivated to understand the origin of these energetic outbursts because we would like to understand solar analogues as well as possible and because the biological consequences of SFs might be profound. The broadband energy release from SFs impinging on the upper atmosphere of Jovian planets is reminiscent of the Miller & Urrey experiments (Miller 1953) in which moderately complex, biologically interesting compounds were rapidly synthesized.

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2. Planetary Provocation

The SF properties are remarkably similar to the flaring behavior of RS CVn binaries. In particular, the duration (a fraction of an hour to days), energy budget (10^{33} to 10^{38} erg), and broadband emission of the SFs are all properties shared with RS CVn flares (Hall 1976). The flares in RS CVns are thought to arise from the interaction of the magnetospheres of the components of the binary (Simon, Linsky & Schiffer 1980; and Gunn et al. 1997). The resulting magnetic reconnection events create Alfven waves which accelerate the available charged particles. However, spectroscopic study of the nine SF stars indicates that they are not binaries.

The detection of the many "hot Jupiters" suggests that these objects may be present in at least 5 or 6% of the local stellar population (Marcy & Butler 2000). If these Jovian planets have a very strong magnetosphere, comparable to that of Jupiter, it is likely that the magnetic fields of star and planet would interact. While the planet would most likely be tidally locked to the star, the star would not be tidally locked to the planet. Therefore, the magnetic field geometry would become increasingly complicated (wound up), increasing the stress tensor until a magnetic reconnection (MR) event would occur, a superflare.

With identical mechanisms underlying both SFs and the flares of RS CVn binaries, the similarity of the properties is naturally explained. There is a fourth constraint that also must be satisfied though; the apparent lack of SFs for our Sun! The suggested planetary provocation mechanism, described above, naturally explains the lack of Solar SFs since Mercury has no significant magnetic field and the planets with strong B fields are too far away from the Sun for strong interactions to occur.

While detailed models of star/planet MR events have not been constructed, it is clear from modern plasma physics journals that such calculations of magnetic reconnection are not yet possible (c.f. the competing theories of (Lazarian & Vishniac 1999, Ji et al. 1998, Biskamp 1997, Pellat, Hurricane & Luciani 1996, Biskamp, Schwarz & Drake 1995). None-the-less, nature "knows" how to make MR events in terrestrial plasma experiments, in solar flares and in the magnetospheres of interacting binaries. It seems plausible, perhaps even likely, that there should be MR events arising from the interaction of solar analogues with close-in planets with Jupiter-like properties. No new physics is required, no unknown objects are hypothesized. Finally, in the two SF stars with measured B fields, κ Ceti (Montesinos & Jordan 1993) and π^1 UMa (Gray 1984), both have fields stronger than a kilogauss, as expected by this model.

3. Conclusion

The high precision spectroscopy required to detect planets via the recoil of their host star precludes mass radial velocity searches of even moderately distant stars. Searches for planetary transit eclipses are now being conducted to uncover some of these more remote exo-solar planetary systems. However, only a very small fraction of planetary systems will show eclipses due to the small range of inclination angles for which transits occur. If this model of superflare creation is borne out, surveys which are sensitive to the photometric signature of these outbursts will provide another opportunity to discover distant planetary systems.

The QUEST project (a 1m Schmidt + 16 CCDs) is currently studying 200 square degrees per night in the U, B & V filter systems, repeating drift-scan swathes on a nightly basis. We expect QUEST to be sensitive to SFs which occur in the equatorial regions being studied. This ongoing survey will provide improved estimates of the frequency with which solar-like stars have unexpectedly large outbursts, and may therefore provide us with additional planets to study.

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