42.17: The Coronae of Inactive Low–Mass Dwarfs

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ABSTRACT

Dwarf M stars are important probes for coronal heating and dynamo theories: they span a region of the H-R diagram where stars are not yet fully convective, and classical dynamo theories are thought to be applicable, and contributions from non-magnetic heating processes are presumably minimized. Further, unlike dMe flare stars, coronal emission on dM stars is more likely to be dominated by steady structures. Unfortunately, despite the large numbers of dM stars in the Galaxy, their low fluxes make them hard to observe and analyze.

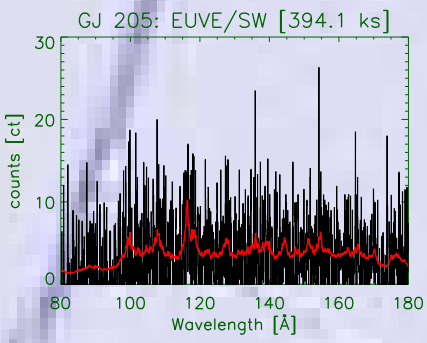
Here we present deep EUVE/SW spectrometer observations of two inactive dM stars, GJ 411 and GJ 205. The former is metal-deficient, while the latter appears to be metal-rich (Mould 1978, ApJ 226, 923). Their spectra are remarkably unlike "normal" stellar coronal spectra.

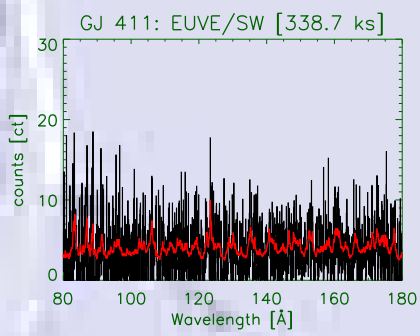
We find lines of `Ar`, `O`, and possibly `Si` in the spectrum of GJ 205; no lines from `Ni` or `Fe` could be identified. No feature in GJ 411 could be conclusively identified.

The spectra from these dM stars are consistent with being produced by a DEM of the same type as the Quiet Sun.

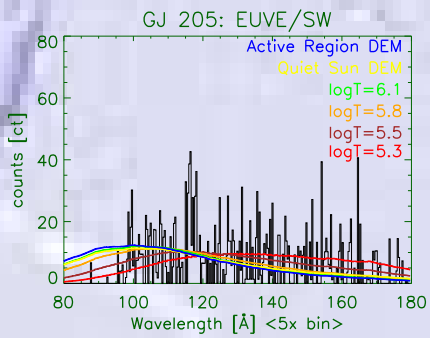
GJ 205	
Other Names	HD 36395 / Wolf 1453
$(RA, Dec)_{2000}$	(05:31:24.85, -03:38:53.4)
(l_{II}, b_{II})	(206.93, -19.45)
Spectral Type	dM1.5
Distance	5.7 pc
m_V	$7^m.98$
$B-V$	1.5
$[m/H]$	0.5
ROSAT/PSPC	0.19 cts s^{-1}
EUVE/DS	0.02 cts s^{-1}
EUVE Observation	Jan/Feb 1997 [394.1 ks]

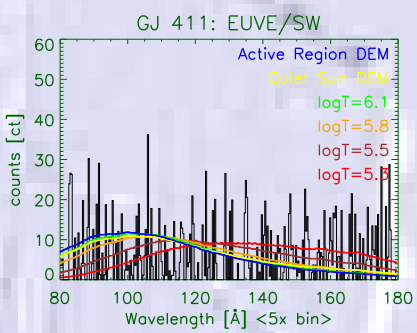
GJ 411	
Other Names	HD 95735 / SAO 62377
$(RA, Dec)_{2000}$	(11:03:22.58, +36:02:09.6)
(l_{II}, b_{II})	(185.12, +65.43)
Spectral Type	dM2
Distance	2.55 pc
m_V	$7^m.49$
$B-V$	1.51
$[m/H]$	-0.35
ROSAT/PSPC	0.18 cts s^{-1}
EUVE/DS	0.02 cts s^{-1}
EUVE Observation	Mar 1995 [338.7 ks]



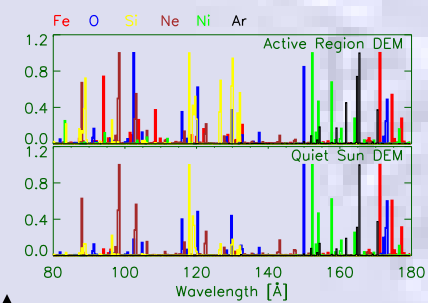


Observed EUVE/SW spectra: The background-corrected spectra are shown at high-resolution (black curve). Overlaid (in red) is the adaptively smoothed form (such that $S/N > 7$; this smoothing does not conserve flux).





Comparison with continuum emission: Spectra are shown rebinned by 5× (black) in order to enhance features. Overlaid on it are continuum spectra normalized to have the same counts as the data, derived from 2 types of Differential Emission Measure (DEM) curves (from Solar Active Region and Quiet Sun data; cf. Brosius et al. 1996 [ApJS 106, 143], Kashyap & Drake 1998 [ApJ 503, 450]), as well as δ-function Emission Measures at $\log_{10}(T)$=(5.3,5.5,5.8,6.1). This explores the hypothesis that the reason for the lack of line emission is that the coronal metallicity is very low. In the case of GJ 205, it is clear that no combination of temperatures is sufficient to explain the observed spectrum as due to low-metallicity plasma emission, whereas a DEM with a sufficiently high transition-region component *may* account for the featureless SW spectrum of GJ 411.



Emission due to lines of different species. The contributions to the line spectrum from various species are shown separated out (in different colors) and normalized. The line strengths were computed using a solar-type Active Region DEM and a Quiet Sun DEM (Brosius et al. 1996, Kashyap & Drake 1998), but abundances are rescaled such that the strongest lines of each species in the EUVE/SW passband all have the same intensity. Comparing this figure with the observed spectrum of GJ 205, we can rule out the identification of the feature at 118 Å with any lines of `Fe`, `O`, `Ne`, `Ni`, etc: any contribution to this feature by these species results in a larger contribution elsewhere in the spectrum, which are not observed. Only a blend of transition-region lines of `O VI` and `Si V` at peak temperatures of $2-3\times10^5$ K, for a Quiet Sun type DEM, are left as possible contributors. However, this requires apparently implausibly large abundances of `Si`, with `[Si/Fe]` >> 10 compared with Solar abundances.

ANALYSIS

We analyzed 300+ ksec of EUVE/SW data on both stars, at full resolution as well as rebinned to bin sizes of 0.3 Å.

We derived the background correction by including the effect of the gradient in the cross-dispersion direction, and estimated the most probable values of the source photons.

We then compared the derived spectra with line lists from CHIANTI (v3) using PINTofALE (Kashyap & Drake 2000; BASI 28, 475; Kashyap & Drake 2000, HEAD 27.05), for various metallicities based on the standard abundances of Anders & Grevesse (1989, Geo.Cos.Acta 53, 197), and adopting the ion balance calculations of Arnaud & Raymond (1992, ApJ 398, 39).

We model these spectra with line fluxes and continuum emission calculated using Differential Emission Measures (DEM) mimicking Solar Active Regions and the Quiet Sun (Brosius et al. 1996 [ApJS 106, 143], Kashyap & Drake 1998 [ApJ 503, 450]).

The spectrum of GJ 205 shows a strong line blend feature at λ118. Note also the presence of statistically significant features coincident with lines of `O VII` λ136, `Ar XII` λ154, and `Ar XIII` λ165. No lines from `Fe` and `Ni` could be positively identified, generally due to the absence of accompanying lines. The spectrum is consistent with a DEM of the same type as that of the Quiet Sun.

The spectrum of GJ 411 does not have identifiable features, and is consistent with a metal-deficient corona with a Quiet Sun type DEM, with enhanced emission measure at transition-region temperatures.

CONCLUSIONS

- The spectrum of GJ 411 is consistent with a metal-deficient corona where the line fluxes are too low to be detected with EUVE. While the data are insufficient to distinguish between an Active Region type DEM and a Quiet Sun type DEM, the flatness of the spectrum indicates possibly high Emission Measure at low-T (which could be due to acoustic wave heating – see Mullan & Cheng [1994, ApJ 420, 392]), while ROSAT/PSPC data show that the Emission Measure at $T > 10^{6.5}$ K is very low: hence, an Active Region type DEM may be ruled out.
- In the case of GJ 205 also, an Active Region type DEM may be ruled out based on the observed lack of lines from highly ionized species. The spectrum is inconsistent with emission from a low-metallicity plasma. The observed feature at 118 Å may be explained as a blend of `O VI` and `Si V` lines, but requires an improbably high `[Si/Fe]`>> 10. These abundance measurements are subject to uncertainties in the DEM, which has a minimum at $\log_{10}$T$\sim$ 5.5. No `Fe` lines could be identified in the spectrum, which suggests that the corona is depleted in `Fe`; this is contrary to IR studies which suggest that `[Fe/H]`$\sim$ 0.5 in the photosphere. `Ar` also appears to be surprisingly overabundant, with `[Ar/Fe]`> 10.

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