Decimetric Continuum Bursts observed with the Owens Valley Solar Array

Gelu M. Nita

Center for Solar-Terrestrial Research
New Jersey Institute of Technology

INTRODUCTION

- A recent statistical study of 412 microwave burst spectra observed with OVSA during 2001-2002 (Nita, Gary and Lee 2004) revealed that about 16% of these spectra display a decimetric (dm) spectral component accompanying the centimetric (cm) emission.

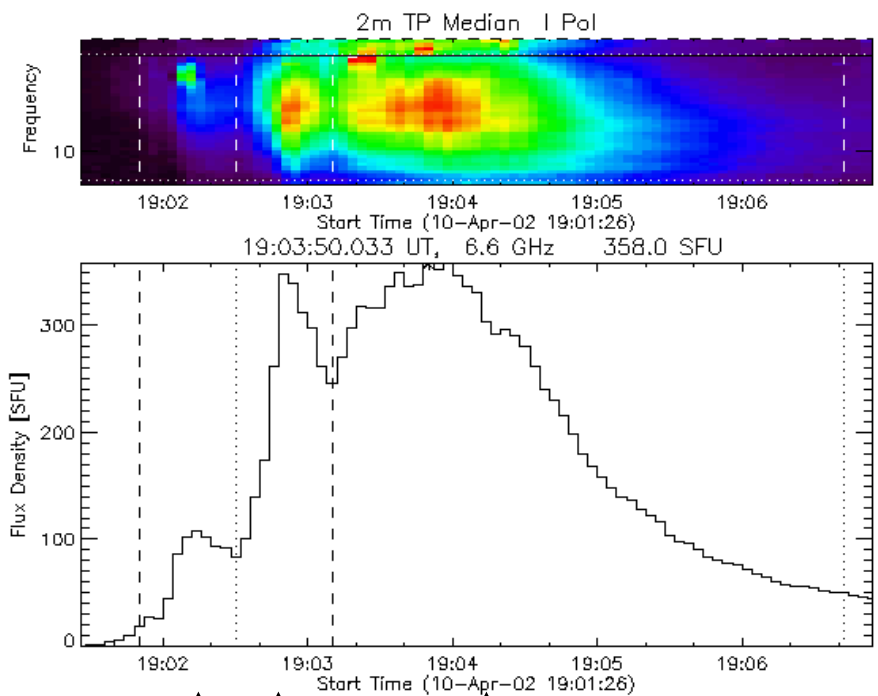
- Rather surprisingly, most of the dm components display smooth spectra, with time scales comparable with those of their cm counterparts. In all such events, the dm and cm spectral components are well correlated in time, and are thus related.

- This study is based on 15 bursts—14 selected from this dataset on the basis of data quality, and one burst that occurred on 2000 March 22, which has been analyzed from a similar perspective by Lee et al. (2002).

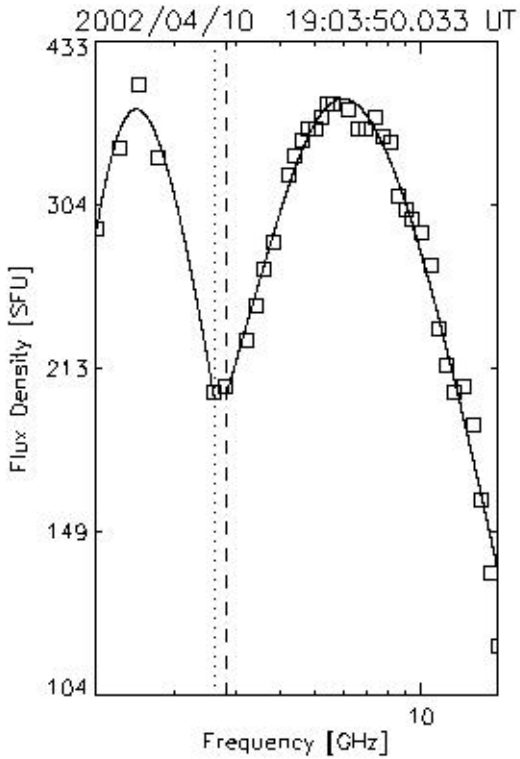
- We find that certain common characteristics of these bursts are not consistent with gyrosynchrotron (GS) or free-free emission mechanisms and we discuss an alternative emission mechanism likely to be responsible for the observed characteristics.

OVSA Data

OVSA records dynamic spectra at 40 Frequencies from 1-18 GHz and 4 sec time resolution



At each instant of time we have resolved the main spectral components



We have divided each analyzed dynamic spectrum into temporal ranges, resolving the main temporal peaks.

For each resolved spectral component we have analyzed:

- –Local and Absolute Peak Frequency
- –Local and Absolute Peak Flux
- –Low and High Frequency Spectral Slopes

Statistics of the Data Set

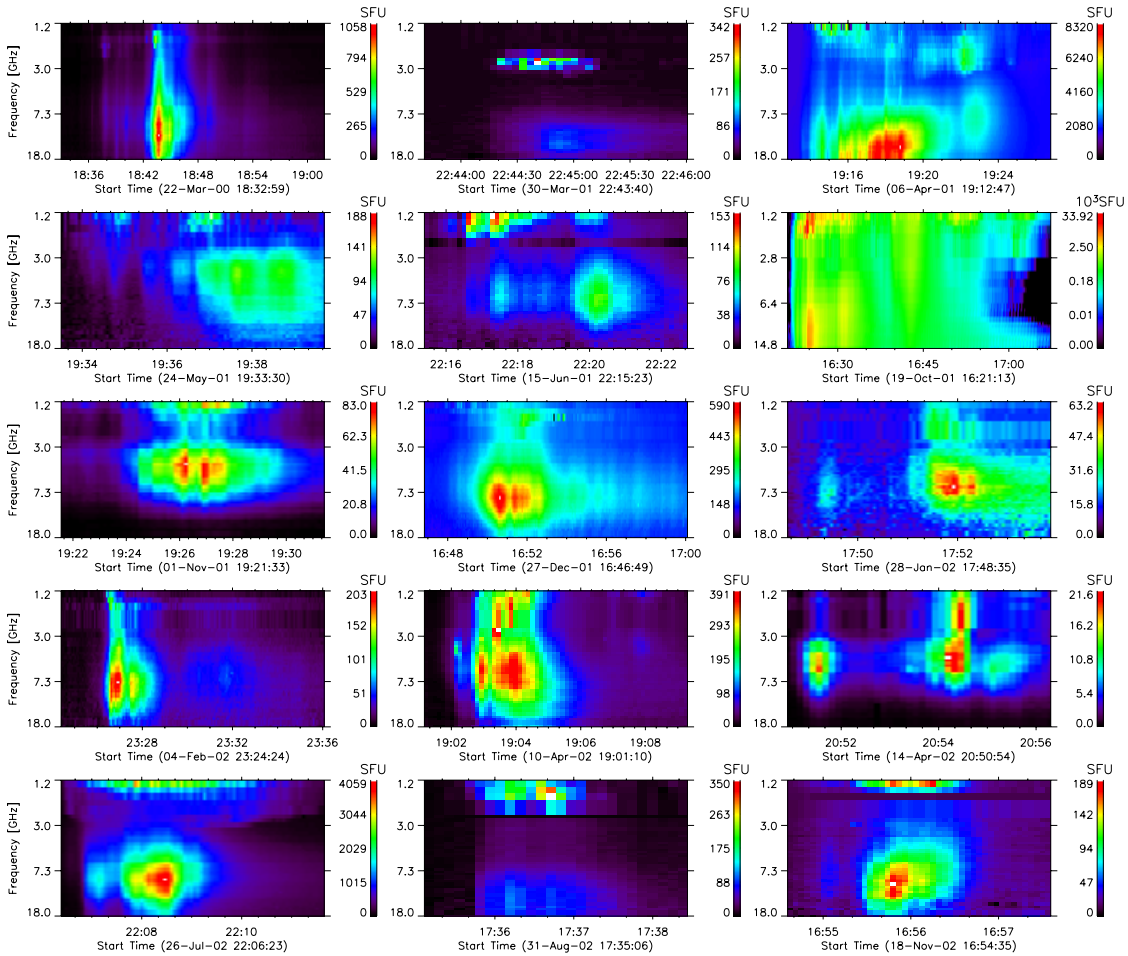
Year	Events	Spectral Components (1, 2, 3 or more)	Temporal Peaks (1, 2, 3 or more)	Snapshots
2001	**228**	**285** (76.8 %, 21.5 %, 1.7 %)	**672** (38.2%, 25.4%, 36.4%)	**29,682**
2002	**185**	**217** (82.7 %, 17.3 %, 0.0 %)	**462** (40.5 %, 24.9 %, 34.6%)	**21,241**
Total	**413**	**502** (79.4 %, 19.6 %, 1.0 %)	**1,134** (39.2 %, 25.2 %, 35.6%)	**50,923**

Enhanced Decimetric Emission

Decimetric Spikes(~2.5%) (Fleishman, Gary, & Nita, 2003, ApJ, 593,571)

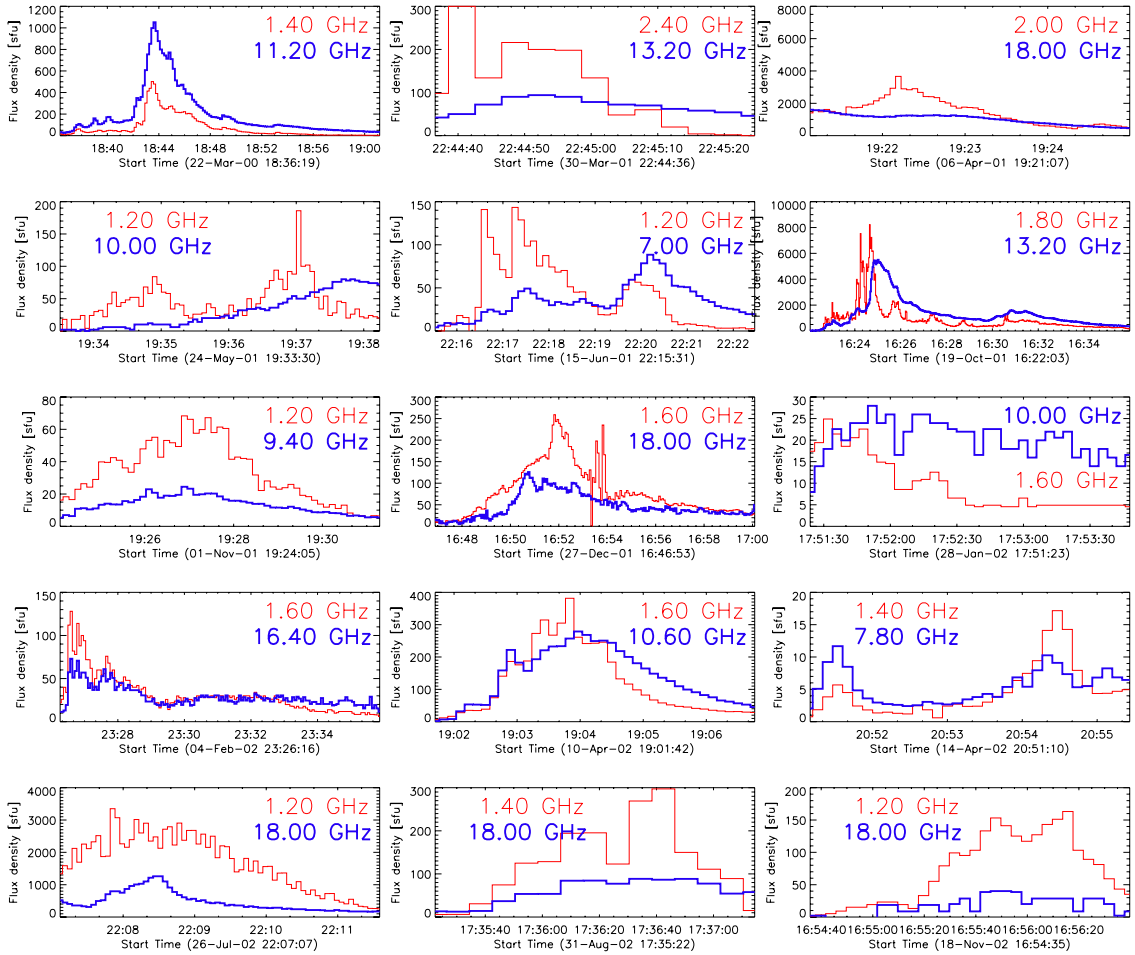
Decimetric Continuum(~16%) (Fleishman, Nita, & Gary , THIS STUDY)

Dynamic Spectra



The common characteristic of these 15 selected spectra is the presence of an enhanced decimetric component accompanying the centimetric emission.

Cm & dm Time Profiles



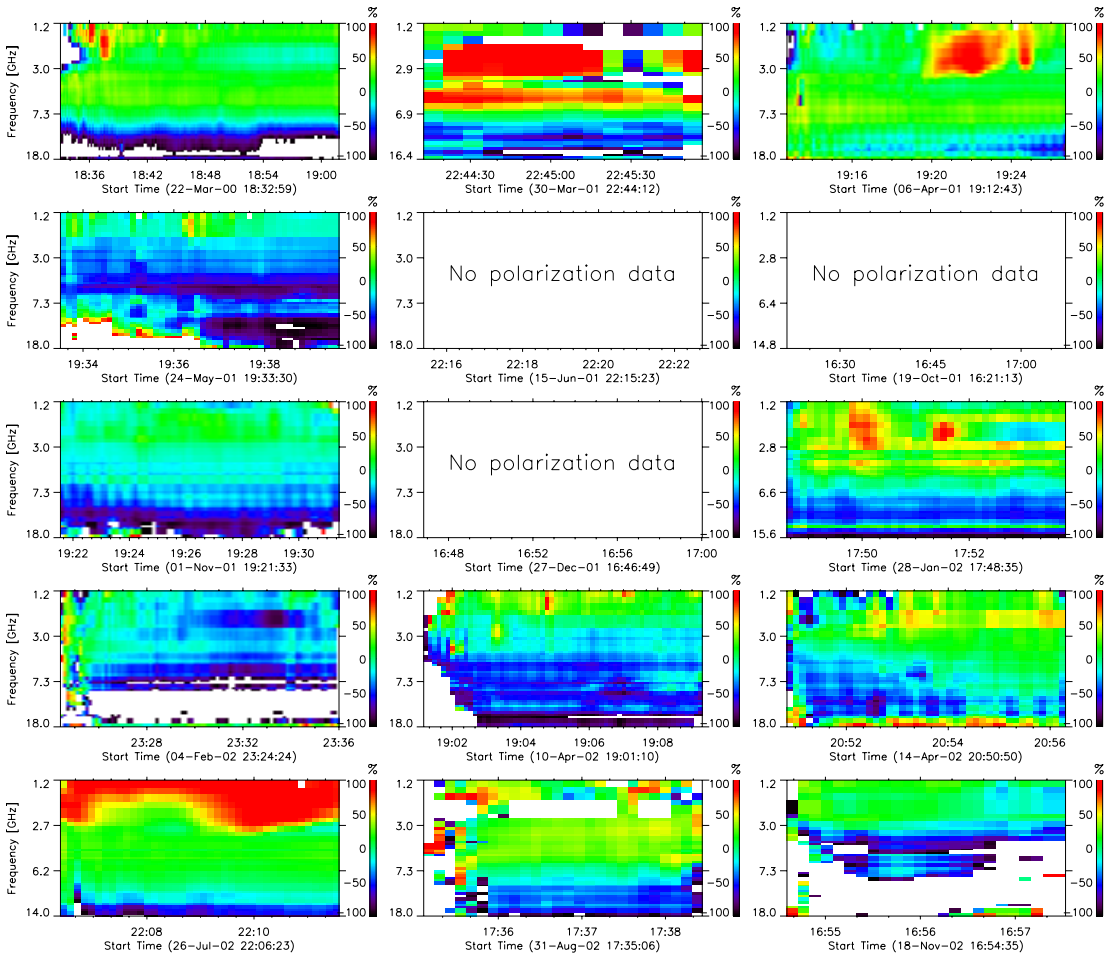
Generally, the time scales of centimetric and decimetric emissions are comparable in each case, as seen in the dynamic spectra and in the time profiles of the dm-cm pairs, although for some particular events, more spiky structures may be occasionally superposed on the smooth decimetric background.

Enhanced smooth dm emission accompanying the GS emission

Such relatively smooth decimetric emission cannot be easily explained in the framework of a coherent plasma emission mechanism, as commonly believed to be responsible for stronger bursts in this frequency range .

(Bastian, Benz, and Gary, 1998; Fleishman, Gary, and Nita 2003; Nita, Gary and Lee 2004)

Polarization Dynamic Spectra



Where available, the polarization dynamic spectra generally reveal a high degree of polarization of the decimetric emission, which in every case is opposite to the polarization present in the optically thin region (above the peak frequency) of the centimetric emission.

HIGH DEGREE O-MODE POLARIZATION OF SMOOTH DECIMETRIC COMPONENT

- Since we expect the optically thin cm emission, due to the GS mechanism, to be *x*-mode polarized, we conclude that the smooth decimetric emission generally presents a high degree of *o*-mode polarization, sometimes as high as 100%.

- The dm polarization spectra do not show the polarization sign reversal at low (optically thick) frequencies characteristic of GS emission, suggesting that the dm component is not simply GS emission in a source of low magnetic field.

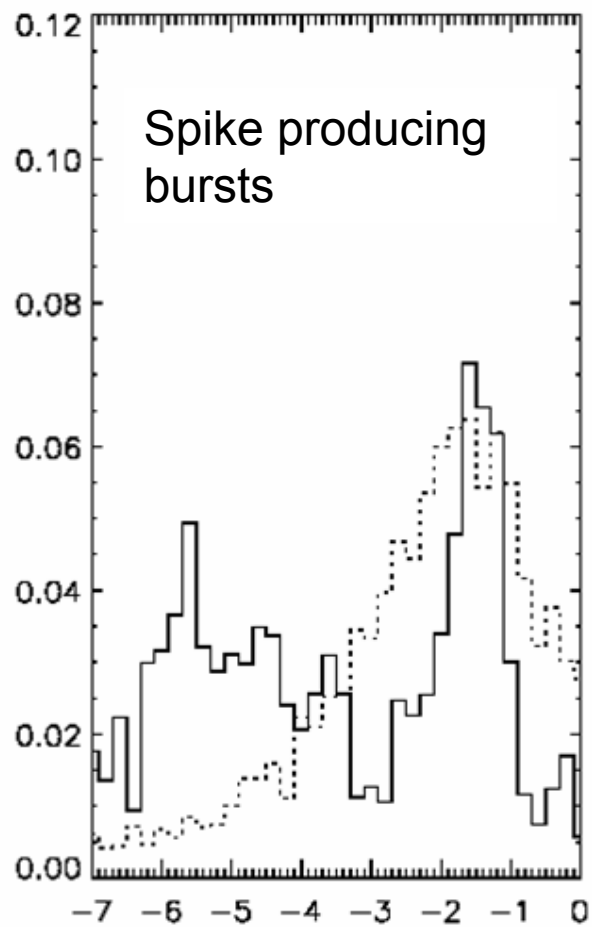
GS Spectral Slope Distribution

According to Kuijpers (1974), dm continuum radiation can be produced by plasma mechanism if the excitation of plasma waves (upper-hybrid waves) occurs due to a quasi-stationary loss-cone instability. The model may ensure ordinary (O) polarization in some particular cases.

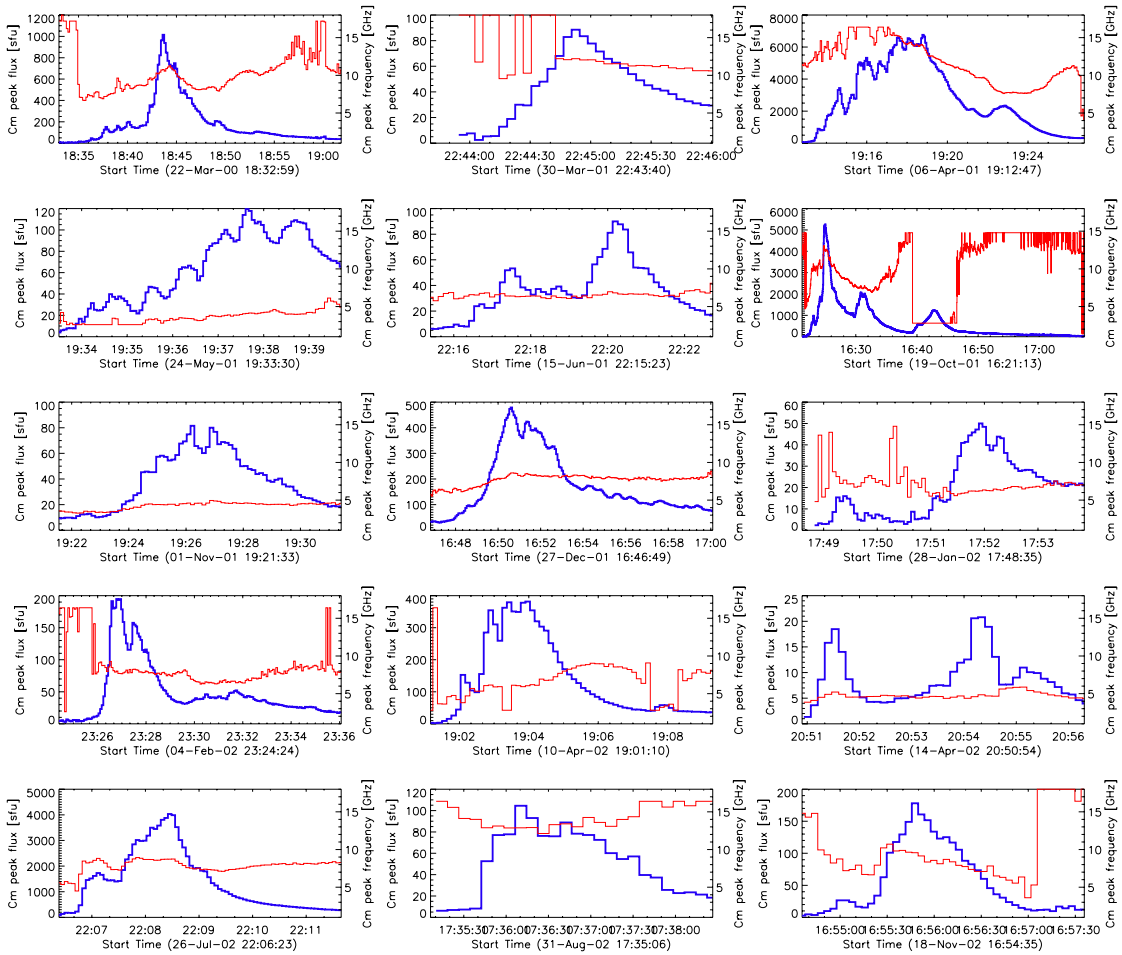
The assumed loss-cone angular distribution should reveal itself in softer (than in case of the isotropic distribution) spectra of the optically thin GS radiation.

The figure compares the distribution of the GS spectral slope of our selected events (thick line) with those corresponding to the entire database (dotted).

Since the GS spectra are mostly harder than in average spectra, no evidence for a loss-cone instability is found in the case of the two-component continuum bursts.



GS Spectral Peak Evolution



- Although the GS peakflux density changes in some cases over several orders of magnitude, the GS peak frequency remains nearly constant, or even increases in the late decay phase of some bursts.

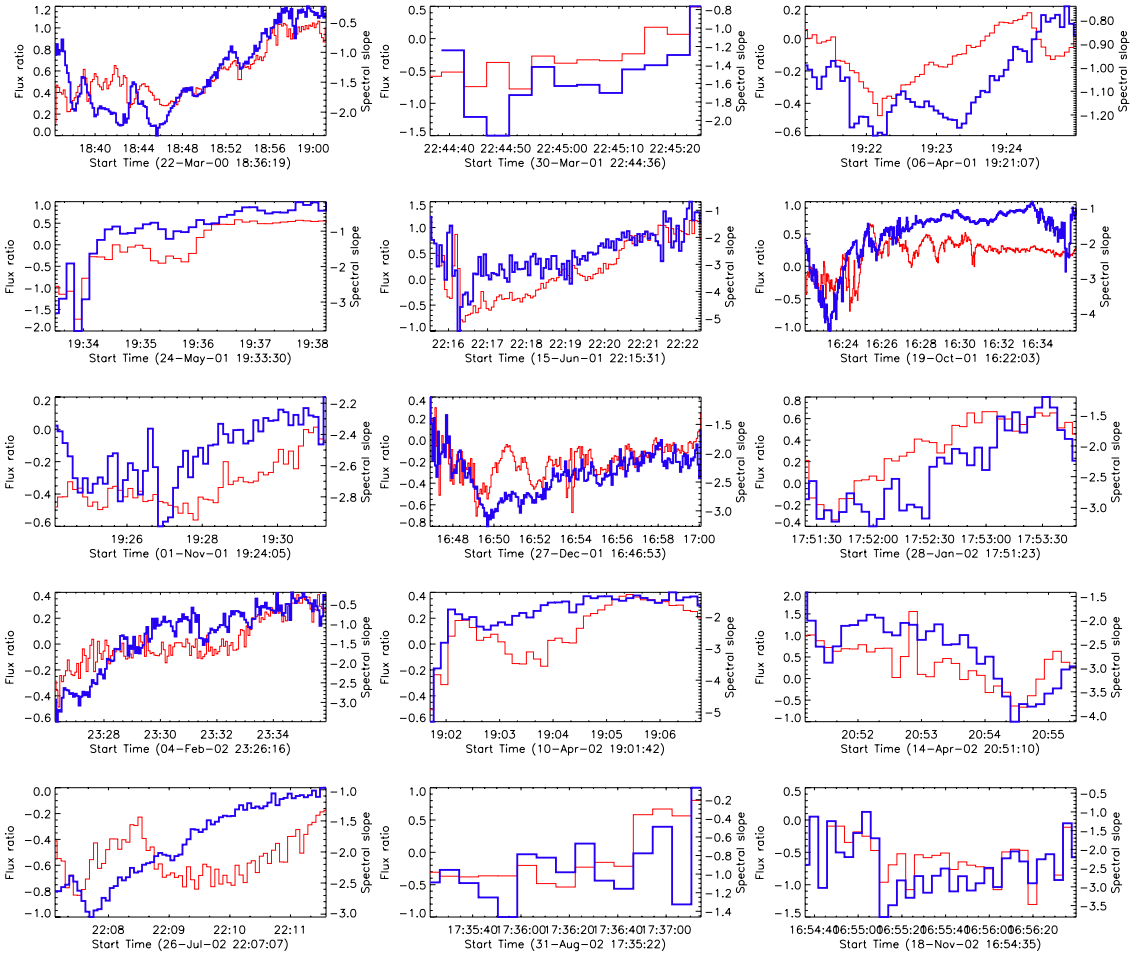
- Had the GS spectral peaks been formed by GS self-absorption in low density plasma, the peak frequency and peak flux would be strongly correlated.

HIGH PLASMA DENSITY AT THE GYROSYNCHROTRON EMISSION SITE SUGGESTED BY A NEW DIAGNOSIS TOOL

- The weak correlation is expected if the GS spectral peak is formed by Razin suppression due to a high plasma density. Thus, this new diagnostic tool (Gary, Melnikov, and Nita, SPD 2004, 88-6) signals the existence of high plasma densities in the GS source of about 10^{10}-10^{11} cm $^{-3}$.

- Assuming that the dm and cm components are produced at or near the same site, we conclude that a high plasma density is favorable for the simultaneous production of GS cm emission and an enhanced smooth decimetric emission.

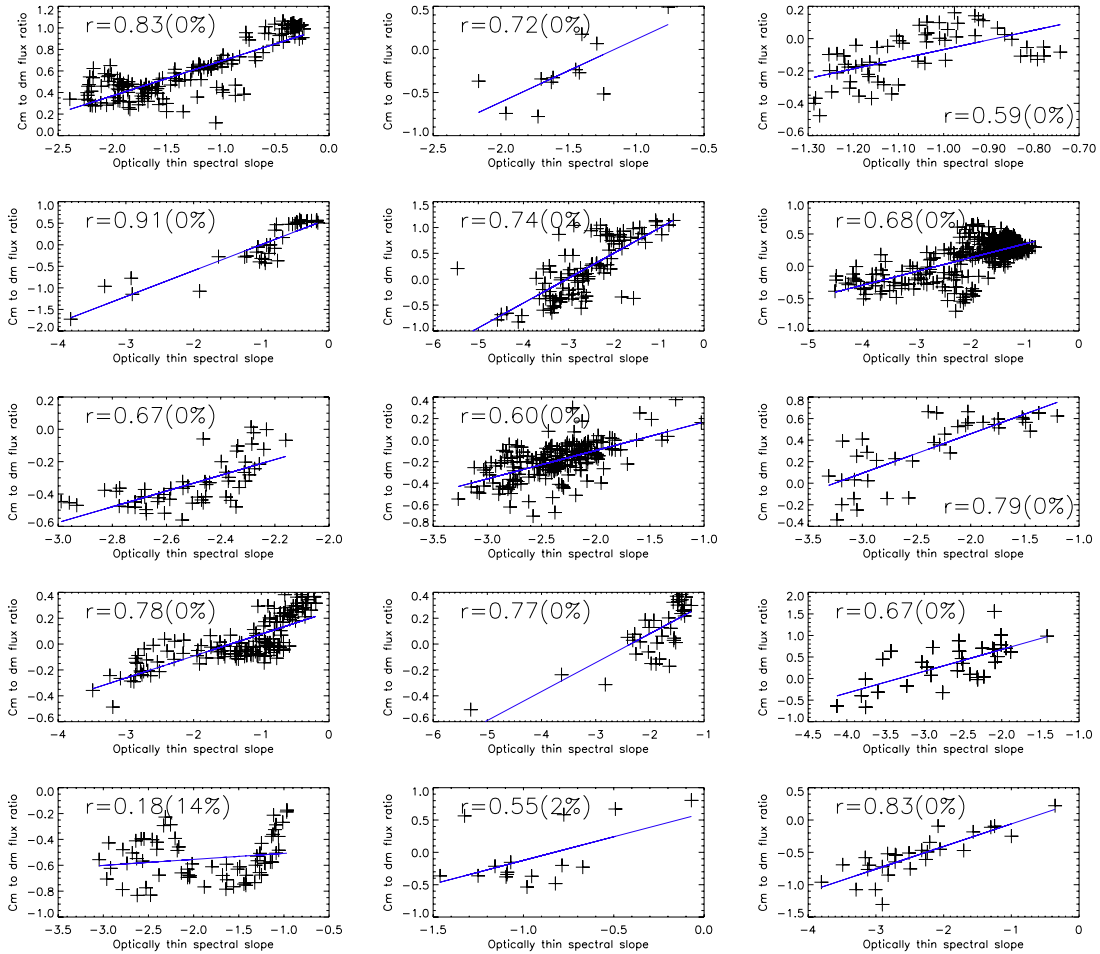
Flux Ratio & GS Spectral Slope



We compare the evolution of the GS optically thin spectral slopes and the natural logarithm of the cm to dm flux ratios.

A very good positive correlation can be observed for most of the time segments in all 15 events.

Correlation Results



The correlation coefficients range from 55% to 91% (with only one exception of 18%), with correspondingly low probability of being random.

Thus, there is generally a strong positive correlation between these two measures, which can be explained by assuming that the same population of energetic electrons produces both emissions.

DECIMETRIC AND CENTIMETRIC EMISSIONS PRODUCED BY THE SAME POPULATION OF ENERGETIC ELECTRONS

If we assume a simple power-law electron energy distribution,

$$N = N_0 \left(\frac{E}{E_0} \right)^{-\gamma}$$

and we assume that the dm and cm flux densities, F_{dm} and F_{cm}, are proportional to the number of electrons at two different energies, E_1 and E_2, we obtain:

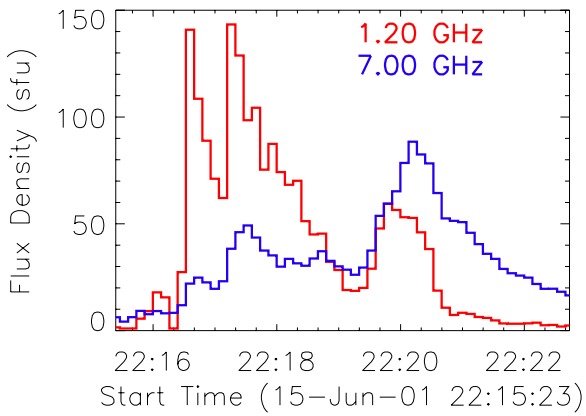
$$Ln\left(\frac{F_{cm}}{F_{dm}} \right) \propto Ln\left(\frac{N_2}{N_1} \right) \propto \gamma \propto \alpha$$

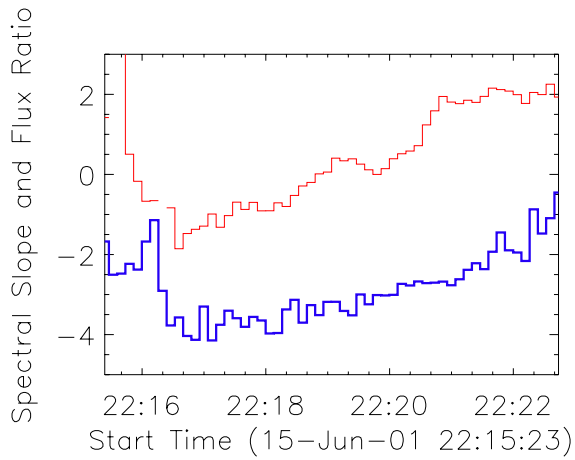
where the last proportionality makes use of the fact that the GS optically thin spectral slope, α, is known to be proportional to the electron power law index, γ.

DECIMETRIC AND CENTIMETRIC EMISSIONS PRODUCED BY THE SAME POPULATION OF ENERGETIC ELECTRONS

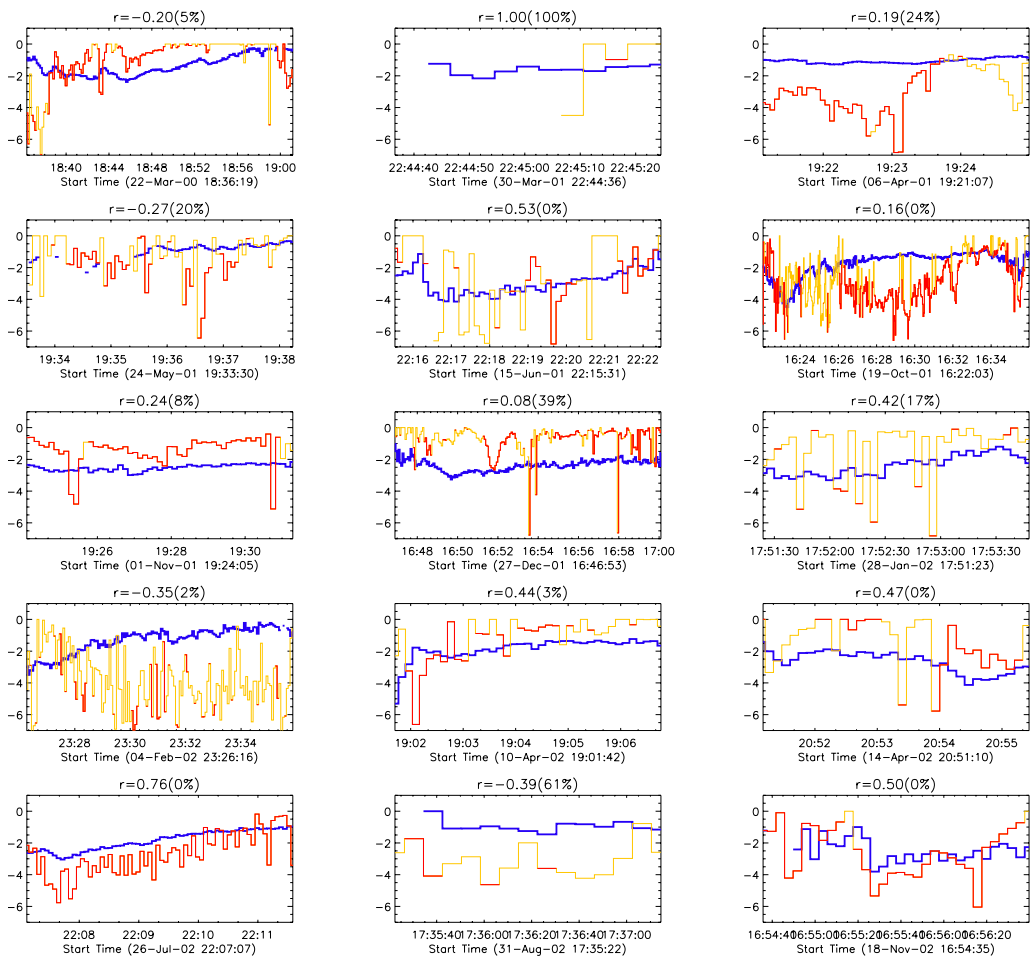
- The dm spectral components appear to be produced by less energetic electrons, while the more energetic electrons from the same distribution produce the cm emission. Such a correlation makes the dm radio emission appear stronger when the GS spectrum is softer, as our data confirm.

- The correlations we found imply that the flux density of the decimetric component is **linearly** dependent on the number of low energy accelerated electrons, which is **NOT** expected for a coherent plasma emission mechanism.





Generally Absent, Weak, Negative, or Random Correlation Between cm and dm Spectral Slopes Above the Spectral Peak



If both spectral components had been produced by the same population of electrons at different GS source sites, we would expect a good positive correlation between the decimetric and centimetric spectral slopes above the corresponding spectral peaks.

Our analysis clearly rule out this possibility in most of our 15 selected bursts.

Common Observed Characteristics of our Two-Component Bursts

- Enhanced smooth decimetric emission accompanying the GS radiation.
- High degree of o-mode polarization of the decimetric spectral component.
- No indication of a loss-cone electron distribution.
- High plasma density at the GS source site
- Decimetric emission produced via an incoherent emission mechanism by the same population of electrons as the GS emission.

Conclusion

- We find that certain common characteristics of the two-component bursts we analyzed are not consistent with gyrosynchrotron (GS) or free-free emission mechanisms, but they agree well with the theoretical predictions for **RESONANT TRANSITION RADIATION** which results from interaction of fast electrons and small-scale turbulence (density inhomogeneities) of the background plasma (Fleishman 2001, Platonov & Fleishman 2002) .
- We conclude that the data presented in this study suggest that the **RTR** emission mechanism plays an important role in a sizeable fraction of bursts (up to 16% of the bursts reported in the study by Nita, Gary and Lee, 2004).

THANK YOU !