NEW THz SOLAR RADIO ASTRONOMY*

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ABSTRACT

New striking aspects of solar activity have been found from observations at frequencies above 100 GHz, provided by the solar submillimeter-wave telescope (SST) at El Leoncito in the Argentina Andes. The SST utilizes a radome-enclosed 1.5-m Cassegrain reflector, operating simultaneously with four 212 GHz and two 405 GHz total power radiometers with 5ms time resolution. Partial overlapping of antenna beams at 212 GHz allow the spatial determination of burst transients as well as estimates of burst source upper limit sizes. Most probable attenuations at El Leoncito are of 0.2 and 0.9 Nepers, at 212 and 405 GHz respectively, along 310 days a year. A new solar burst spectral component has been discovered, exhibiting an intense impulsive bulk emission peaking somewhere in the THz range. It appears along with, but is separated from the well-known microwave emission spectral component. Rapid subsecond submm-w pulsating bursts are associated to all events observed, sometimes without any detectable bulk emission component. Their onset times correlate well with the launch times of coronal mass ejections. However, there are distinctions on the rapid structures also found in the THz burst component. The findings of THz solar activity impose severe constraints to existing models and present new challenges for interpretation of physical processes at the origin of the flaring phenomena, suggesting the acceleration of high energy electrons (> 10 MeV). Observations in this unexplored range are essential. We report current THz developments at El Leoncito with the upgrade of the SST radiometers to increase the sensitivity by a factor of about 10. Uncooled bolometers are being developed to used at the SST focal plane at 670 and 850 GHz. New far-IR camera for the 10-μ (30 THz) solar observations is being installed. Solar THz spatial experiments are being considered in the 2-10 THz range for the next cycle maximum.

Nearly forty years have elapsed since the first attempts to detect solar activity in the THz range [1,2]. New striking aspects of solar activity are been found from observations at frequencies above 100 GHz, provided by the solar submillimeter-wave telescope (SST) at El Leoncito at 2550-m altitude in the Argentina Andes [3], installed in 1999, operated regularly since 2002. The SST utilizes a radome-enclosed 1.5-m Cassegrain reflector, shown in Fig. 1(a). The radiation incoming from the subreflector is received by four 212 GHz, and two 405 GHz feed-horns placed in the focal plane, producing beamsizes of 4 arcmin and 2 arcmin, respectively, illustrated in Fig. 1(b). All total power radiometers operate with 5ms time resolution. Partial overlapping of antenna beams allow the spatial determination of burst transients with relative accuracies of the order of 10 arcseconds.

Sensitivities are critically dependent on atmospheric transmission, which are measured frequently. Typical attenuations at El Leoncito are of 0.2 and 0.9 Nepers, at 212 and 405 GHz respectively, along 310 days a year, exhibiting small seasonal dependence, as shown in Fig. 2 [4]. Transmissions were found to be better compared to other mountain sites located at similar or higher altitudes, an effect that might due to the location between two Andes chains, one in the west sided, which shield the Pacific controlled weather, another chain in the east side, isolating the site from the continental South-American weather.

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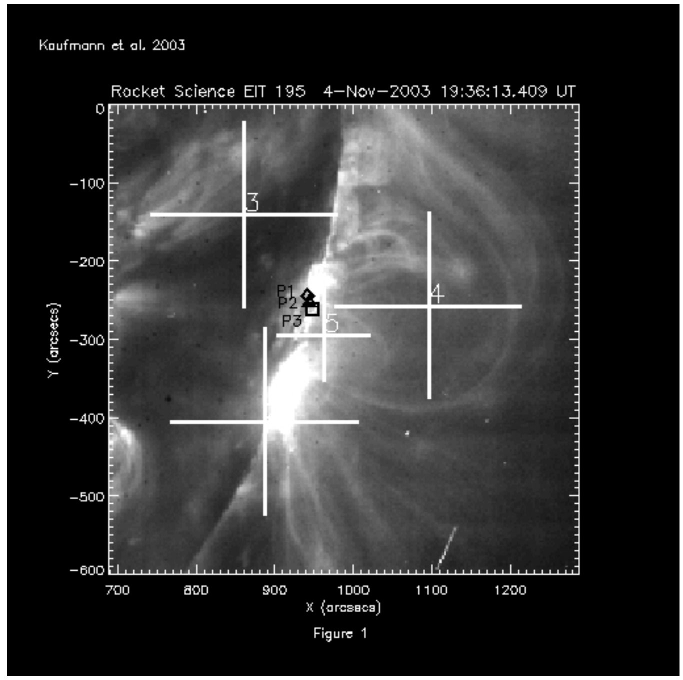

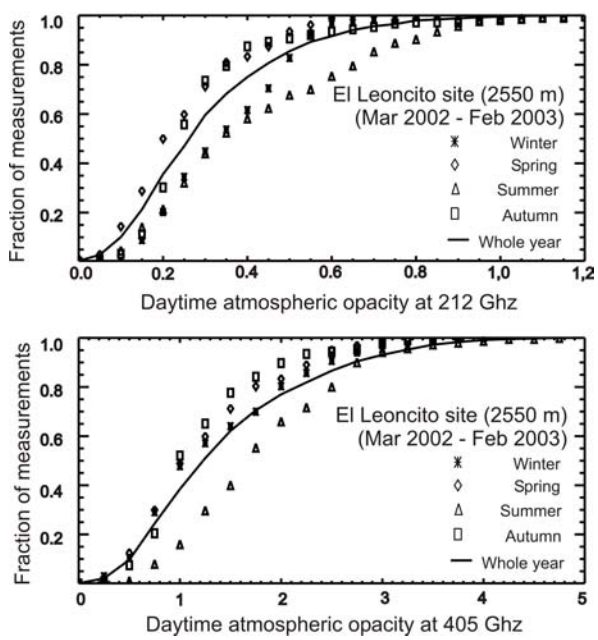

Fig. 2. One year of daytime atmospheric opacity (in Nepers) measured at El Leoncito [4].

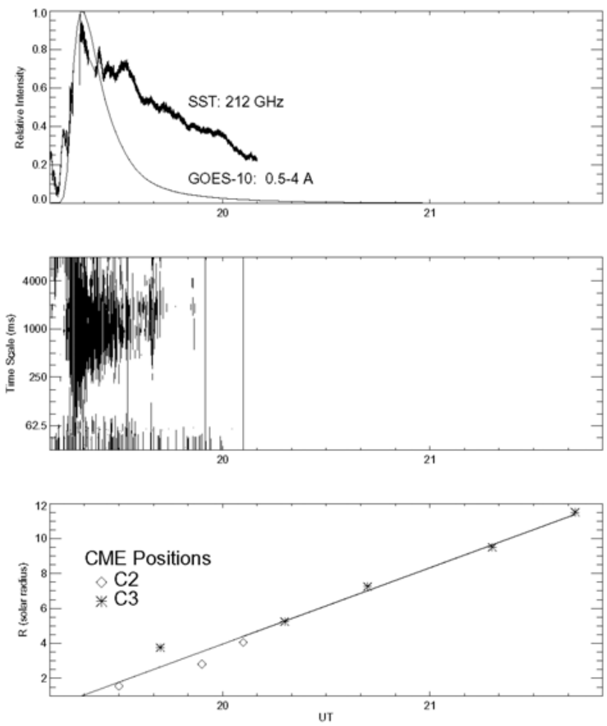

Fig. 3. The onset of rapid sub-second pulsations at 212 GHz for the April 6, 2001 solar burst, is shown in wavelet decomposition in the middle. The launch time is Obtained by extrapolating LASCO images to the solar surface, shown at the bottom panel [6].

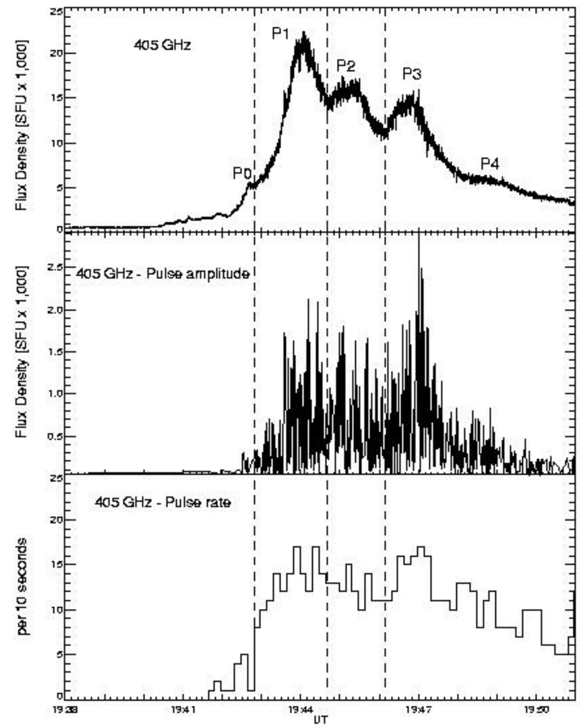

Fig. 4. The November 4, 2003 large burst exhibited 405 GHz fluxes two times bigger than the 212 GHz fluxes. Superimposed rapid time structures amplitudes and rates are shown in the middle and bottom panels [7]. See also Figs. 1 and 5.

Rapid subsecond submm-w pulsating bursts are associated to all events observed, sometimes without any detectable bulk emission component [5]. In general pulse fluxes also increase with frequency. The onset time of increased pulse occurrence rates precede or correlate well with the launch time of coronal mass ejections [6]. One example is shown in Fig. 3.

A new solar burst spectral component has been discovered, particularly well identified during the November 4, 2003 “mega-flare”, exhibiting an intense impulsive bulk emission peaking somewhere in the far infrared range. It appears along with, but is separated from the well-known microwave synchrotron emission component. The time profiles at the two submm-w frequencies were identical, with the 405 GHz fluxes shown in Fig. 4 twice as much as the 212 GHz fluxes. Rapid superimposed time structures, shown in Fig. 4 middle and bottom panels, were observed at both frequencies, being of the order of about 6% of the underlying flux level. The impulsive source, and the superimposed subsecond pulses, remained remarkably confined within 15 arcseconds along the 10 minutes of the event duration (see Fig. 1 (b)). Optically thick flux densities and high brightness temperatures cannot be reconciled with thermal models for interpretation. Highly energetic non-thermal acceleration mechanisms are further favored by the excellent time correlation found with X- and γ-rays detected by satellites.

The nature of the flare T-rays component is mysterious. Larger fluxes for shorter submillimeter wavelengths, found for both the impulsive component and for the pulses, suggest optically thick sources irrespectively of mechanism.Emitting source densities should be very high, either at the solar surface or above it, which is difficult to reconcile using current models. The double spectral structure might be attributed to two populations of electrons, with distinct energy distributions, accelerated nearly simultaneously. Broadband coherent synchrotron emission at microwaves has been suggested as the result from “microbunching” instability on beams of high energy electrons producing incoherent synchrotron radiation peaking somewhere in the THz range or above[8,9].

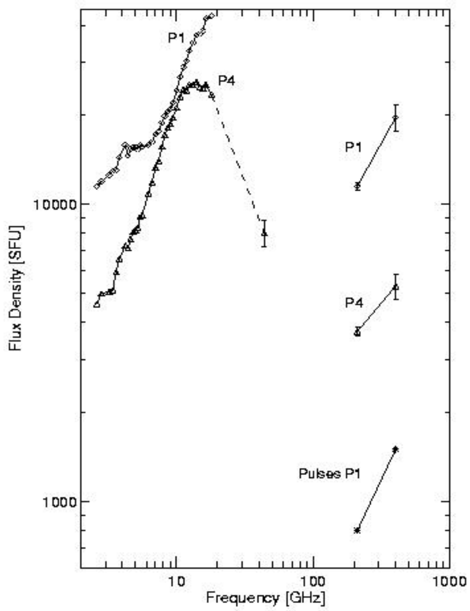

Fig. 5. Spectra obtained for time structures P1 and
P4 of November 4, 2003 solar burst (top of Fig. 4)

These results impose severe constraints and challenges for interpretation, which are strongly dependent on new observations in the THz range. Current THz developments at El Leoncito include the replacement and upgrade of the SST 212 and 405 GHz radiometers, using new generation of lower system noise mixers and large band IF amplifiers, that will increase the sensitivity by a factor of about 10. A high-speed far-IR camera for the 10-μ (30 THz) atmospheric window is being installed to operate together with the SST, as well as with rapid optical H-α images and coronagraph operated in nearby site by the National University of San Juan (Argentina) jointly with Max-Planck Institute for Solar System Research, Lindau (Germany). A new space experiment for the THz range is currently being considered for a French-Chinese mission [10].

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