Mid-IR observations of a C2 flare: Characterizing the flare dynamics at Chromospheric heights

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Introduction

The analysis of solar flares in mid-IR wavelengths is an unexplored field of research and just few events have been reported in the literature (e.g. Kauffman et al. 2013, 2015; Miteva et al. 2016; Gimenez de Castro et al. 2018). These events, with the exception of a C7 class observed by Penn et al. (2016), were all classified in soft X-rays as X and M class events. These studies, reported a temporal and/or spatial agreement of mid-IR emission with white-light (Kauffman et al. 2013, Gimenez de Castro et al. 2018, Penn et al. 2016), microwaves (Kauffman et al. 2013) and ultraviolet (UV) emission (Miteva et al. 2016).
In this work we report the observation of a C2.0 class flare in mid-IR wavelengths at λ = 10 μm (ν = 30 THz). The mid-IR emission shows a very good agreement with the emission from other instruments observing the chromosphere, particularly with the UV data from AIA in 1600 and 1700 Å. We could not find any evidence of white-light emission associated to this event. On the other side, hard X-rays data is not available during the flare time.

Observations

The AR30T telescope
Mid-IR observations are provided by the AR30T telescope. It is located at 2500 m.a.s.l. at Observatorio Astronómico Félix Aguilar, San Juan, Argentina. It is formed by a FLIR sc645 infrared camera, attached to a D = 20 cm Newtonian telescope. The detector is a uncooled microbolometer 640x480 pix^2, observing in the wavelength range of 7.5 – 13 μm (40 – 23 THz) with a cadence of 1 second and a diffraction limit ~13".

Complementary data
We complement the Mid-IR observations with the following data: UV 1600 and 1700 Å from AIA/SDO (Lemen et al. 2012), HMI 6173 Å and magnetograms from HMI/SDO (Scherrer et al. 2012), Hα data from the Hα solar telescope for Argentina (HASTA, Bagalá et al. 1999), Soft X-ray data from GOES and microwaves observations from the Expanded Owens Valley Solar Array (EOVSA, Gary et al. 2018).

Analysis of the event

The solar flare SOL2019-05-15T19:24 was classified as a C2.0 in soft X-rays, starting at 19:15 UT. The flare occurred in the active region AR12741 (N07W36), being the most intense flare registered in the AR during its transit. Fig. 1 shows snapshots at different times of the flaring region as observed by AIA in 1600 Å (AIA1600) and by the AR30T telescope. The presence of several and simultaneous bright kernels is observed in AIA1600 data. These bright kernels are also observed in Hα and AIA 1700 Å data.

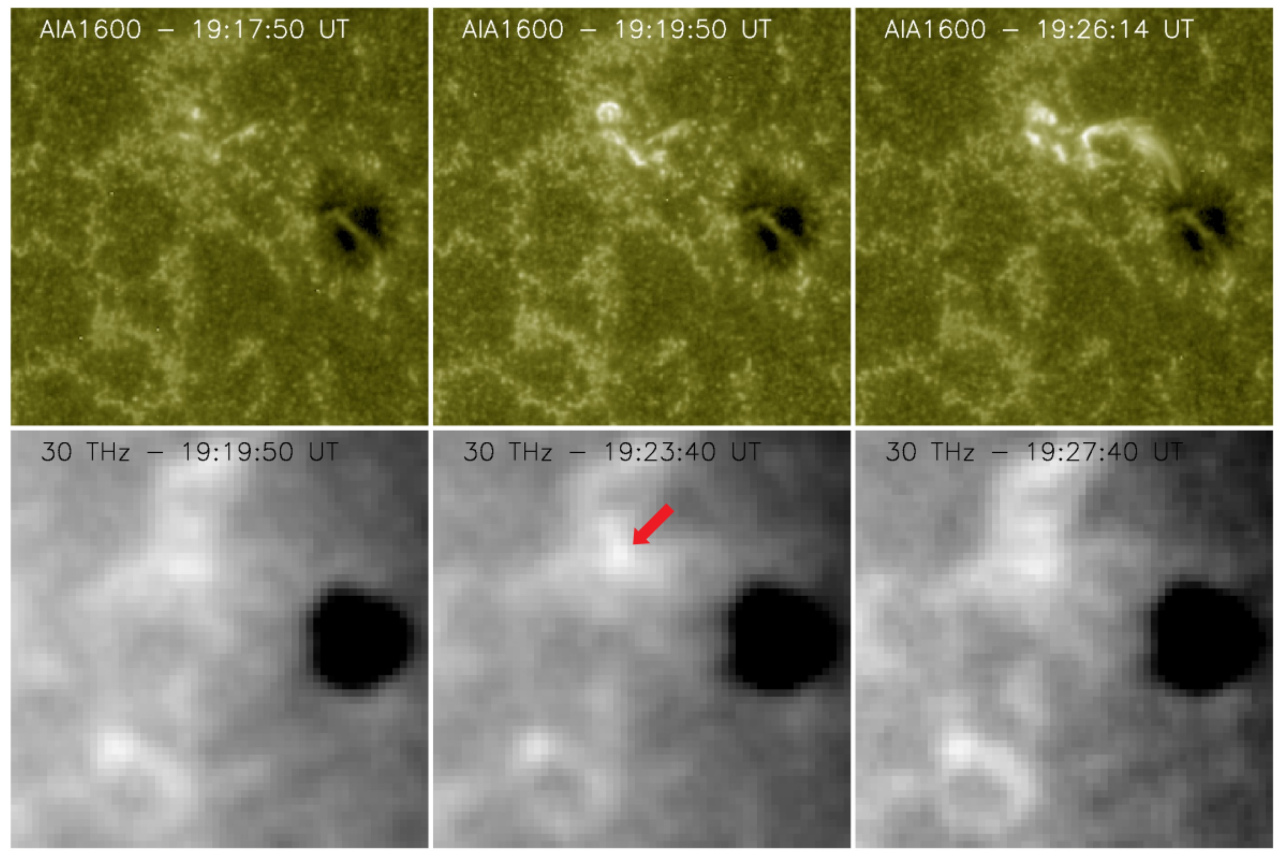

Figure 1. The evolution of the flaring region as observed by AIA1600 (upper) and AR30T (lower). The red arrow indicates the flare position in 10 μm. The images have a vertical and horizontal size of 150".

Temporal evolution

Fig. 2 shows the temporal evolution of the flaring region in several wavelengths. The 30 THz and 8 GHz fluxes are shown in Solar Flux Units (SFU = 10^{-22} Wm^{-2}Hz^{-1}). The 30 THz flux values were obtained under the Rayleigh-Jeans approximation to a black body.
The calibration in brightness temperature is done considering a quiet Sun temperature of 5000 K (Turon & Léna, 1970). The flaring area was estimated in ~2x10^{18} cm^2.

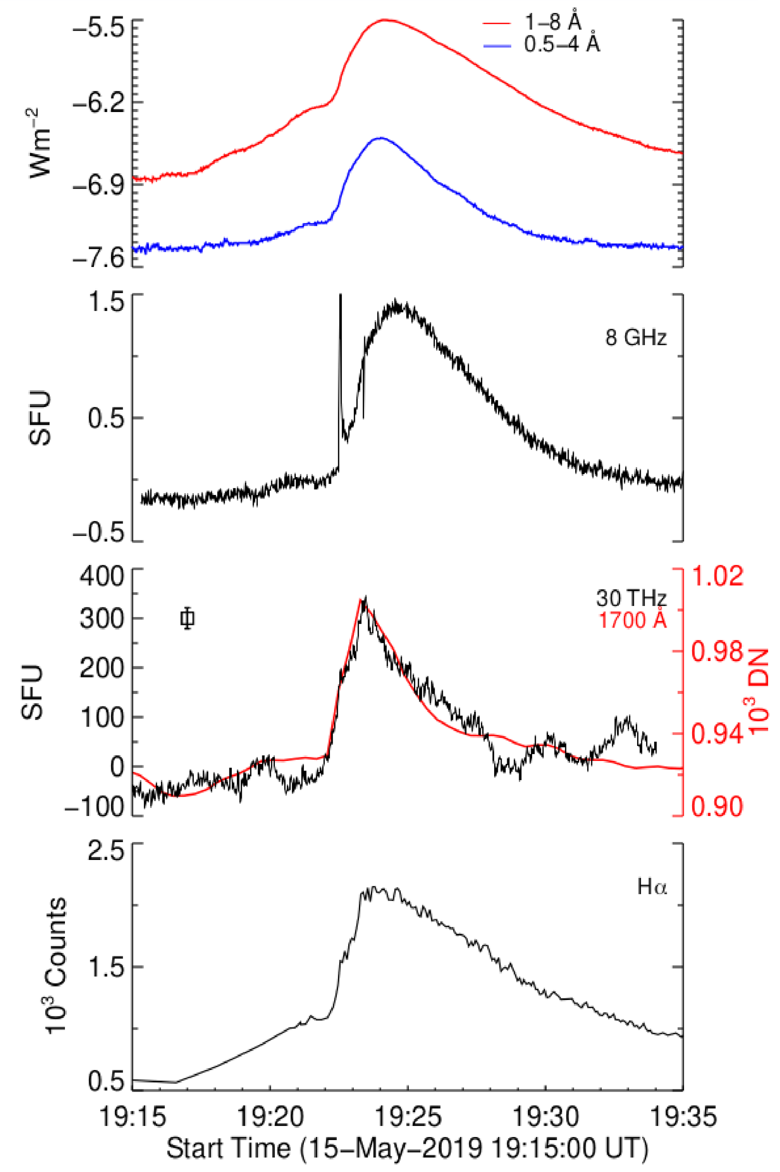

Figure 2. Temporal evolution of the flare in: GOES X-rays, Microwaves from EOVSA, 30 THz with AIA1700, and Hα.

Two kernels in mid-IR

Fig. 3 a) shows the flaring region as observed in AIA1600 at flare peak time. Panel b) displays the flaring region in mid-IR after the subtraction of a 60 pre-event images averaged. The scale is given in contrast excess (CE). The maximum CE ~ 0.6 % corresponds to a temperature excess brightness ΔT~30 K. The two unresolved bright sources observed in 30 THz are separated by ~18" and are spatially associated with the multiple bright kernels in AIA1600.

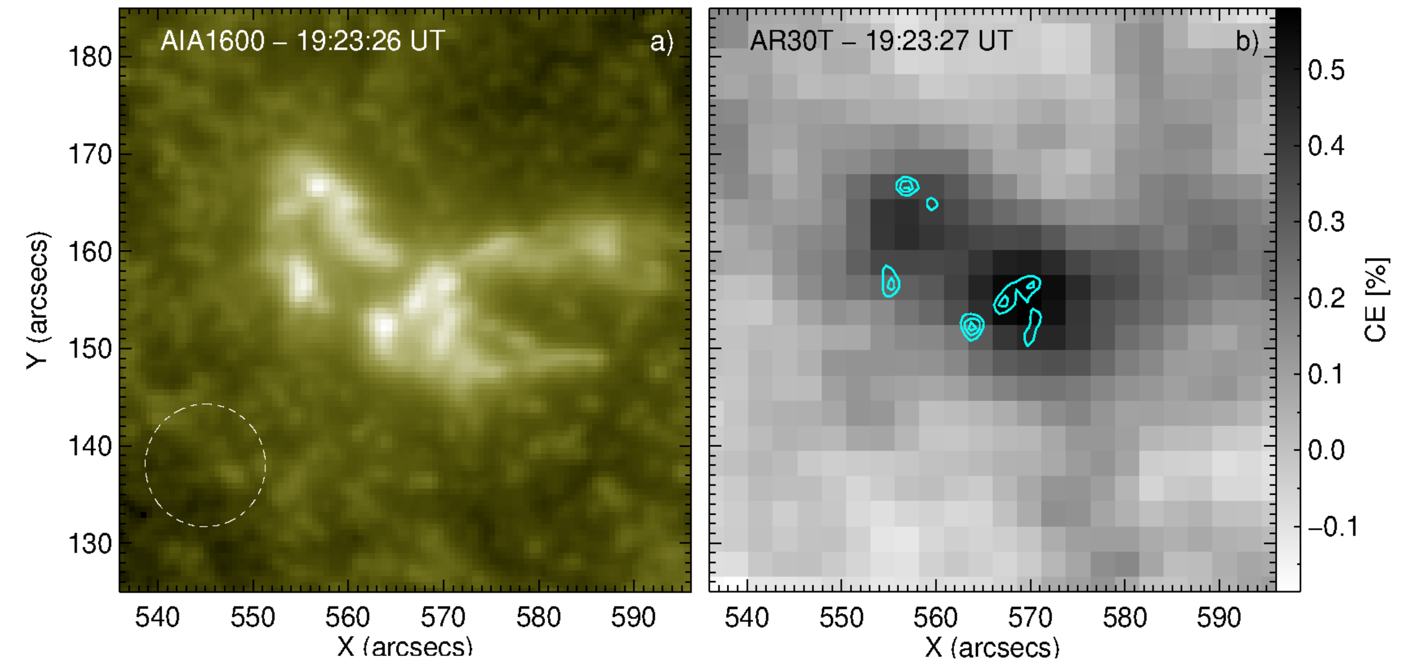

Figure 3: Panel a) The flaring region at flare peak time by AIA1600. The white circle indicates the Airy disk size in 30 THz. Panel b) the same area by AR30T. The contour curves indicate the 50,70 and 90% of the maximum intensity in a).

A flare driven by heat conduction

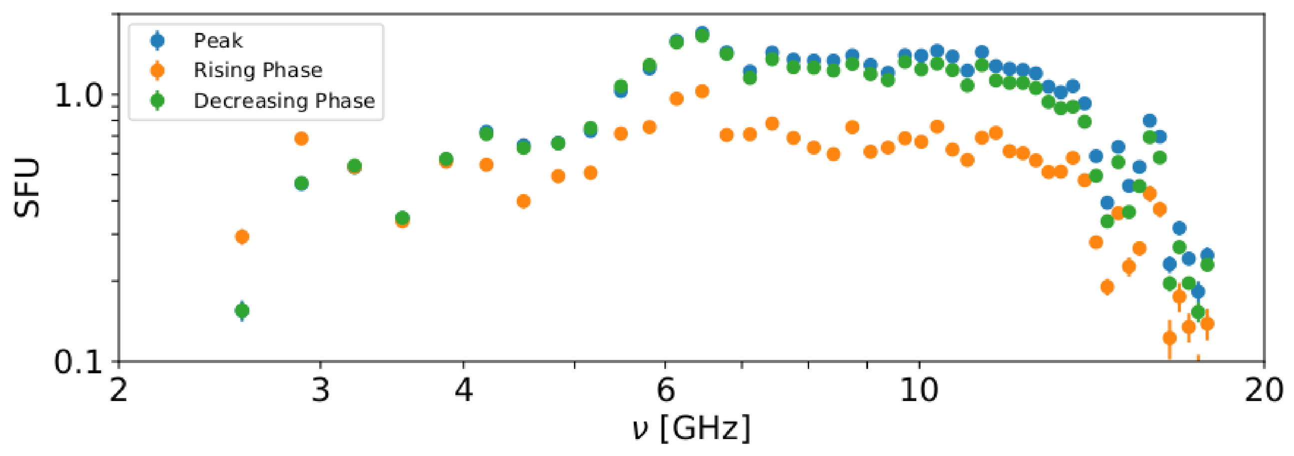

Figure 4. Microwave spectra obtained at different phases of the flare. Every spectrum is a 90 s time integrated.

Fig. 4 shows the time integrated spectra taken at different phases: rising, peak and decreasing phase. The flat appearance of the spectra during the different phases of the flare leads support to an optically thin thermal emission. The similar aspects between the 8 GHz and Soft-X-rays profiles (see Fig. 2) reinforce the evidence for the thermal nature of the emission.
All these evidences, support the heat conduction as the main mechanism of energy transfer during the flare.

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