Implications of the mid-IR for ALMA flare observations

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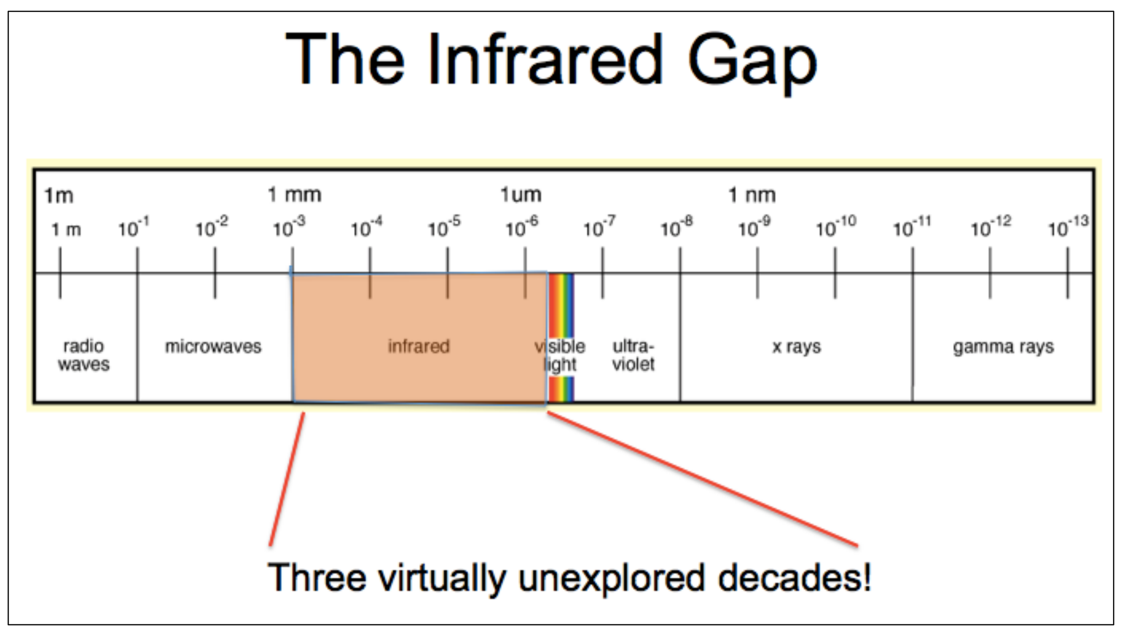
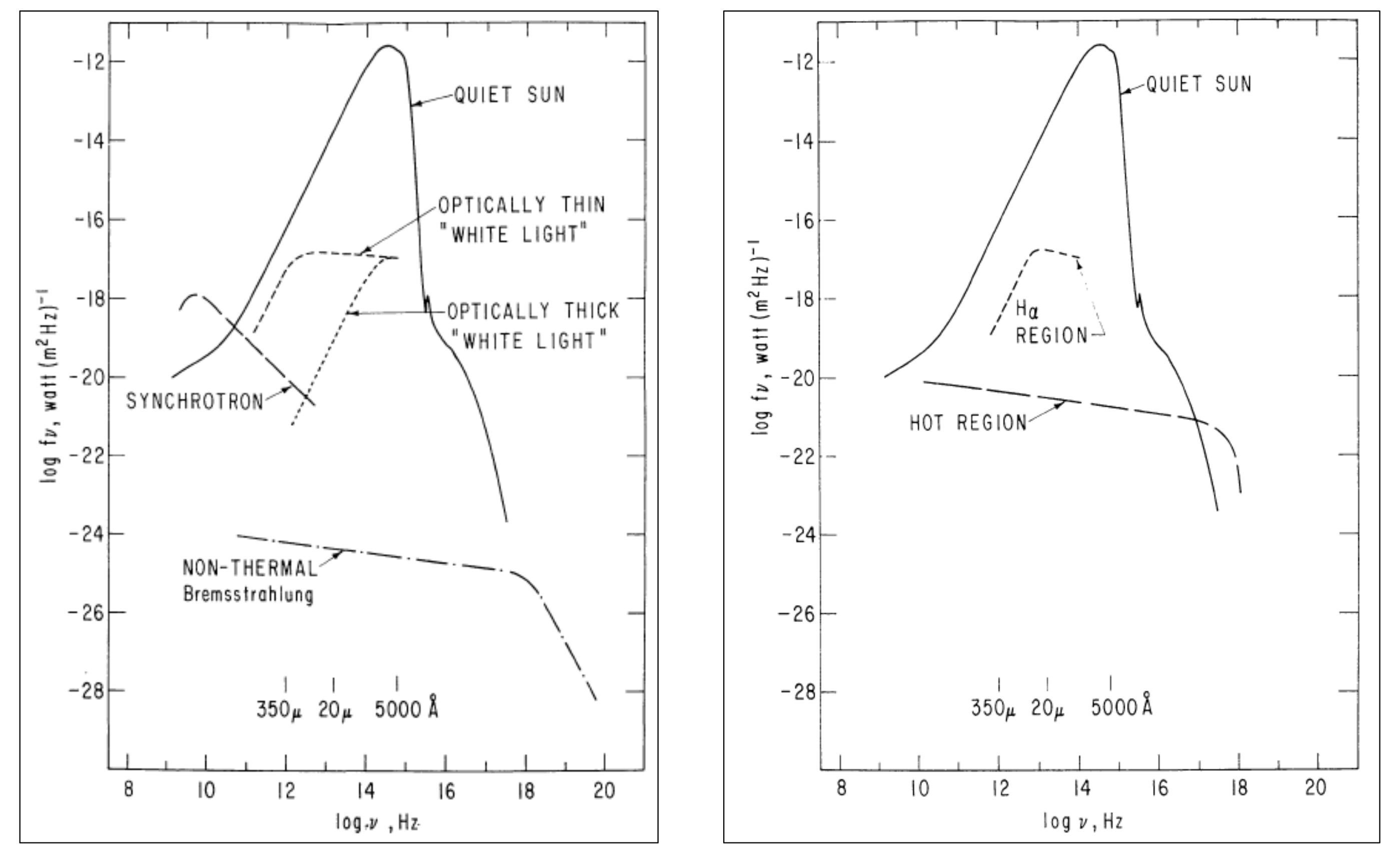


Above: *There really is a gap in our observational parameter space, being fiilled in now via ground-based IR observations from above, and ALMA from below.*

Synopsis: Mid-IR observations (the 10μ band) of solar flares have now become possible (Kaufmann et al. 2015; Trottet et al. 2015; Penn et al. 2016). This poster reviews the new data in the ALMA context.

Right: *Schematic global spectra of a solar flare as it appeared to Ohki & Hudson (1975), for the impulsive phase (;eft) and the gradual phase (right) of a solar flare.*



The new IR observations: Several flares have now been observed in the 10μ band (Kaufmann et al. 2015). The most detailed results come from observations at the McMath-Pierce telescope of SOL2014-09-24 (Penn et al. 2016). Figures 1-4 (map, timeseries, overlays, spectrum) show these observations, made with independent QWIP array detectors in broad passbands at 5.2 μm and 8.2 μm.

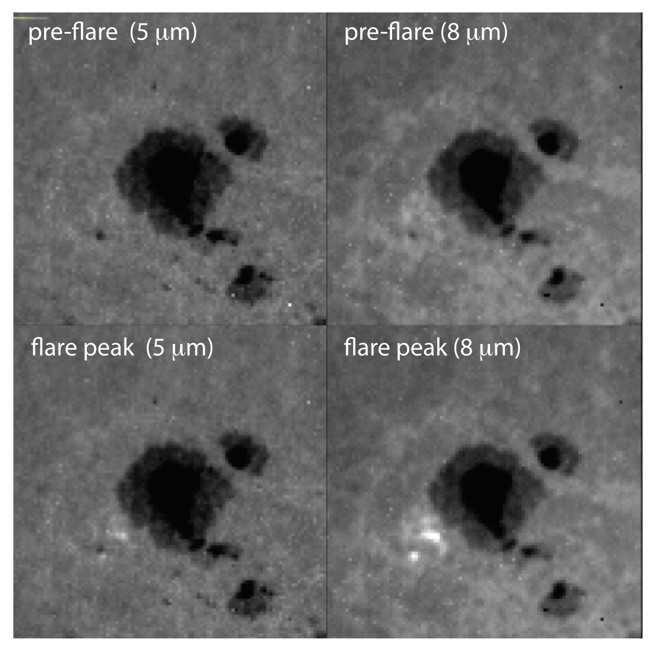


Fig. 1: *Peflare (upper) and flare (lower) images in the two mid-IR passbands. Note the well-resolved sunspots and faculae, and the excellent signal-to-noise ratio for the flare emissions. The flare footpoint sources are not resolved spatially.*

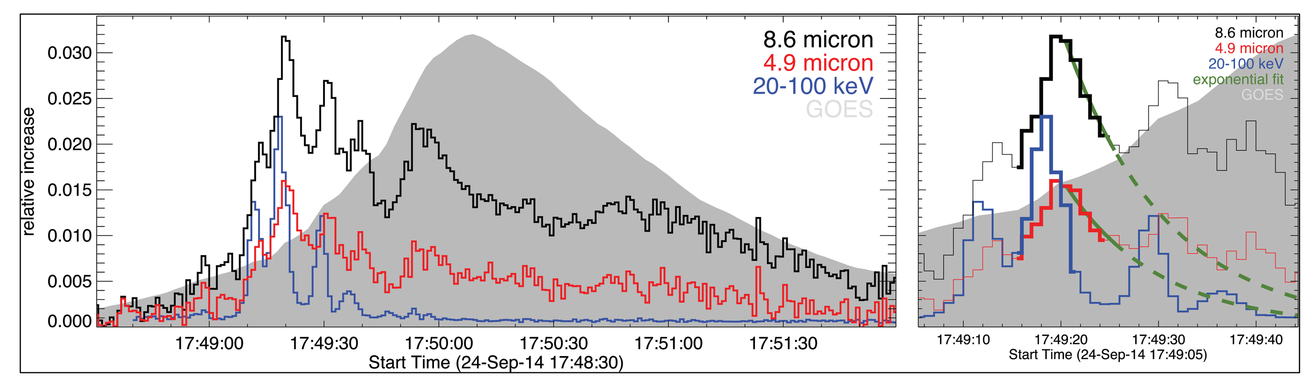


Fig. 2: *Light curves of the two mid- IR bands and hard X-rays observed by RHESSI. The background gray figure shows GOES 1-8Å. The IR time variability is not well resolved at 1 s.*

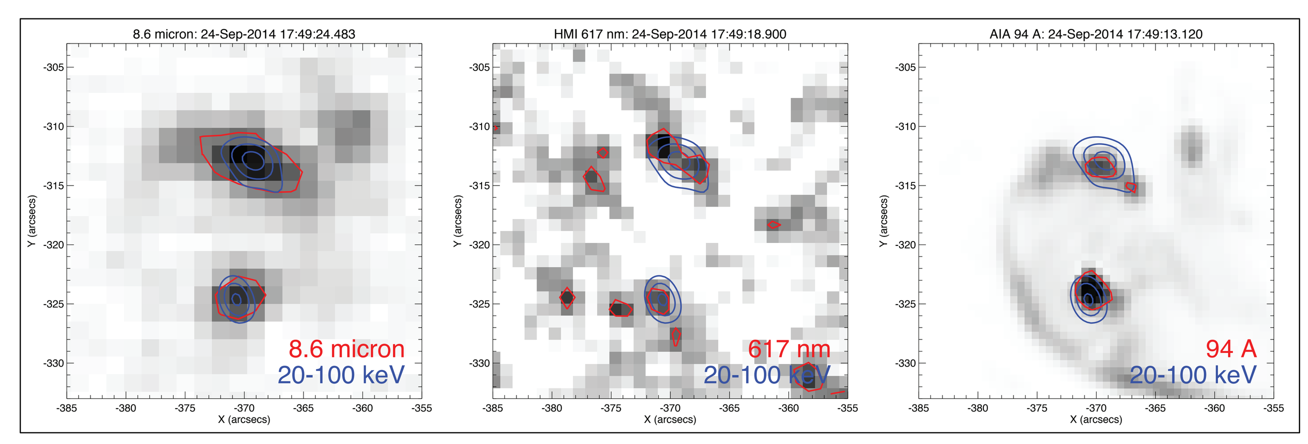


Fig. 3: *Images at 8.2μ, HMI white light, and AIA 94Å, overlaid with RHESSI hard X-ray contours.*

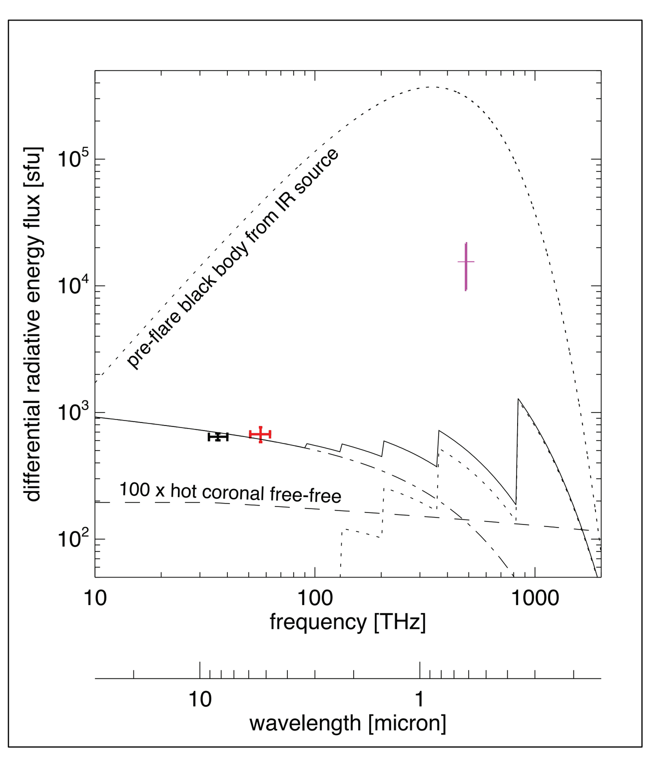
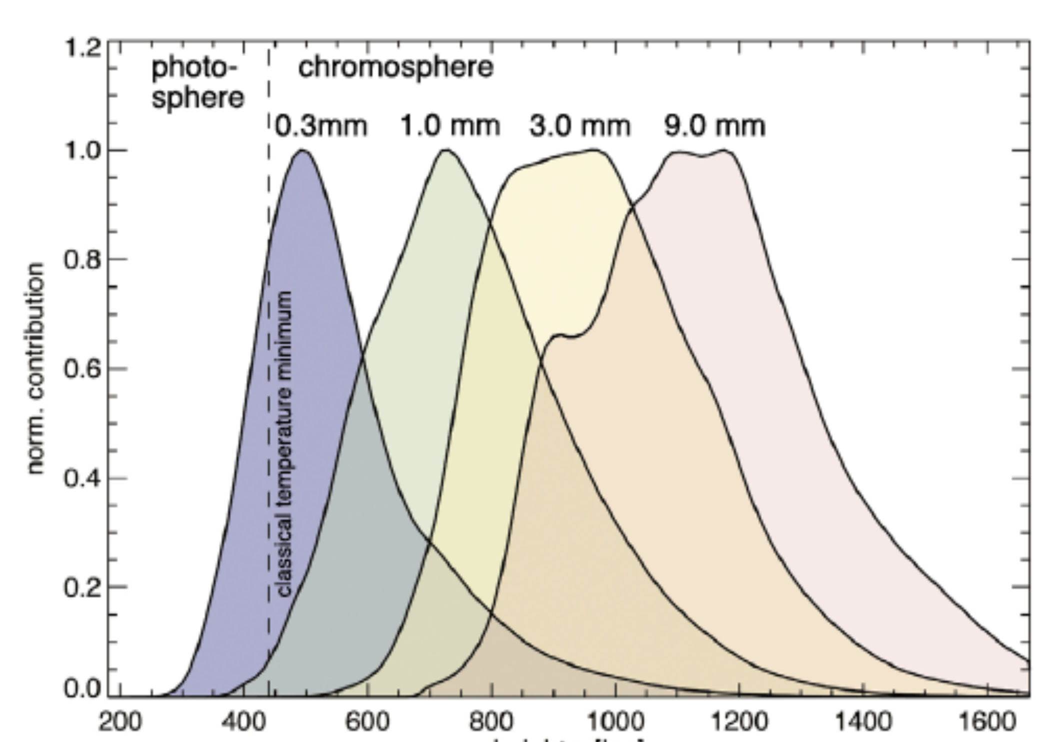


Fig. 4: *Spectrum at the peak of the flare, combining the two mid-IR points with the HMI observation in "white light." The infrared spectrum matches that expected from optically-thin thermal bremsstrahlung.*

Significance: The excellent signal-to-noise ratio in the observations of SOL2014-09-24 leads to great optimism about future observations, since it was a minor event (GOES class C7.4). We were surprised to see the clear identification of the mid-IR sources with the impulsive-phase signatures in the deep atmosphere. These data therefore will contribute enormously to our knowledge of the main flare energy release.

Other new IR observations: The observations described above add to the remarkable progress of the group of Pierre Kaufmann (São Paulo) in several directions, including the observation of several other flares at 30 THz (the 10μ band). They have also successfully observed solar flares in the "sub-THz" range at 212 GHz and 405 GHz. These systematic observations come from a dedicated facility at the El Leoncito site in the Andes. Most recently, this group has recently completed a successful balloon flight pioneering solar observations in the far IR at 3 THz and 7 THz. All of this contributes to filling in the great spectral gap that has heretofore existed.

Implications for ALMA: *Between the new mid- and far-IR observations now appearing, and the forthcoming ALMA flare observations, we will be able to* characterize the flaring atmosphere directly, using the easy-to-characterize continuum rather than having to rely on the complexities of radiative transfer in spectral lines. The figure below (Wedemeyer et al. 2016) shows the likely contribution functions for the ALMA spectral bands, illustrating how they fully map out the domain of the chromosphere. **The IR and ALMA observations will complete our empirical knowledge of the flaring atmosphere.**



References

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Penn, M. et al. 2016, ApJL 819, 30
Trottet, G. et al. 2015, ApJ 290, 819
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