Statistical Characteristics of Faculae on Precision Solar Photometric Telescope Ca II K Images

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Data Description

- Photometric Solar Patrol Telescope (PSPT) from 1998–2003
  - 2048×2048 pixel images, $1''$ square pixels
  - For this analysis, Ca II K filtergrams used: 393.4 nm center, 0.25 nm bandpass
- Cartesian Full Disk Telescope 1 (CFDT1) images from San Fernando Observatory (SFO)
  - 512×512 pixel images, $5''$ square pixels
  - Ca II K filtergrams with 393.4 nm center, 1 nm bandpass
  - Analysis of these images previously reported in detail (see `http://www.csun.e`

Data Analysis 1

- San Fernando Observatory (SFO) algorithms applied to PSPT images to:
  - Fit an elliptical limb to the images
  - Divide each image by a mean quiet sun (QS) limb darkening (LD) curve
  - Pixel contrast defined as fractional change in brightness of pixel with respect to QS LD at that disk location
- Individual features identified using "three-trigger" algorithm (Preminger, Walton, & Chapman 2001, *Solar Phys.* **202**, 53)
  - Three contiguous pixels meeting a "trigger" contrast criterion constitute a feature
  - All pixels contiguous to these three which meet a "threshold" criterion are added to this feature
  - Trigger and threshold are both set to that contrast for which 0.02 of quiet sun pixels are brighter; $+0.05$ for PSPT and $+0.02$ for CFDT1 images

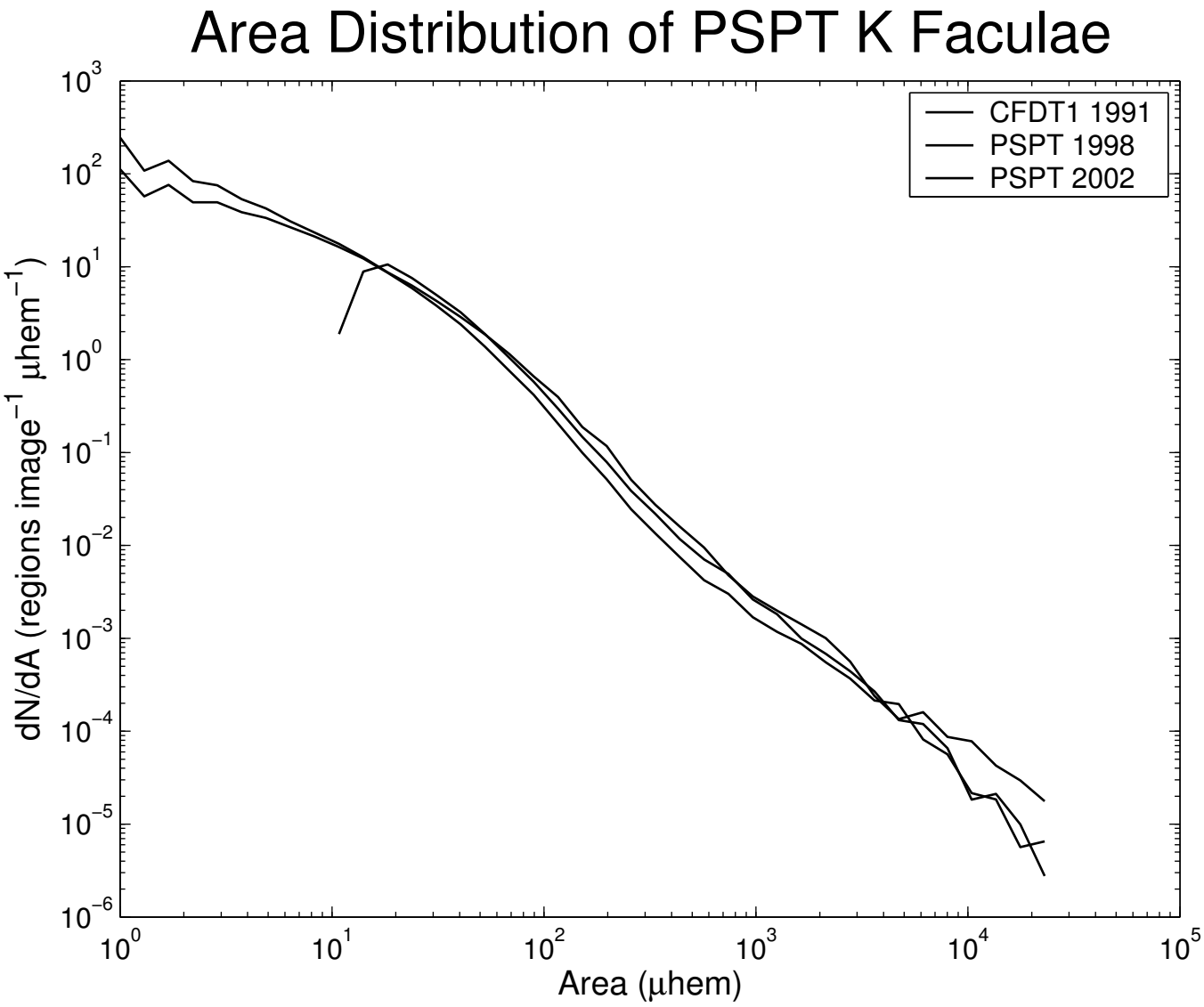
Data Analysis 2

- Photometry carried out for each feature. Values computed:
  - Area in millionths of a solar hemisphere (μhem; $1\ \mu\mathrm{hem} \approx 3 \times 10^6\ \mathrm{km}^2$).
  - Average contrast
  - Maximum pixel contrast
  - Photometric excess; *i.e.*, contribution of each feature to excess emission in filter bandpass

Differential Distribution of Bright Regions

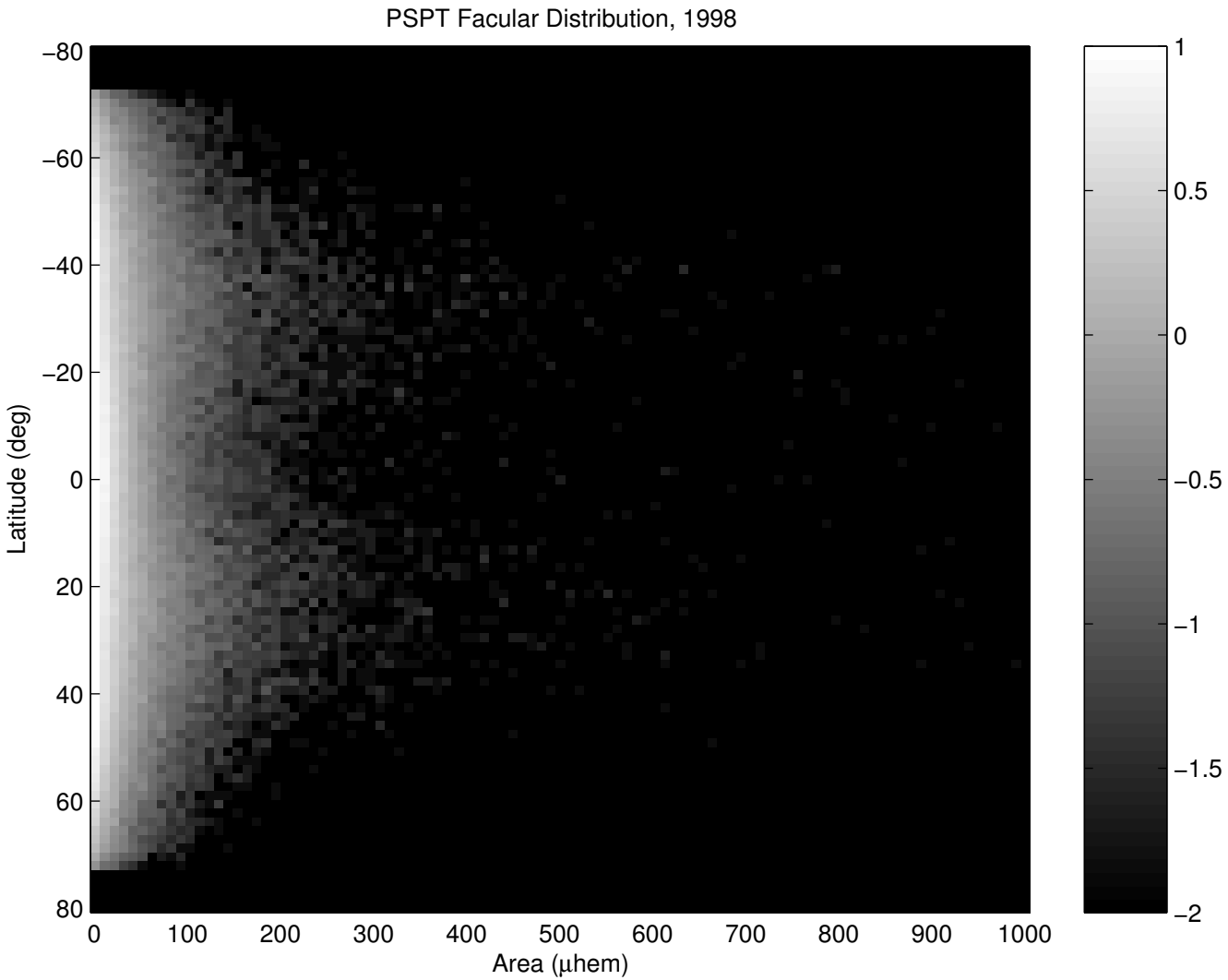
Next page: Differential distribution of identified bright features on PSPT images for 1998 and 2000, and that previously identified from CFDT1 images in 1991. Notice the excellent agreement at large region sizes between the old and the new data, which we attribute to the careful choice of trigger levels. Also note that the new data show a flattening of the distribution at small feature sizes, implying that large numbers of undetected small features in the previous data set do not contribute significantly to irradiance.

variability.

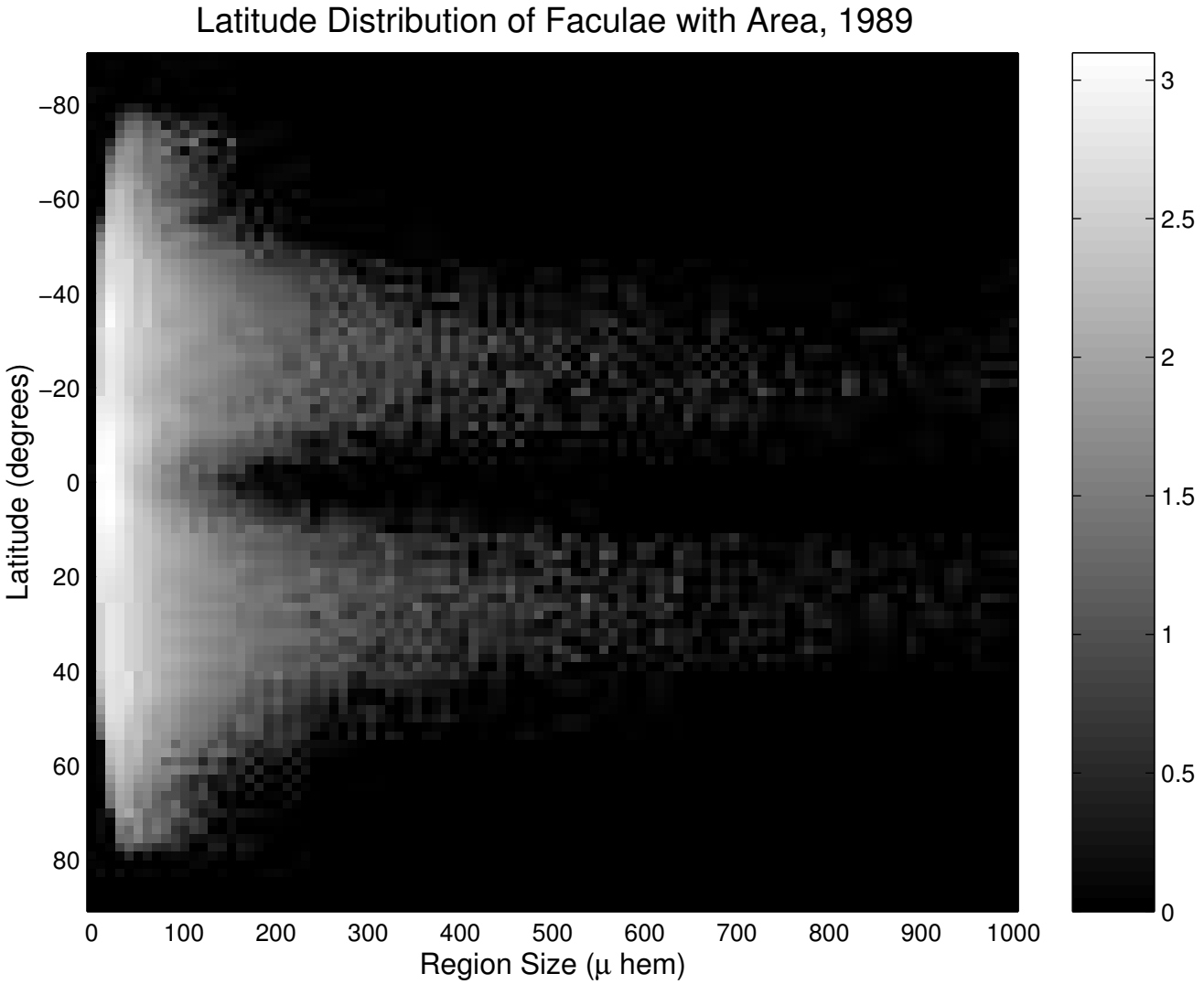

Area Distribution of PSPT K Faculae
CFDT1 1991
PSPT 1998
PSPT 2002
dN/dA (regions image^{-1} μhem^{-1})
Area (μhem)
10^{3}
10^{2}
10^{1}
10^{0}
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{0}
10^{1}
10^{2}
10^{3}
10^{4}
10^{5}

Distribution of Areas of Regions

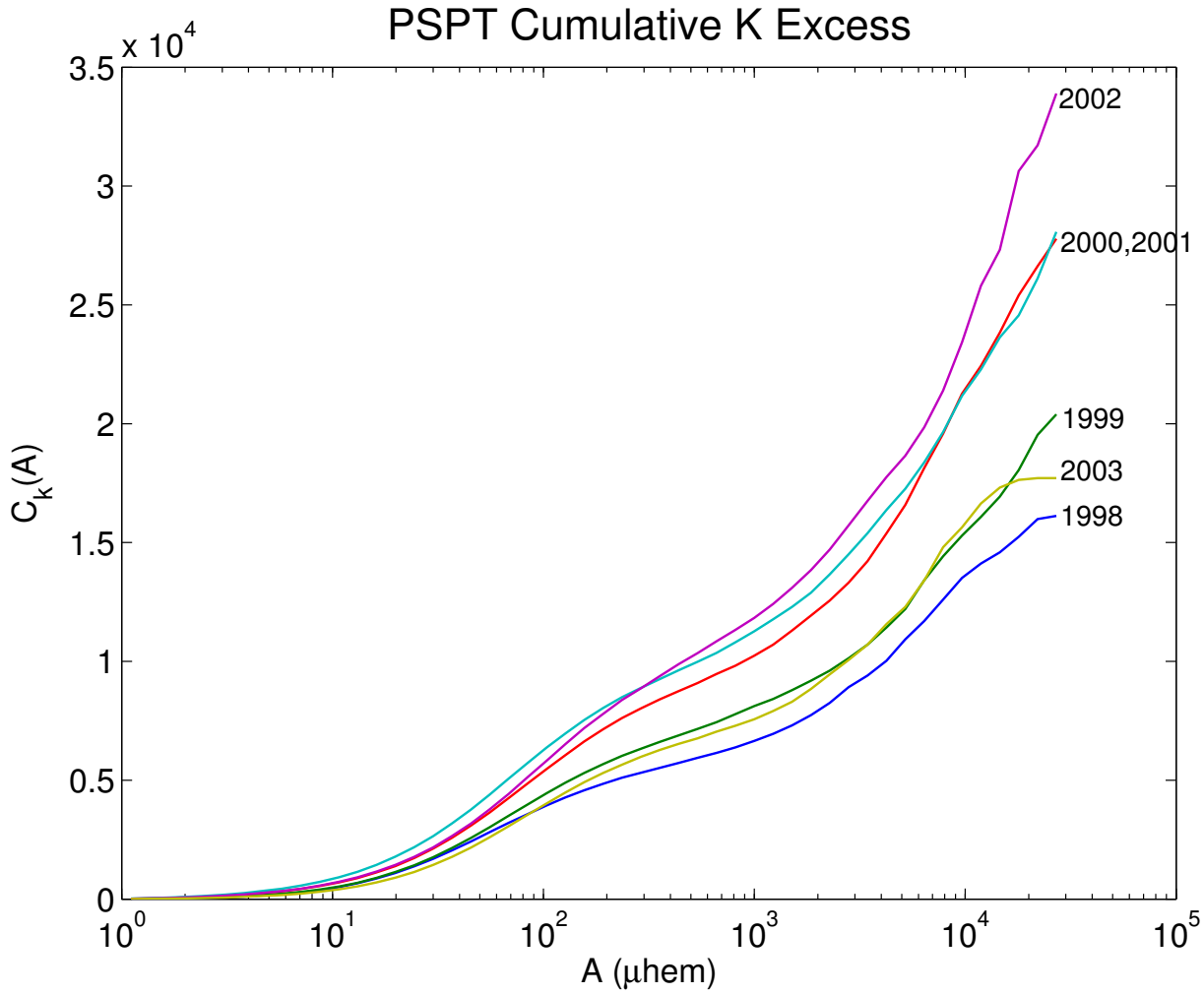
- Two-dimensional histograms (right) show number of bright regions in area-latitude bins
- Gray scale is $\log_{10}$ of number of regions in each (size,latitude) bin, per image
- Comparing PSPT to CFDT1,we see a similar pattern: regions larger than about $100\mu\mathrm{hem}$ are concentrated in activity belts
- This size was taken as the boundary between “network” and “facular” regions for comparison of each feature type’s contribution to total solar irradiance (S) variability



Distribution of bright regions on PSPT K images in 1998 with area and latitude.



Distribution of bright regions on CFDT1 K images in 1989 with area and latitude.



Above: each curve is the cumulative contribution to the Ca II K spectral excess of all regions that size or smaller for the indicated year. Essentially the entire difference between 1998 and 2002 is due to faculae ($A > 100\mu$hem).

Facular Excess for Small ($A < 100\mu\mathrm{hem}$) and Large Regions

Year	Total Excess (ppm/image)	Small Regions (ppm/image)	Large Regions (ppm/image)
1998	1.61×10^4	0.37×10^4	1.24×10^4
2002	3.50×10^4	0.54×10^4	2.96×10^4
Change	1.89×10^4	0.17×10^4	1.72×10^4

1998 is not quite at solar minimum. However, we see that the total change from 1998 to 2002 in the excess is dominated by the largest regions, with about 90% of the change from regions larger than $100\ \mu\mathrm{hem}$ in area.

Implications for Irradiance Changes

- A.M. Cookson (poster, this meeting) has modeled the total solar irradiance S during cycle 23 using these same PSPT data. Her results:
  - A model of the form

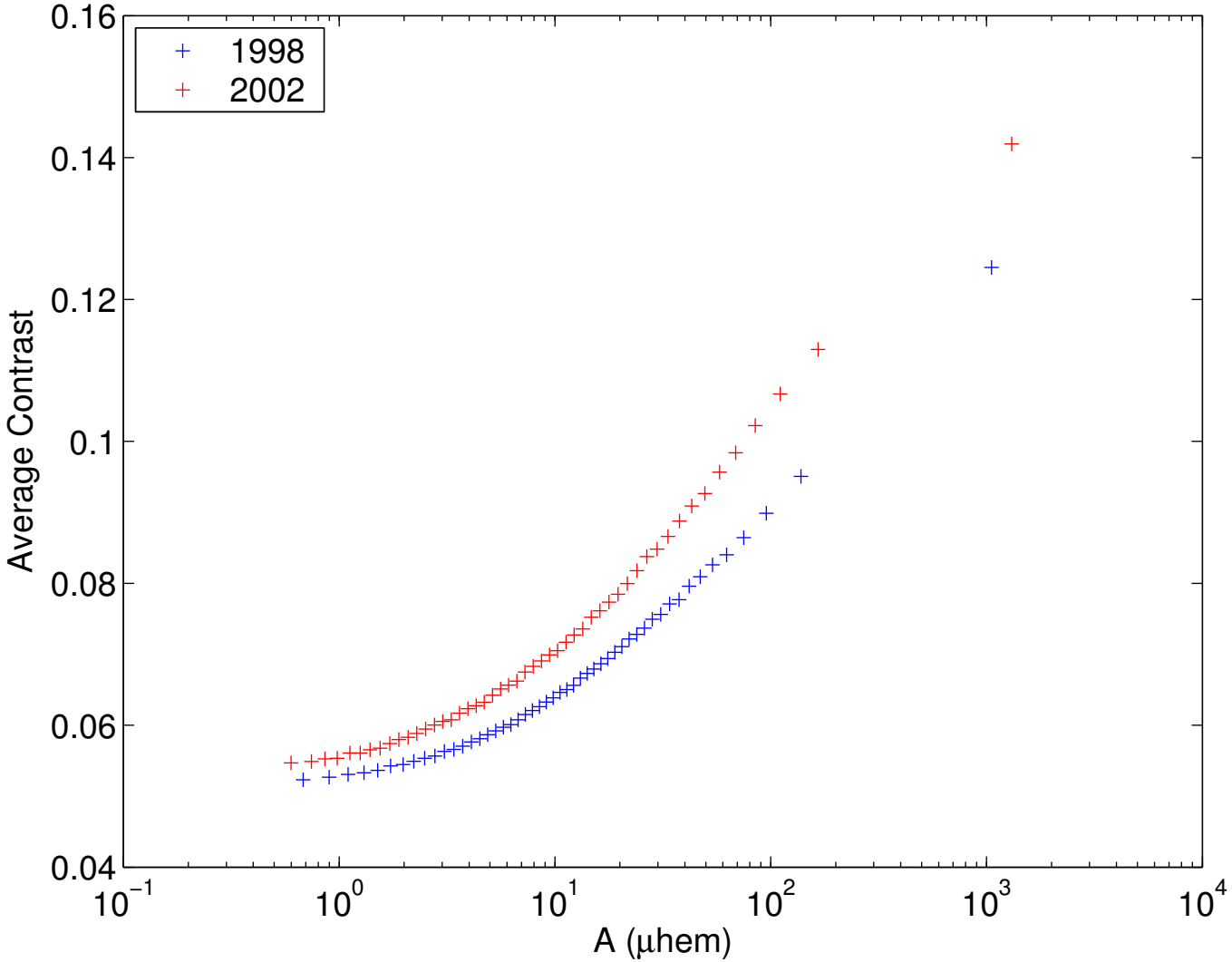
$$S = S_0 + a\Sigma_r + b\Sigma_K$$

    fits the data fairly well ($R^2 = 0.75$)
  - Σ_r and Σ_K are the *photometric sums*, and measure the relative change in spectral irradiance in the PSPT red and Ca II K filters, respectively
  - Σ_r is flat during the solar cycle
  - $\Rightarrow$ The Σ_K term represents the solar-cycle timescale change in S
- Combined with the results of this poster, we conclude that large faculae dominate the solar cycle change in S

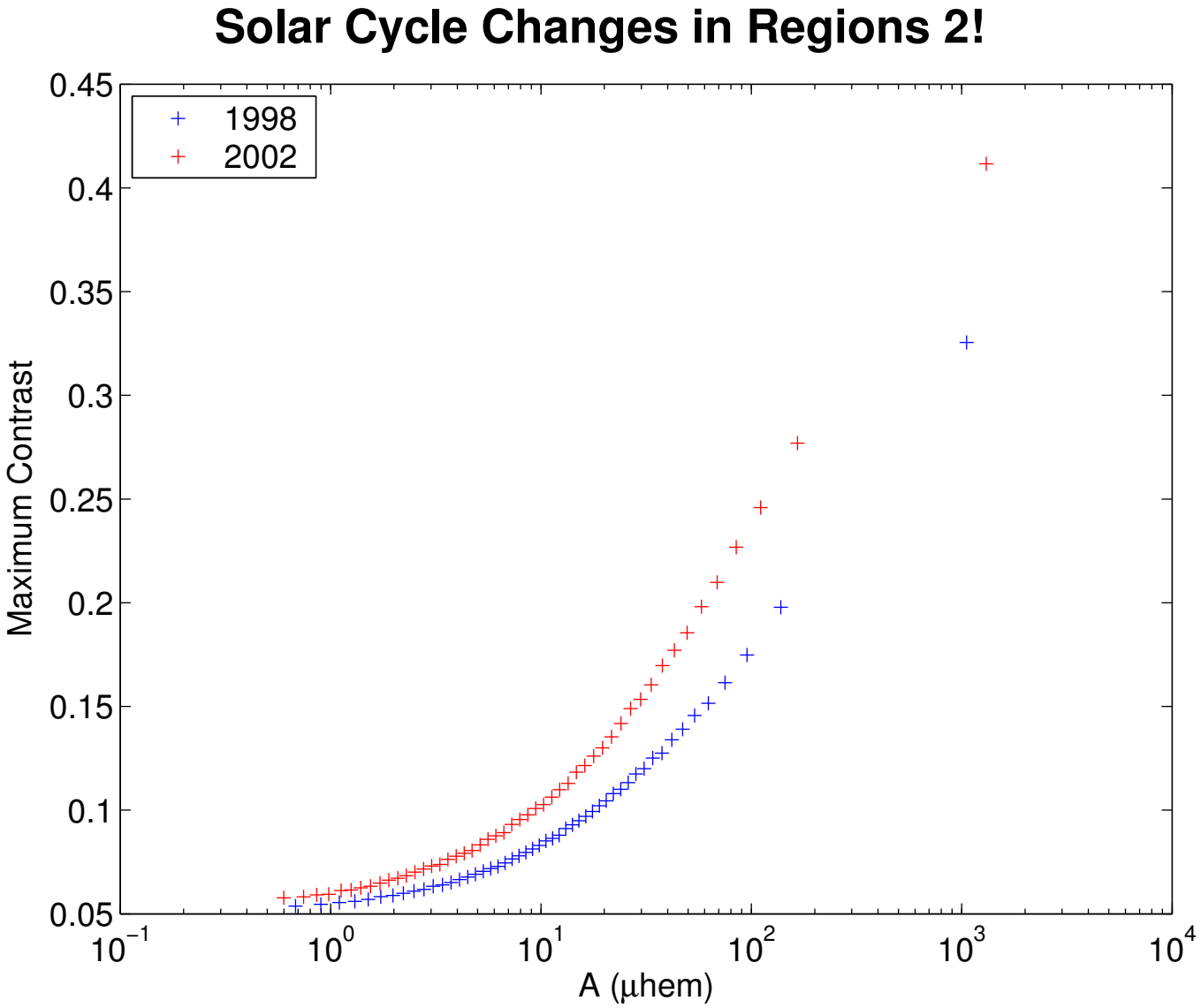
Solar Cycle Changes in Regions?

- Comparing $C_K(A)$ with dN/dA plots leads to the conclusion that, on PSPT images, faculae change during the solar cycle
- That is, if dN/dA is essentially the same in 1998 and 2002, but $C_K(A)$ is larger for a given A, regions of a given size must be systematically brighter in 2002 than in 1998
- This was tested by looking at the average contrast of regions as a function of their area for 1998 and 2002

Solar Cycle Changes in Regions!



Average contrast of bright regions in 1998 and 2002 as a function of region size, for all regions on PSPT images. Note the increase of about 15% in the contrast between these two dates for the largest regions.



Maximum contrast of bright regions in 1998 and 2002 as a function of region size, for all regions on PSPT images. An increase of about 25% in the maximum contrast is seen.

Acknowledgements

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