Two Mysteries of Solar Activity Indices:

#1.Why are RGO spot areas 40-50% larger than SOON and MWO areas? (quick review of Sol. Phys. 289, 1517;2014)

#2.Why are the 11 - yr behaviors of Ca K plage areas and WL facular areas so different?

Peter Foukal,

Heliophysics, Inc.

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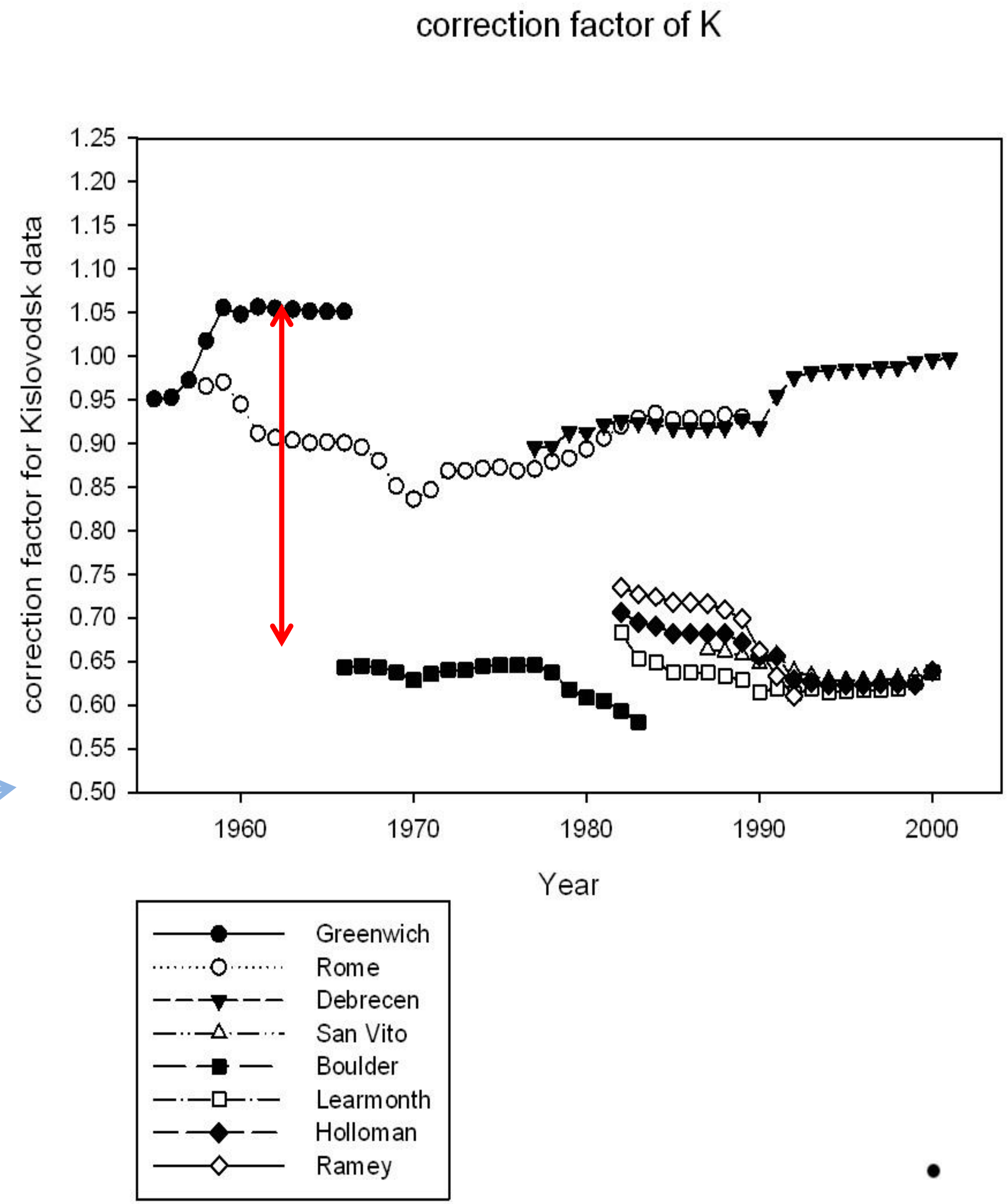
RGO and SOON

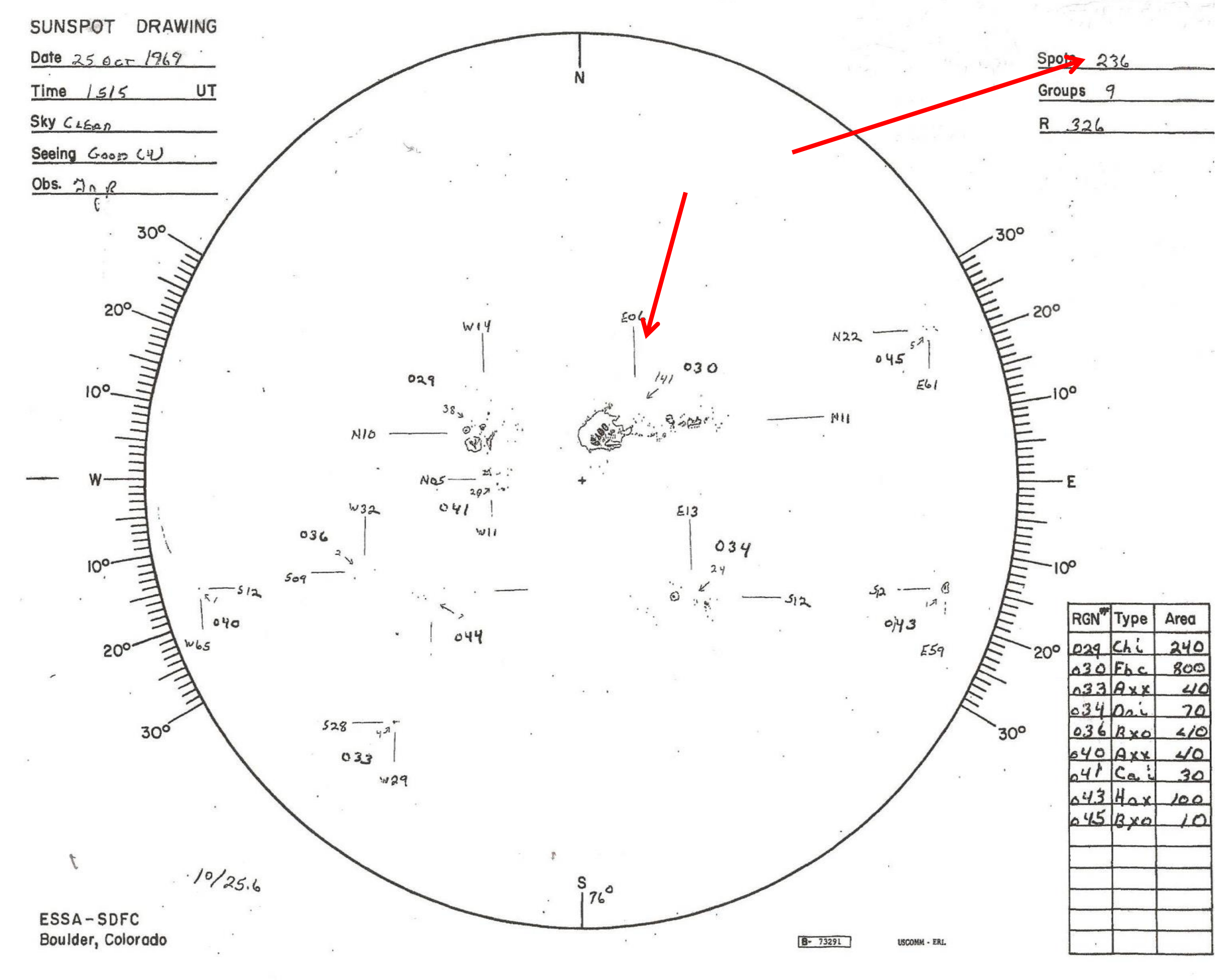
•RGO/SOON ~ 1.4 (Hathaway et al.,2002).

•This difference has existed since SOON measurements began in Boulder in 1966.

(from Baranyi et al., 2013).

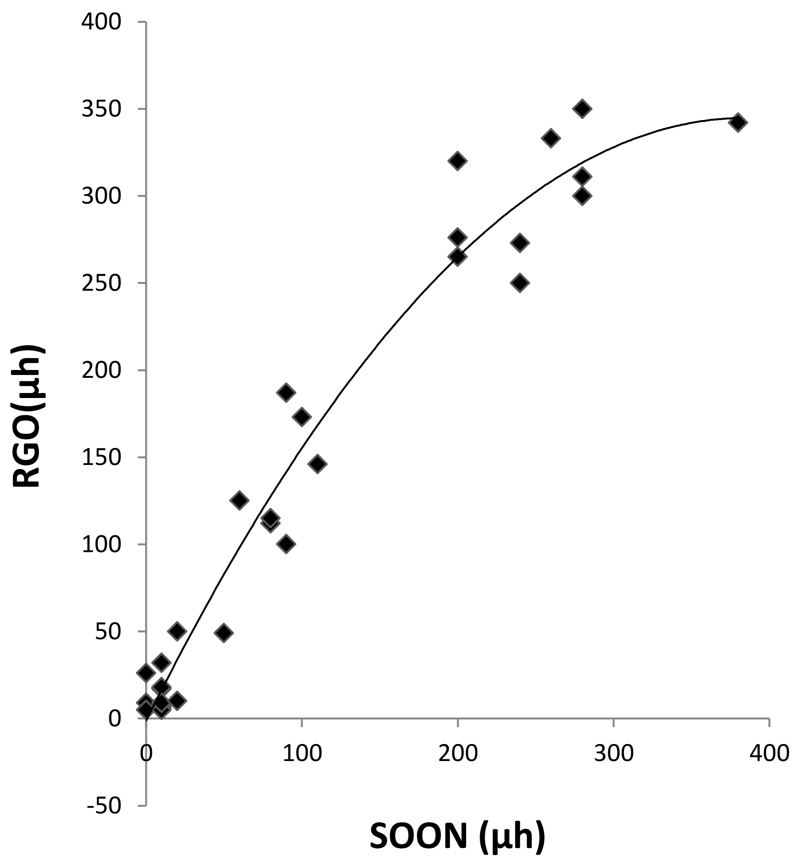


At high Rz, often > 100 spots on a SOON drawing *were marked only as dots*. Their areas were measurable on RGO plates.



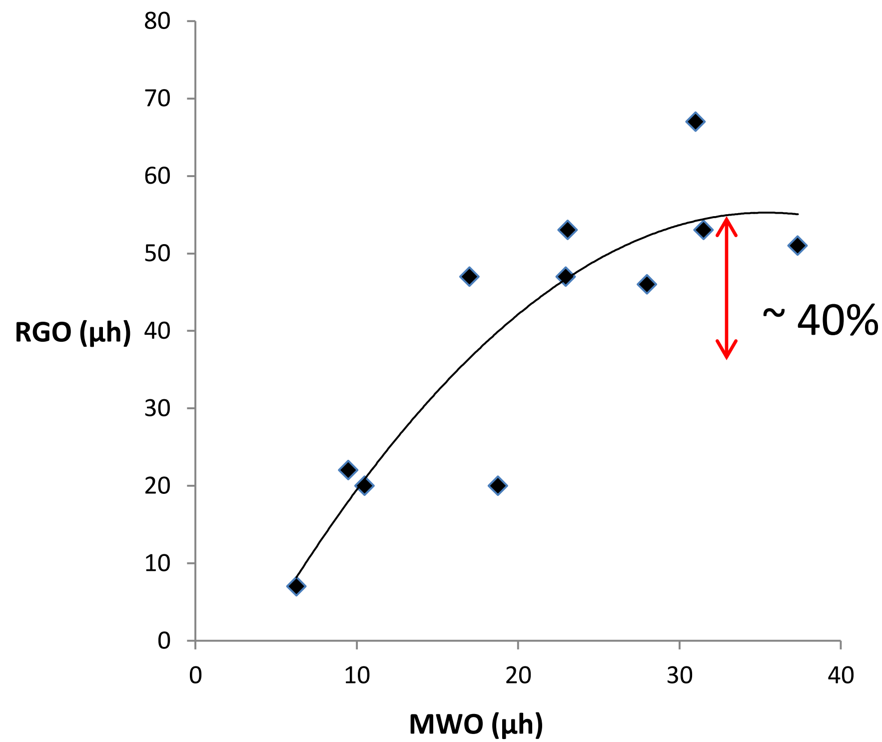
SOON's under-estimate of the smallest spots is not the only factor.

- The neglected area of < 10μh spots is sufficient to account for most of the difference between RGO and SOON areas.
- But RGO > SOON even for medium-sized spots (< 300μh). RGO ~ SOON for larger spots.
- For explanation, see below



Why is RGO/MWO (umbral areas) ~ 1.4?

- Difference first noted by Hathaway et al. 2002;
- Like SOON, MWO under- estimated smallest umbral areas. MWO (Howard et al. 1984) focused on solar rotation, not spot areas.
- Also, placement of their 0.3 mm thick cursor *inside* the umbral border under-estimates area by ~ 40% for largest umbrae, about as observed;
- A similar error may explain why SOON < RGO for all but largest spots. (N.B.: it is less serious for whole spots than for umbrae).



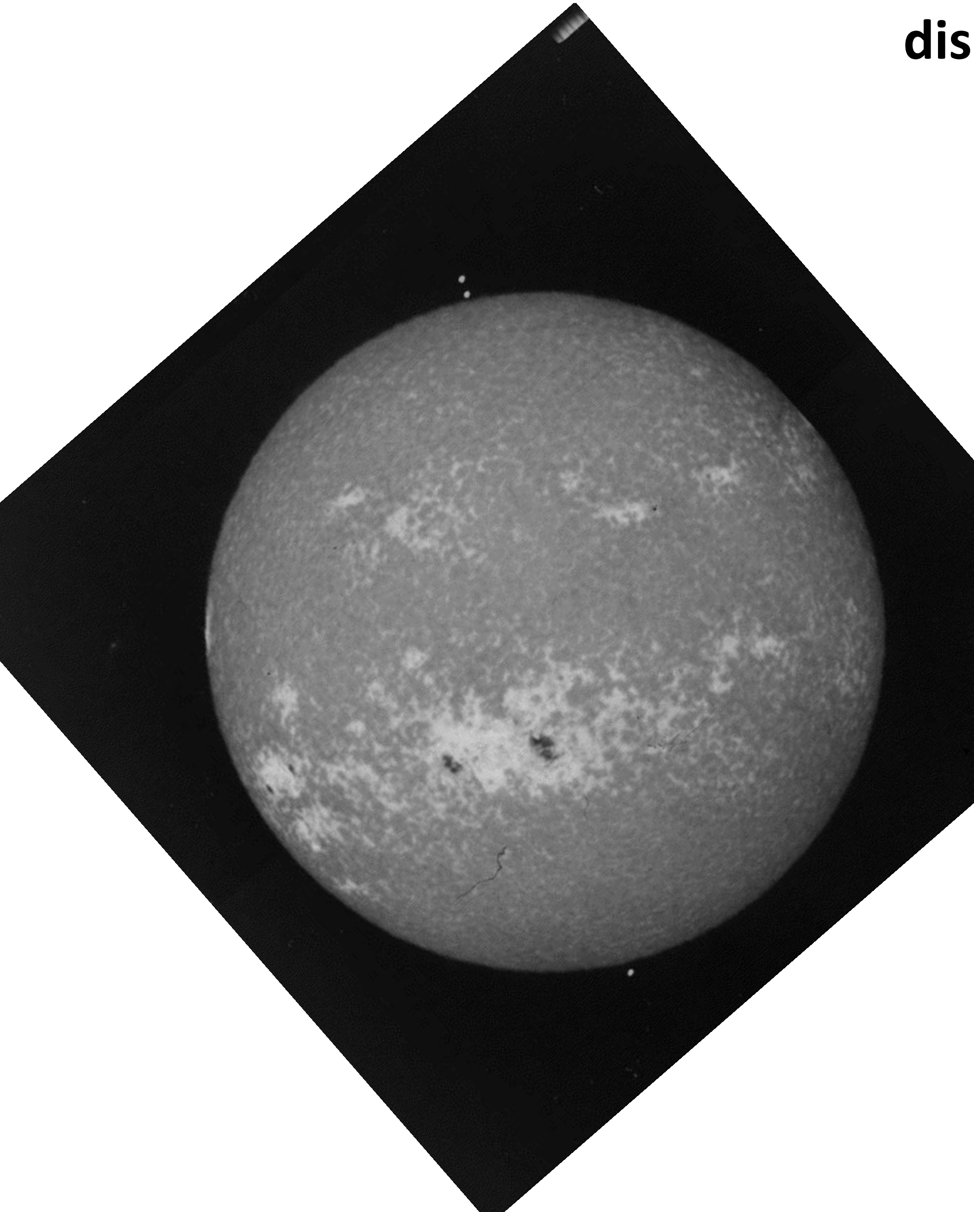
Implications of our RGO/SOON explanation for irradiance studies

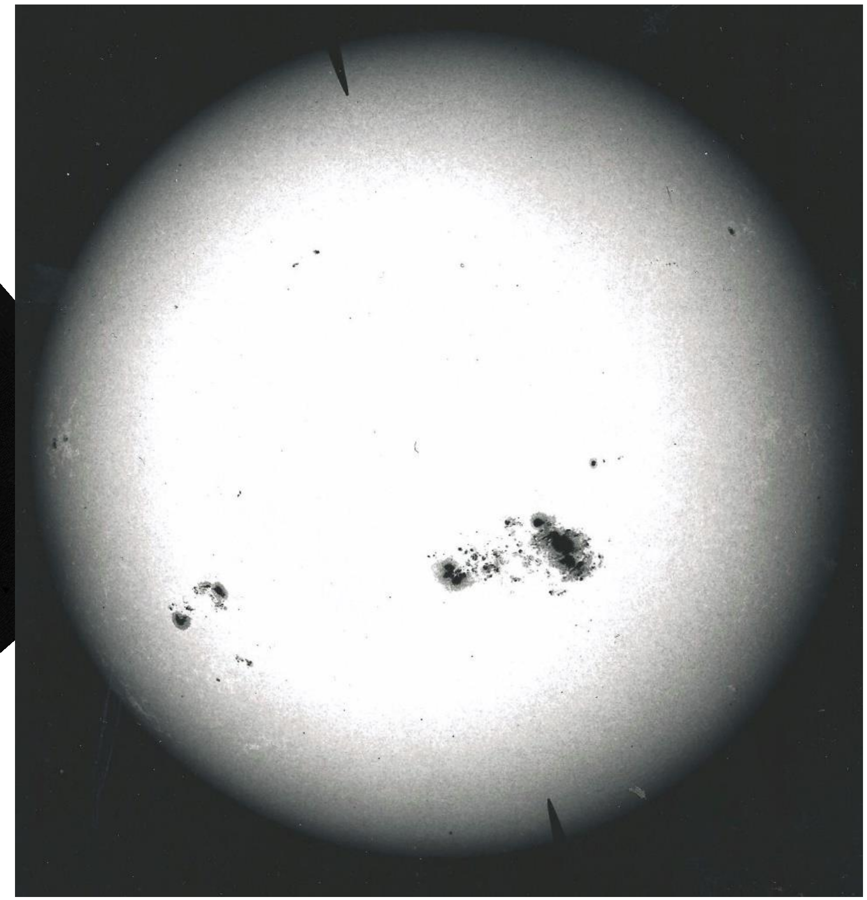
- Sunspot blocking calculated from RGO areas prior to 1976 should be decreased by a factor of ~ 0.8, reflecting the much (~ 5 x) lower *photometric contrast* of the small - spot component of the RGO areas.
- Upward correction of spot blocking calculated after 1976 from (uncorrected) SOON areas is appropriate because of SOON's under- estimated *area* of small spots. But because of their lower *contrast*, the correction factor is probably closer to ~ 1.2, than to the ~1.5 suggested by some recent purely statistical studies (e.g. Balmaceda et al. 2009).

Now, for something completely different…..

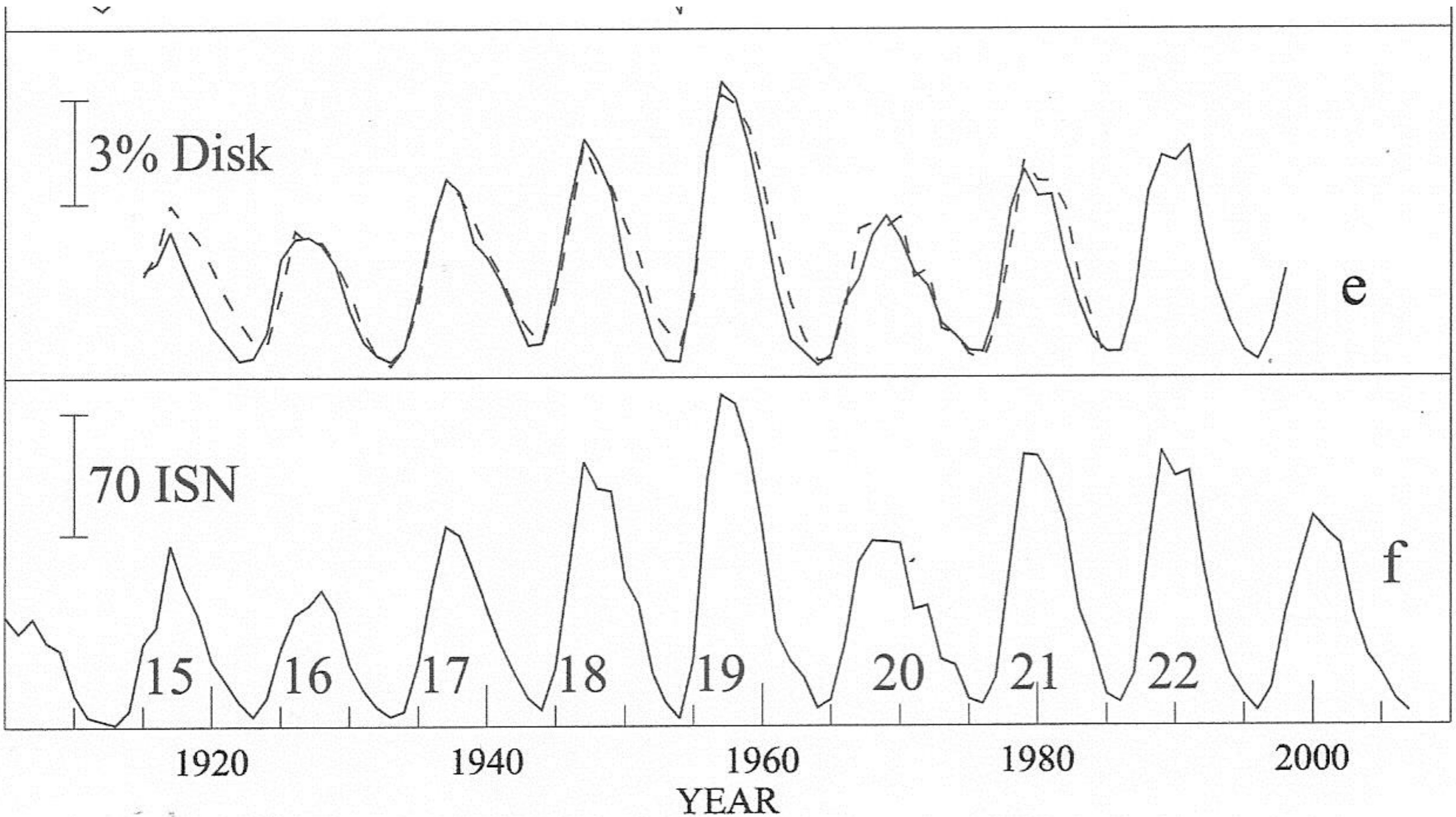
Mystery #2: If CaK plages delineate the chromospheric boundaries of WL faculae, why are their 11 – yr behaviors so different?

WL faculae consist of flux tubes *small enough* (Spruit, 1976) to be bright near the limb. Ca K plages cover them (plus larger flux elements not brightened near limb) and are visible across the whole disk.





Plage areas correlate *positively* with sunspot number even at highest activity in cycles 18,19.



RGO WL facular areas correlate *negatively* with spot area and Rz at highest activity(from Brown & Evans,1980)

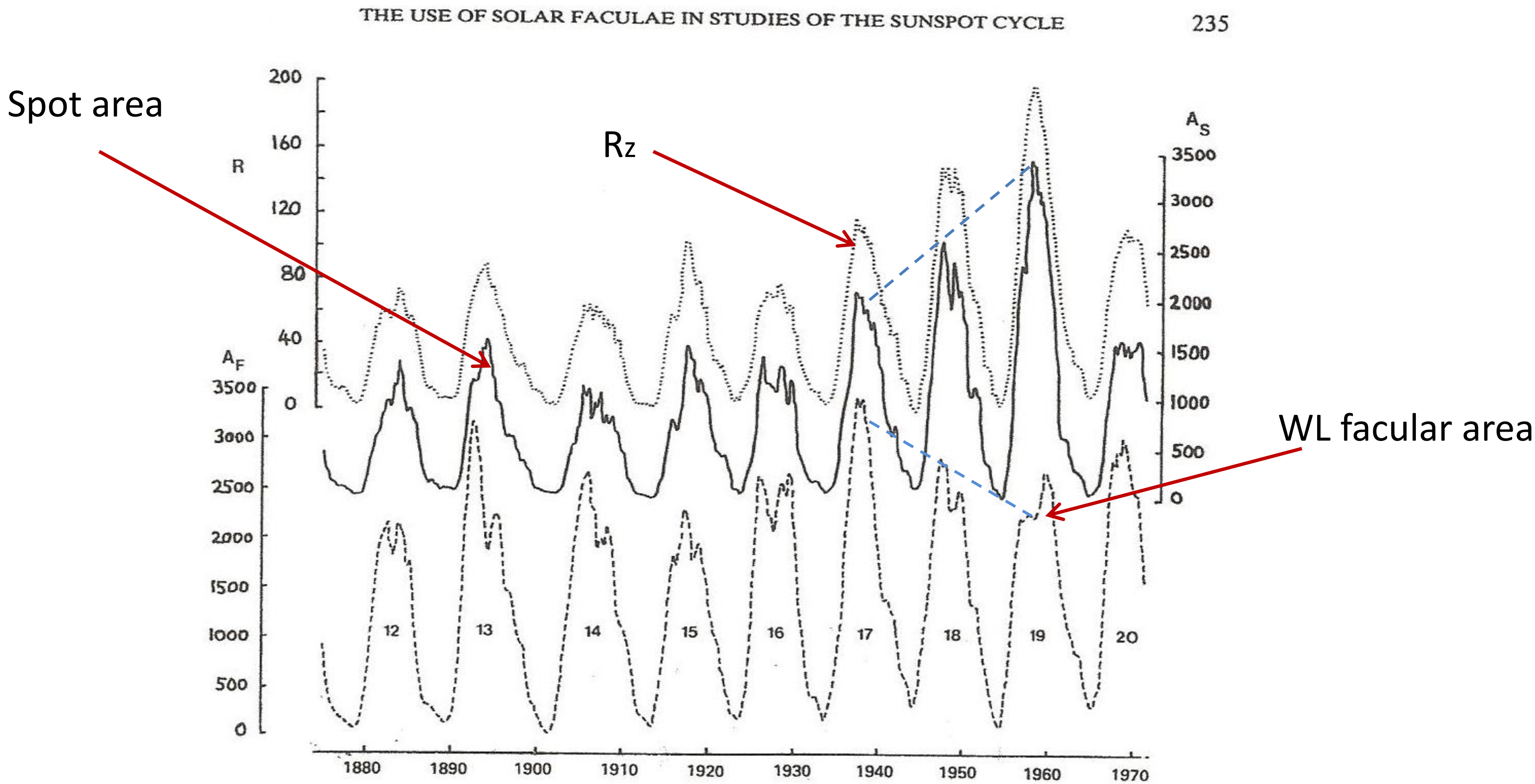


Fig. 1. Variation of 13-month running mean values of Zürich sunspot number R (upper curve), Greenwich sunspot areas A_S (centre curve) and Greenwich faculae areas A_F (lower curve), 1875–1972.

Several factors contribute to the relation between projected areas of WL faculae and CaK plages:

$$A_{pn} = \alpha\beta\gamma A_f + \beta A_s + \partial$$

A_{pn} = CaK plage area (in millionths of disk);

A_f = WL facular area;

A_s = sunspot area;

α= correction for limited zone of facular visibility near limb;

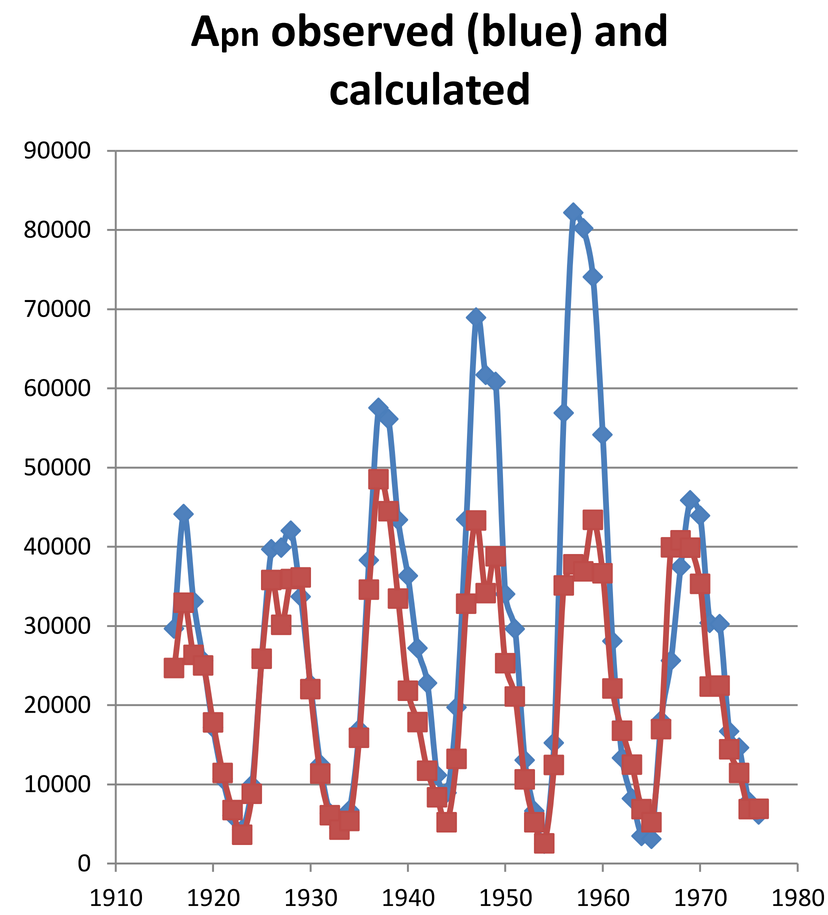
β = correction for increased area of a plage (or spot) in CaK relative to the corresponding facula or spot in WL;

γ = correction for area projection = $\int \mu d\mu$, where $\mu = \cos\theta$, θ = heliocentric angle;

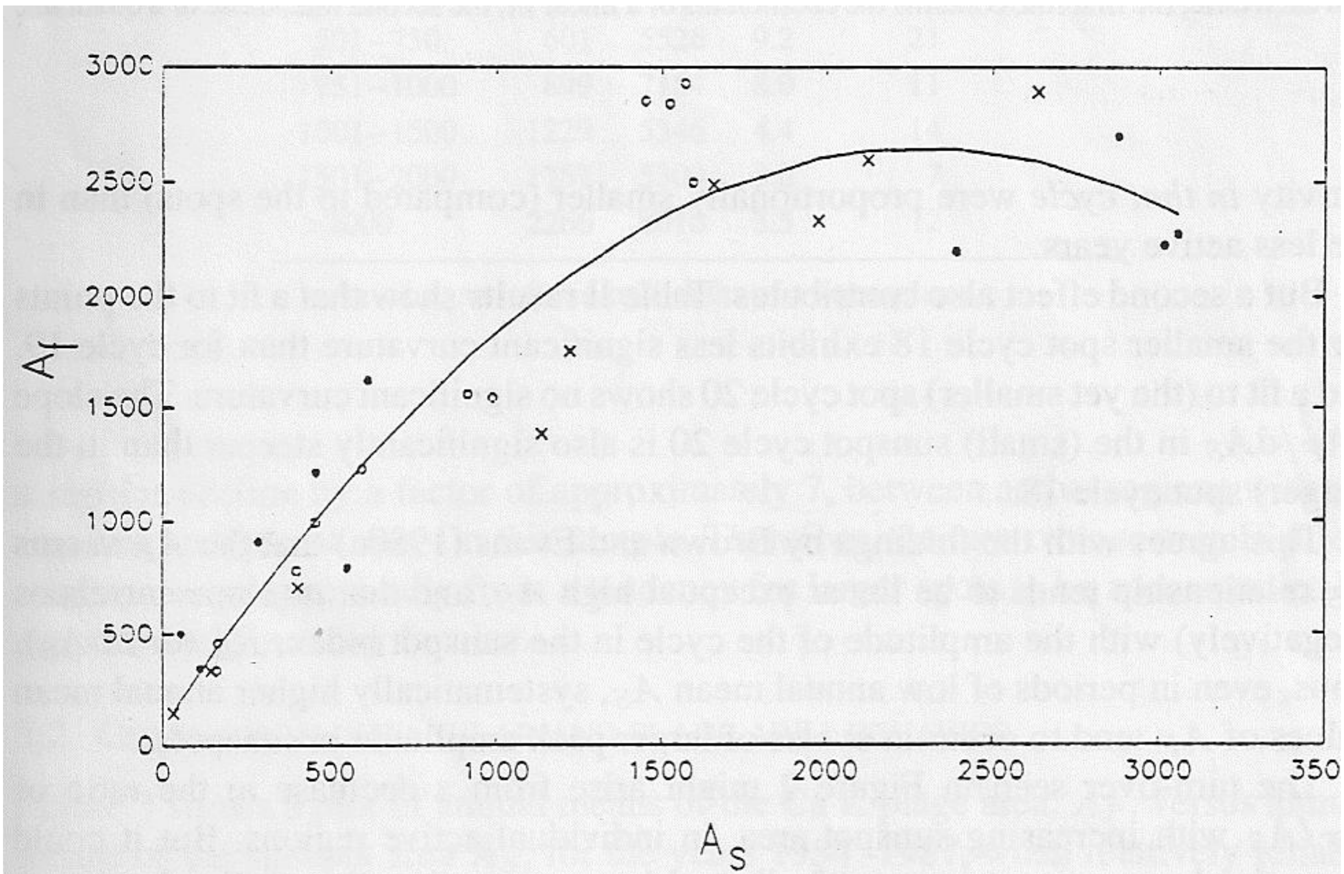
∂ = correction for Ca K plages too weak to appear as WL faculae.

The correction factors, αβγ and ∂, are insensitive to activity level. So area of *smallest* flux tubes must ↓while area of *all* flux tubes ↑ to explain difference between observed and calculated A_{pn}

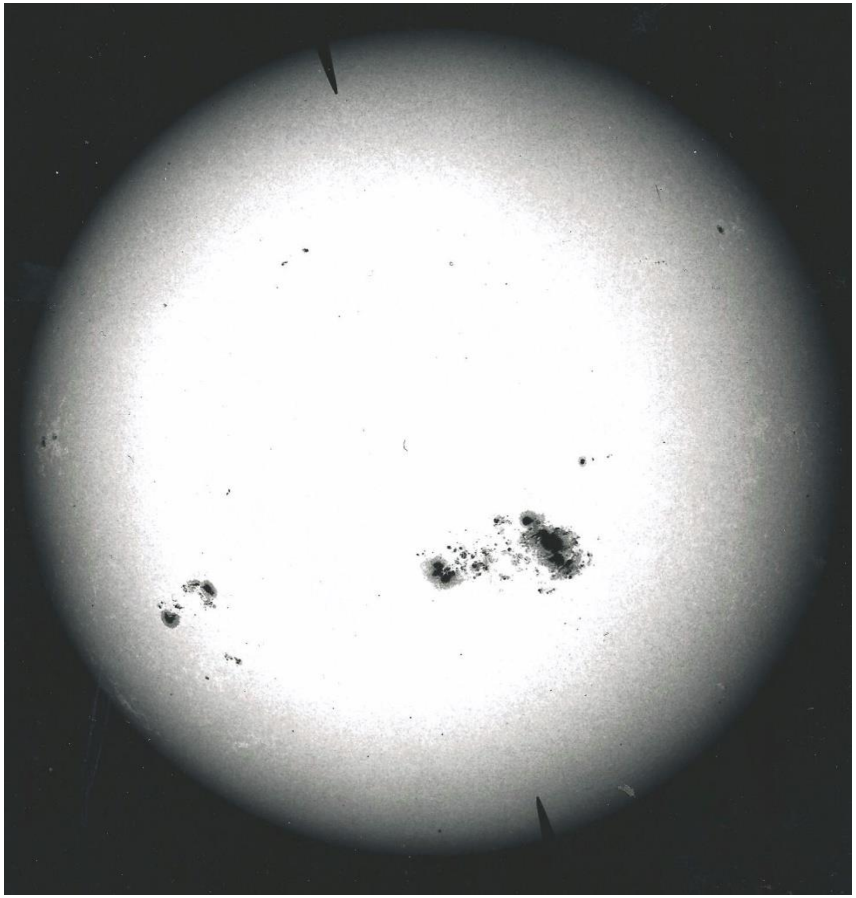
- α ~ 2 (geometry; visible zone: heliocentric θ> 35 deg.);
- β ~ 2.8 (measured directly from faculae, plages;
- γ ~ 2.5 (from integration of $\mu\int d\mu$ between θ = 0 to 35;35 to 80 degs);
- ∂ ~ 725 (from y – intercept of A_{pn} regressed versus A_f)

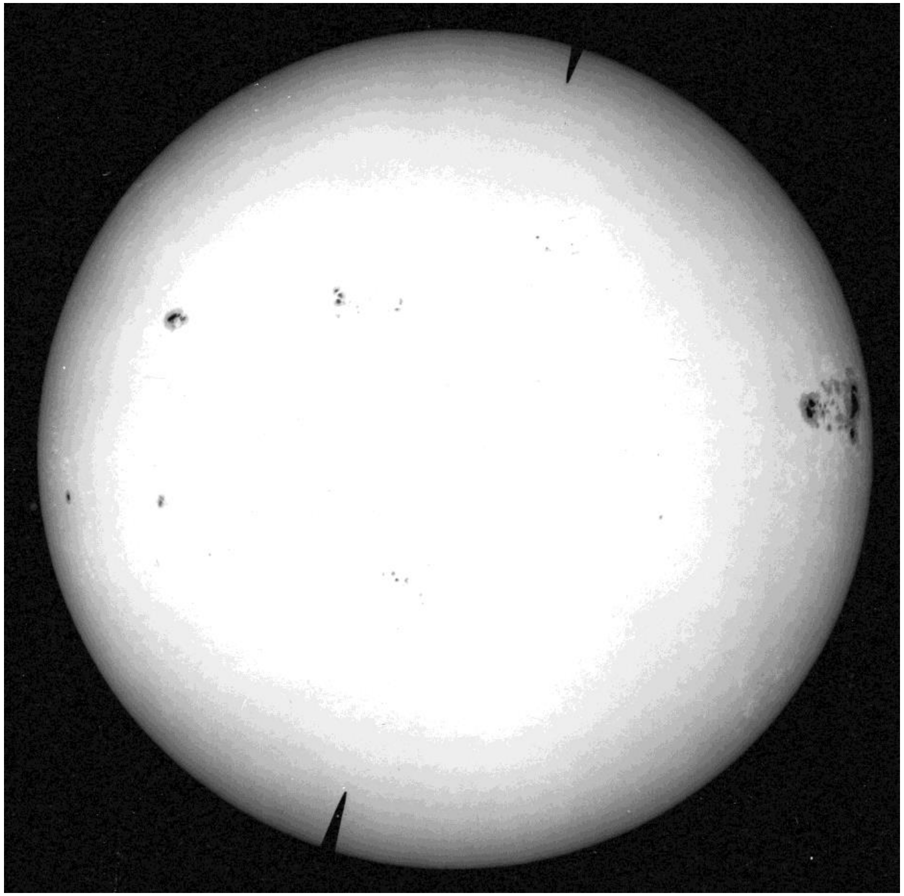


This agrees with: Ratio of WL facular areas to *sunspot* areas decreases at highest activity in cycles 18,19 (Foukal,1993).



Huge spots (e.g. April, 1947) are not accompanied by proportionately huge faculae





An explanation of Mystery #2

- At the highest levels of solar activity, the distribution of photospheric magnetic flux tubes shifts toward larger sizes. That is, away from WL faculae and toward pores and spots.
- So, around the peaks of cycles 18 and 19, magnetic flux *appears increasingly in flux tubes too large to be bright near the limb*, but observable as Ca K plages on the disk.
- This is why Ca K plage areas (and also other chromospheric/T-region indices like F10.7, Mg II, Ly alpha) that include flux tubes extending into the sunspot size range, correlate positively at all activity levels, while the area occupied by WL faculae decreases at the highest activity levels.
- Attention to the *physical basis* of solar activity indices can yield important new insights into stellar magnetism and dynamos.