Preliminary Results of Automatic Identification of Sunspots in HMI/SDO data

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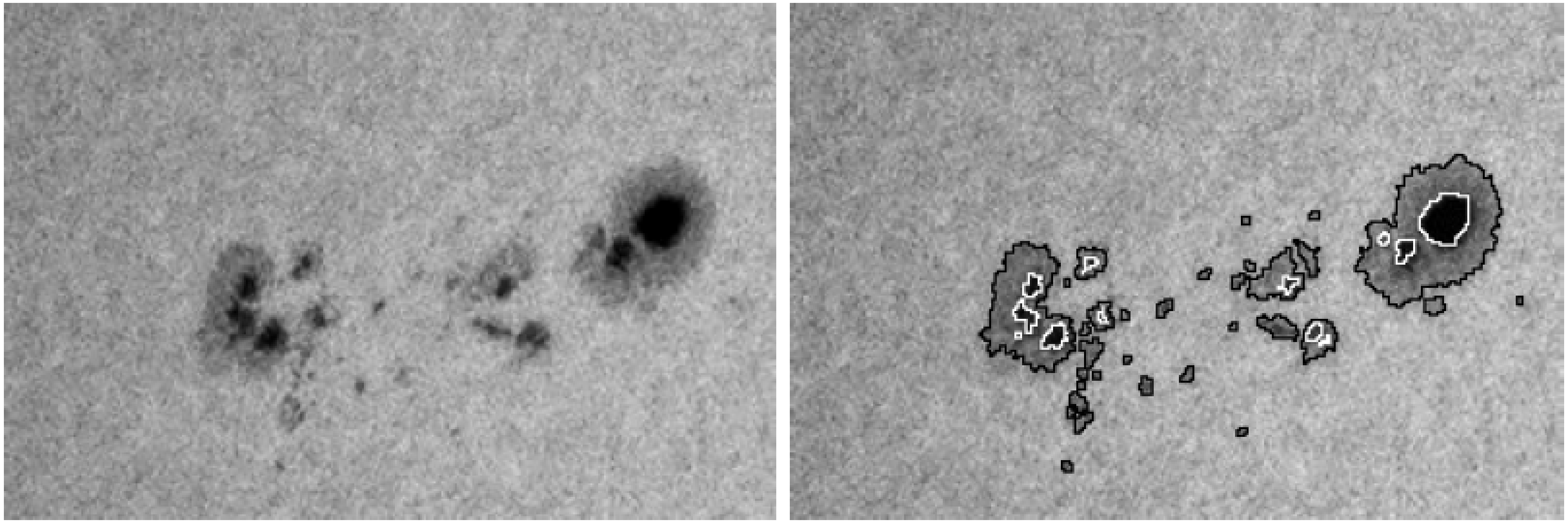
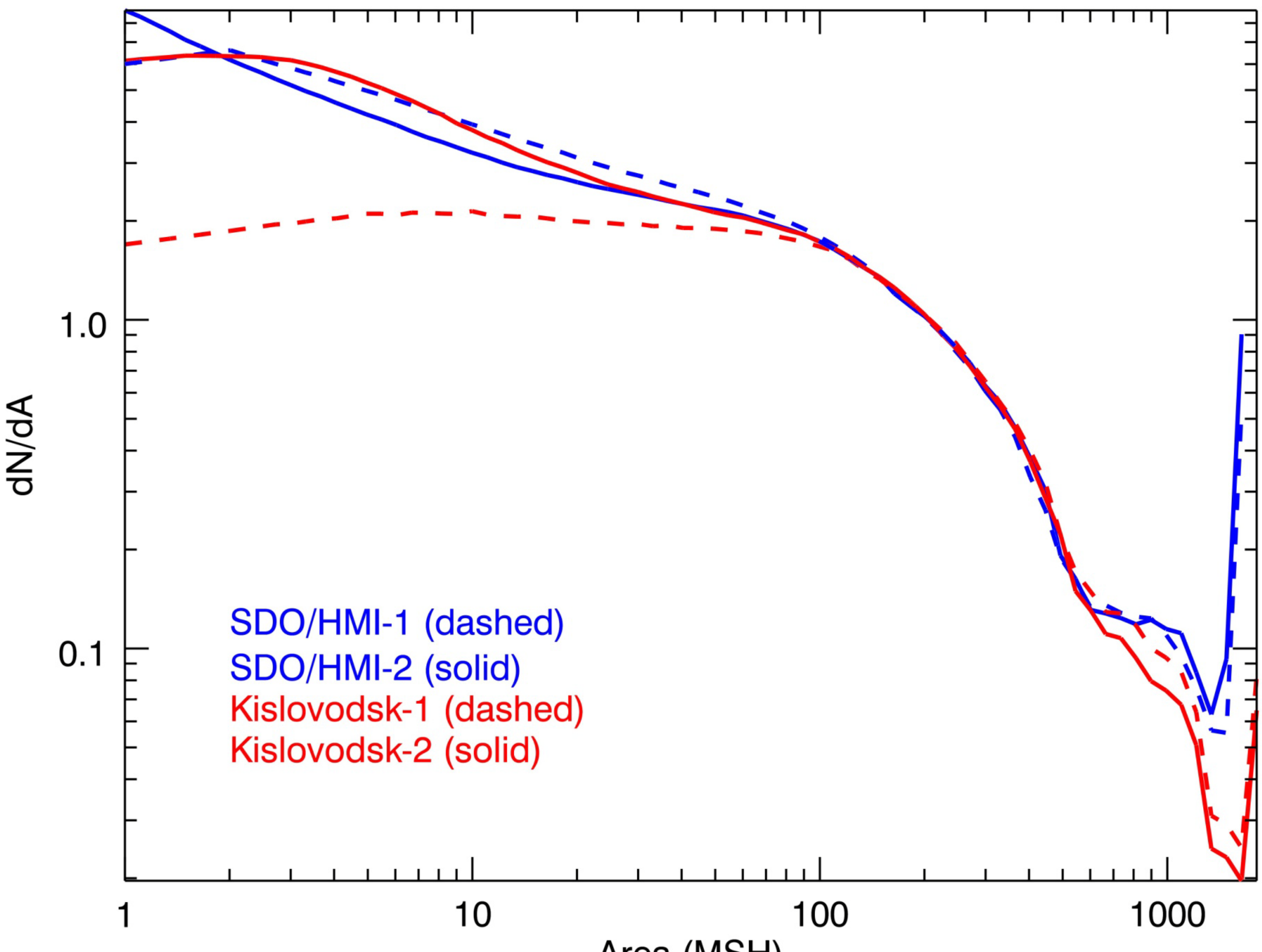
Method

- Determine center-to-limb variation of intensity.
- Identify features using criteria, which combine intensity threshold and “border method” (intensity gradient).
- “grow” features by adding boundary pixels (based on intensity gradient)



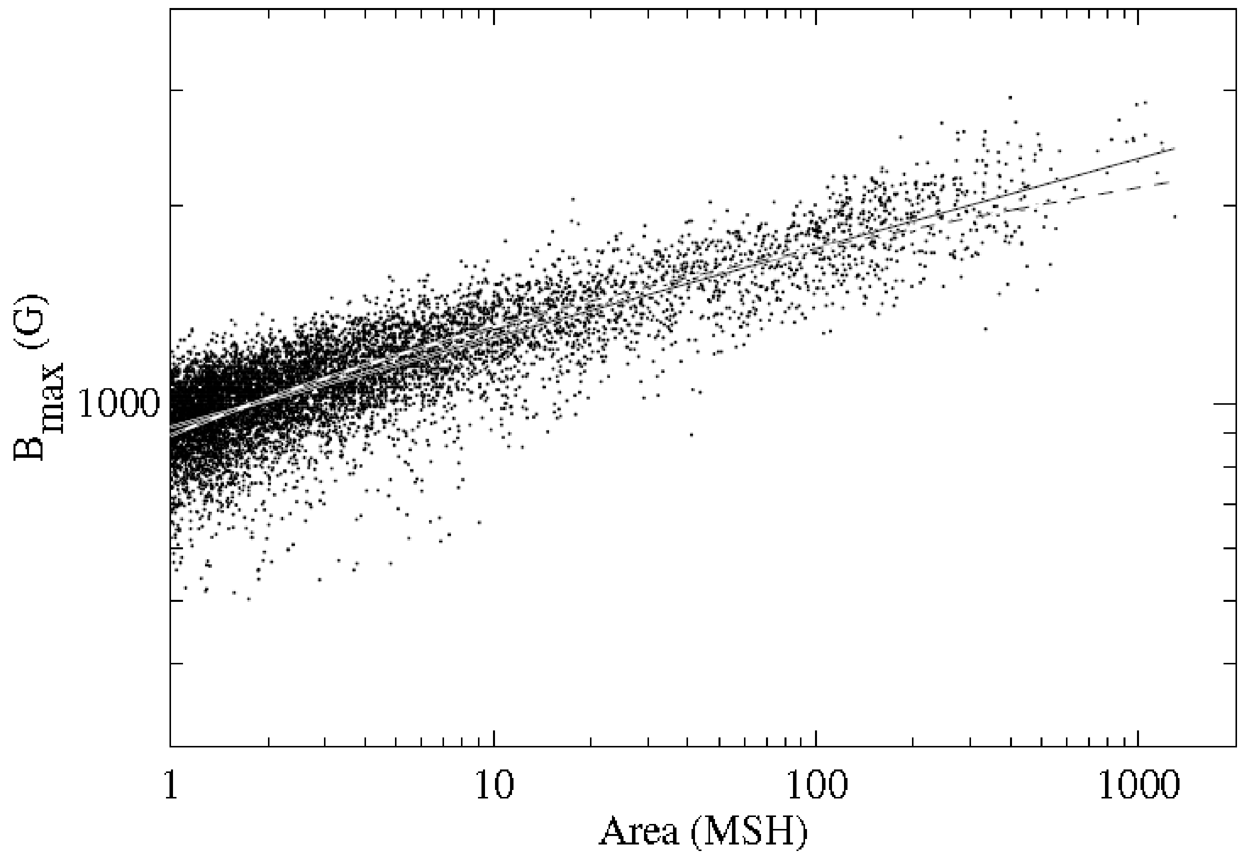
Data Set

- HMI/SDO daily observations in quasi-continuum (hmi.Ic 45s) during June 2010 – September 2012; one image per day (taken at 5:00 UT) is used.
- Total number of features 14094 sunspots and pores.
- Limited sunset of $r/R < 0.5$ (within 30 degrees from disk center): 4874 features: 3184 pores and 1690 sunspots.



SDO/HMI-1 (dashed)
SDO/HMI-2 (solid)
Kislovodsk-1 (dashed)
Kislovodsk-2 (solid)
dN/dA
1.0
0.1
1
10
100
1000
Area (MSH)

Area - Bmax



log(A) - linear(BMAX)

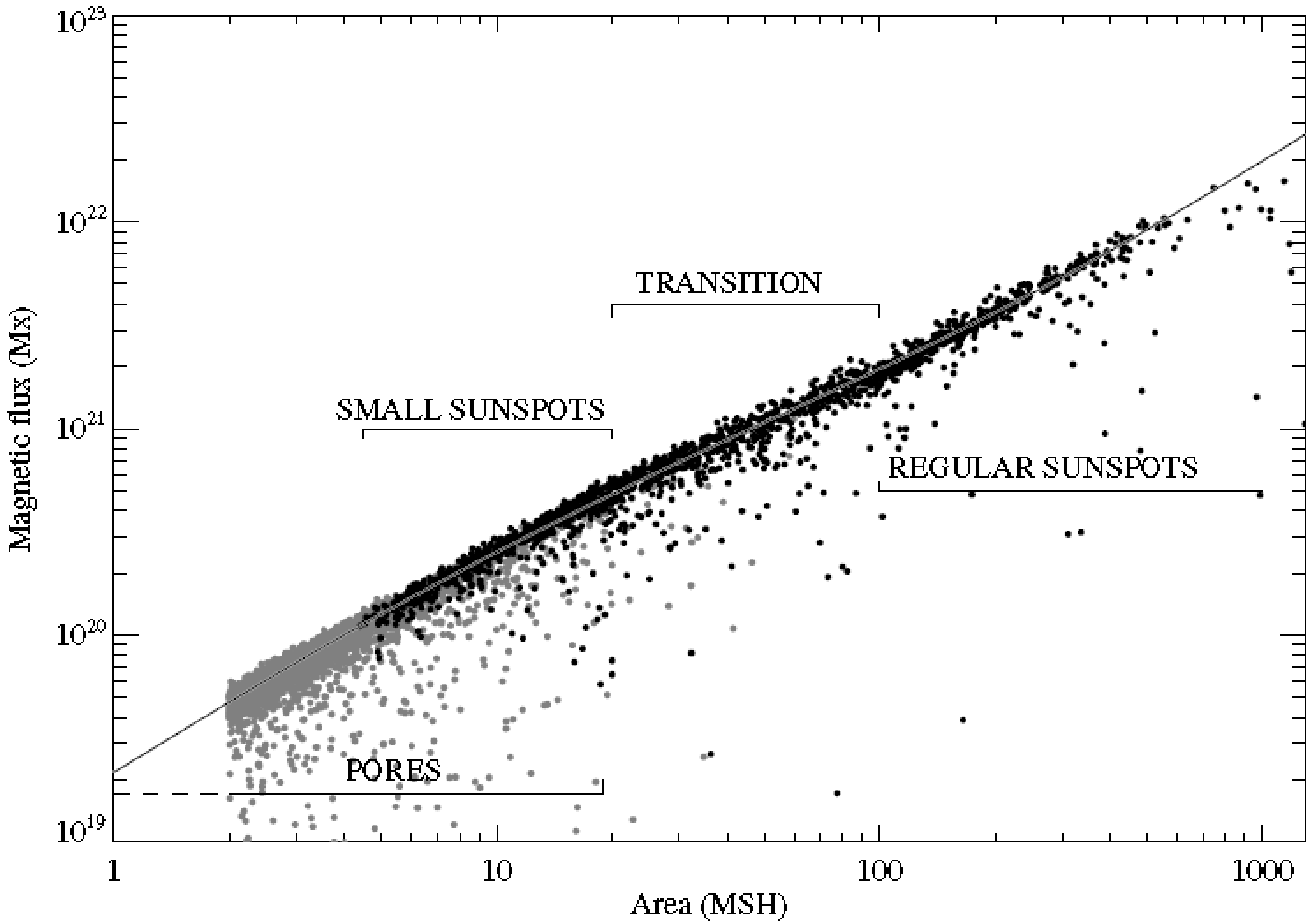
log(A) - log(BMAX)

Area - Bmax

-Ringnes and Jensen (1960); Pevtsov et al (2013): stronger sunspot cycles show steeper log (A) ~ f(Bmax) dependency , e.g. Cycle 15 - 980, Cycle 16 - 970, Cycle 17 - 1410, Cycle 18 - 1610, and (rise of) Cycle 19 -1710.

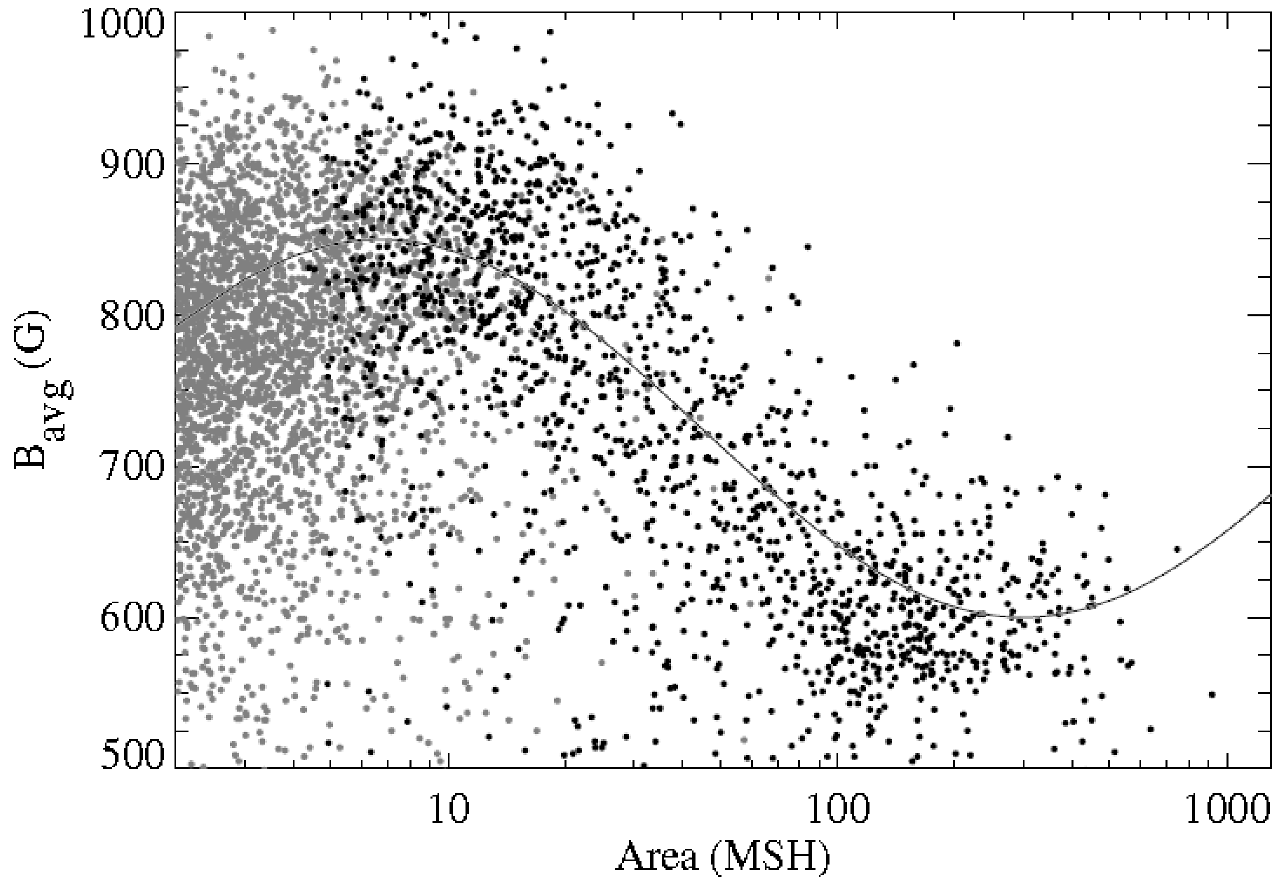
- While there is no physical model explaining the observed functional relation-ship between magnetic field and area of sunspot, log(A) -log(BMAX) relation-ship can be derived from the distribution of magnetic field of magnetic dipole situated at a certain depth below the photosphere (Ikhsanov, 1968). Dipole field was found to be a good representation of sunspot magnetic field (Bumba, 1960; Skumanich, 1992).

Area-Flux



10^{23}
10^{22}
10^{21}
10^{20}
10^{19}
Magnetic flux (Mx)
TRANSITION
SMALL SUNSPOTS
REGULAR SUNSPOTS
PORES
1
10
100
1000
Area (MSH)

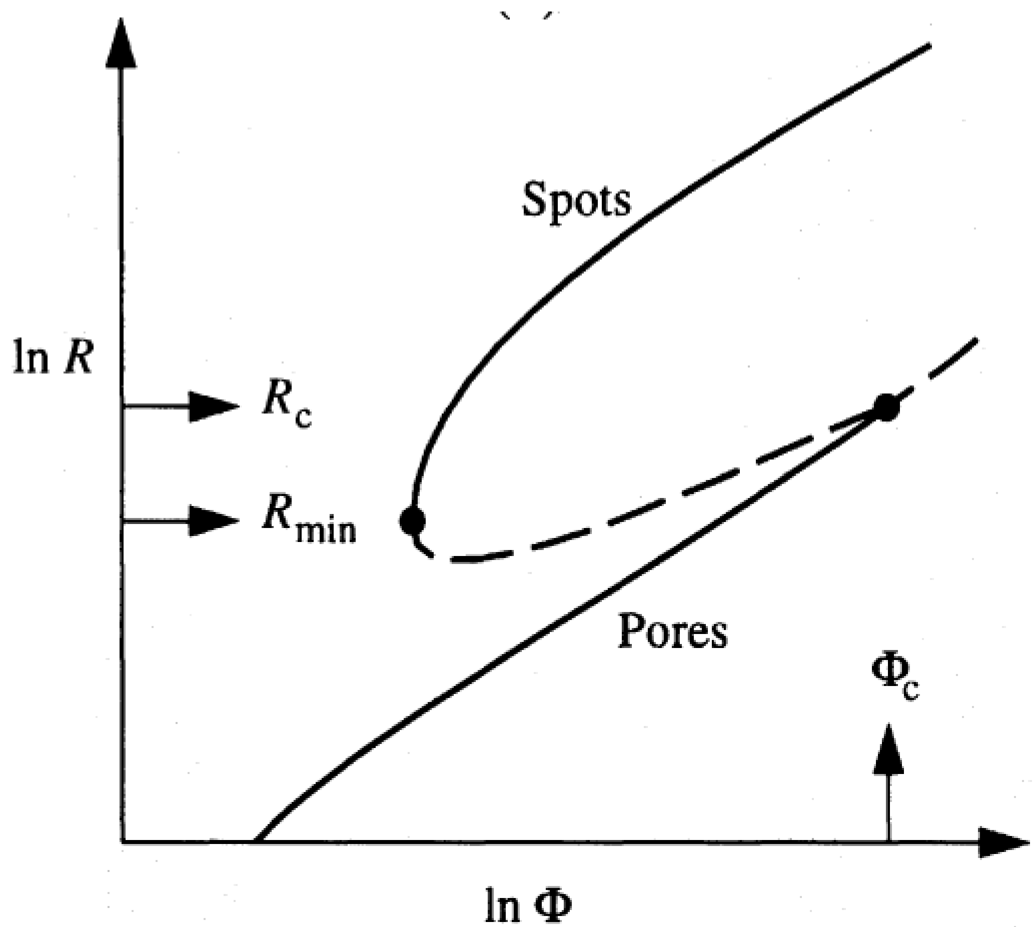
Average B - Area



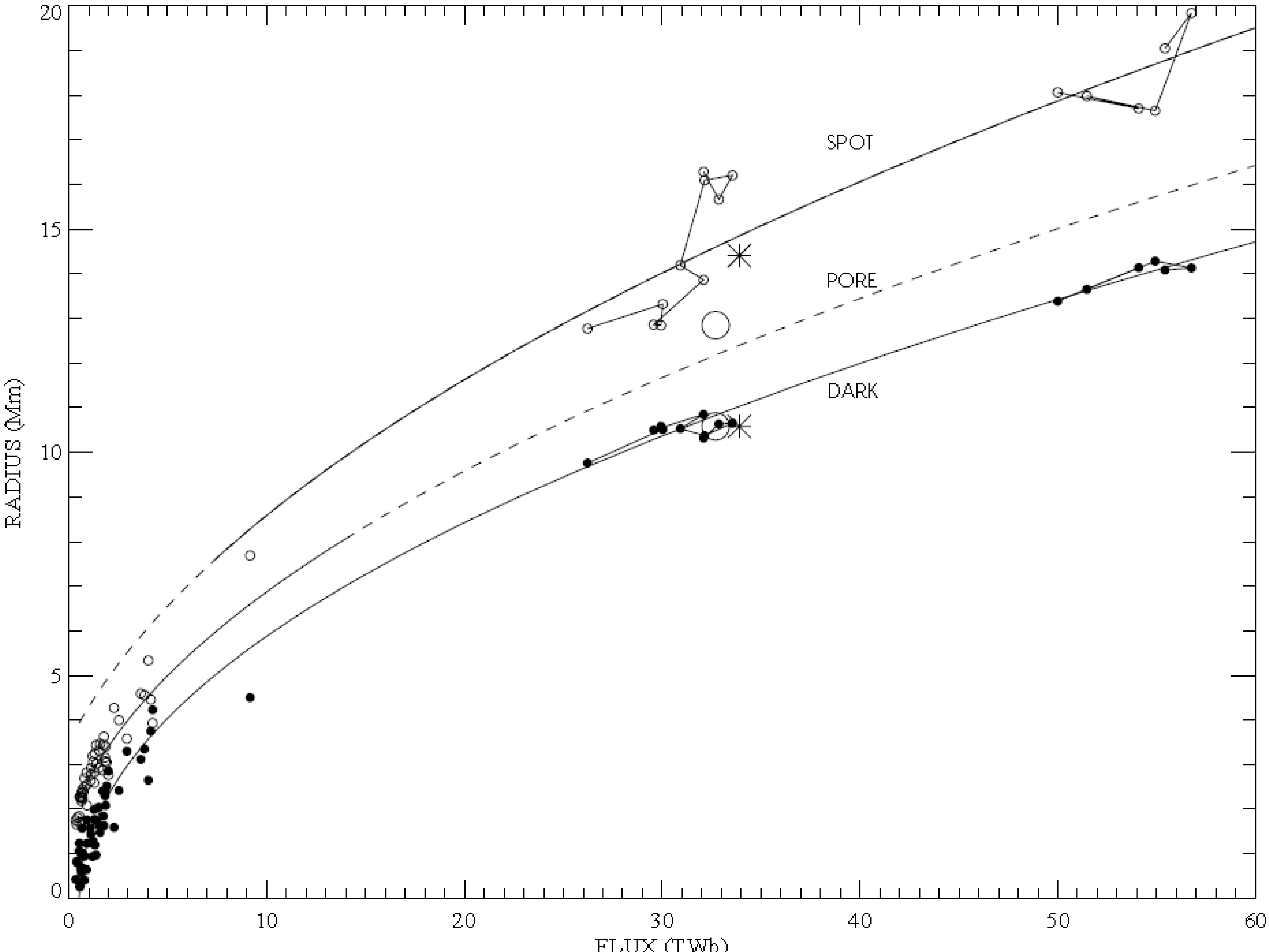
Area - Flux

- Smallest sunspots ~4.5 MSH=4.2Mm diameter
- Largest pores ~19 MSH=8.5 Mm diameter
  Bray and Loughhead (1964): smallest sunspot ~3.5 Mm in diameter and largest pores ~7 Mm
- Rucklidge, Schmidt, and Weiss (1995) – model of abrumpt development of penumbra
- Skumanich (1999): dipole field model; sunspots and pores evolve along the same area-flux dependency

Area - Flux

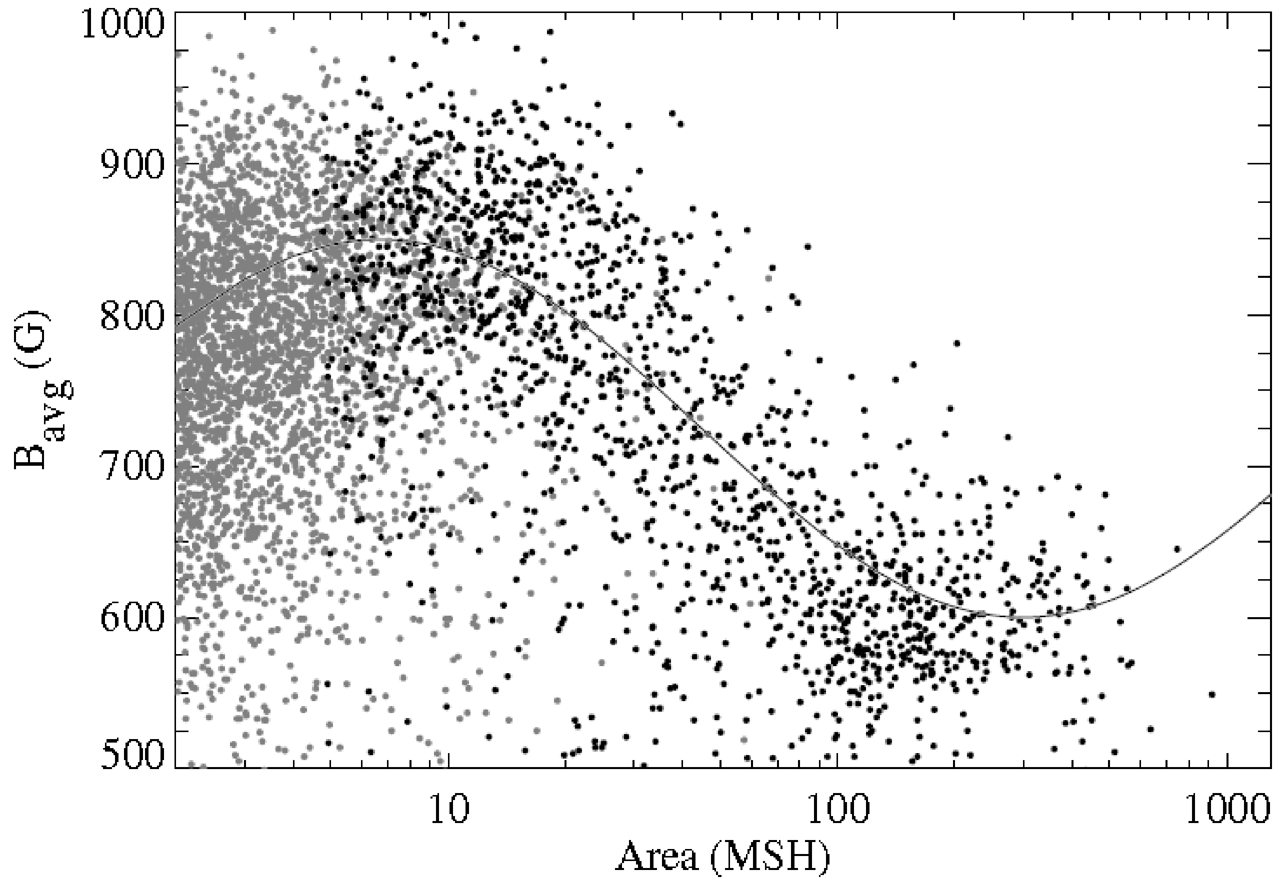


Rucklidge, Schmidt, and Weiss (1995)

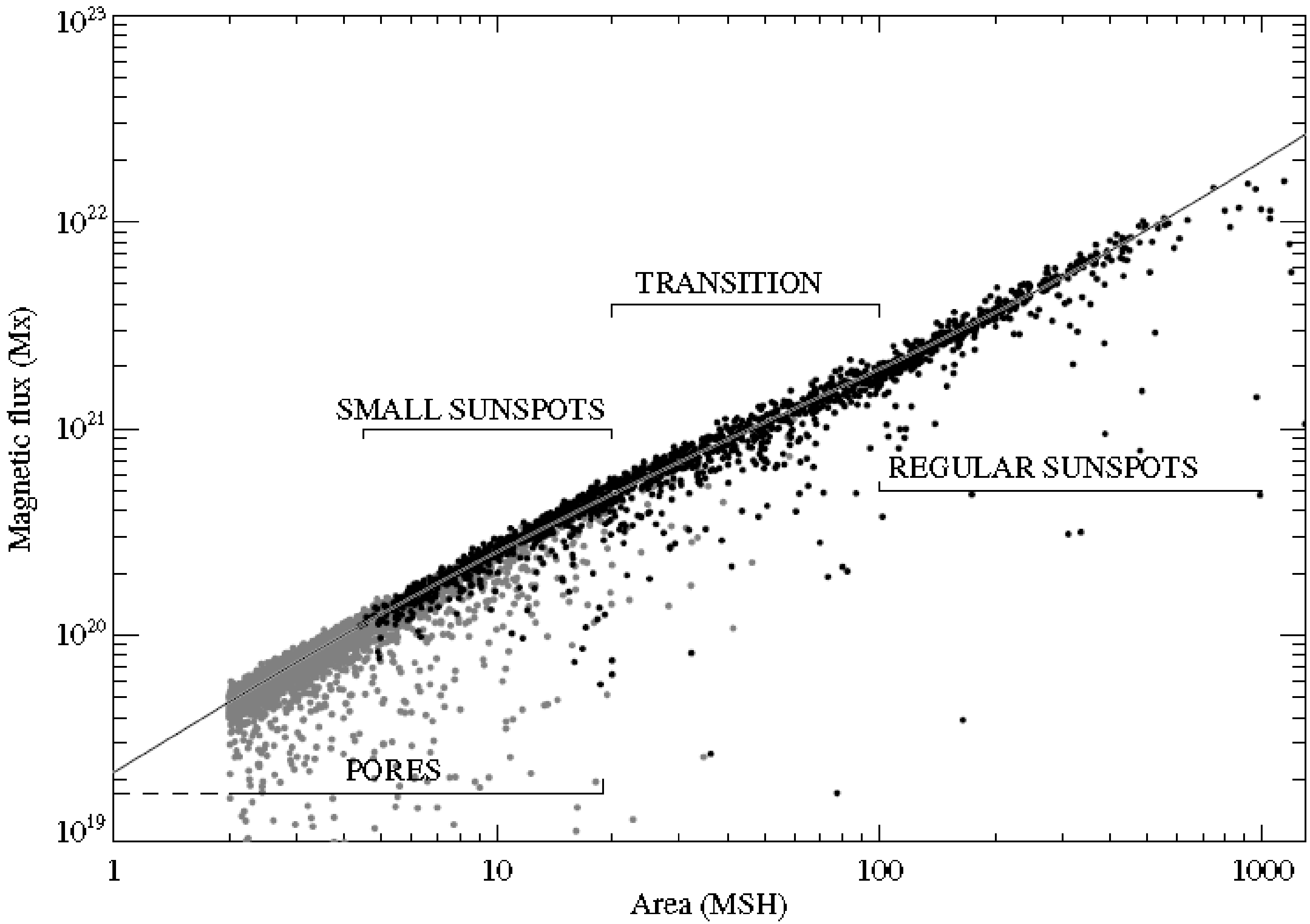


Skumanich (1999)

Average B - Area

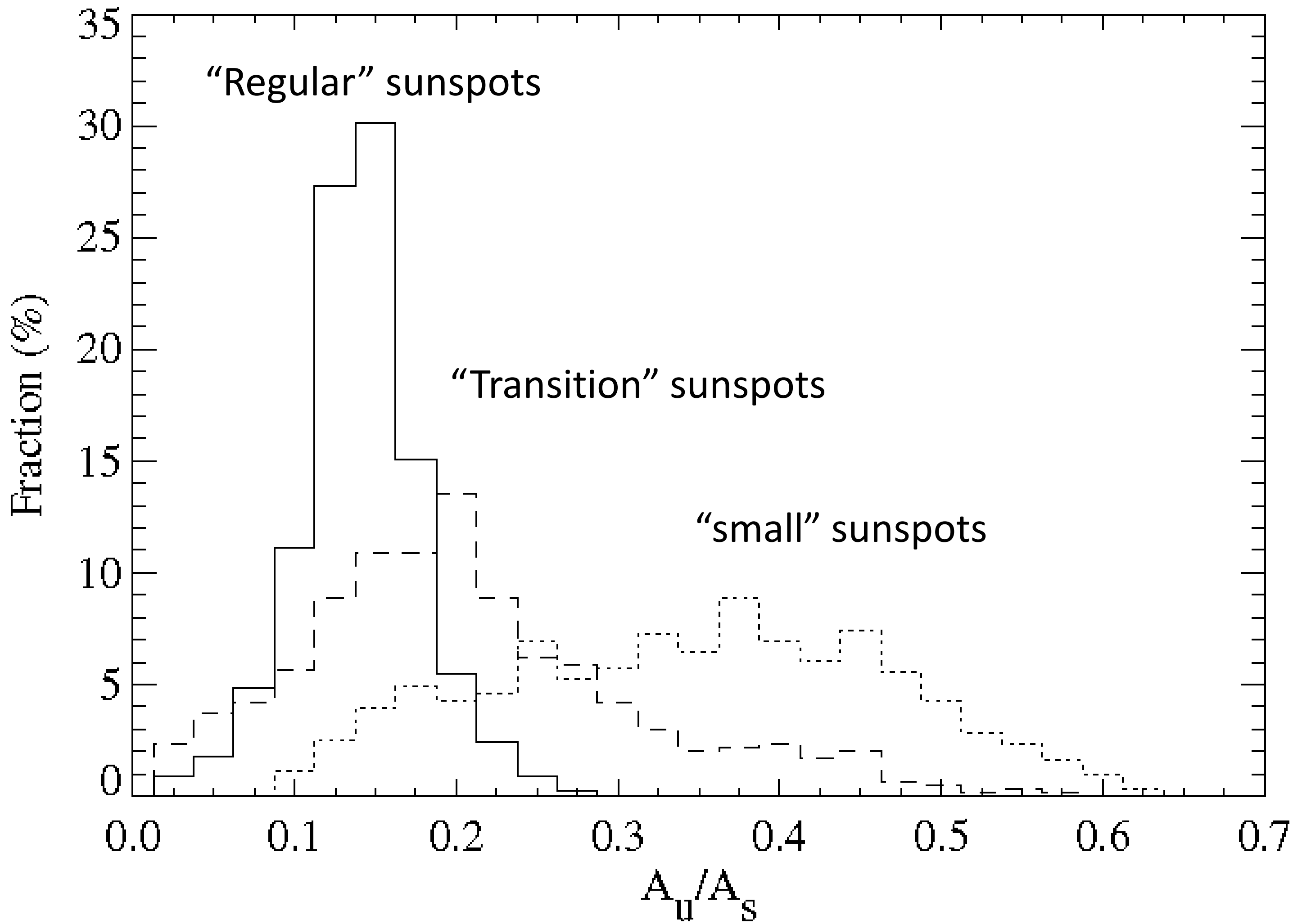


Area-Flux



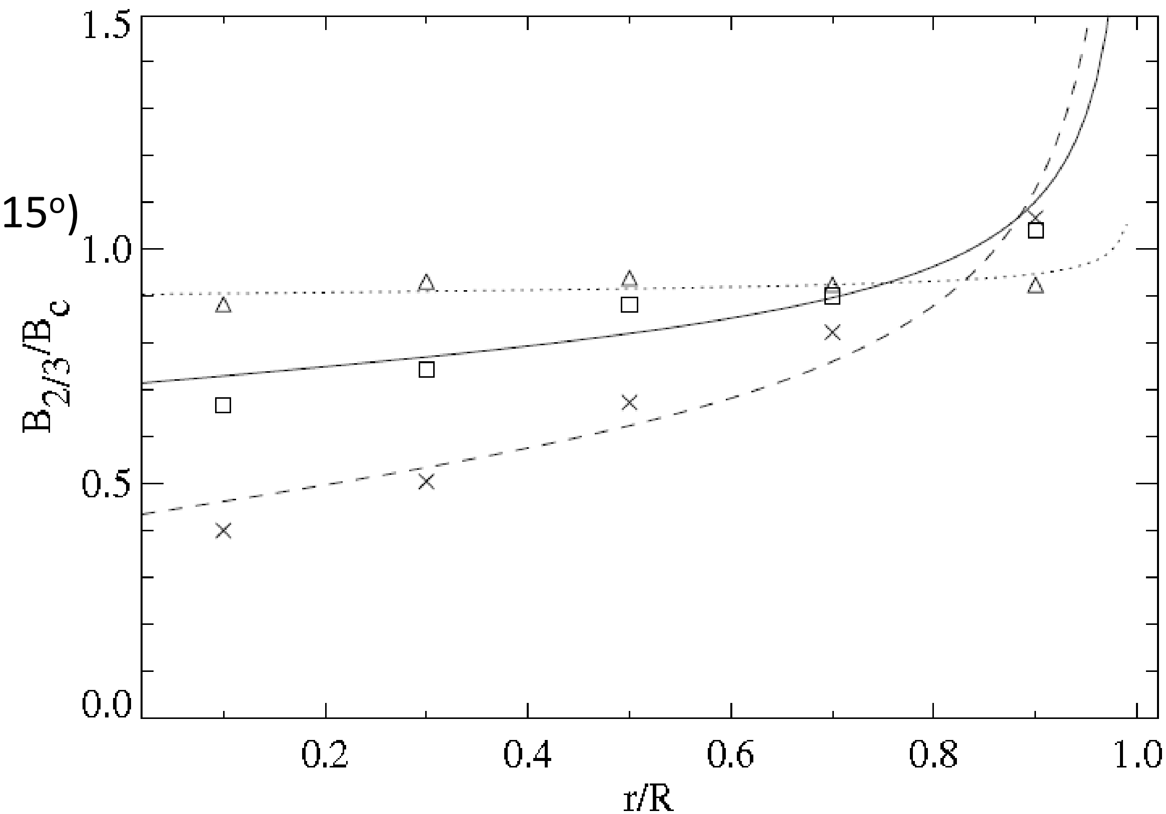
TRANSITION
SMALL SUNSPOTS
REGULAR SUNSPOTS
PORES
Magnetic flux (Mx)
Area (MSH)
10^{23}
10^{22}
10^{21}
10^{20}
10^{19}
1
10
100
1000

Bimodal distribution of Sunspot Properties



Penumbra formation ?

Triangle - Small sunspots (γ=1°)
Square- Transition sunspots (γ=15°)
X- "regular" sunspots (γ=38°)



$$\mathrm{B}_c^{LOS} = \mathrm{B}_c \cos\rho$$

$$\mathrm{B}^{LOS} = \mathrm{B}\ \cos(\gamma - \rho)$$

$$\frac{B_{2/3}^{LOS}}{B_c^{LOS}} = \frac{B_{2/3}\cdot\cos(\gamma-\rho)}{B_c\cdot\cos\rho} = \frac{B_{2/3}}{B_c}(\cos\gamma + \sin\gamma\cdot\tan\rho)$$