Boulder Solar Observatory Sunspot Drawings and Sunspot Group Reports

The sunspot drawings are observations by the solar patrol of the Boulder Solar Observatory, run by the ESSA Space Disturbance Forecast Center (now the NOAA Space Weather Prediction Center) in Boulder, Colorado, under the direction of P.S. McIntosh. A 4-inch refractor was used to make drawings of 20-cm original diameter. Sunspot groups are assigned according to a judgment of bipolar pairs based on spot group evolution and the structure of associated H-alpha plages.

In 1970, serial numbers appearing adjacent to some of the sunspot groups are the last three digits in the McMath-Hulbert calcium plage associated with the group. Note that frequently two or more sunspot groups occur within the same McMath-Hulbert plage. Sometimes these groups are assigned the same McMath-Hulbert plage number with an alphabetic suffix indicating the relative ages of the groups. Usually a single number is placed with only the most important group within the plage.

The sunspot group reports include year/month/day, universal time, Boulder Solar Observatory region number, type (3 letter code – McIntosh modified Zurich classification, the type of the largest spot within the group, and the relative spot distribution or compactness), magnetic class A or B (Mt. Wilson), corrected area in millionths of a solar hemisphere, extent in longitude (in degrees), Space Environment Services Center (SESC) region number and station name (4 letter code).

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C
C                   S U N S P O T  GROUP REPORTS
C                     Boulder Sunspot Drawings
C
C  Column  Fmt  Description
C-------------------------------------------------------------------------
C   1- 4   I4   Year  e.g. 1978
C   5- 6   I2   Month -- 01 for January, 02 for February, 03 for March, etc.
C   7- 8   I2   Day of month
C      9   1X   Blank
C  10-13   I4   Universal Time
C     14   1X   Blank
C  15-19   I5   Boulder Solar Observatory region number -- sometimes the last three
                 digits in the McMath-Hulbert calcium plage associated with the
                 group
C  20-23   4X   Blank
C  24-26   A3   Type -- 3 letter code* -- in the early years, one letter -- the
                  Zurich classification of sunspots -- A, B, C, D, E, F, H.
                  By Oct 1966 the revised classification devised by McIntosh (NOAA)
                  Used a 3-letter designation - the Modified Zurich class, the
                  type of the largest spot within the group, and the relative spot
                  distribution or compactness of the group. For definitions and
                  illustration of the types, see McIntosh, Solar Physics,
                  vol. 125, 251-267, 1990.
C  27-35   9X   Blank
C     36   A1   Magnetic class A or B by Mt. Wilson -- A = alpha -- All the
                  magnetic measures in the group are of the same polarity; B =
                  beta -- A bipolar group in which the magnetic measures indicate
                  a balance between the preceding and following spots.
C  37-43   7X   Blank
C  44-48   I5   Corrected Area in millionths of a solar hemisphere
C  49-52   4X   Blank
C  53-57  F5.2  Extent in longitude (in degrees)
C  58-60   3X   Blank
C  61-65   I5   SESC region number
C  66-74   9X   Blank
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C  75-78   A4   Station name
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Modified Zurich classification of sunspots:

The sunspot region type is represented by three consecutive uppercase letters. It is the revised classification devised by P.S. McIntosh of NOAA. It consists of a modified Zurich Brunner class, the type of largest spot within the group, and the relative spot distribution or compactness of the group. This classification is included in the USSPS code, IUWDS, Synoptic Codes for Solar and Geophysical Data, Third Revised Edition, p. 108, 1973. A discussion of the rationale and interpretation of this classification is included in the McIntosh review paper on sunspot observations in The Physics of Sunspots, Sacramento Peak National Observatory, 1981. Also, see The classification of sunspot groups, by Patrick S. McIntosh, Solar Physics, vol. 125, Feb. 1990, p. 251-267.

The definitions of the classification and an illustration of the types of sunspots follow.

When possible, separate bipolar sets of spots are identified by measured magnetic polarities, by the positions of spots relative to lines of polarity reversal inferred from structures on H-alpha filtergrams, and by the record of birth and evolution of spots. If these observations are not available, the following definitions identify most unipolar and bipolar spot groups: (see Figure [TBD] and definitions to follow)

Unipolar Group: A single spot or a single compact cluster of spots with the greatest distance between two spots of the cluster not exceeding three heliographic degrees. In modified Zurich H-class groups, this distance is measured from the outer penumbral border of the largest spot to the center of the most distant spot in the group. Strong new spots which are clearly younger than the nearby h-type spot (see Penumbra: Largest Spot) are usually members of a new emerging bipolar group and should be called a separate group.

Bipolar (Elongated) Group: Two spots or a cluster of many spots extending roughly east-west with the major axis exceeding a length of three heliographic degrees. An h-type major spot can have a diameter of three degrees, so a bipolar group with an h-type spot must exceed five degrees in length.

Modified Zurich Class (first upper case letter in Table):

A A unipolar group with no penumbra.

B A bipolar group with no penumbra. There is no upper limit to the length of Class B groups.

C A bipolar group with penumbra on spots of one polarity, usually on spots at only one end of an elongated group. Class C groups become compact class D when the penumbra exceeds five degrees in longitudinal extent. There is no upper limit to the length of Class C groups.

D A bipolar group with penumbra on spots of both polarities, usually on spots at both ends of an elongated group. The length does not exceed 10 degrees of heliographic longitude.

E A bipolar group with penumbra on spots of both polarities and with a length between 10 and 15 heliographic degrees.

F A bipolar group with penumbra on spots of both polarities and with a length exceeding 15 heliographic degrees.

H A unipolar group with penumbra. Attendent spots are less than three heliographic degrees from the penumbra of the main spot. The principal spots are nearly always the leader spots remaining from an old bipolar group. Class H groups become compact Class D when the penumbra exceeds five degrees in longitudinal extent.

Note that Zurich classes G and J are missing in this revision. Class G groups are included in the definition of classes E and F, and class J groups are included in class H.

Penumbra: Largest Spot (second upper case letter in Table):

"x" No penumbra. The width of the gray area bordering spots must exceed three arc seconds in order to classify as penumbra.

"r" The penumbra is rudimentary. It is usually incomplete, irregular in outline, as narrow as three arc seconds, brighter intensity than normal penumbra and has a mottled, or granular, fine structure. Rudimentary penumbra represents the transition between photospheric granulation and filamentary penumbra. Recognition of rudimentary penumbra will ordinarily require photographs or direct observation at the telescope.

"s" Symmetric, nearly circular penumbra with filamentary fine structure and a spot diameter not exceeding 2 1/2 heliographic degrees. The umbrae form a compact cluster near the center of the penumbra. Also, elliptical penumbrae are symmetric about a single umbra. Spots with symmetric penumbra change very slowly.

"a" Asymmetric, or complex penumbra with filamentary fine structure and a spot diameter along a solar meridian not exceeding 2 heliographic degrees. Asymmetric penumbra is irregular in outline or clearly elongated (not circular) with two or more umbrae scattered within it. The example in the figure is transitional between "s" and "a". Asymmetric spots typically change form from day-to-day.

"h" A large symmetric penumbra with diameter greater than 2 heliographic degrees. Other than size, it has characteristics the same as "s" penumbra.

"k" A large asymmetric penumbra with diameter greater than 2 heliographic degrees. Other than size, its characteristics are the same as "a" penumbra. When the longitudinal extent of the penumbra exceeds five heliographic degrees, it is almost certain that both magnetic polarities are present within the penumbra and the classification of the group becomes Dkc or Ekc or Fkc.

Sunspot Distribution (third upper case letter in Table):

"x" Single spot.

"o" An open spot distribution. The area between leading and following ends of the group is free of spots so that the group appears to divide clearly into two areas of opposite magnetic polarity. An open distribution implies a relatively low magnetic field gradient across the line of polarity reversal.

"i" An intermediate spot distribution. Some spots lie between the leading and following ends of the group, but none of them possesses penumbra.

"c" A compact spot distribution. The area between the leading and following ends of the spot group is populated with many strong spots, with at least one interior spot possessing penumbra. The extreme case of compact distribution has the entire spot group enveloped in one continuous penumbral area. A compact spot distribution implies a relatively steep magnetic field gradient across the line of polarity reversal.

The first letter of the McIntosh classification is essentially the Brunner classification with the following exceptions:

McIntosh types:	Ero and Fro	
	==========	
	Eso Fso	
	Eao Fao	Brunner class G
	Eho Fho	
	Eko Fko	
	==========	
	Hrx	
	Hsx	Brunner class J
	Hax	
	==========	

References

McIntosh, P.S. (1990), The Classification of Sunspot Groups, Solar Physics, 125, Feb. 1990, p. 251-267. [see http://link.springer.com/article/10.1007%2FBF00158405]

McIntosh, P.S. (1981), The Physics of Sunspots, Sacramento Peak National Observatory, 1981. [see http://books.google.com/books?id=rnPvAAAAMAAJ&dq=related:ISBN0521860032]

Synoptic Codes for Solar and Geophysical Data (1993), Third Revised Edition, pp. 157

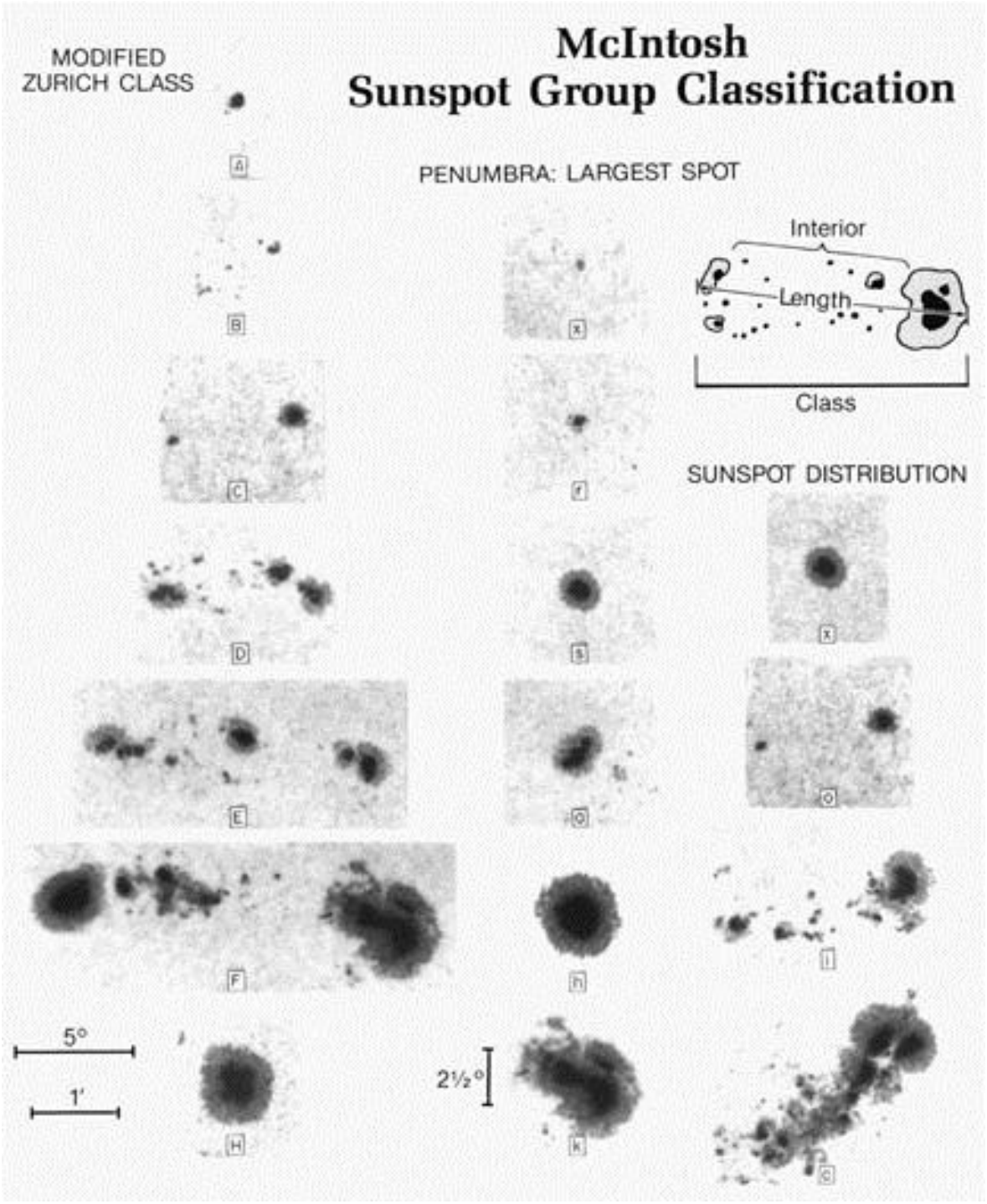

Figure 1. McIntosh Sunspot Group Classification (reference: www.petermeadows.com)