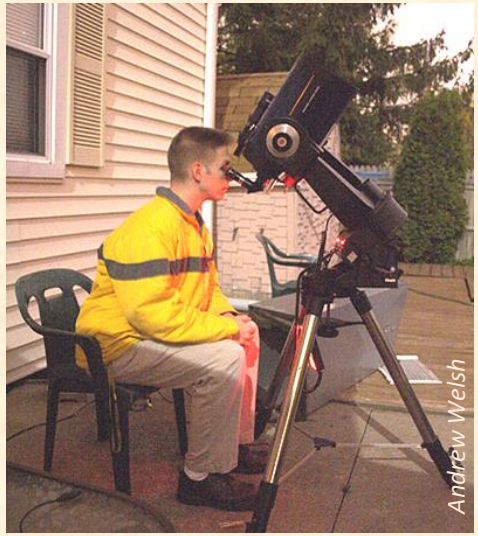
The R_i human factor: human vision

- No biological change in the detector at century scales (eye + visual cortex)
- **Capacity to "integrate" seeing distortions** (not a simple averaging !):
  - Visual cortex plays an essential role
  - Until recently (SDO, HMI), capacity to detect the smallest spots was superior to photography and CCD
- **Imaging data not directly comparable or substitutable**:
  - Effects of sensor/optical resolution, seeing will have a different influence on the resulting counts for images and human eye



The R_i human factor: optical factors

- ***No specific aperture required for SIDC contributing observers***
- *How is the detection of the smallest spots influenced by the resolution?*
- Two factors:
- **Theoretical optical resolution** (unobstructed aperture):
  - Rayleigh criterion: $\theta = 138 / D(mm)$
  - Dawes criterion: $\theta = 116 / D(mm)$
- **Seeing:**
  - variable with time, daytime range similar for all low-altitude sites:
    1.5 to 3, typ. 2 arcsec (equiv. D= 45 – 90 mm, typ. 70 mm)
  - Large apertures more affected (size of turbulent eddies ~8 -12 cm):

➡ **Reduces the difference of effective resolution between small and large apertures (> 10 cm)**

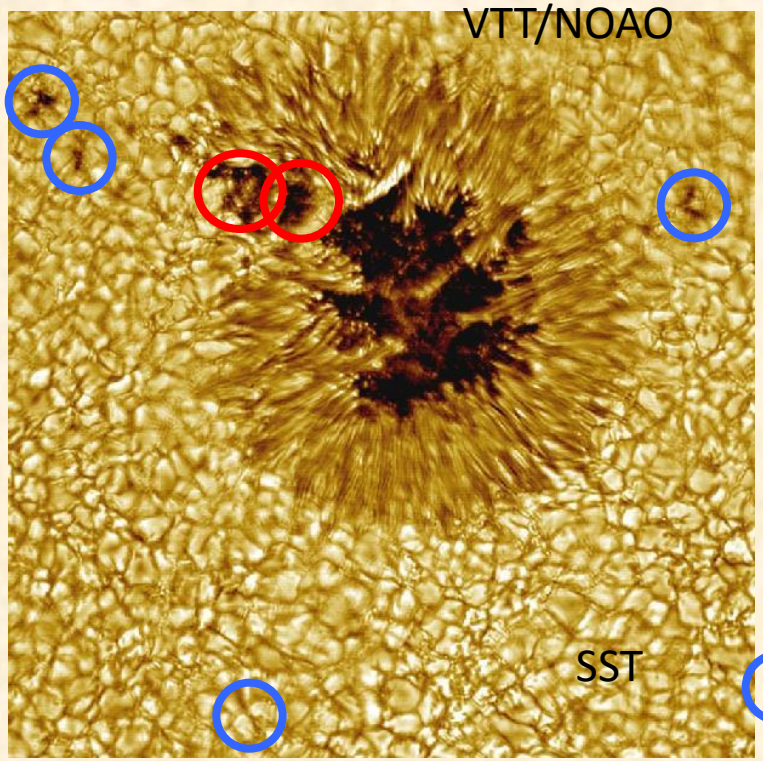
What is the smallest possible sunspot ?

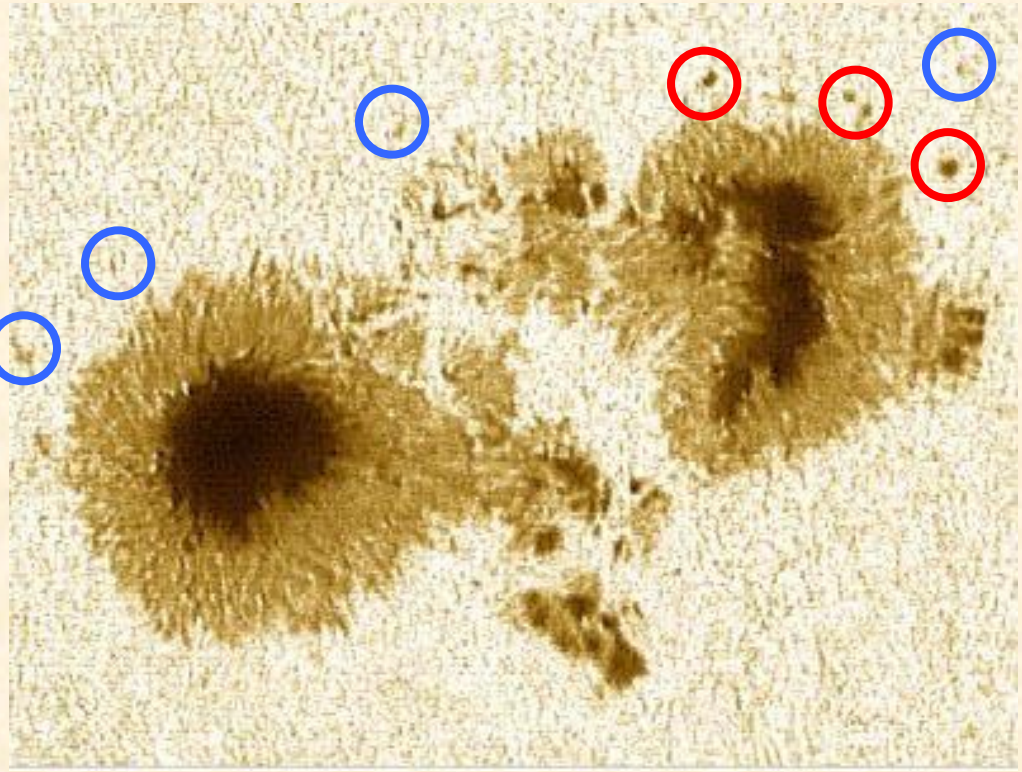
- Various definitions:
  - Semantic problem “pore” vs “sunspot”:
    - Pore = small spot without penumbra
    - Pore = random intergranular blemishes that are not real sunspots

Source	Spot diameter	Spot lifetime	Pore diameter	Pore lifetime
Bray & Laughhead 1964	With penumbra		Without penumbra	
Waldmeier *(Husar 1967)*	**>3” (2000km) = 1 granule**	**> 30 min**	< 3”	< 30min
Bruzec & Durrant 1977	>10” (6000km)	> 1 day	< 5”	< 1 day
McIntosh 1981	**> 4” (2500km) = 1 granule**		< 4”	

- Overall agreement: lowest spot size near 2000 km (3 arcsec)
  - Dictated by granulation dynamics rather than spots (cancellation of convective motion): lifetime: avg. 10 min (up to 30 min)

Sunspots and “pores”





Sunspot

Pore

What is the smallest possible sunspot ?

- Best "observational" definition:

	Diameter	**Lifetime**	**Outline**	**Contrast**	Penumbra
Granulation (pore)	< 3″ < 2500km	**< 30 min**	**Fuzzy** **Irregular**	**low**	none
Sunspot	> 3″ > 2500 km	**> 30 min**	**Sharp** **~ round**	**High** **Dark core**	none

- Simple criteria naturally adopted by all observers
  - No major discrepancies due to personal subjective interpretation

→ Match of the smallest real-spot angular size with usual seeing (3 arcsec) and telescope aperture D= 50 mm:

  - Limited gain in small spot counts at apertures > 50 - 80 mm

(cf. Svalgaard, private communication)

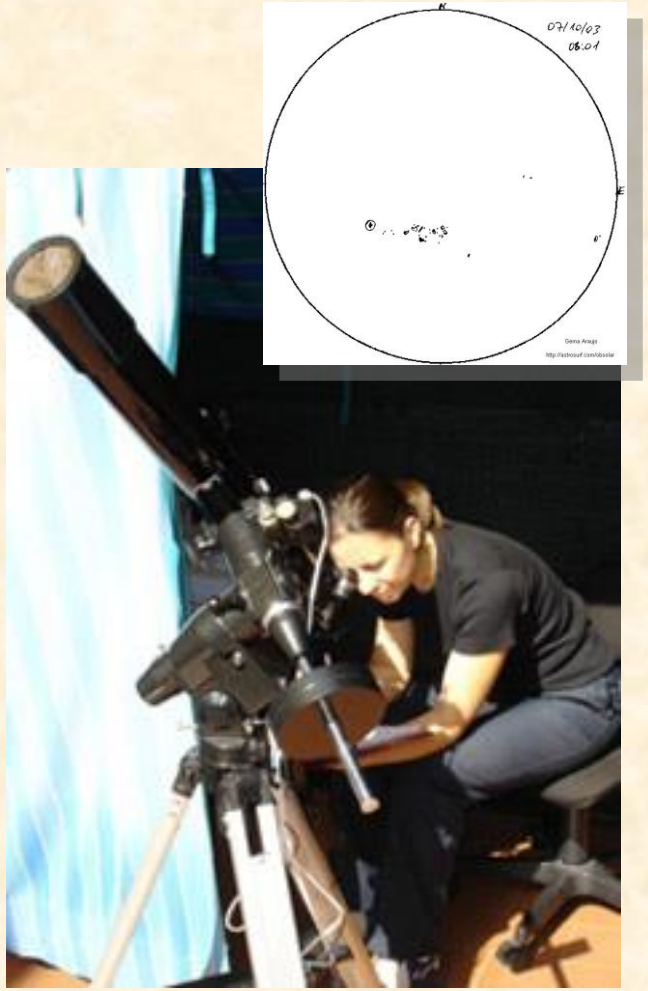
→ **Small-aperture bias only expected for early historical observations before the 19th century (D << 70mm)**

The R_i human factor: SIDC "freewheel" philosophy

- **No detailed counting rules imposed to SIDC observers.**
  - Observers reluctant to obey rules
  - Danger of imposed rules: slow insidious return to natural practices
  - Relying on the **observer experience**:
    - Same observer & instrument over years or decades

➡ **Long term self-consistency is more important than equivalence to a model** (network average, pilot station)

➡ **Importance of dedicated amateurs vs "volatile" professionals.**



The R_i human factor: random variations

- **Causes of random variations**:
  - Daily mood, mistakes
  - Daily changes of the observer (group splitting, umbral splitting)
  - Seeing variations
  - Random daily subset of network contributors (local weather) ~50/85
- **Sampling = One-day binning (UT)** >> "aliasing":
  - Fast small-scale changes in active regions (small short-lived spots)
  - Limb transits of large active regions
  - Strong effect mainly when a single spot/group on the solar disk!

Equivalent to **detector noise**

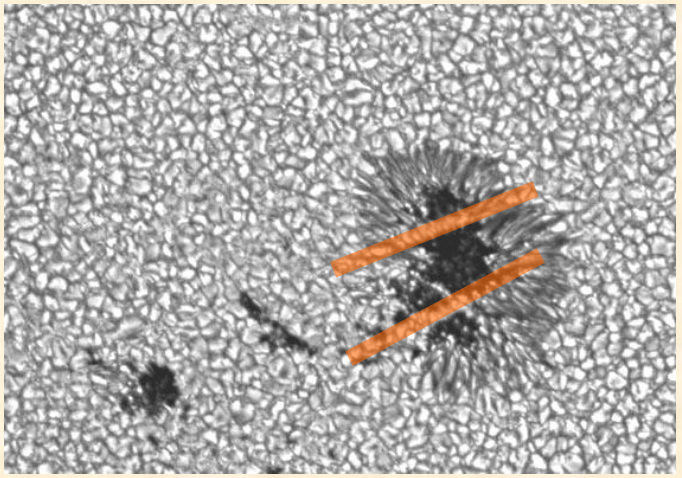
- **Filtered out by the daily tracking of K coefficients:**
  - Elimination of outliers based on standard deviation of daily K values.

Main biases: Group and umbral splitting

- **Group splitting:**
  - Topological criteria without external information (magnetograms)
  - No general scientific rule
  - Impact on W number limited:
    - Involves only a minority of groups
    - Can raise or lower W
- **Umbral splitting**:
  - Each umbra in common penumbra is counted as a separate spot (Wolfer rule)
  - Two umbrae considered as split only if separated by a complete light bridge
  - Prone to interpretation
  - Can lead to a net bias

Various group splitting rules *(Kunzel 1976)*:

- Non-bipolar groups: all spots within 5°x5° (60,000 x 60,000 km)
- Bipolar groups: up to 20° extension
- Rules for marginal cases:
  - Two spots up to 15° apart form a single group if they are the remainder of a large extended group
  - A bipolar collection of spots forms one group if Lat(West) ≤ Lat(East)
  - Typical tilt angles: 1-2° at 10° latitude, 4° at 30° latitude



The R_i human factor: observer bias

- **Causes of biases**:
  - **Splitting of large complex groups**
  - **Splitting of multiple umbrae in common penumbra**
  - Frantic quest for the largest count (including tiny ephemeral blemishes)
  - Prior consultation of other observations (WEB CCD images) leading to expectations:
    - Bias emerging in recent years?
- **Sources of trends** (slow variations in the personal biases):
  - Observer ageing (visual acuity; age > 50)
  - Trend in sky quality (urbanization)
  - Slow evolution of network members
  - Instrument ageing
- **Tracked by K-coefficient system**:
  - **Uncorrelated biases (network)**: independent worldwide observations
  - **<u>One special case: the Zürich-Locarno reference station</u>**

An essential step: processing method

- **Change in the data processing method**
  = primary cause of possible biases

➡ **Problem common to all indices**

- **Zürich-Locarno Sunspot Index**:
  - Choice to drop smallest spots (Wolf)
  - Magnetic needle corrections (Wolf)
  - Weighting of sunspot counts (Wolfer – Waldmeier ?)
  - Change of primary station (Zürich – Locarno)
  - Change in the composition of network (observer mix, geographical distribution): e.g. Zürich-SIDC transition
    - Smaller impact for large networks (SIDC strategy)
  - Manual method: sparsely documented (occasional indications scattered over many different issues of the Mitteilungen)

An essential step: processing method

- **The case of the American number R_A (AAVSO)**:
  - Lack of reference station
  - Manual processing
  - Additional observer rating factor
  - Flaws in the processing method: found after 50 years
  - Original data lost before 1992 ➡ No correction possible

<u>The Golden rules</u>

1. **Archival of all raw input data**
2. **Detailed documentation of the processing method and definitions and of the observing technique**
3. **Tracking of processing changes**
4. **Change only when it is essential (e.g. discovery of a flaw)**
5. **Long overlap periods:**

   ***old and new indices computed in parallel** (min. one solar cycle)*