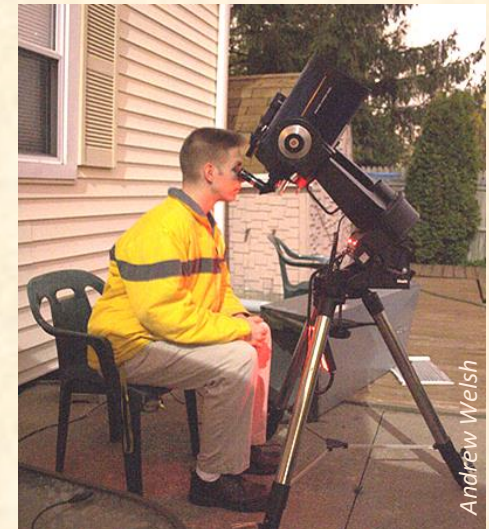
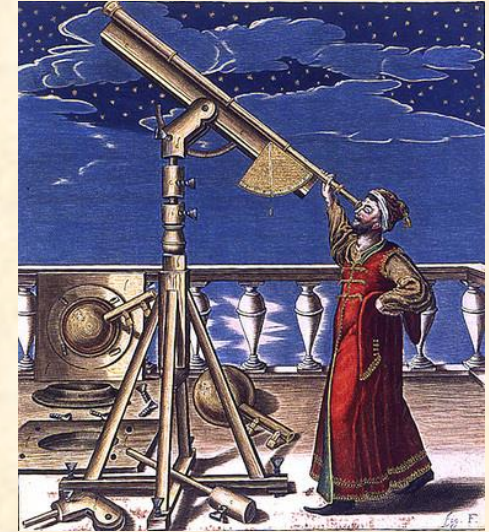


The R_i human factor: human vision


- 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: $\theta = 138 / D(\text{mm})$
 - Dawes criterion: $\theta = 116 / D(\text{mm})$
- **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)**

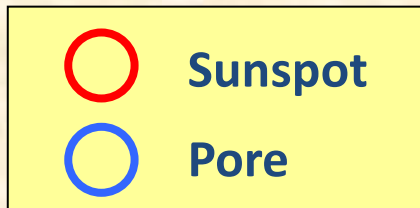
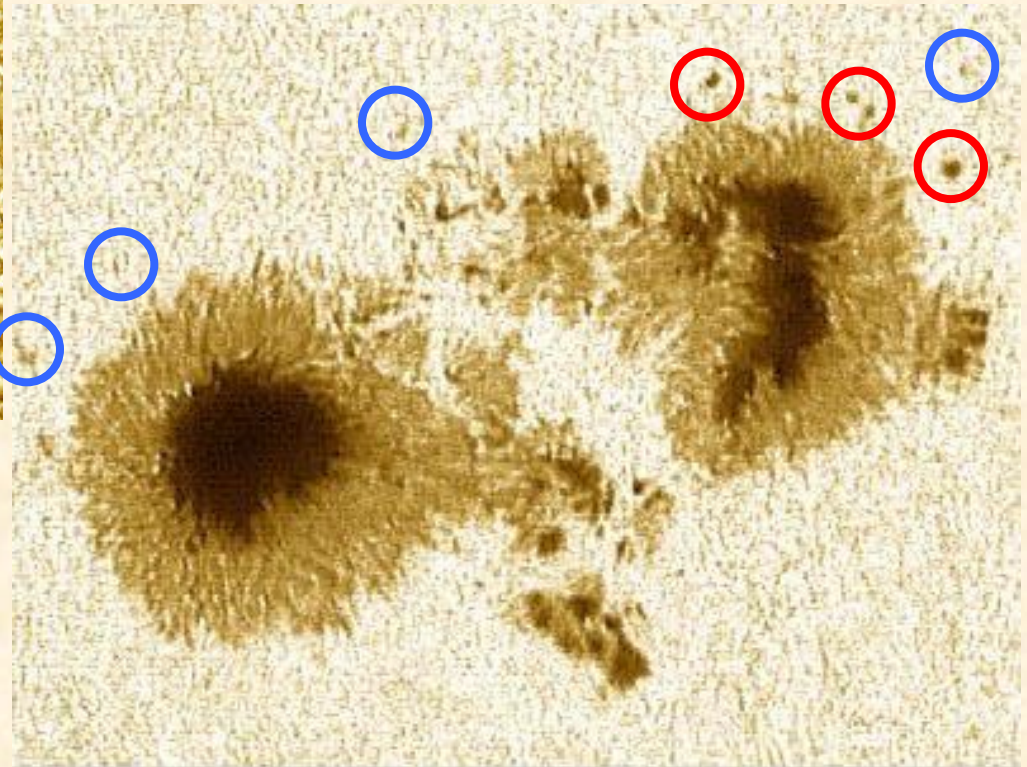
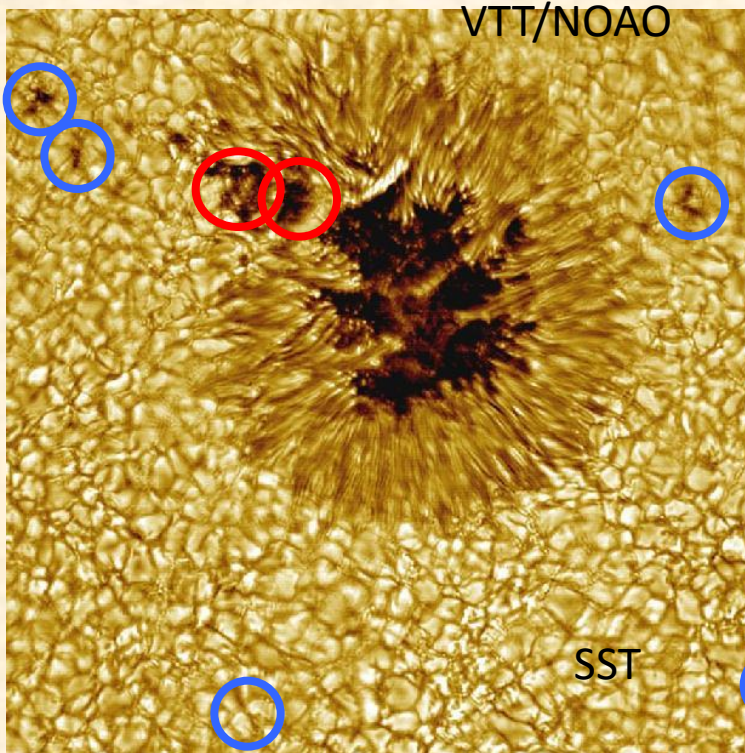
What is the smallest possible sunspot ?

- 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 (<i>Husar 1967</i>)	>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”



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)

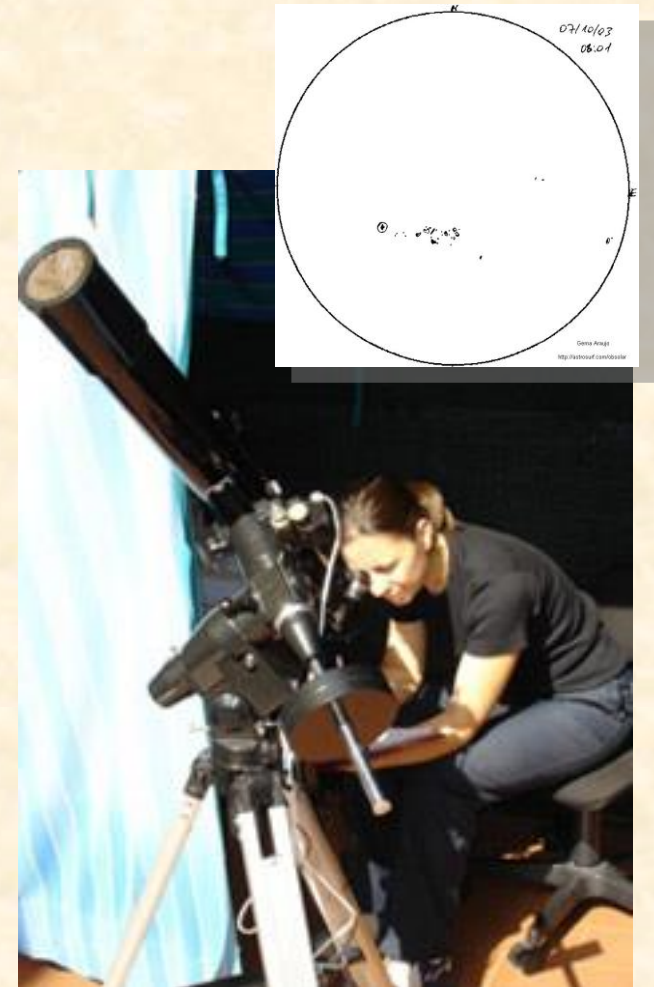
 **Small-aperture bias only expected for early historical observations before the 19th century ($D \ll 70$ mm)**

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) \gg "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**

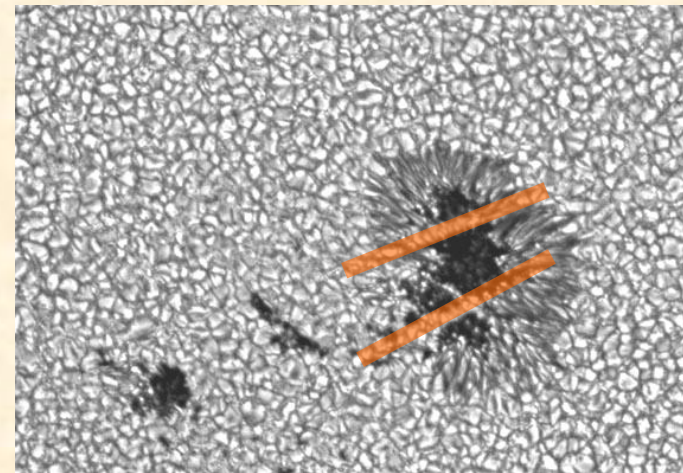
- **Filtered out by the daily tracking of K coefficients:**
 - Elimination of outliers based on standard deviation of daily K values.

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 (Wolf 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 $5^\circ \times 5^\circ$ (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 $\text{Lat}(\text{West}) \leq \text{Lat}(\text{East})$
 - Typical tilt angles: $1\text{--}2^\circ$ 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
 - **One special case: the Zürich-Locarno reference station**

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

The Golden rules

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)