Sunspotter: Using Citizen Science to Determine the Complexity of Sunspots

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& **the Sunspotter Zooniverse Team**

Citizen Science in the Realm of Solar Physics

IRISH RESEARCH COUNCIL
An Chomhairle um Thaighde in Éirinn

LOCKHEED MARTIN

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Science Goal

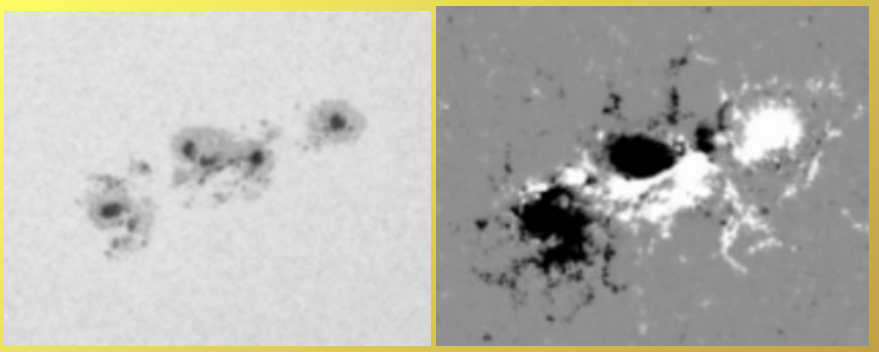
To construct a quantitative measure of **complexity** for sunspot group photospheric magnetic fields
…and to answer:

Phase 1

- Do more **complex** groups produce more **eruptions**?
- Can accurate knowledge of comlexity improve eruption forecasts?

Phase 2 *(Launch June 13)*

- Are they **born** or do they **evolve** to become complex?



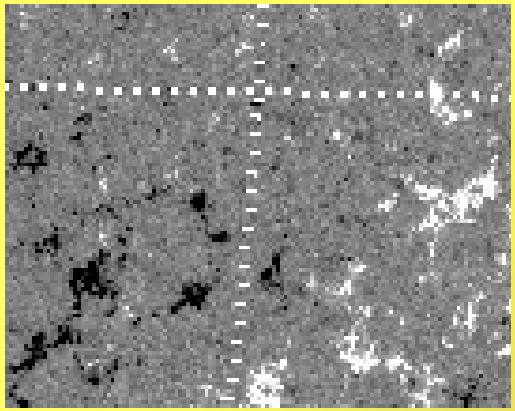
What do We Mean by Complexity?

1. Complexity characterises [something] with many [parts] in intricate arrangement.

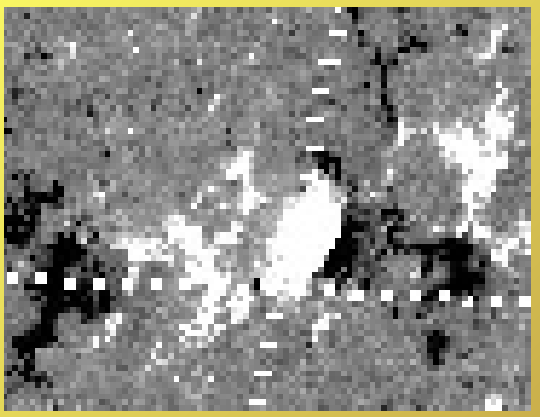
2. 'Complexity science' is the study of the [phenomena] that emerge from a [collection] of interacting [objects].

3. Displaying **variation** without being **random**.

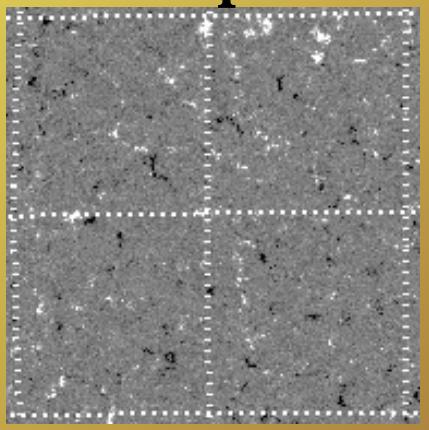
Simple



Complex



Simple



Previous Work

Proxies for Complexity

- **Fractal Dimension**

  (Abramenko 2005; McAteer et al. 2005; Ireland et al. 2008; Conlon et al. 2008)

  - **Does not scale well with eruption productivity** (Georgoulis 2012)
  - **Difficult to interpret physically**

- **Magnetic Inter-connectivity**

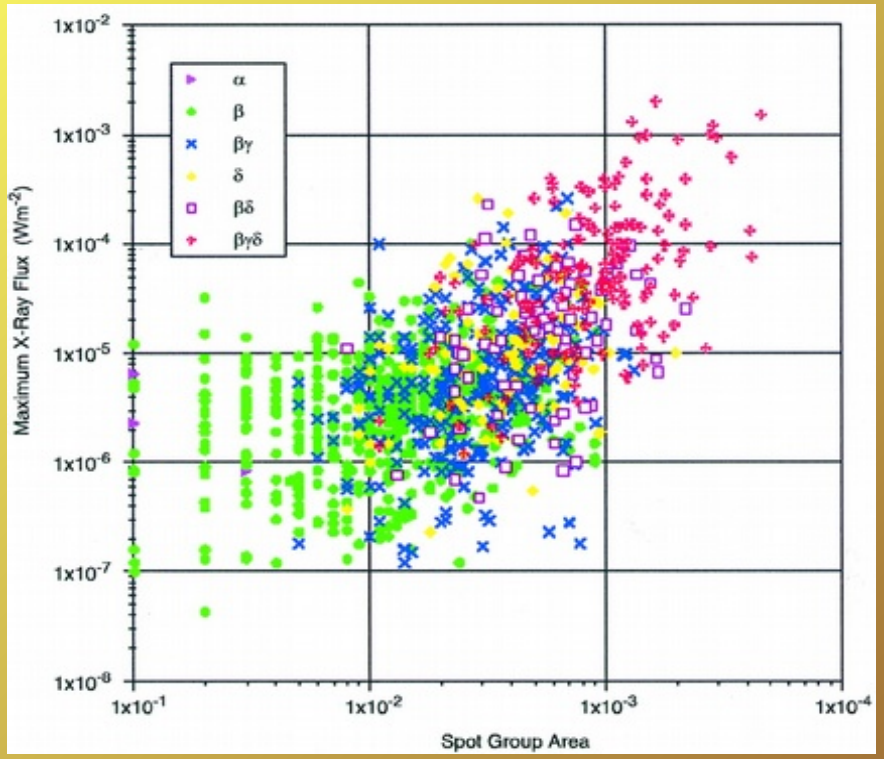
  (Georgoulis & Rust 2007; Ahmed et al. 2010)

  - **Heavily dependent on position**

- **Expert Classification**

  (NOAA/SWPC; Hale 1919)

  - **Unreliable** (single human)
  - **Vague** definition
  - Only a handful of classes (**poor resolution**)



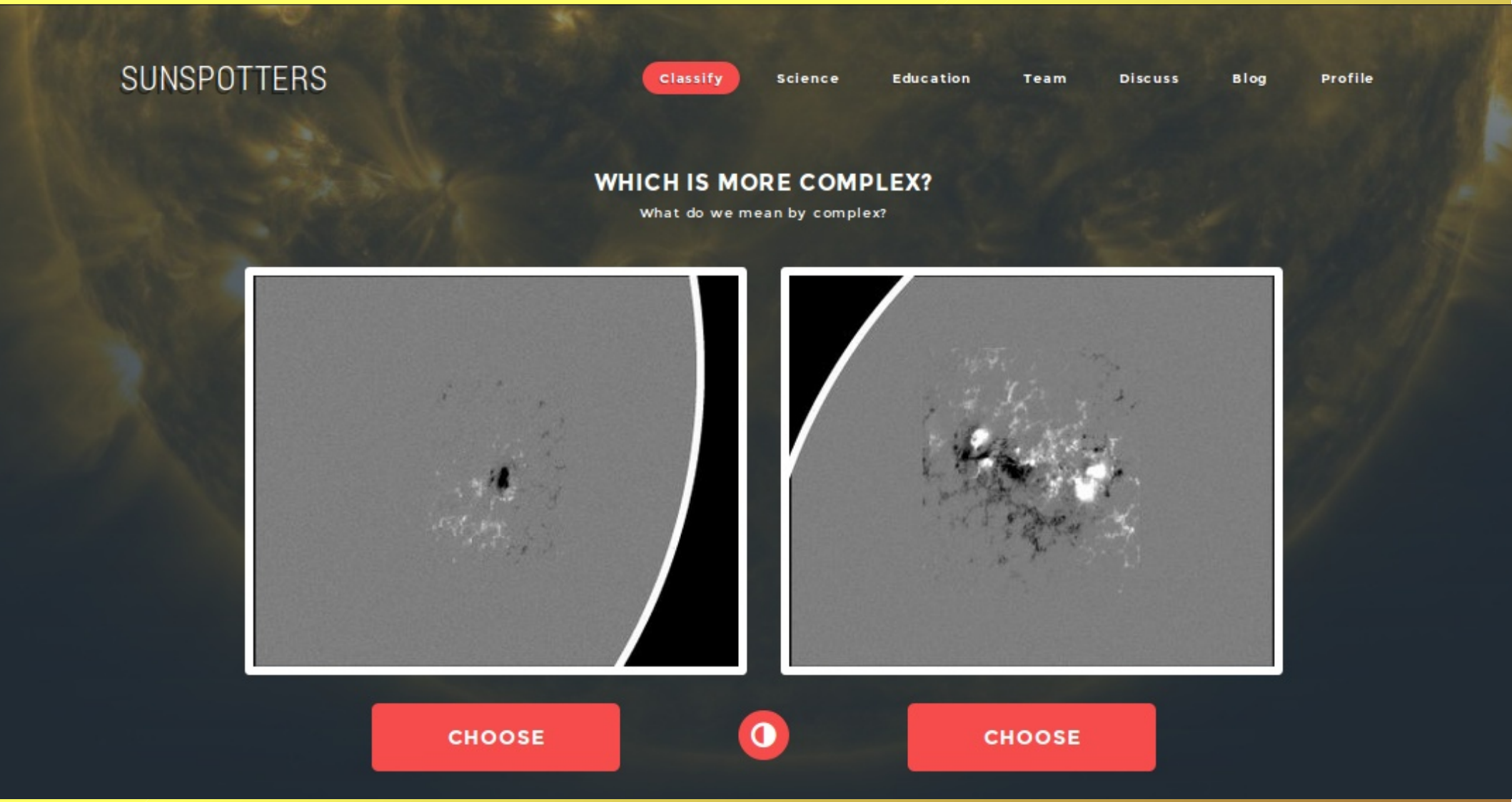
Sammis, Tang & Zirin (2000)

Method

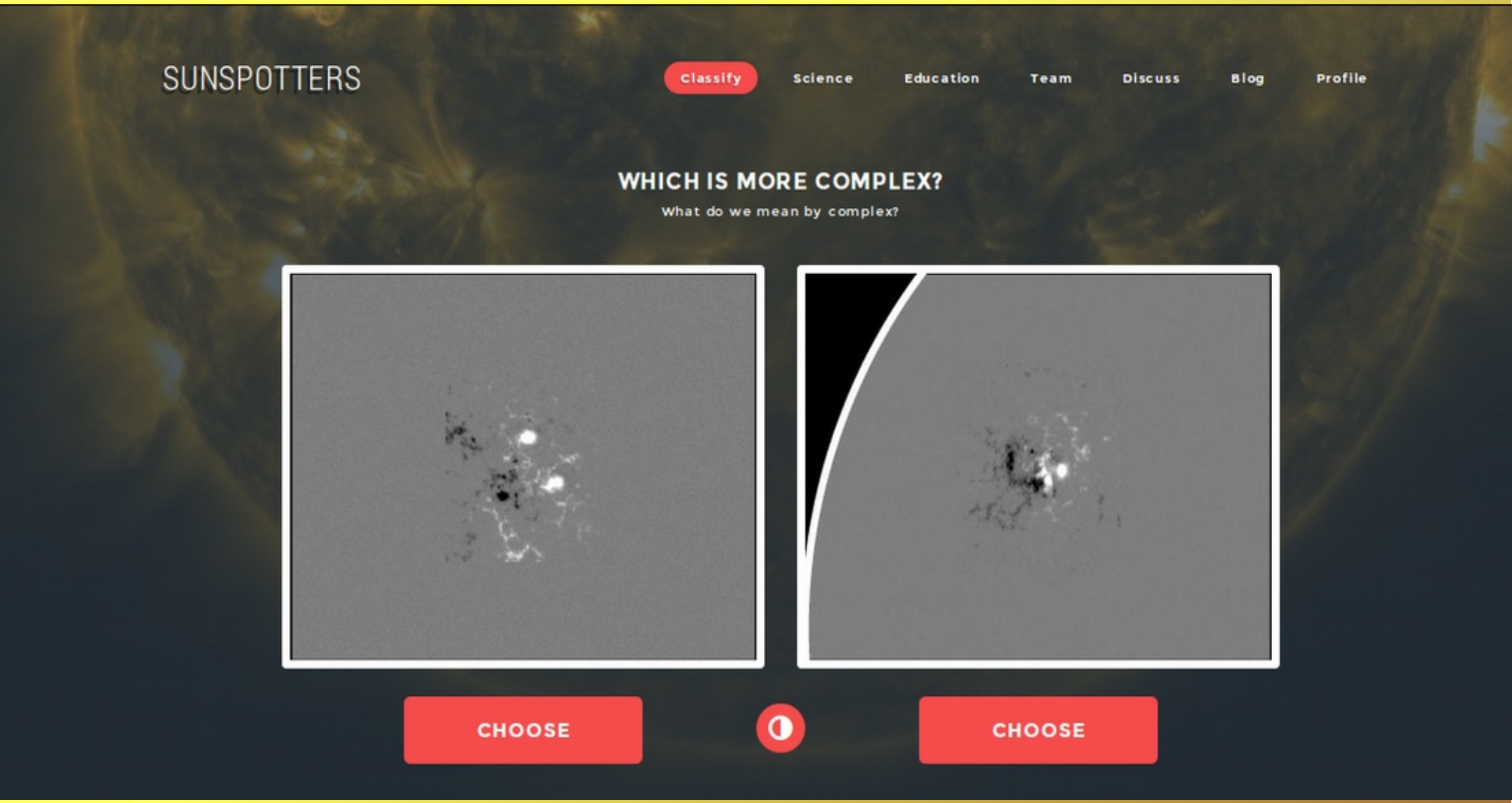
Phase 1 Data set

- **13k** sunspot group detections from NASA All-Clear Workshop
- Detections based on **NOAA ARs** (must have WL spots)
- MDI LOS cutouts scaled to +/- **1kG**
- Sunspot groups are shown **to-scale** but binned by Lon.
- Volunteers are asked to **compare individual pairs** of sunspot groups
- From Phase 1: **~1600** volunteers, **~13k** images, **320k** classifications (clicks), **50/image**
- Elo ranking algorithm used to convert the list of classifications into a ranked list

Web Interface Example

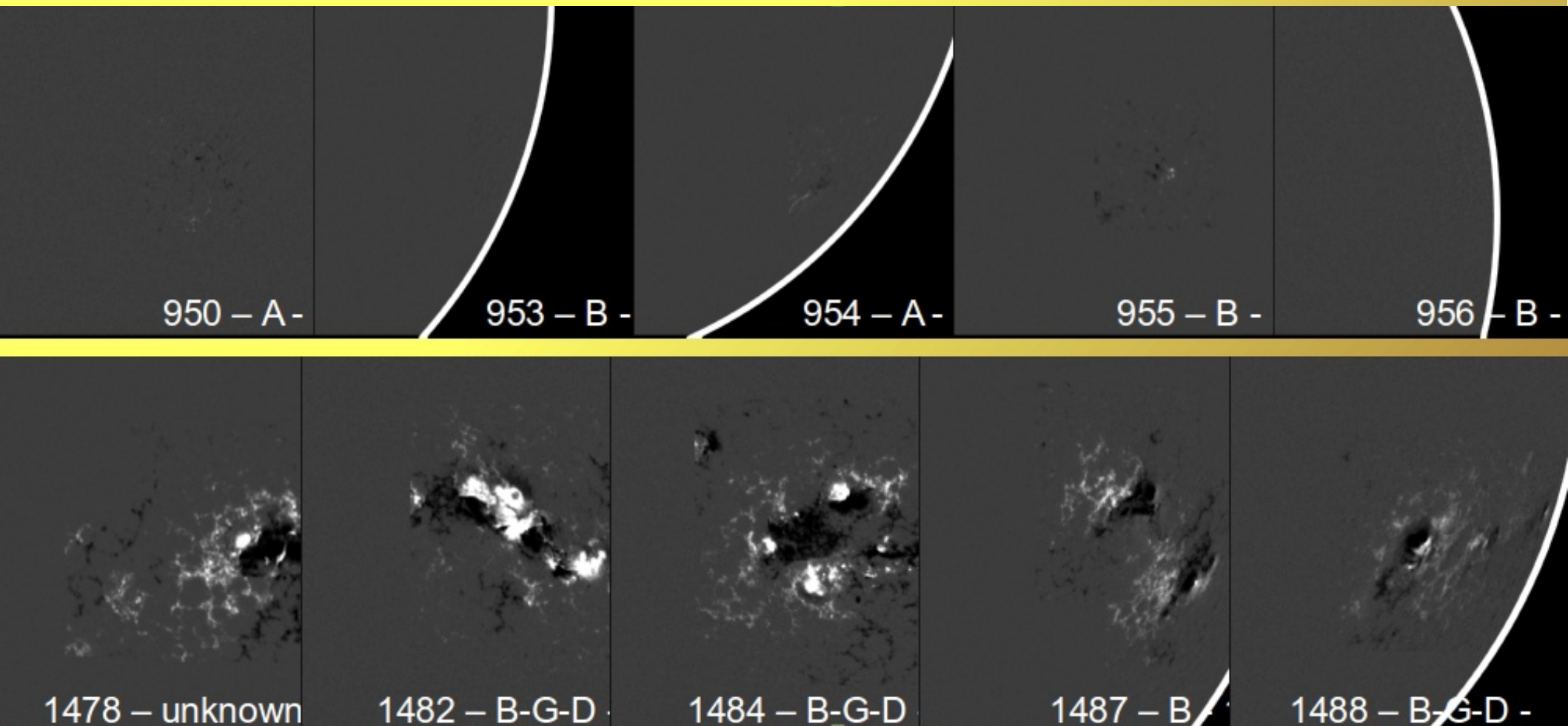


Web Interface Example

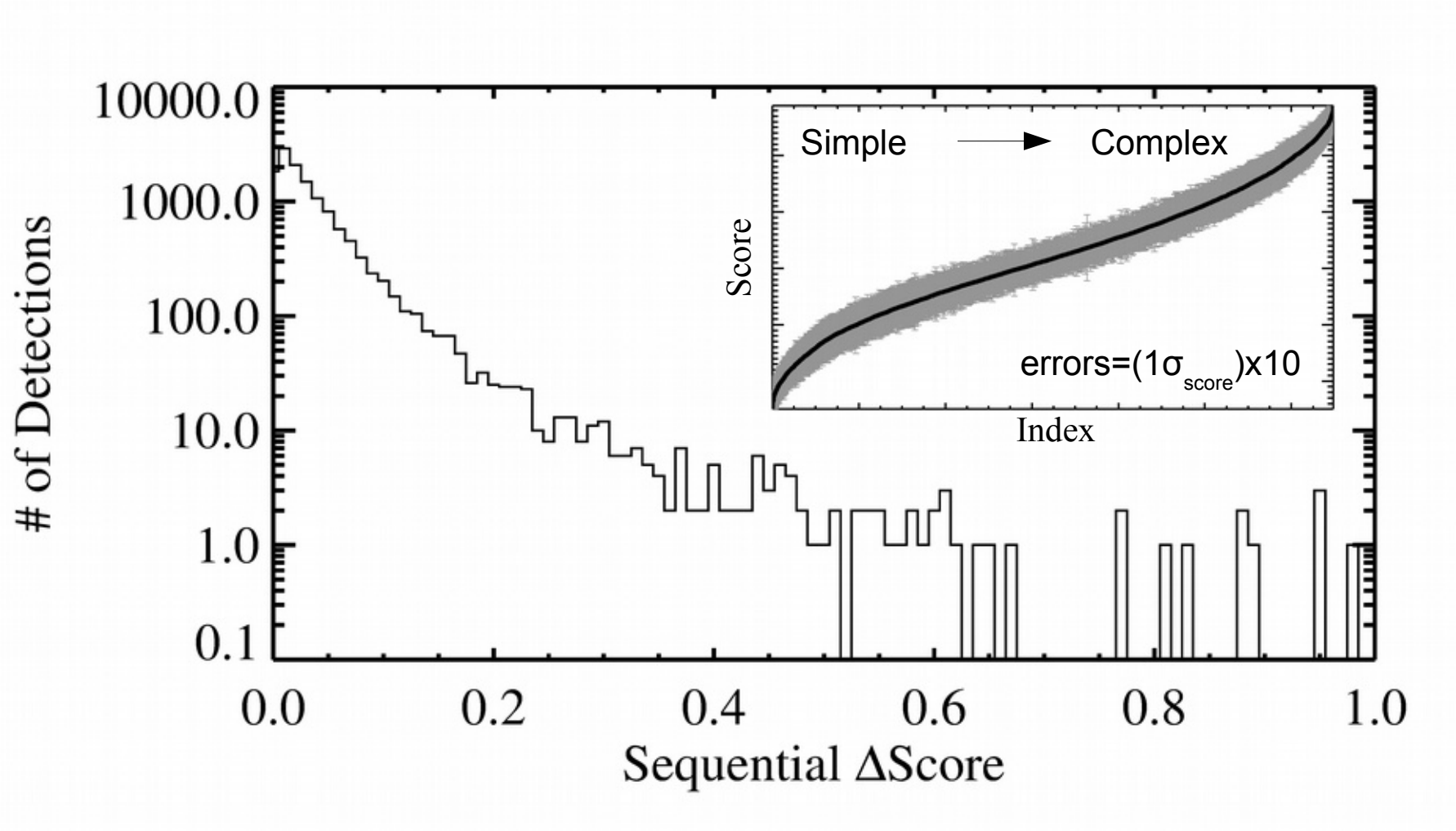


Least/Most Complex

- Which are the **least** / **most complex** sunspot groups?
  - (unit-less) Elo Score **ranges**: 950 – 1488
  - Hale Class – **Least**: Alpha, Beta – **Most**: Beta-Gamma-Delta

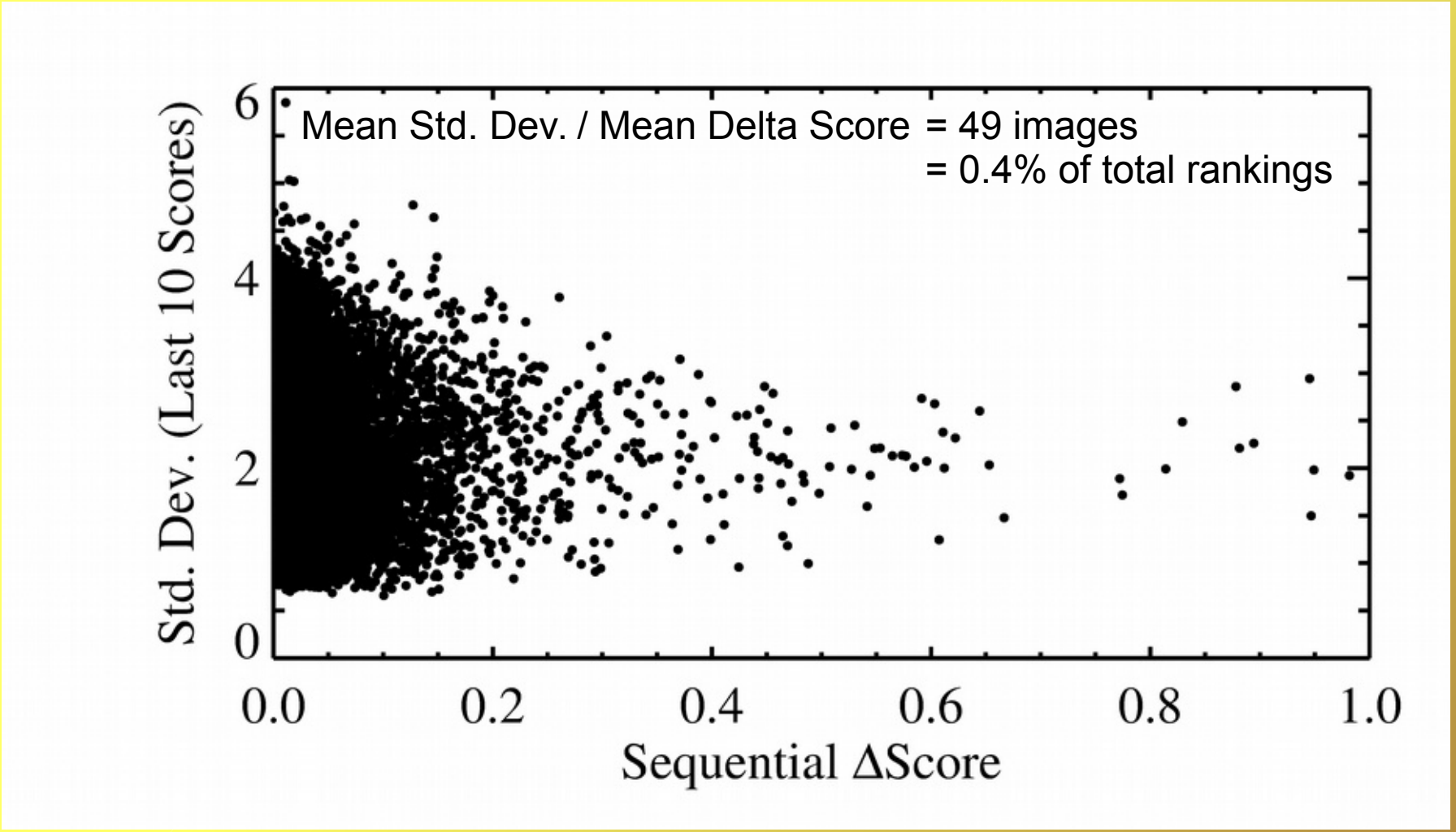


Elo Score



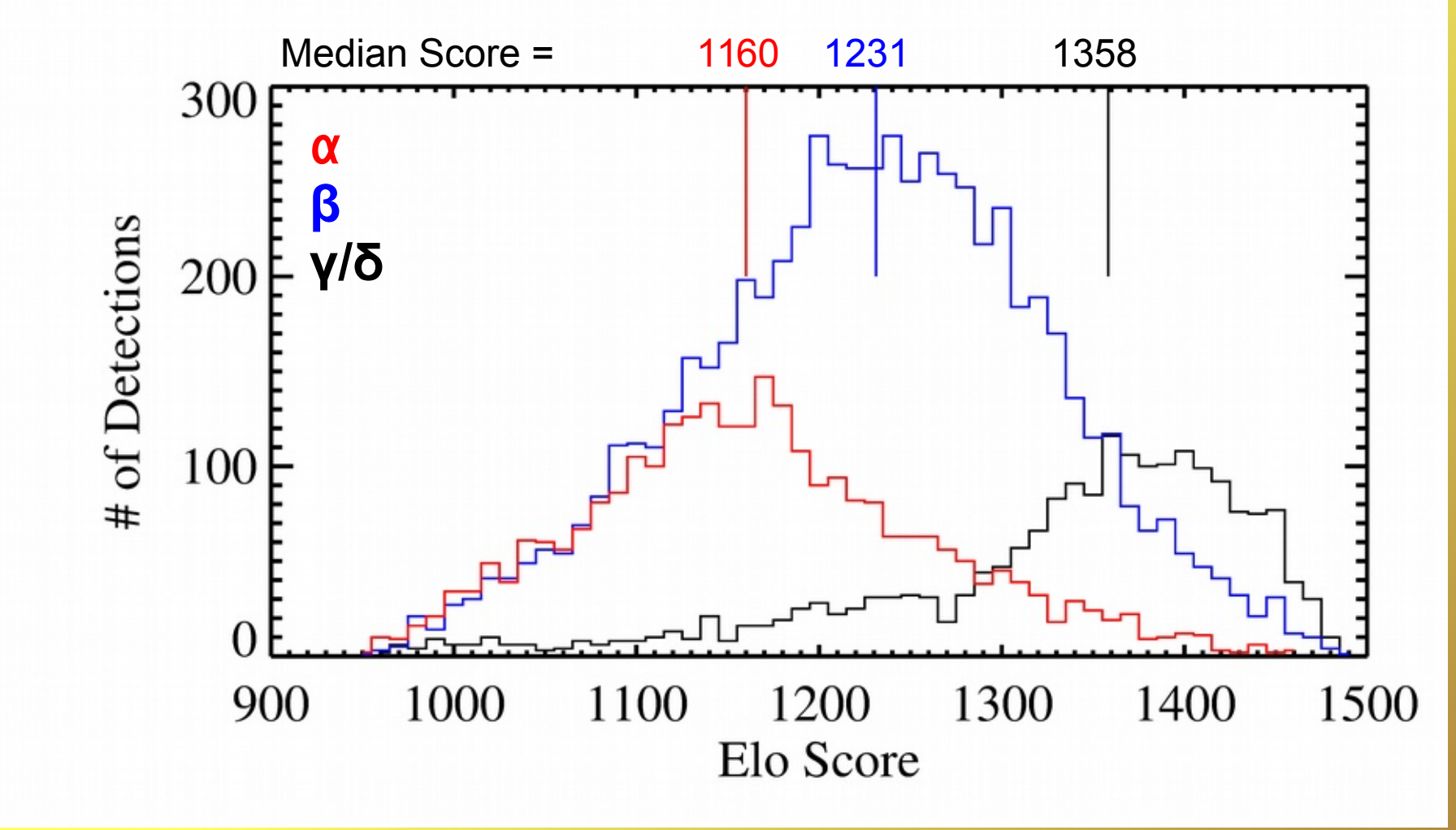
- **Difference** in sequentially ranked detection complexity **scores**

Elo Score



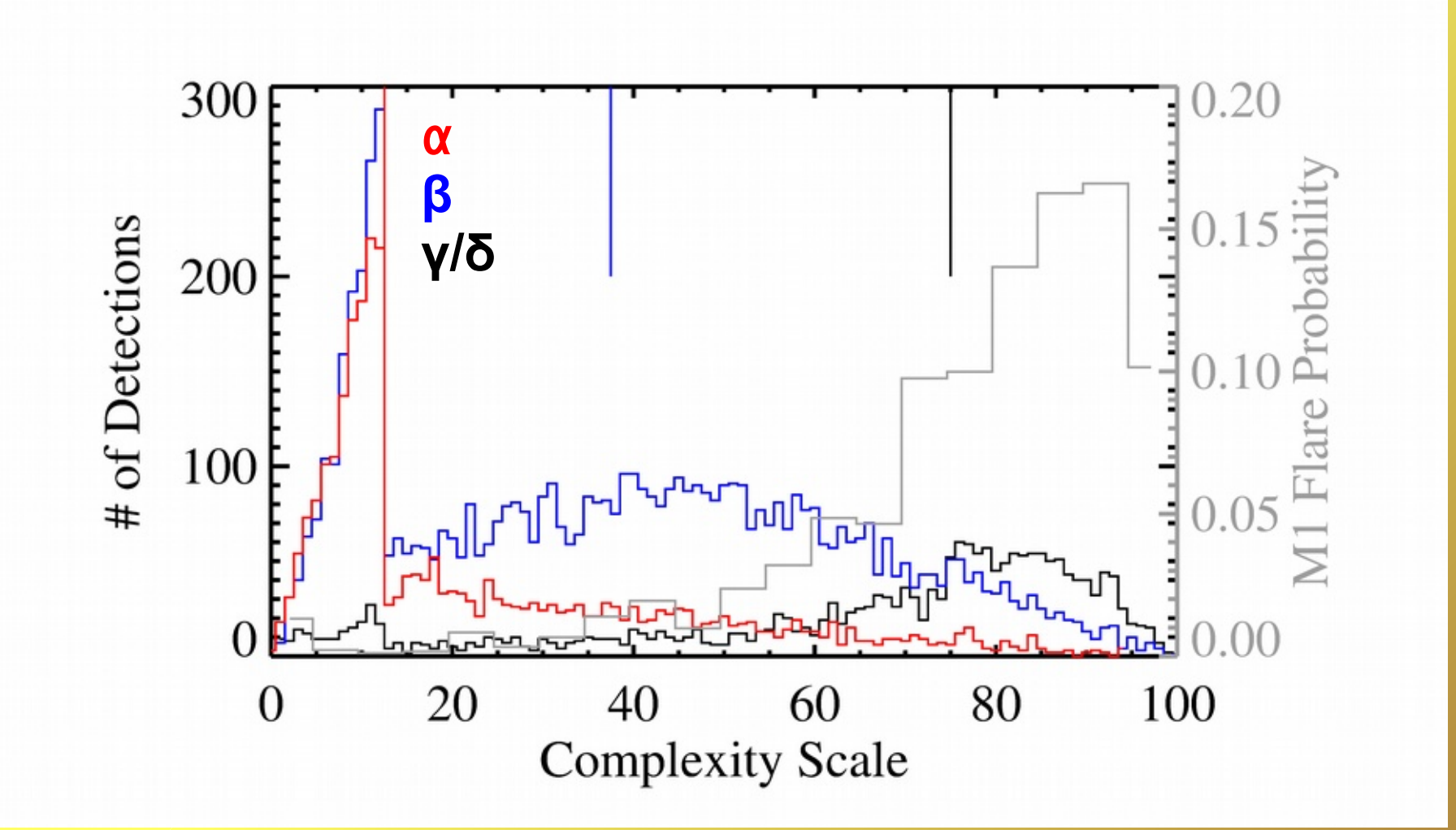
- **Std. Dev.** of Last 10 Rankings Vs. Sequential Score **Difference**
- Detections could **jump** up or down by **~50 images** (out of ~13k)

Elo Score to Scale



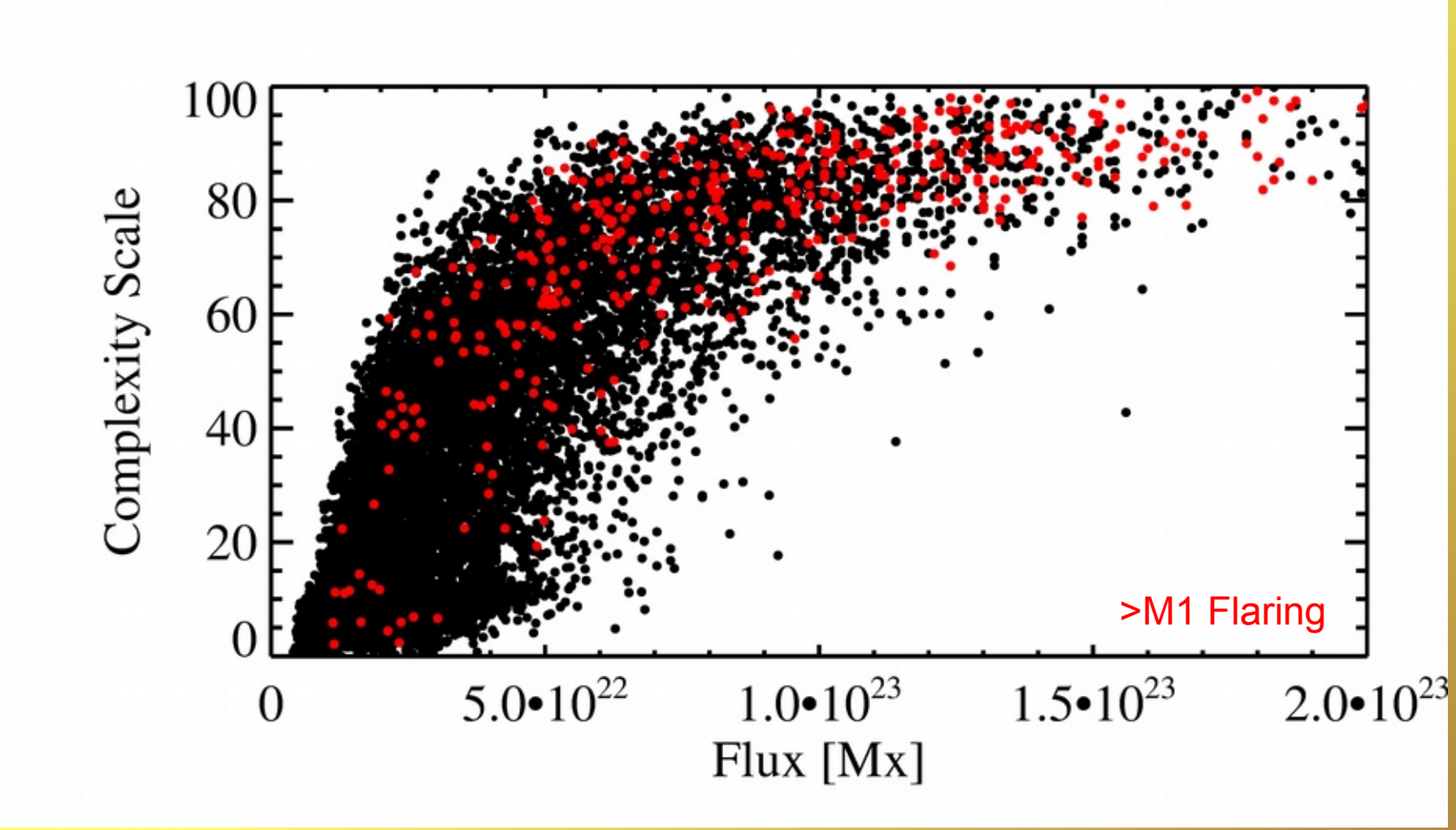
- Converting from Elo score into a complexity scale
- Use Hale-class Elo-score median values as a reference

Complexity Scale



- **α**'s range 0–25, **β**'s range 25–50, and **γ/δ**'s range 50–100
- **M1 Flaring** regions clustered at **>60** complexity units

Results



- Comparing complexity scale to total LOS flux
- Complexity improves separation between flaring and non-flaring detections

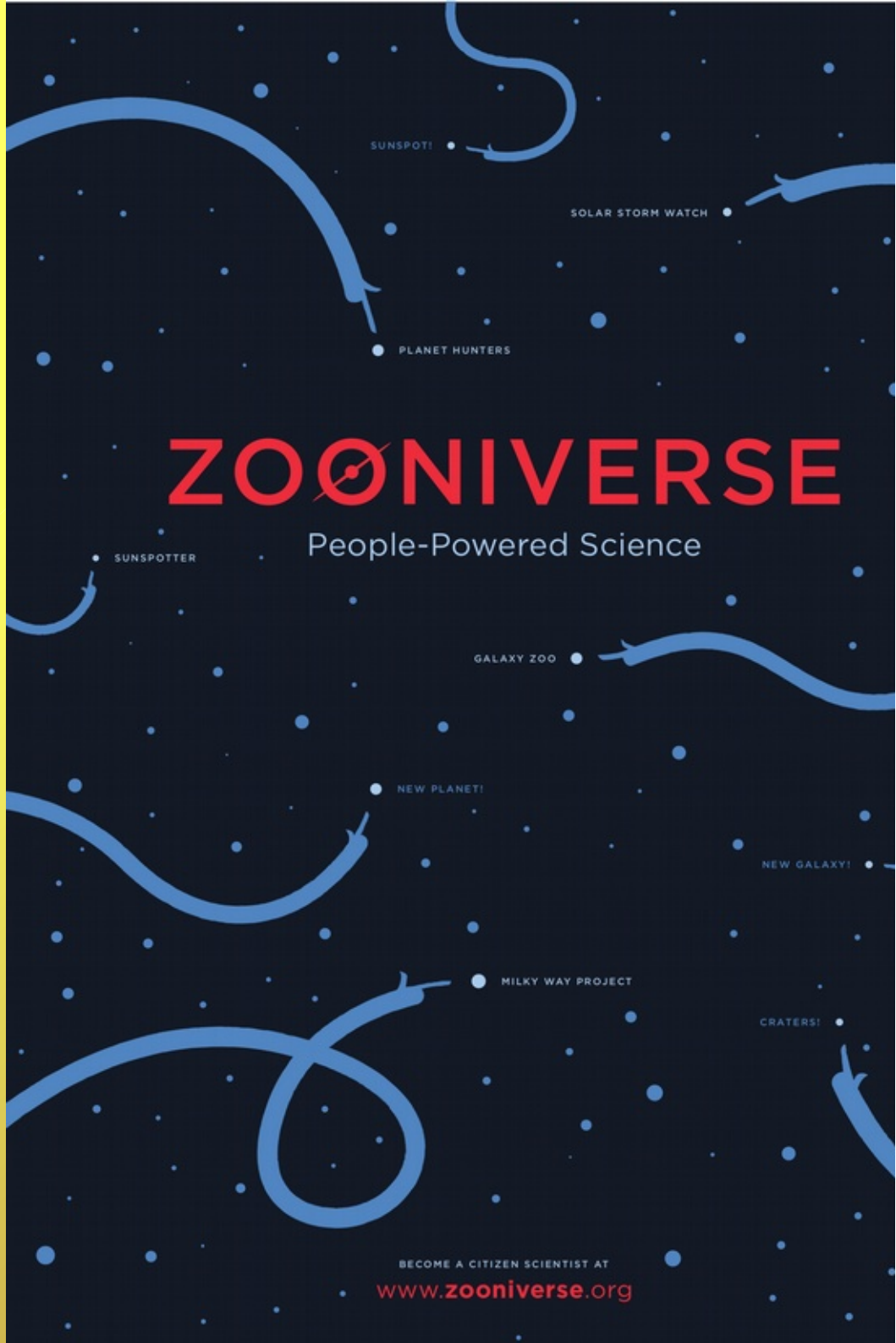
More **complex** SSGs are more **flare** active!

Next Step:
To compare complexity scale flare-predictive power to other physical properties

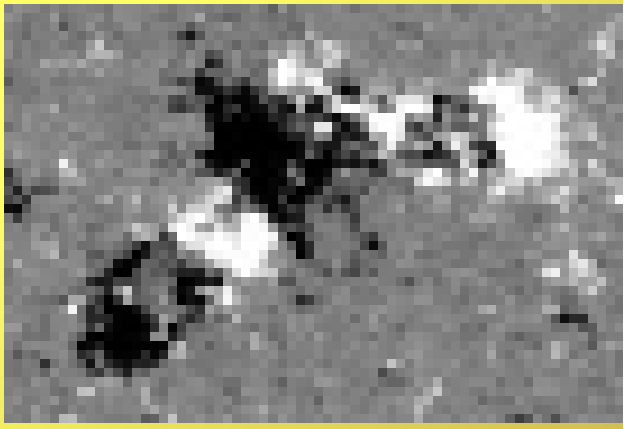
Citizen science is a great way to do **novel research**, while **engaging the public**!

Sign up to the **Zooniverse mailing list** to keep up with project developments (e.g. Re-Launch on **June 13, 2014**)

Contact Sunspotters Team:
pohuigin@gmail.com



Project Phases



1. Existing **collaborative dataset**
   - Allows comparison to many SSG properties
2. New completely **automated dataset**
   - Covers entirety of SOHO/MDI lifetime
3. Transition to SDO/HMI datatet
   - Will allow **realtime classifications**…
   - Potential for classifications to be fed into operational forecasting system