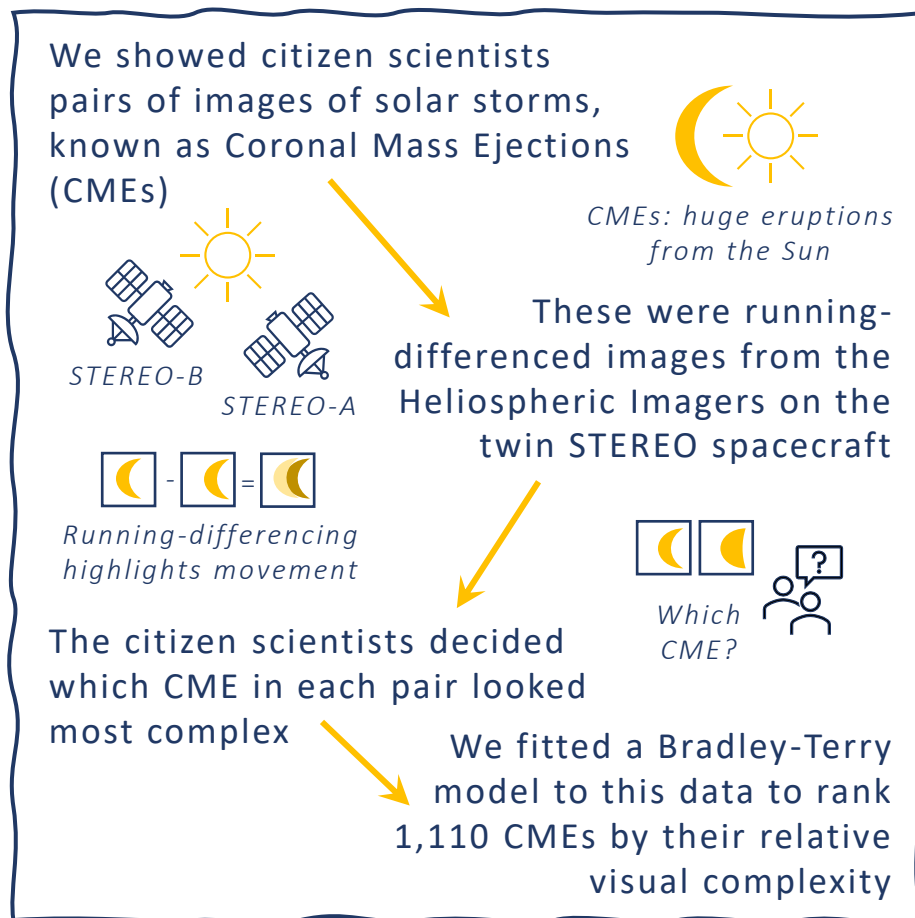


# THE VISUAL COMPLEXITY OF CORONAL MASS EJECTIONS

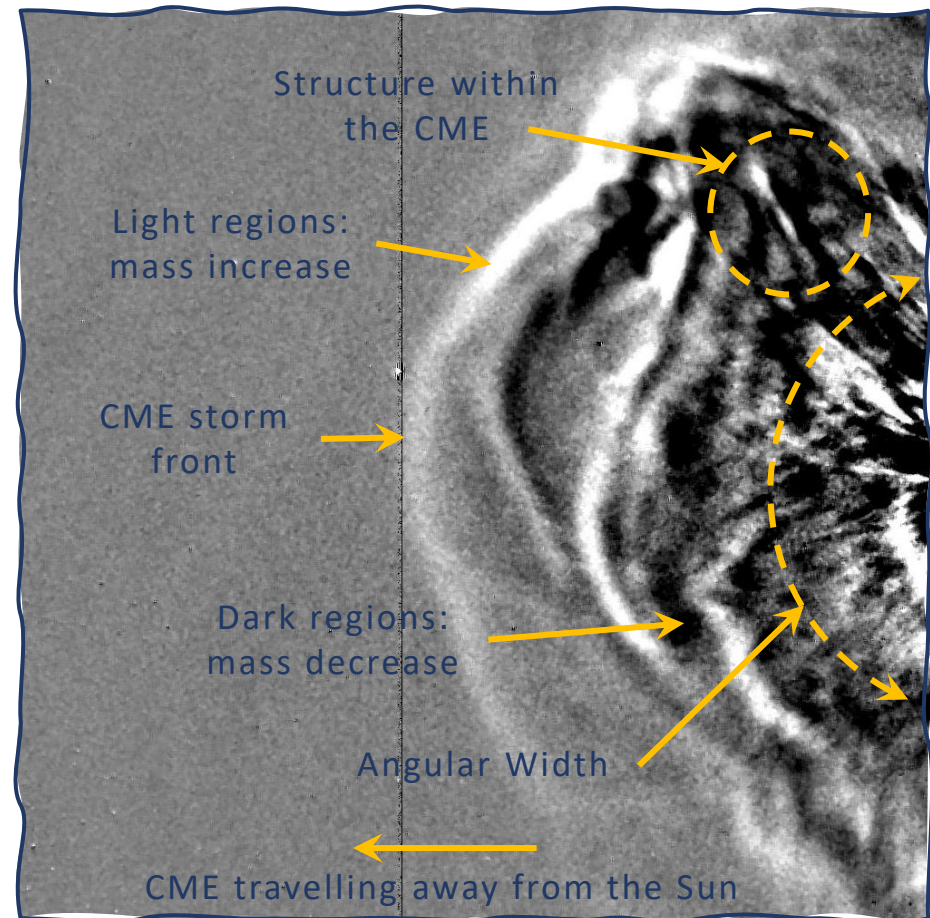
SCIENCE  
MUSEUM  
ZOOIVERSE

A research project by:

S. R. Jones ([s.jones2@pgr.reading.ac.uk](mailto:s.jones2@pgr.reading.ac.uk)), C. J. Scott and L. A. Barnard (University of Reading, UK),  
R. Highfield (UK Science Museum Group), C. J. Lintott (University of Oxford, UK),  
E. Baeten and 4,027 other Zooniverse citizen scientists



The methods we used in our study.  
Our citizen science project can be viewed here:  
[Protect our Planet from Solar Storms](#)



An example labelled running-differenced image of a Coronal Mass Ejection (CME) taken by the Heliospheric (white-light wide-angle) Imagers on the STEREO spacecraft

# WHAT WE ALREADY KNOW

On average...

## SOLAR MAXIMUM

## SOLAR MINIMUM

More CMEs

Fewer CMEs

*e.g. Robbrecht et al. 2009*

Wider CMEs

Narrower CMEs

*e.g. Yashiro et al. 2004, Harrison et al. 2018*

More sunspots  
*Schwabe, 1843*

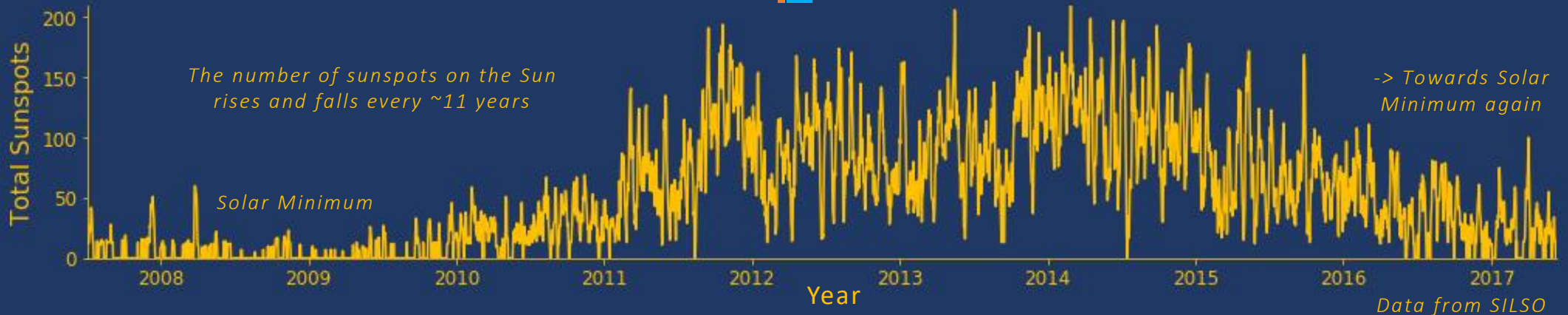
Fewer sunspots

Slower CMEs

*e.g. Yashiro et al. 2004, Gopalswamy 2016, Petrie 2015, Barnes et al. 2019*

Faster CMEs

*Solar Maximum*



# CONCLUSIONS FROM OUR RESEARCH

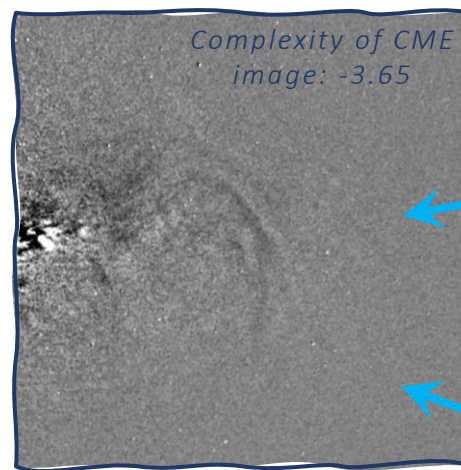
On average...

**SOLAR  
MAXIMUM**

**SOLAR  
MINIMUM**

CMEs appear more complex

STEREO-A CMEs averaged 0.4 in 2013



Narrower

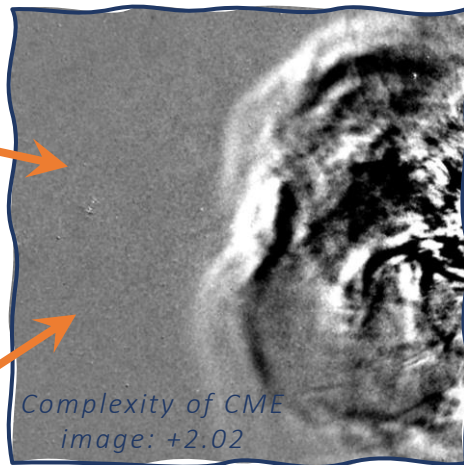
Complexity is correlated with angular width, as measured in the HELCATS catalogue.

Correlation coefficients:  
All STEREO-A CMEs: +0.60  
All STEREO-B CMEs: +0.43

More "bright" pixels

Complexity is correlated with the number of pixel values in the top (brightest) 12.5% of the colour map.

Correlation coefficients:  
All STEREO-A CMEs: +0.63  
All STEREO-B CMEs: +0.64

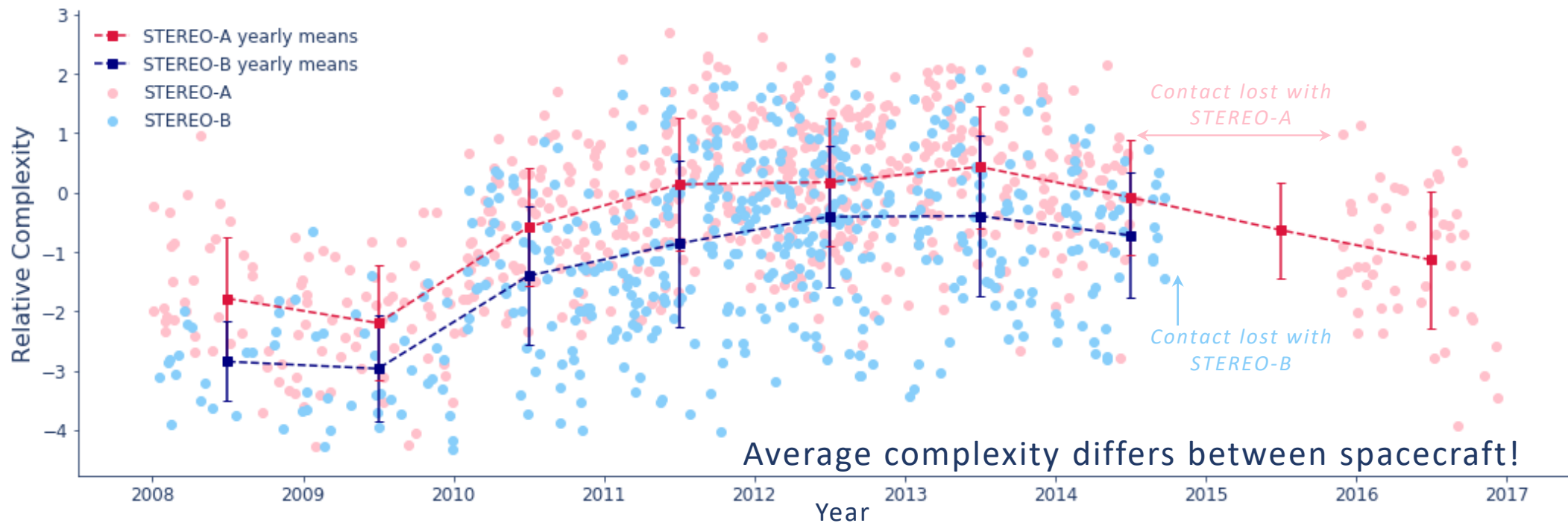


Wider

CMEs appear less complex

STEREO-A CMEs averaged -2.2 in 2009

Fewer "bright" pixels



# WHAT DOES THIS MEAN?

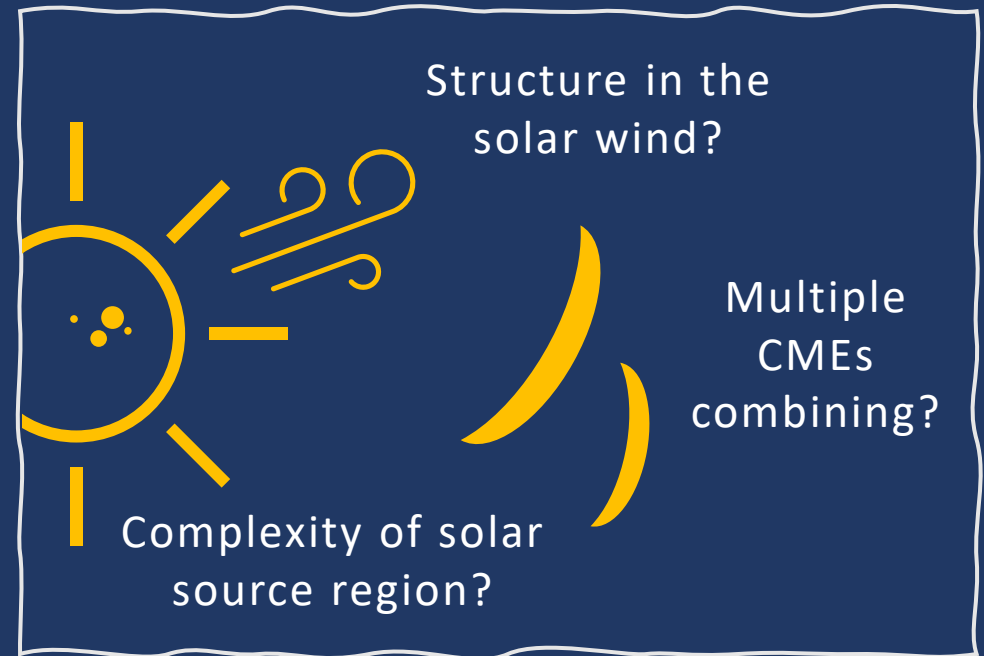
*The appearance of CMEs is changing through the solar cycle. This suggests further research is necessary to:*

Quantitatively determine which CME features are changing



*The qualitative CME characteristics which the citizen scientists used to describe a complex CME*

Investigate what is causing the CMEs to appear differently



*Cartoon showing possible reasons for the appearance of CMEs to change over the solar cycle*

Our results suggest that there is some predictability in the structure of coronal mass ejections, which may help to improve future space weather forecasts.