Commentary on "Algorithms for Solar Active Region Identification and Tracking"

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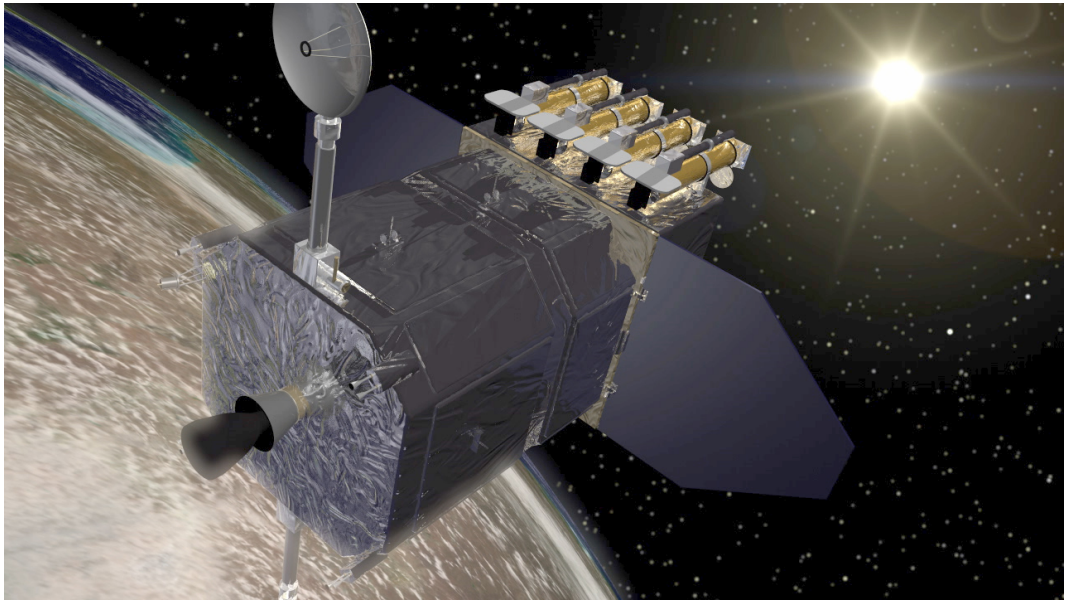
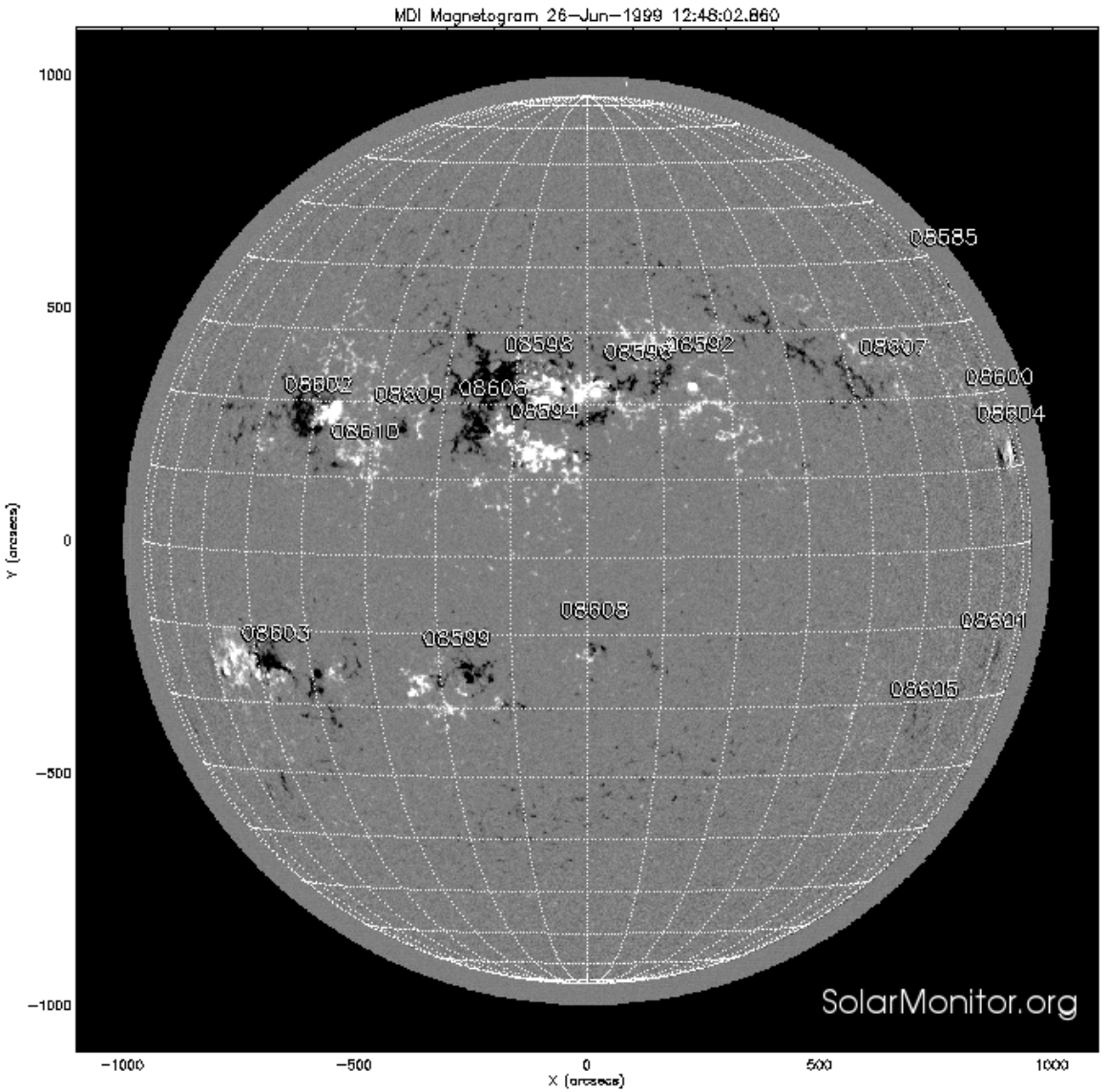
SDO and Solar Statistics



The Solar Dynamics Observatory (SDO) was launched on February 11, 2010 with the goal of better understanding the Sun's influence on Earth and near-Earth space. **Image Credit:** NASA

- Compared to older generation observatories, SDO generates an enormous volume of high cadence solar data.
- The continuous science data downlink rate is 130 Mb/s, enough to fill a typical CD every 36 seconds.
- Sophisticated, robust, and automatic analysis procedures are needed to supplement/replace manual techniques.

Sunspot Classification



- Sunspot classification is typically done manually by experts.
  - Impractical for massive data streams.
- Inconsistencies stemming from human observer bias.
  - Classification may not be reproducible.

Mount Wilson Classification Scheme

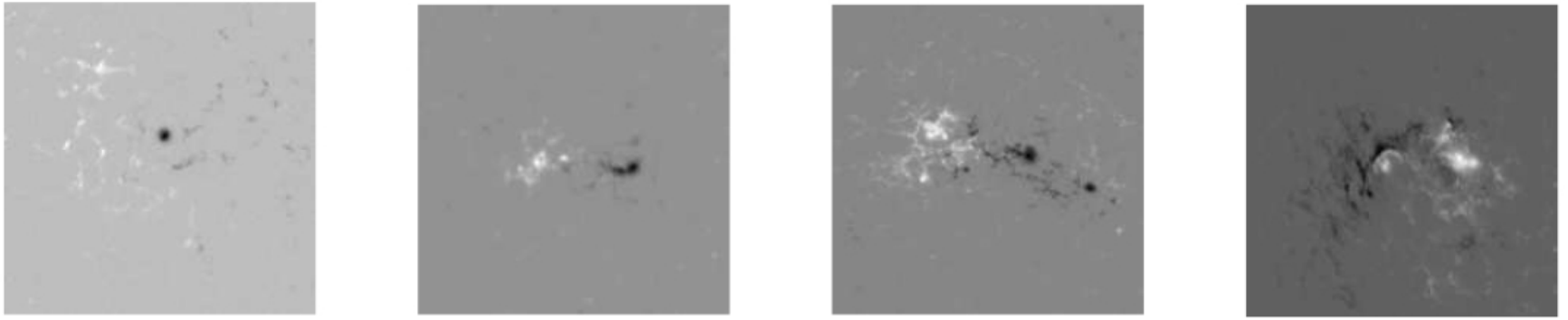
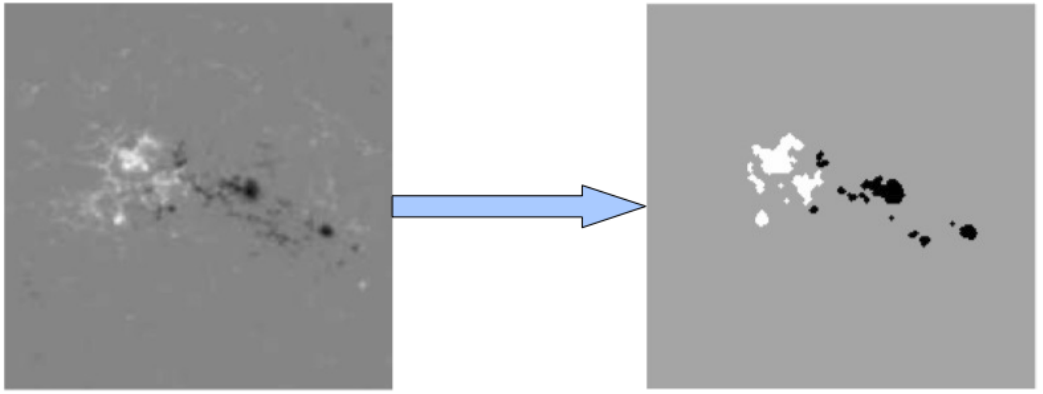


Figure: Four classes of sunspot groups according to the Mount Wilson scheme: (left to right) α, β, $\beta\gamma$, $\beta\gamma\delta$

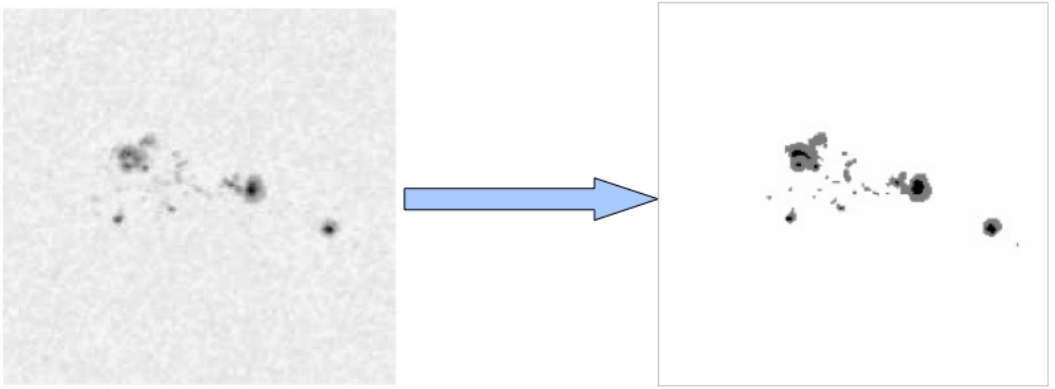
- α: a single unipolar spot which may be linked with plage of opposite magnetic polarity.
- β: pair of spots with opposite magnetic polarity (bipolar), but with a simple and distinct spatial division between the polarities.
- $\beta\gamma$: a bipolar group sufficiently complex that a straight line cannot divide the two polarities.
- $\beta\gamma\delta$: a bipolar $\beta\gamma$ group with umbrae of opposite polarity inside a single penumbra.

Steps Towards Automated Classification

1. Locate active region pixels in magnetograms and identify polarities.



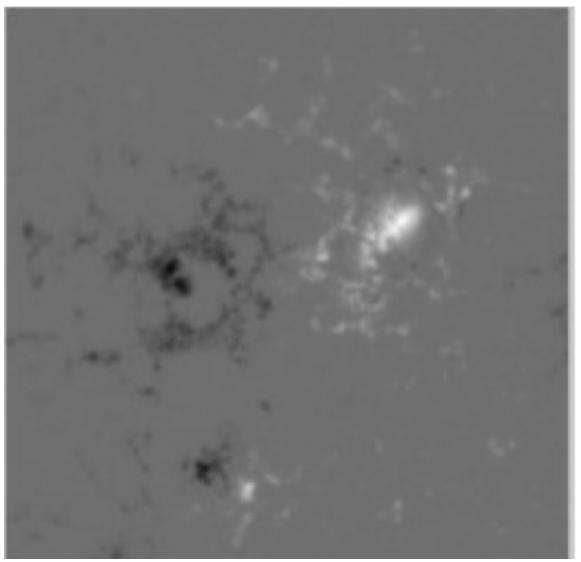
2. Identify umbrae/penumbrae in white-light images.



3. Extract science-driven numerical features to use as attributes in a supervised learning algorithm. (See my poster for details!)

Fully Automated Classification?

- Our current method of sunspot classification is "semi-automated."
  - The active regions come "pre-cut."
  - Difficulties arise when there are multiple active regions in the same cutout.



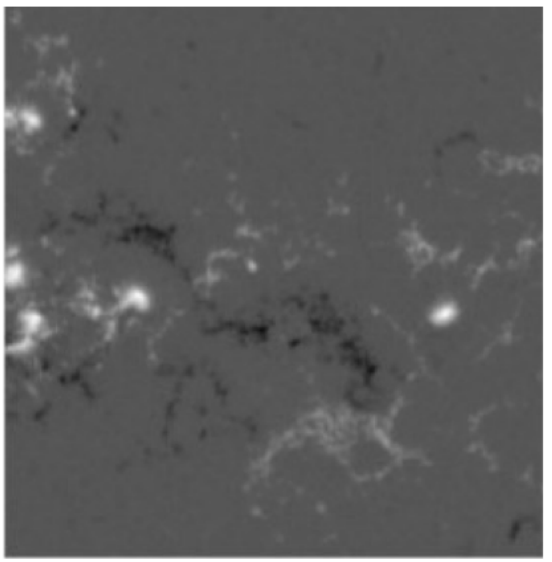
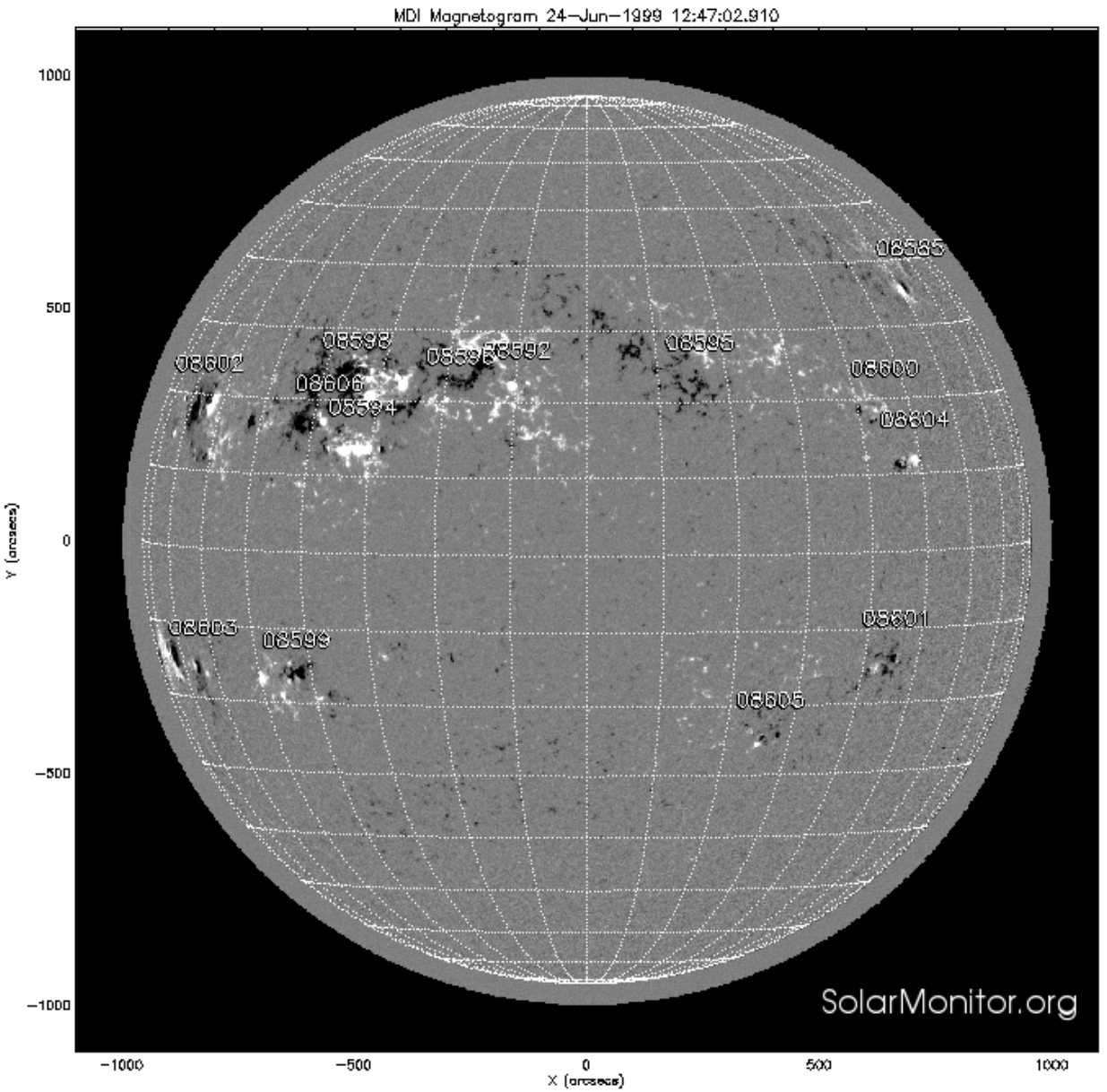
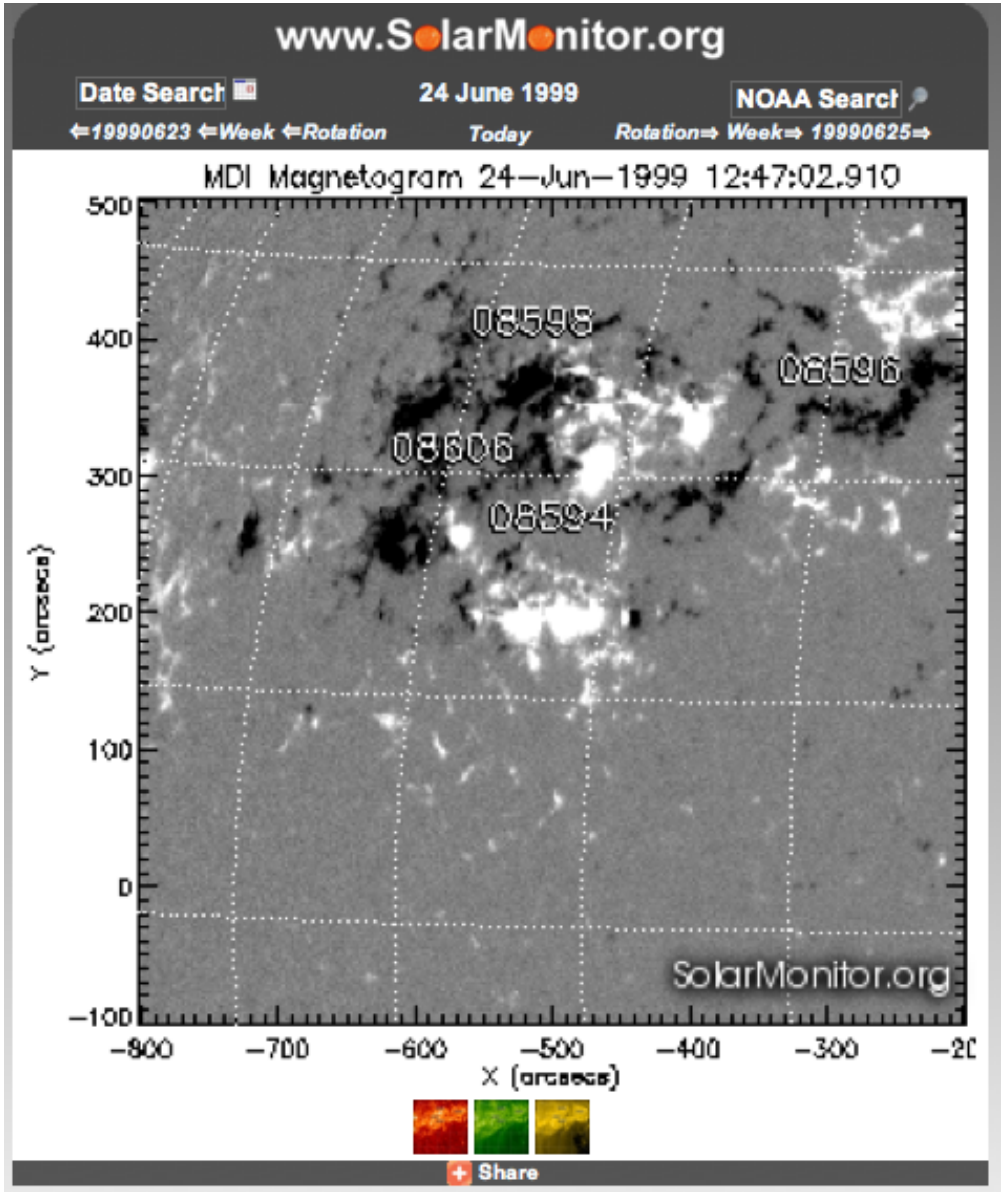


Image: (Left) Two active regions that are easily distinguishable; (Right) Multiple active regions not easily distinguishable

Multiple Merging Active Regions

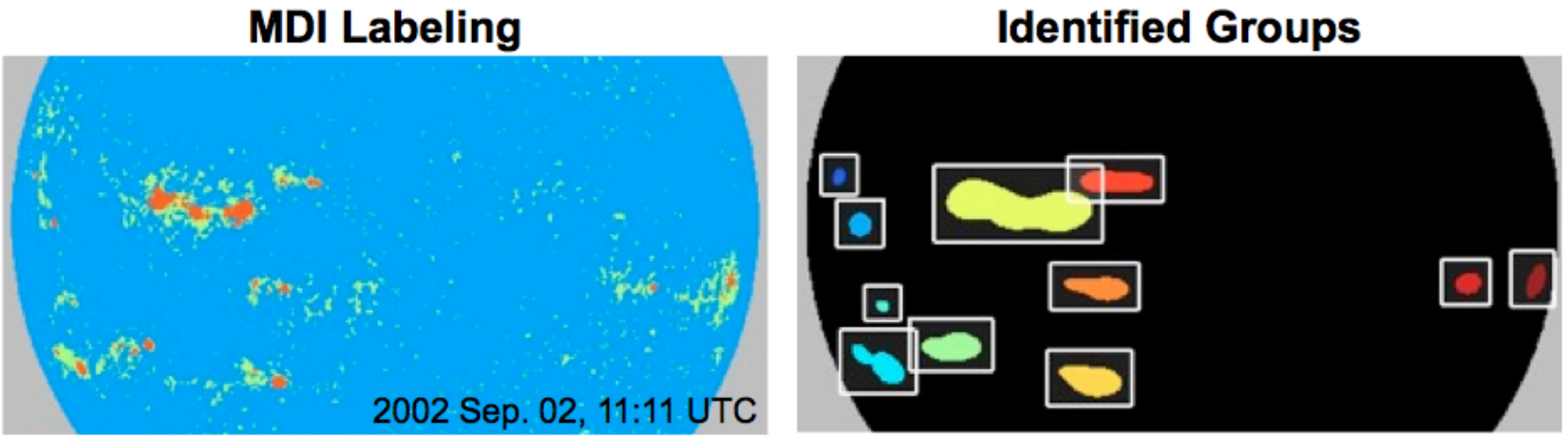


Multiple Merging Active Regions→Bad Classification



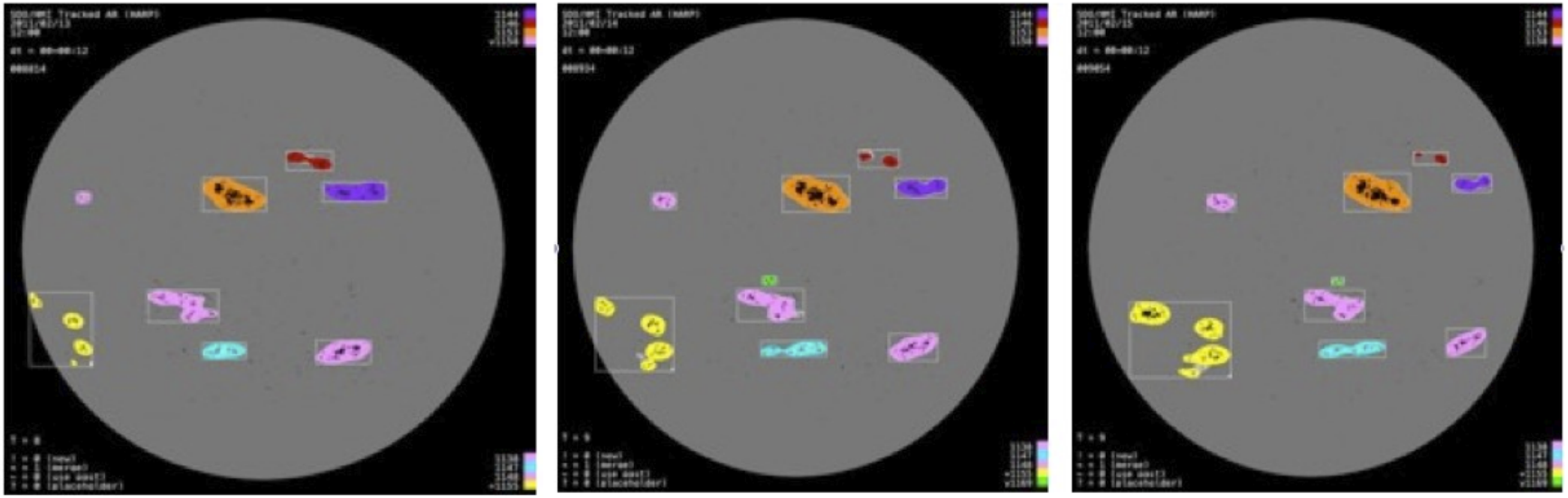
- Sunspot classification is based around the morphology of individual active regions.
- Erroneously treating two (or more) active regions as a single active regions introduces artificial complexity that will lead to obviously incorrect classification (i.e $\alpha \rightarrow \beta\gamma$).

Partial Solution: Grouping and Tracking



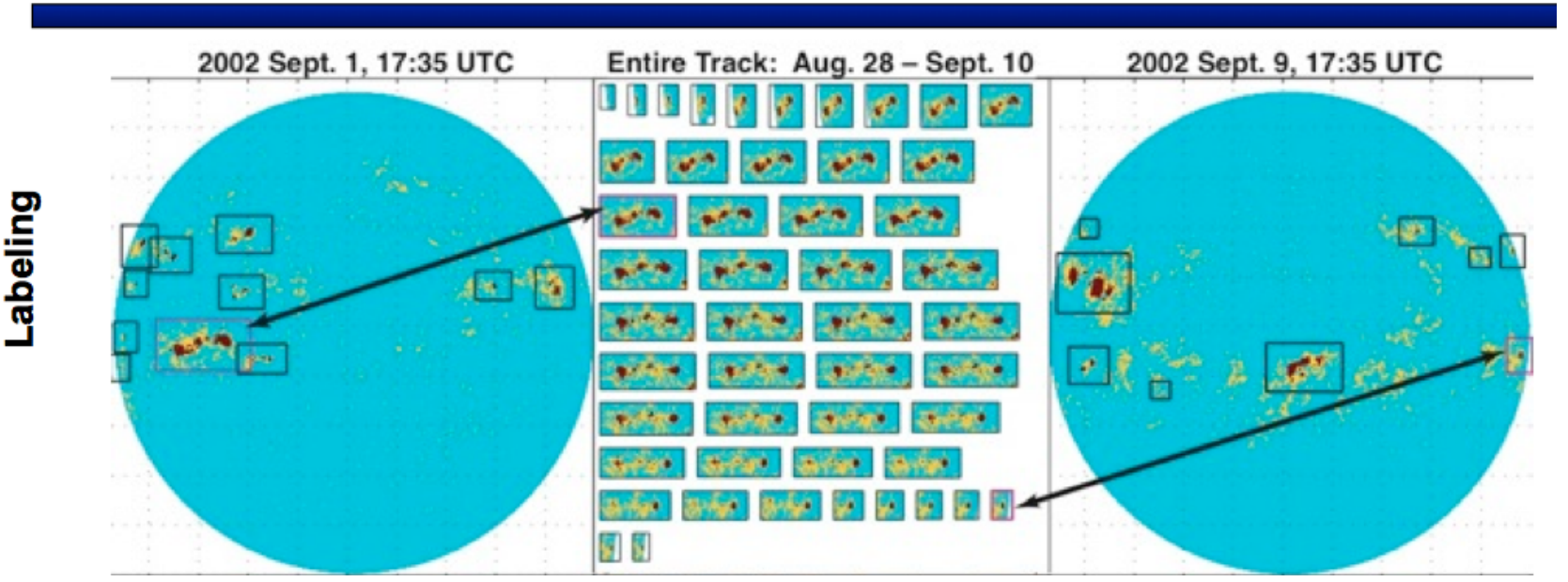
- We can use group labels to filter out pieces of magnetic flux that are not associated with the sunspot/active region of interest.

Partial Solution: Grouping and Tracking



- By tracking active regions over multiple frames, we can sometimes distinguish separable regions before (or after they merge) and make judgements about the number of distinct regions in a given location.
- Classification according to the Mount Wilson scheme may not be ideal for merging active regions, but recognizing those situations has been non-trivial.

Beyond Classification



- Our ultimate goal is to capture evolutionary patterns in sunspot groups and predict energetic events such as solar flares and CMEs that are known to be associated with sunspots/active regions.
- This will require a massive amount of data (not a problem in the era of SDO) and the ability to track particular sunspots/active regions.

Acknowledgements

Automating sunspot classification is joint work with:

- Vinay Kashyap (Smithsonian Astrophysical Observatory)
- Thomas Lee (Department of Statistics, University of California, Davis)
- David van Dyk (Statistics Section, Imperial College London)
- C. Alex Young (NASA Goddard Space Flight Center)

For Further Reading I


Turmon, Pap, Mukhtar
"Statistical Pattern Recognition for Labelling Solar Active Regions: Application to SoHO/MDI Imagery"
ApJ, 2002, 396-407.


M. Turmon, H. Jones, J. Pap, O. Malanushenko.
"Statistical feature recognition for multidimensional solar imagery
Solar Physics, 04/2010


Stenning et al.
"Morphological Image Analysis and Its Application to Sunspot Classification."
Statistical Challenges in Modern Astronomy V, 2011.