A statistical study of quiescent and eruptive prominences at solar minimum via an automated tracking system

Ivan Loboda, Sergey Bogachev
Lebedev Institute of the Russian Academy of Sciences

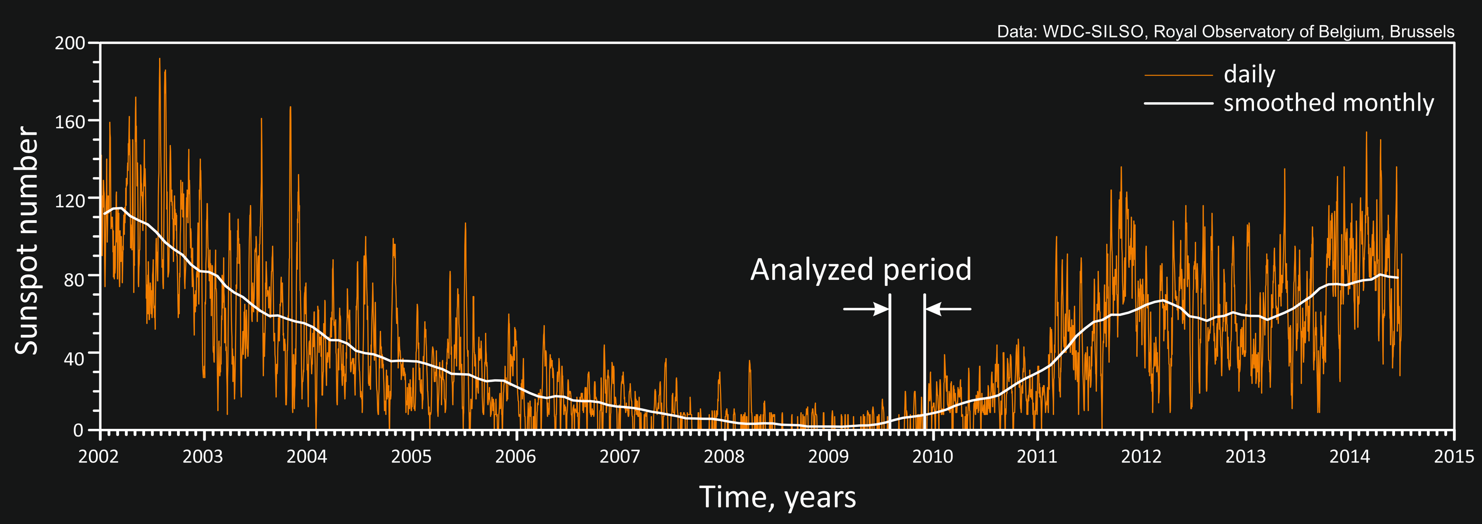
1. Motivation

For a comprehensive study of prominences one should supplement isolated observations with a statistical approach. For this purpose we have developed an automated system capable of precisely locating prominences on EUV images.

2. Data

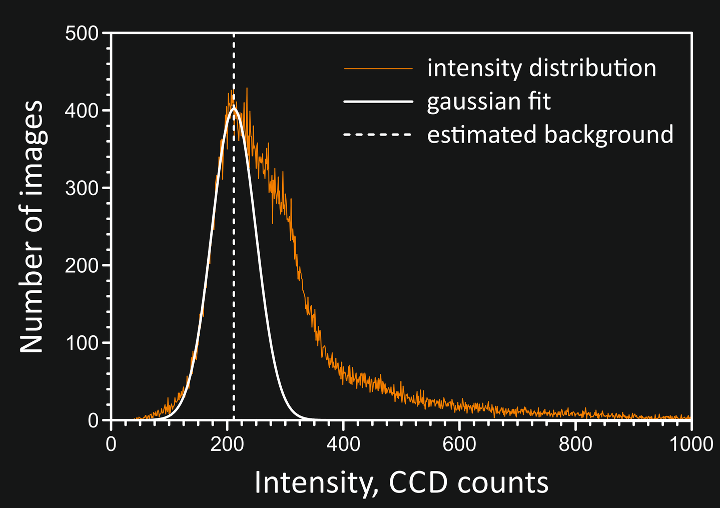
In our study we use the following dataset, obtained at the end of the prolonged minimum between the 23rd and 24th solar cycles:

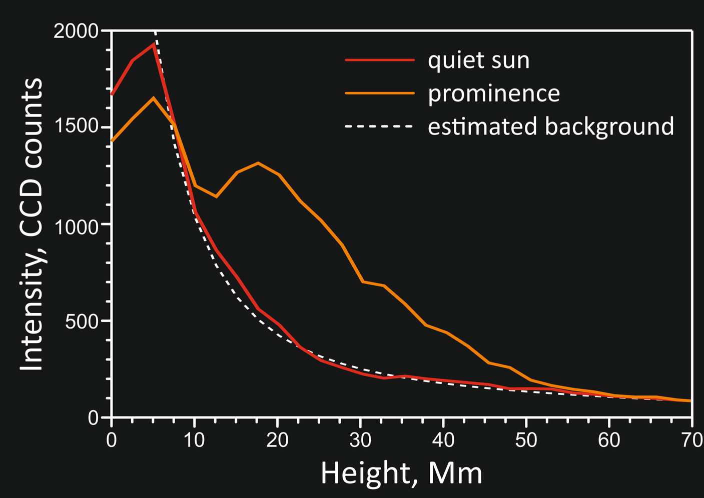
Instrument:	TESIS (CORONAS-Foton)
Spectral line:	He II 304 Å
Resolution:	1.7", half images reduced to 3.4"
Cadence:	5 minutes
Observation period:	August 2009 — November 2009
Number of images:	18812



3. Estimation of background

Prominences are observed against a strong, rapidly changing background. To find it we build an intensity distribution for each pixel above the limb and fit its left slope.





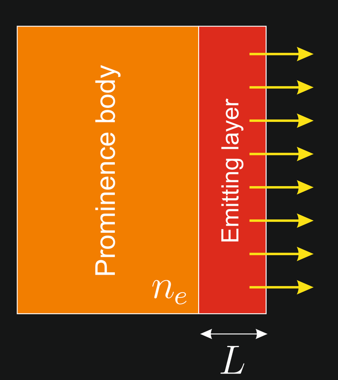
We then use this background to normalize the image:

$$Normalized = \frac{Image+\gamma}{Background+\gamma}$$

where: $noise\ at\ the\ higher\ heights \ll \gamma \ll signal\ at\ the\ lower\ heights$

4. Models & assumptions

To estimate the mass of a prominence we assume that electron density n_e is constant along the line of sight, and that observed radiation is mostly formed in an outer layer of thickness $L \sim 1/n_e$, so that its intensity is:

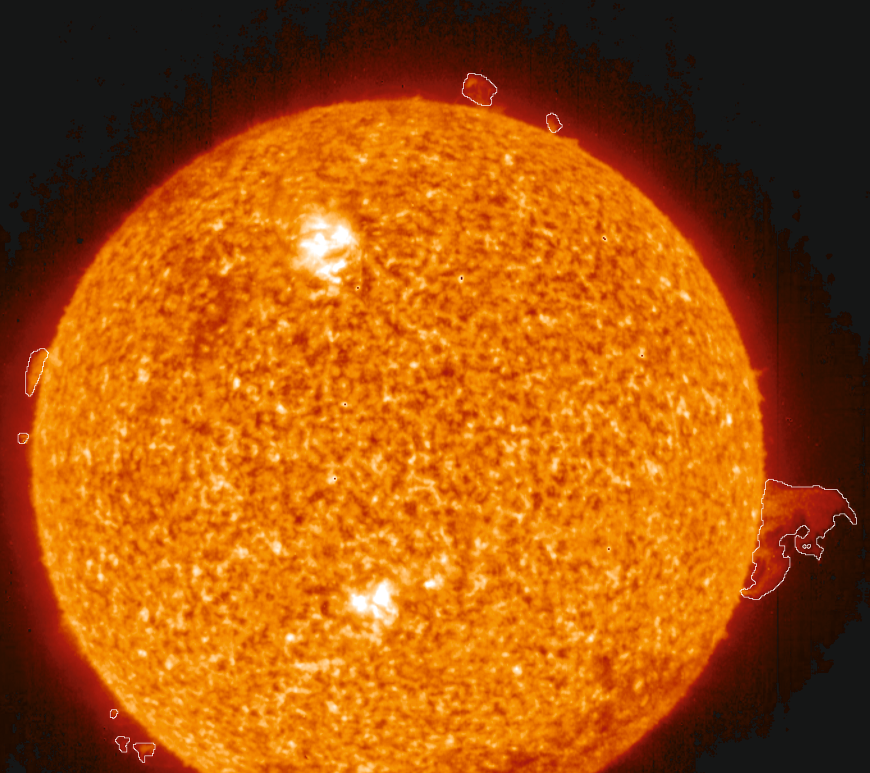


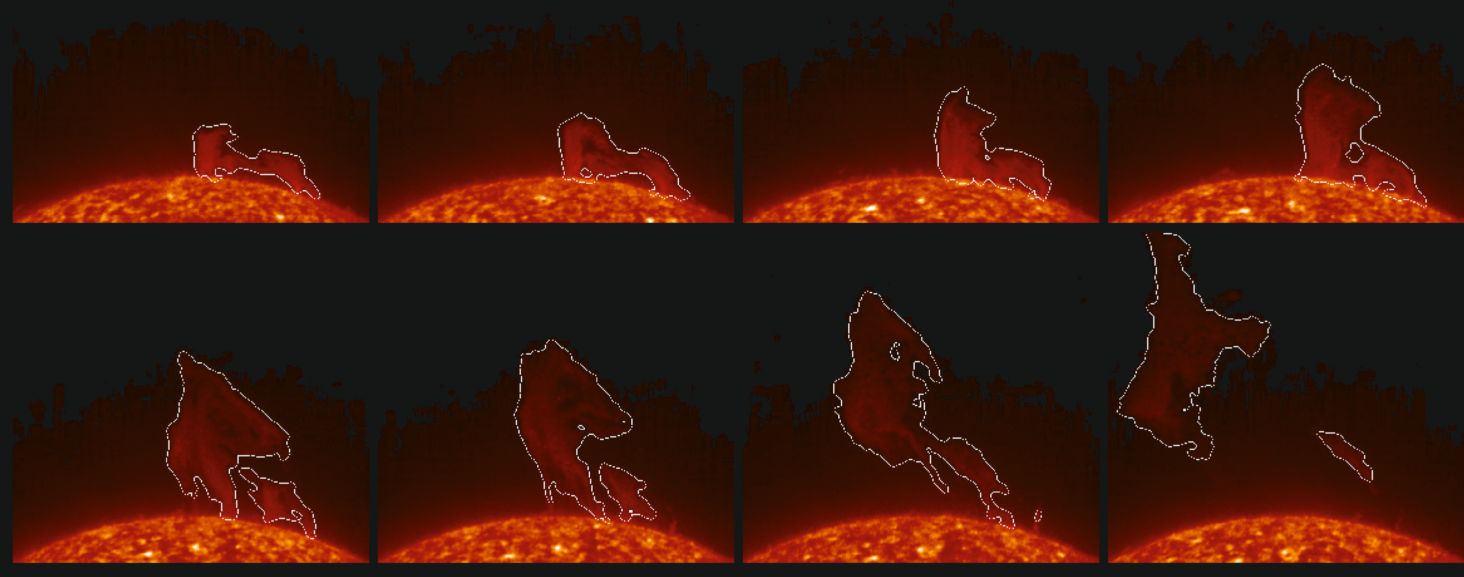
$$I \sim L n_e^2 \sim n_e$$

Later we choose the proportionality coefficient such, that for all detected prominences their mean electron density would equal 2×10^{10} cm^{-3}.
To estimate prominence's thickness at a given point we use the following equation:

$$D = 2\left[D_{max}^2 - (D_{max} - R)^2\right]^{1/2}$$

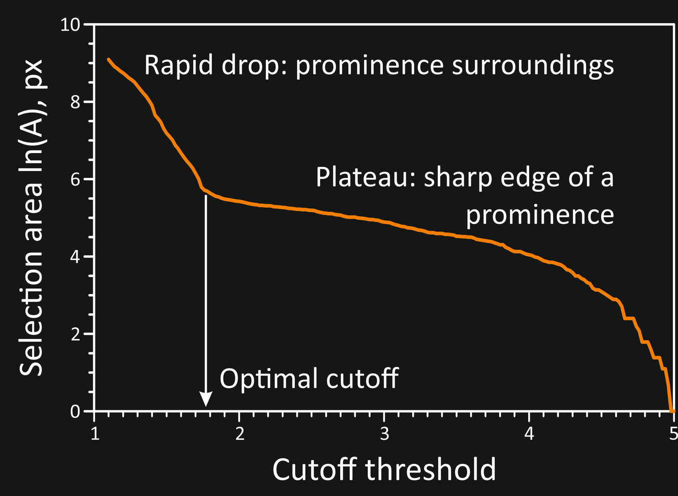
where R is the shortest distance to the edge of the prominence, and D_{max} is the maximal thickness of the prominence ($D_{max} = max[R]$).

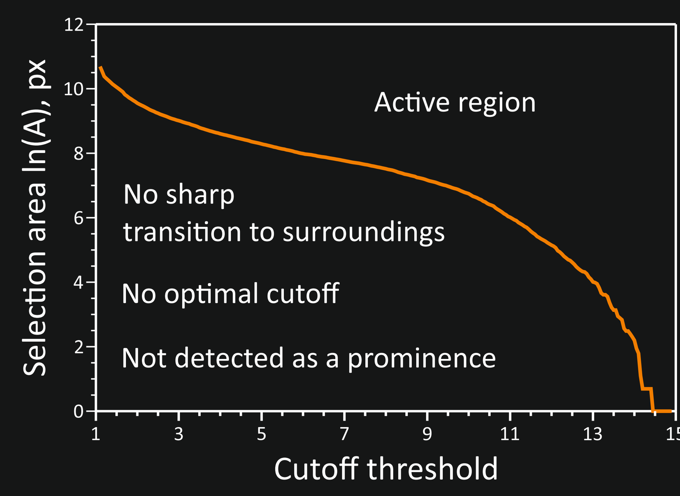




5. Detection & classification

We use the same technique to determine the optimal intensity threshold for each prominence and to distinguish between prominences and active regions.





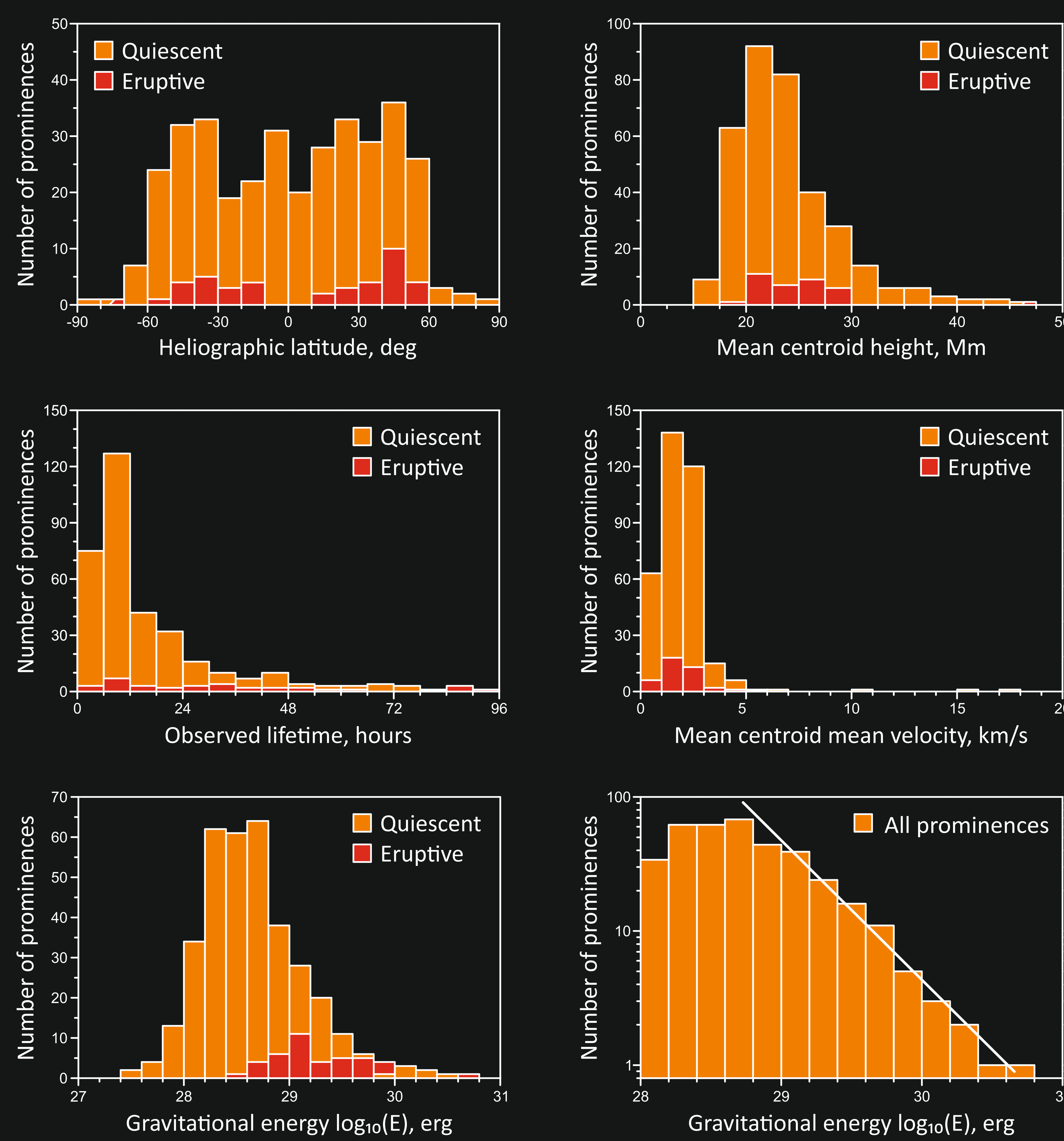
For each prominence we measure its position and size, estimate its volume, mass and gravitational energy. We also mark erupted parts of prominences whose centroid is lifted above the threshold of 50 Mm. Finally, use a synoptic map to track these prominences on a series of consecutive images.

6. Statistics

We have obtained latitudinal positions, heights, lifetimes, velocities as well as estimates of gravitational energy for the total of 348 quiescent and 41 eruptive prominences. We have also found that within the sensitivity range of our system energy distribution can be approximated with a formula:

$$N_E \sim E^{-\psi}, \quad \psi = 1.1 \pm 0.2$$

i.e. gravitational energy is equally destributed among the prominences of different size.



7. Further study

Our next goal is to adapt our system to streaming processing of data from other satellites, primarily SDO and STEREO, and to observe variations of prominences' characteristics troughout the solar cycle.