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ACTIVE AND QUIESCENT PROMINENCES OF SOLAR CYCLE 24

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Abstract: *We present the results of a statistical study on the association between prominences/filaments, detected by Kislovodsk Mountain Astronomical Station of the Pulkovo Observatory, and active regions (listed by the NOAA Space Weather Prediction Center). The study covers the period of solar cycle 24 (December 2008 – December 2019) and includes 1735 active regions, 21186 prominences and 45279 filaments. Our results show that most of the H-alpha prominences/filaments tend to form outside active regions and most of the active regions are not producing a single prominence in their lifetime.*

АКТИВНИ И СПОКОЙНИ ПРОТУБЕРАНСИ ОТ 24-И СЛЪНЧЕВ ЦИКЪЛ

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Ключови думи: *Протуберанси, влакна, слънчева активност, слънчев цикъл*

Резюме: *Представяме резултатите от статистическо изследване на връзката между протуберанси/влакна, регистрирани от Планинската астрономическа станция Кисловодск на Пулковската обсерватория, и активни области (публикувани от Центъра за прогнозиране на космическото време на Националната агенция на океанските и атмосферни изследвания на САЩ). Изследването обхваща периода на 24-ия слънчев цикъл (декември 2008 – декември 2019 г.) и включва 1735 активни области, 21186 протуберанса и 45279 влакна. Нашите резултати показват, че повечето протуберанси/влакна, наблюдавани в линията Hα, се формират извън активни области, както и повечето активни области не образуват нито един протуберанс по време на съществуването си.*

Introduction

Quiescent prominences (QPs) may retain their global properties relatively constant for periods up to few solar rotations. Usually they form outside active regions (ARs) on higher latitudes. Despite their shape often remains nearly unchanged in long time ranges, high-resolution observations reveal that their fine structure is dynamic. The lifetime of quiescent prominences varies, but is strongly dependent on their latitudes – in polar regions they live 5.2 solar rotations on average, while near the equator this period decreases to 3.3 rotations [1].

Active prominences (APs) emerge in or close to ARs. They are dynamic structures with clearly noticeable movements and typical lifetime of a few hours [2]. They are smaller in size than QPs, have similar temperature, but are denser and with stronger magnetic field [3].

As structures formed in significantly hotter and less dense environment, the geometry, dynamics and the existence of prominences are determined by the properties and evolution of the magnetic fields that support and isolate the prominence material in the corona. The connection with solar magnetic field is also proved by the dependence between their number, size and their

distribution at different moments of the 11-year solar cycle [4]. Their behavior is similar to the one of sunspots – during solar minimum we observe less filaments, they are smaller in size, shorter-lived and much less active. Around the maximum of the cycle, not only their number and activity increases, but prominences (similar to the sunspots) migrate – from average latitudes of ± 30º at the beginning of the cycle to about ± 17º at the end [5].

The solar cycle (SC) 24 began in December 2008 with a solar minimum that had lasted longer than average reaching record low levels of solar and geomagnetic activity [6] and ended 11 years later in December 2019, according to the data presented by SILSO Database of Royal Observatory of Belgium, Brussels. The 24th solar maximum happened in April 2014. SC24 had a low level of activity and fewer sunspots than average [7]. Still, some powerful events did occur, such as the active region (AR) 12192. It emerged in October 2014 and was the largest AR since November 1990 [7].

We present a statistical analysis on the link between ARs and prominences/filaments, observed during the SC24 (December 2008 – December 2019). Determining whether a prominence is related to an AR we divide them into AP and QP.

Data Sources and Association Criteria

Using the ARs listing of the NOAA Space Weather Prediction Center we considered all ARs between 11018 (appeared on 2009 May 23) and 12753 (2019 December 26) as belonging to the SC24. Although the first one was observed 6 months after the beginning of the SC, it was the first AR formed at latitude higher than 30° since December 2008 and we assume it as a starting point in our study. The daily reports of the H-alpha (6563 Å) telescope of Kislovodsk Mountain Astronomical Station of the Pulkovo Observatory are used to associate prominences and filaments with the events from our ARs sample. Finally, our sample includes 1735 ARs, 21186 prominences and 45279 filaments in the period of SC24. Due to the common nature of prominences and filaments, in our study we consider them as one process and both terms are used interchangeably.

Taking into consideration their shapes and sizes, to link a prominence/filament to an AR we require the difference between their given latitudes to be less or equal to 7° when they are detected on the same side of the central meridian.

Results

We compare the yearly mean total number of ARs and prominences with the progression of the SC, presented by the yearly mean sunspot number (Figure 1, left). Both sunspots and ARs follow nearly the same trend and peak in 2014. Prominences, on the other hand, reach maximum in 2012 and their activity slowly begins to decrease except for the period 2013-2014, when at the end they reach second (smaller) peak that coincides with the maximum of SC24.

A different point of view to the activity during the last solar cycle gives the comparison between the days with lack of activity events per year (Figure 1, right). The sunspots show typical behavior as in the period 2011-2015 only 3 days are spotless (two in 2011 and one in 2014) and in the years close to the solar minimum these days are more than 200. Least days without ARs are registered in the year of 24th solar maximum (2014) – 155. In the years around it (2012-2015) the number of days without observed prominences is almost a constant (94-98), but the absolute minimum is reached in 2017 when only 78 days were prominence-less. At the same time in the previous year (2016) the maximum is reached – in 129 days no prominence or filament was registered.

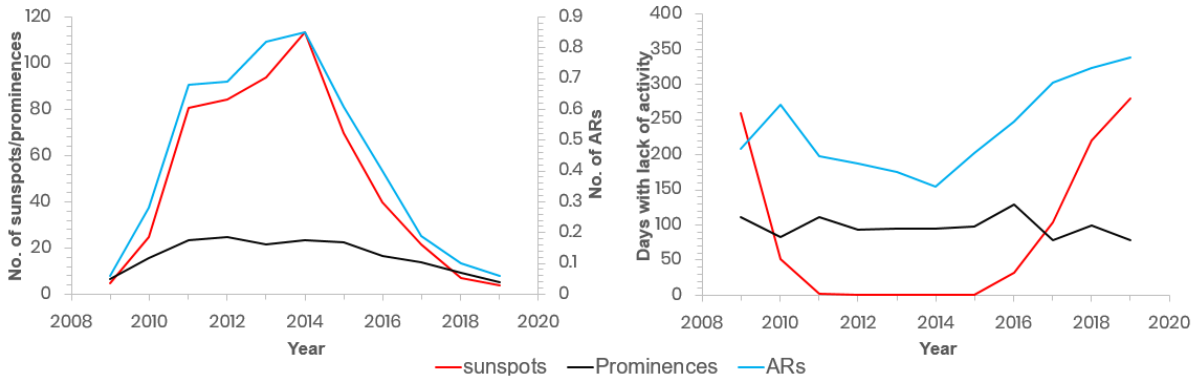

Fig. 1. Yearly mean total number of ARs, sunspots and prominences (left) and days with lack of ARs, sunspots and prominences per year (right)

The summary of the data for the SC24 (Table 1) shows that almost all detected prominences (about 99%) are formed outside ARs. Out of 66465 events, in only 947 cases a nearby AR is linked to the observed filament. This is significantly different from the generally accepted view that about 2/3 of prominences are quiescent. The reason for this result may be in the large event sample or in the high sensitivity method of detection of H-alpha prominences by Kislovodsk Mountain Station that successfully registered almost all events no matter how small or insignificant they appear [8].

Table 1. Association rates between ARs and prominences/filaments of SC24

		Prominences/filaments			
		Number		**%**	
AR-related		947		1.4	
Non-AR-related		65518		98.6	
Total		66465			
		-less	**-productive**	**-rich (≥3)**	**Total**
ARs	**Number**	1089	646	58	1735
	%	62.8	37.2	3.3	
				9.0	

On the other hand, statistics show that almost 63% of all ARs of SC24 did not produce any prominence. In 646/1735 (37%) cases at least one filament was associated with an AR and 58 of these ARs can be defined as prominence-rich, because they produced 3 or more filaments. This is 3.3% of all ARs and 9% of the 646 prominence-productive ARs.

Conclusions

We present a preliminary results of a study on the prominences and their connection with solar active regions in the last solar cycle 24 that covers the period between December 2008 and December 2019. Our analyses show that the peak of prominences activity is observed two years before the maximum of the solar cycle. Almost 99% of 66465 prominences/filaments can be classified as quiescent since they are not linked with an AR. On the other hand, 37% of ARs produced at least one filament and more than 3% of them were identified as a source of at least 3 filaments.

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