3.p09

Small-scale Motions as the Precursors

Daikichi SEKI[1,2],
Kenichi OTSUJI[2], Hiroaki ISOBE[3],
Kiyoshi ICHIMOTO[2],

in Solar Filaments
of Eruptions

Takako T. ISHII[2]
Kazunari SHIBATA[2]

1. GSAIS, Kyoto University
2. Astronomical Observatory, Kyoto University
3. Kyoto City University of Arts

Abstract

- **Filaments**, the dense cooler plasma floating in the solar corona supported by magnetic fields, generally **exhibit certain activations before they erupt**. In our previous study (Seki et al. 2017), we observed that the standard deviation of the line-of-sight (LOS) velocities of the small-scale motions in a filament increased prior to its eruption.
- However, because that study only analyzed one event, **it is unclear whether such an increase in the standard deviation of LOS velocities is common in filament eruptions**.

Abstract

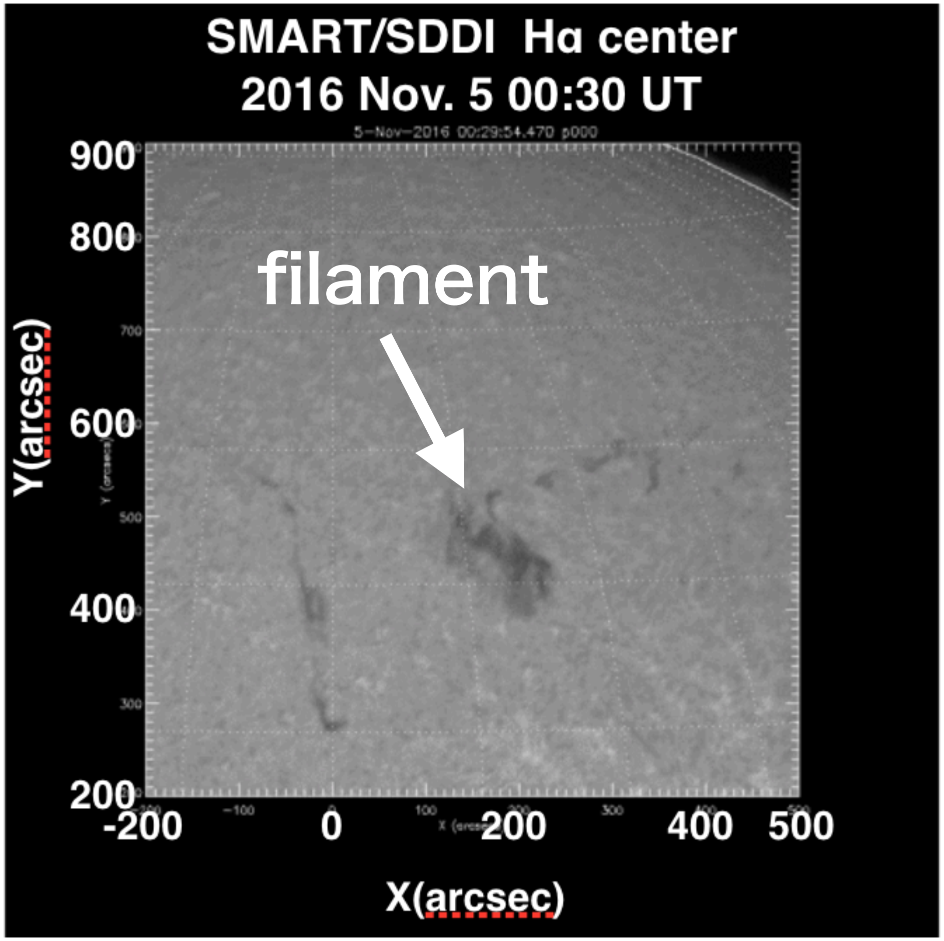
- In this study, **12 filaments** that vanished in Hα line center images were analyzed in a manner similar to the one in our previous work; these included two quiescent filaments, four active region filaments, and six intermediate filaments.
- We verified that **in all the 12 events, the standard deviation of the LOS velocities increased before the filaments vanished**. Moreover, we observed that the quiescent filaments had approximately 10 times longer duration of an increase in the standard deviation than the other types of filaments.
- We concluded that the standard deviation of the LOS velocities of the small-scale motions in a filament **can potentially be used as the precursor of a filament eruption**.

Introduction

- **Filaments**, or prominences, **dense cooler plasmas** floating in the solar corona, often become unstable and erupt **(filament eruptions)**.
- **Filament eruption** often **follows filament activations** such as;
  - the slow rise (*Sterling & Moore 2004; Sterling et al. 2011*)
  - the turbulent motion (*Tandberg-Hanssen 1995*).

Introduction

- Filament eruptions are often accompanied by flares and CMEs, and possibly **cause severe space weather effects** (*McAllister et al 1996*).

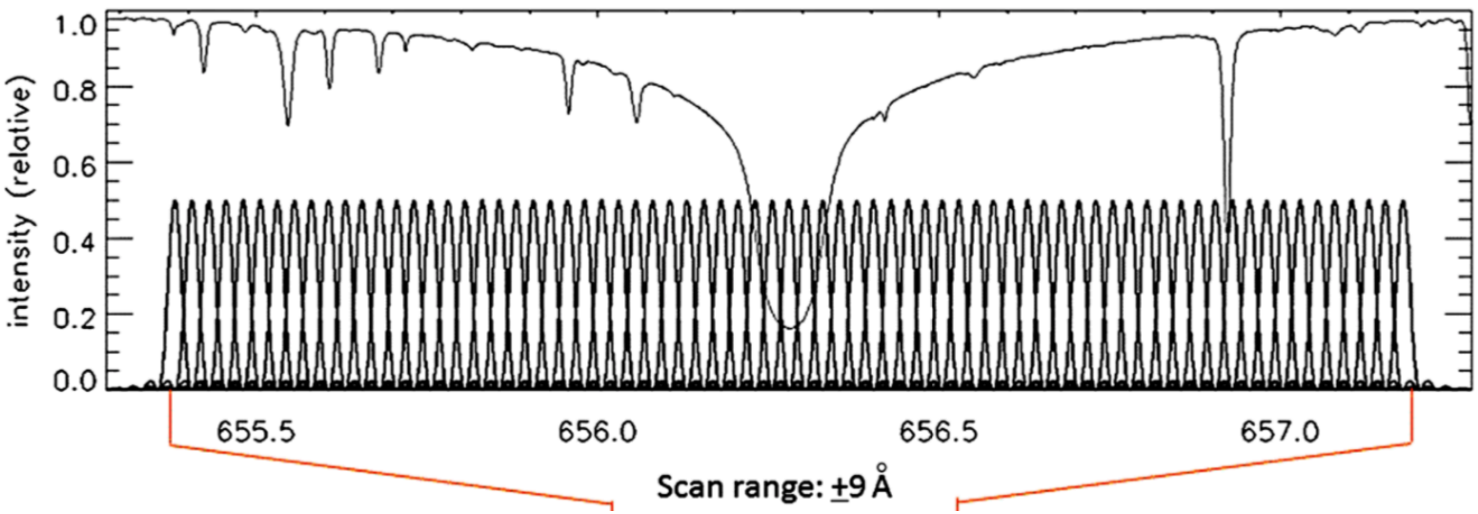


? Main Question ?

➡ *Is it possible to quantify the filament activation or its turbulent motion to predict solar eruptive phenomena?*

Observation

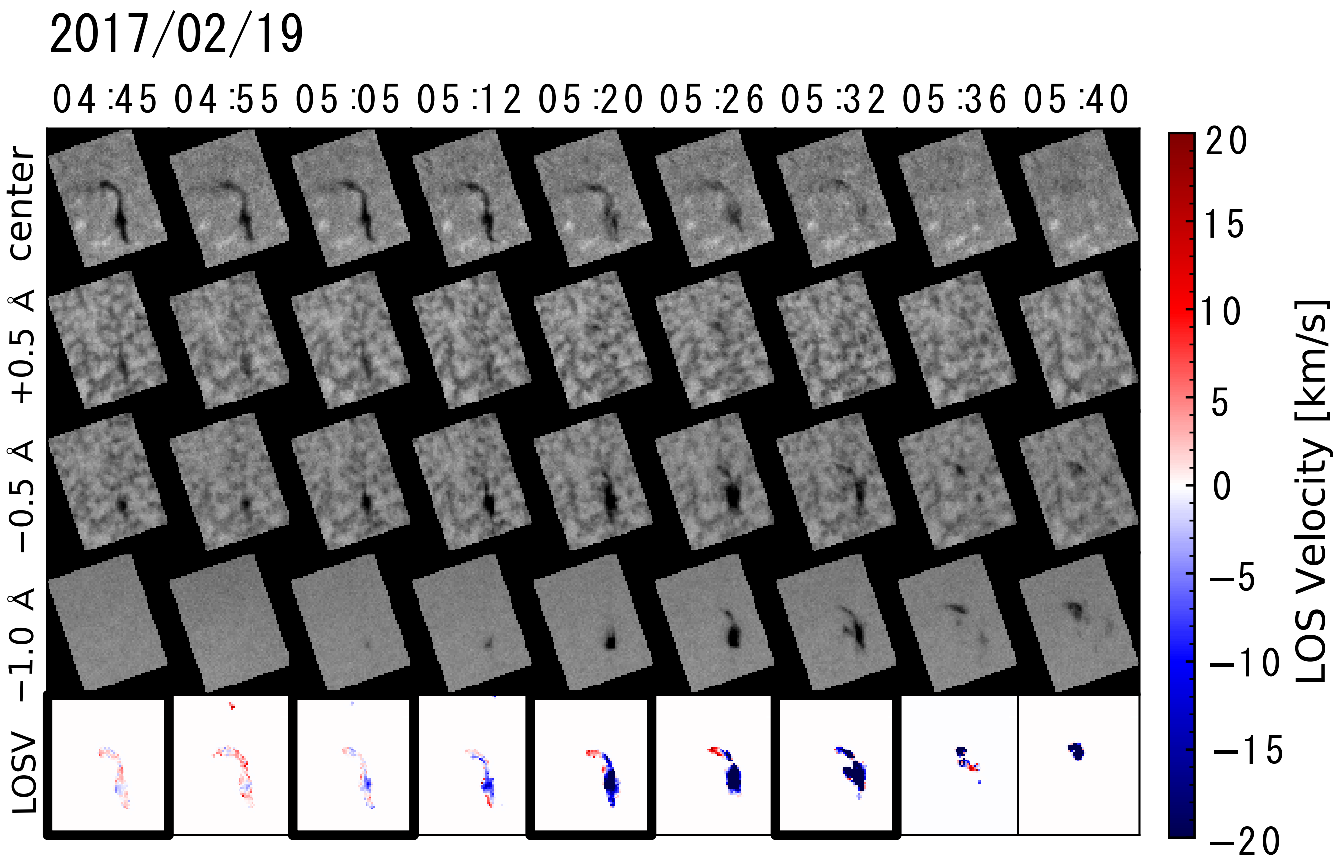
- **The Solar Dynamics Doppler Imager (SDDI)** installed on **the Solar Magnetic Activity Research Telescope (SMART)**
- Wavelength: **-9.0 Å** ~ **+9.0 Å** at **steps of 0.25 Å**



- Time cadence: **15 sec**
- Spatial sampling: **1.23 arcsec pix^{-1}**

Observation

- The advantages of the SDDI are **the wide wavelength coverage** around Hα and **the high spectral and temporal resolution.**
- These enable us to obtain the **line-of-sight (LOS) velocity** distribution **in unprecedented detail**.



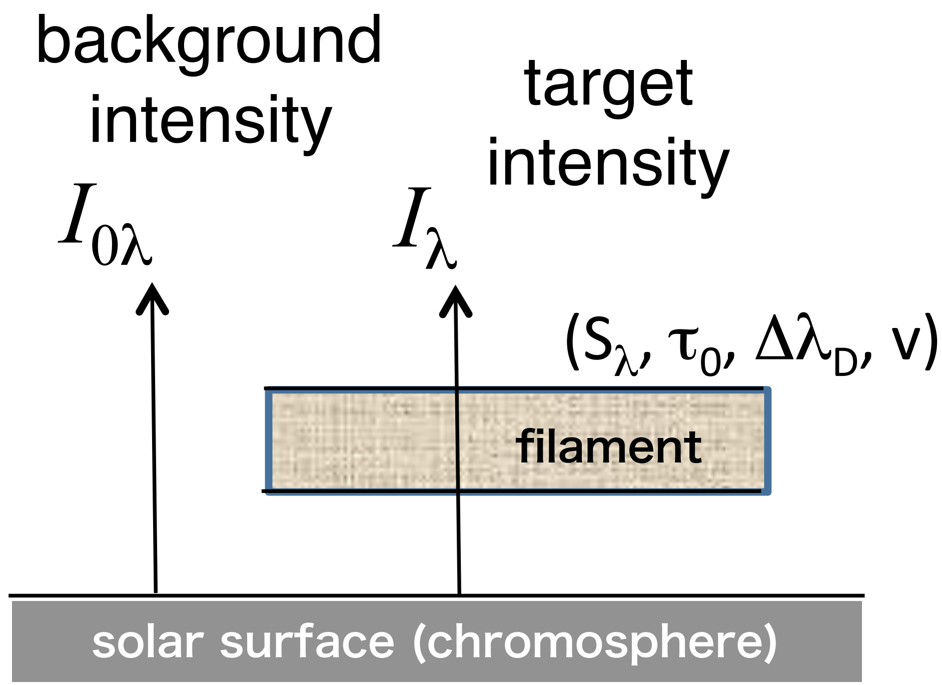
***From top to bottom*:** Time series of Hα images at the line center, +0.5 A, -0.5 A, and -1.0 A and of the LOS velocity map of the filament on February 19, 2017 (Event 12).

Model

$$C_{\lambda} = \frac{I_{\lambda} - I_{0\lambda}}{I_{0\lambda}} = \left(\frac{S_{\lambda}}{I_{0\lambda}} - 1\right)\left(1 - e^{-\tau_{\lambda}}\right)$$

$$\tau_{\lambda} = \tau_{0} \exp\left[-\left(\frac{(1 - v/c)\lambda - \lambda_{0}}{\Delta\lambda_{D}} \right)^{2} \right]$$

□ : fitting parameters



assumption:

1. S_{λ} : constant along the LOS direction.
2. S_{λ} : constant along the wavelength.
3. τ_{λ} : gaussian

S_{λ}: source function

τ_{0}: optical depth

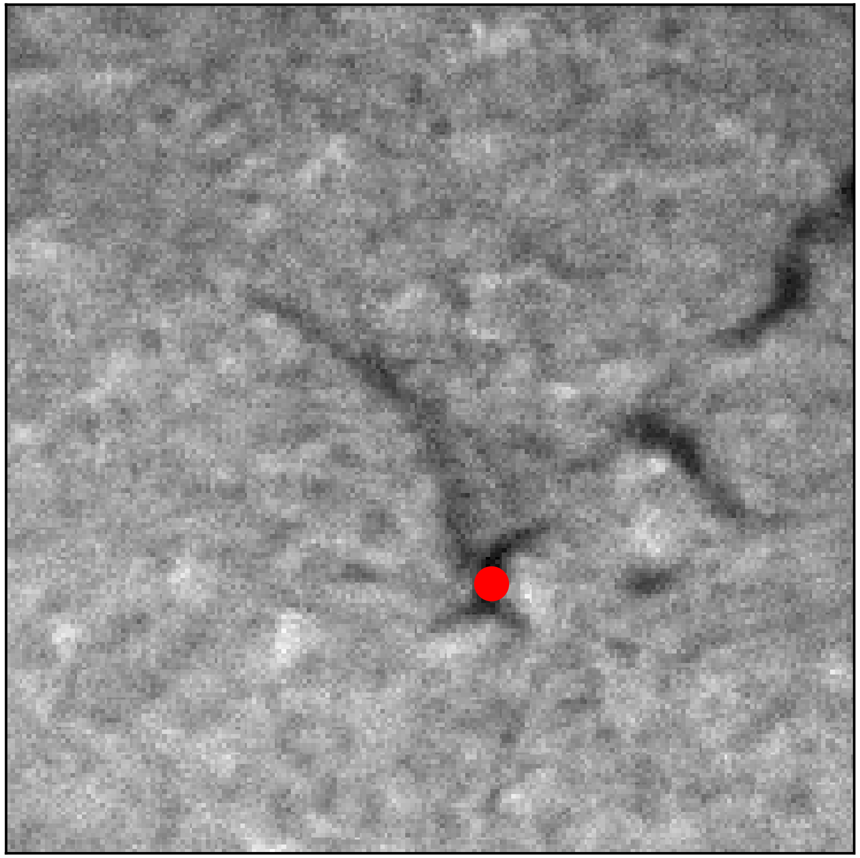
v: doppler velocity

$\Delta\lambda_{D}$: doppler shift

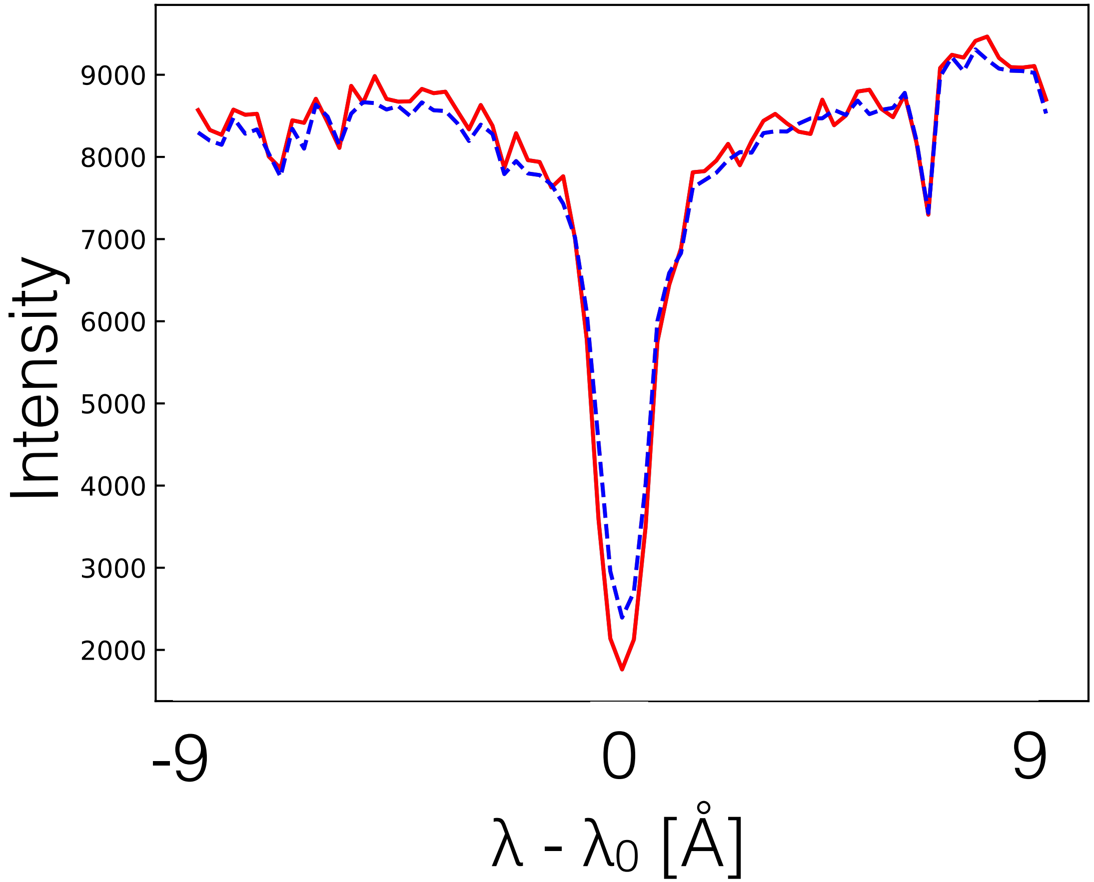
λ_{0}: Hα line center (6562.8 Å)

Model

Cloud model (Beckers 1964)



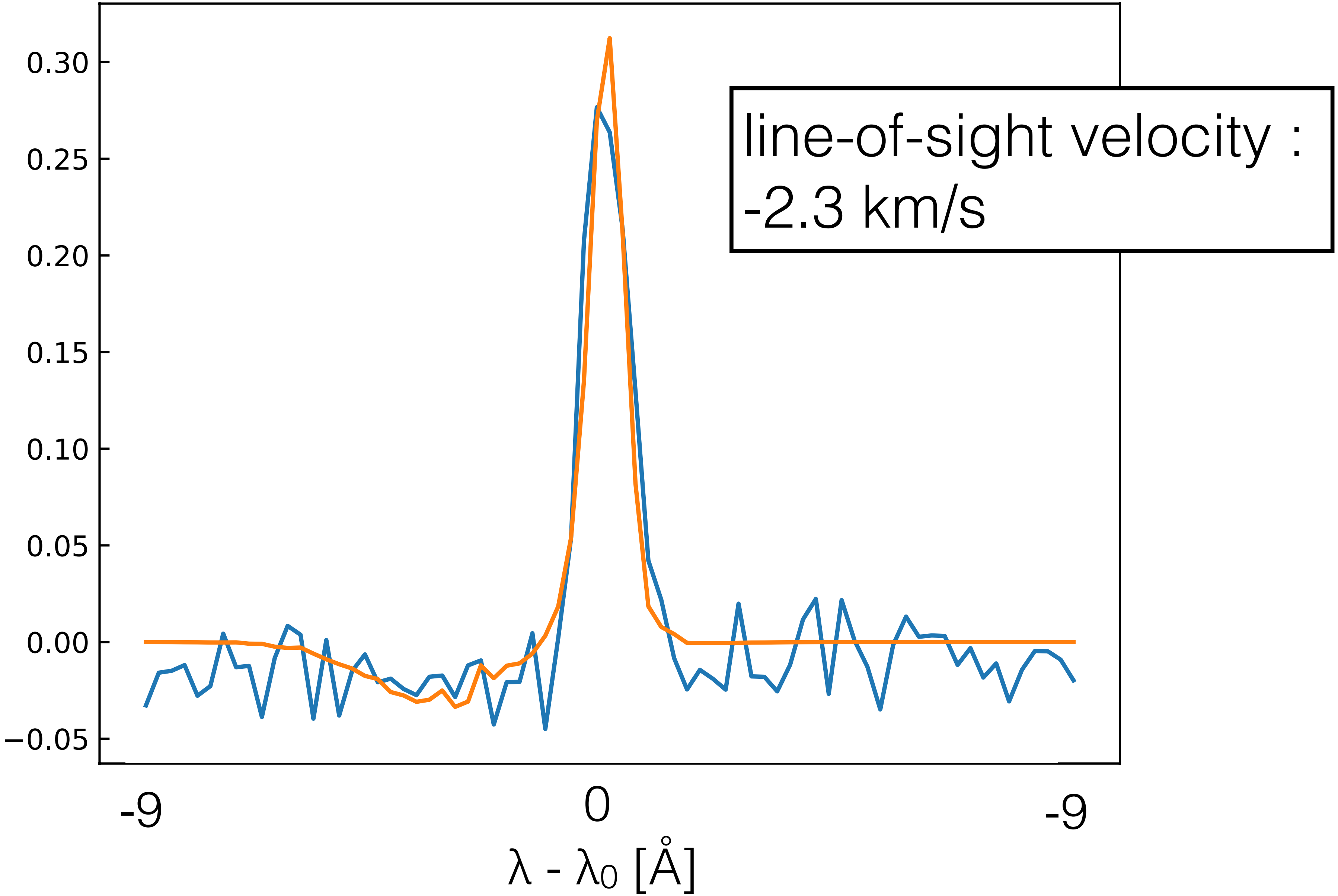
Target and **Background*** intensities



* median intensity

Model

Contrast function C_λ and optimization result

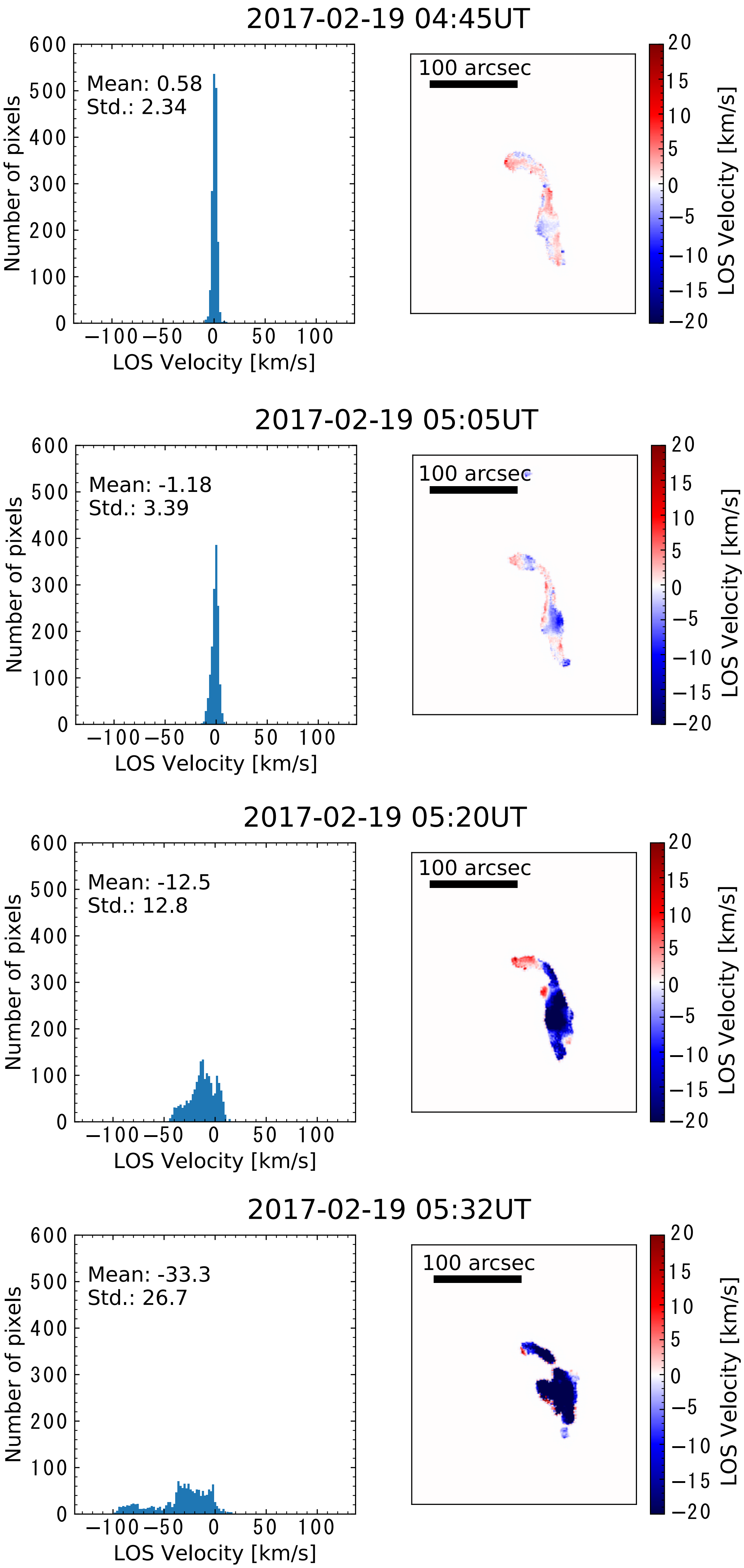


Result—Event list

Table 1. Filament disappearance events observed by SDDI (May 2016–May 2017)

Event	Date[a]	F.D. Time[b] [UT]	Type[c]	Flare Time[d] & Class [UT]	CME[e] [UT]	Analyzed[f]
1	2016 May 4	01:20	AF (NOAA 12541)	01:20 (B 6.9)	–	yes (Fig. 11)
2	2016 May 13	22:09	QF	–	–	no
3	2016 May 13	22:35	AF (NOAA 12544)	22:38 (B 5.5)	–	no
4	2016 Jul 7	07:58	AF (NOAA 12561)	07:55 (C 5.0)	–	yes (Fig. 12)
5	2016 Aug 10	03:13	IF (NOAA 12574, 12575)	–	04:00	no
6	2016 Sep 4	03:37	IF (NOAA 12586)	–	–	yes (Fig. 5)
7	2016 Sep 9	05:44	IF (NOAA 12588)	–	–	yes (Fig. 6)
8	2016 Sep 9	22:27	AF (NOAA 12588)	22:29 (B 4.0)	–	yes (Fig. 13)
9	2016 Oct 1	03:06	QF	02:23 (B 3.5)	02:30	no
10	2016 Nov 4	04:47	QF	–	08:00	yes (Fig. 3)
11	2016 Nov 5	03:40	IF (NOAA 12605)	04:30 (B 1.1)	04:36	yes (Fig. 7)
12	2017 Feb 19	05:40	IF (NOAA 12636)	05:47 (B 3.1)	–	yes (Fig. 1, 2, 8)
13	2017 Apr 2	06:29	IF (NOAA 12644, 12647)	–	–	no
14	2017 Apr 23	04:52	AF (NOAA 12651)	–	–	yes (Fig. 14)
15	2017 Apr 23	05:40	IF (NOAA 12652)	05:50 (B 1.7)	06:00	yes (Fig. 9)
16	2017 Apr 24	02:06	QF	–	05:34	yes (Fig. 4)
17	2017 Apr 30	00:38	IF (NOAA 12653)	01:00 (B 3.0)	02:36	yes (Fig. 10)

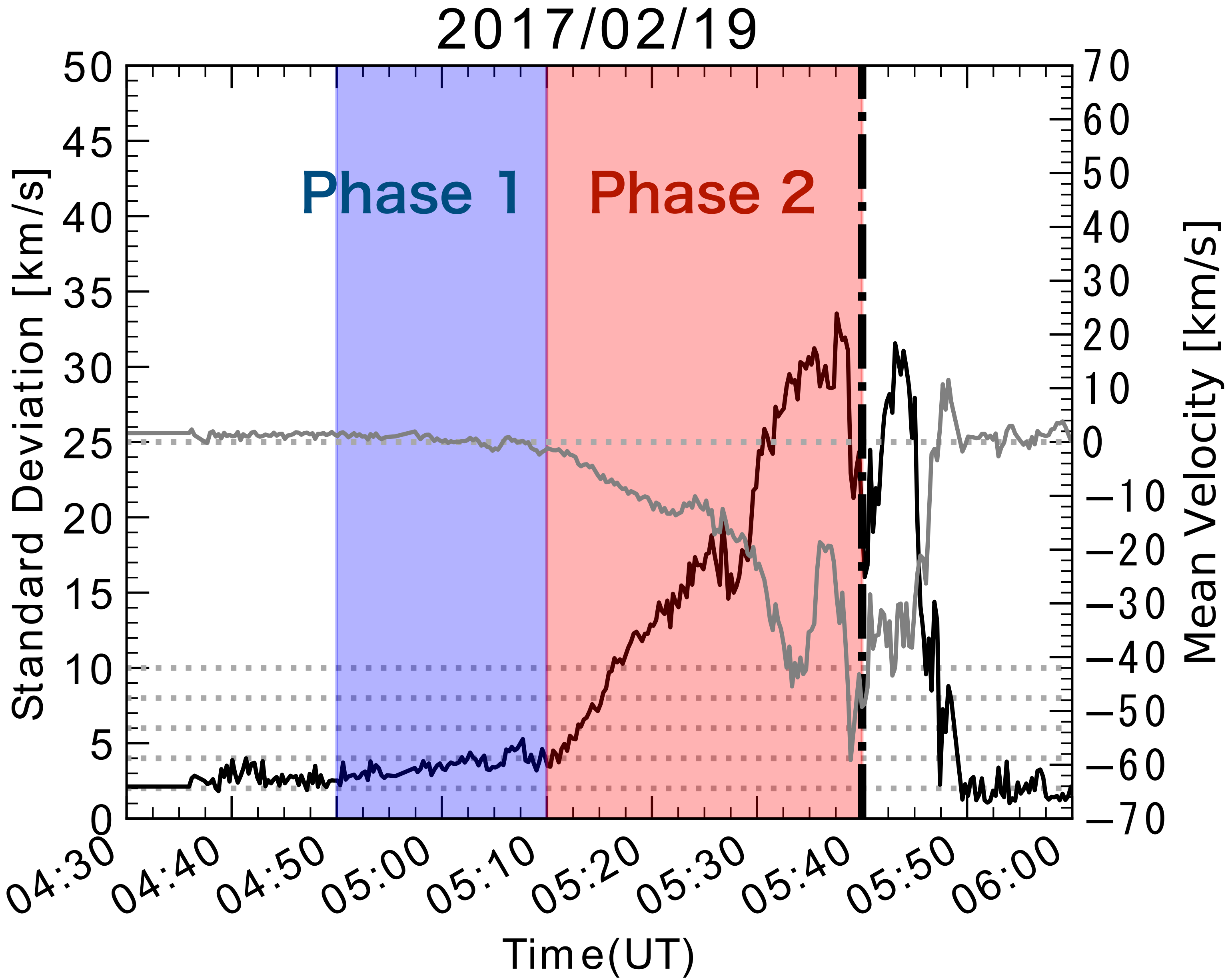
(a) The date on which the event started. (b) The time when a filament completely vanished in Hα line center as observed by the SDDI. (c) The type of filament; AF, QF, and IF imply active region filament, quiescent filament, and intermediate filament, respectively. (d) The peak time and the class of a flare determined by soft X-ray flux in the GOES 1.0–8.0 Åchannel. (e) The time when the associated CME was first observed by SOHO/LASCO C2. (f) If not analyzed, it is because of the presence of terrestrial clouds in the images or the location of a filament.



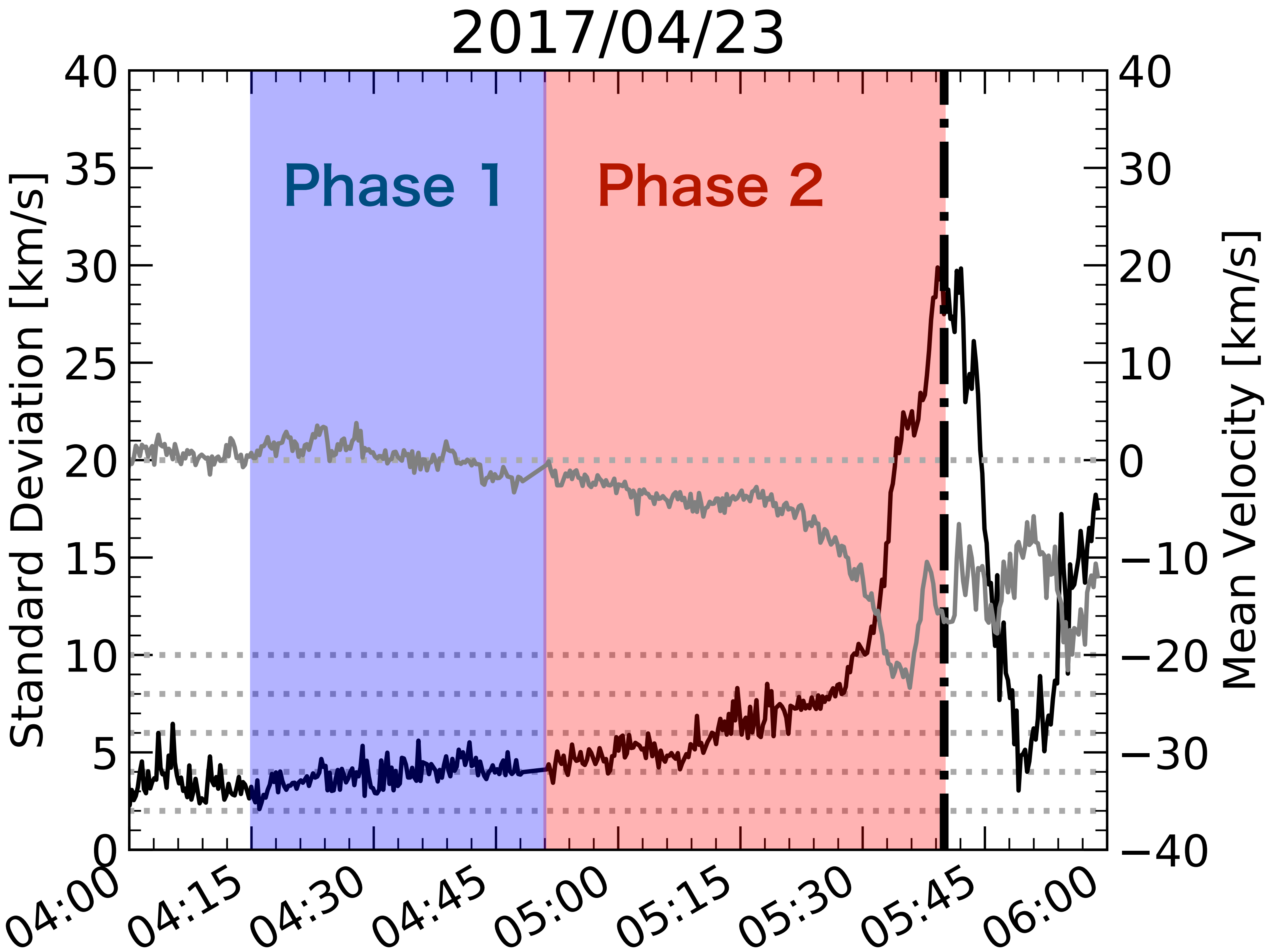
Left : Histograms of the LOS velocity images. Each histogram corresponds to the right image. The mean and standard deviation of the LOS velocity are written on the upper left. Each bin represents 2 km s^{-1}.

Right : Four LOS velocity images inside the black rectangles of Fig.1. Note that the LOS velocity map on each right panel is shown with a scale of lower and upper limits of ± 20 km s^{-1}.

Result—Event 12 (intermediate)



Result—Event 15 (intermediate)



Discussion

Table 2. Properties and durations of Phases 1 and 2.

Event	Type	Phase 1 [hours]	Phase 2 [hours]	CME [UT]	Figure
1	AF (NOAA 12541)	0.18	1.0	–	Fig. 11
4	AF (NOAA 12561)	–	0.17	–	Fig. 12
6	IF (NOAA 12586)	–	3.5	–	Fig. 5
7	IF (NOAA 12588)	1.2	0.75	–	Fig. 6
8	AF (NOAA 12588)	14*	0.27	–	Fig. 13
10	QF	25–42	3.5	08:00	Fig. 3
11	IF (NOAA 12605)	20*	1.2	04:36	Fig. 7
12	IF (NOAA 12636)	0.32	0.32	–	Fig. 8
14	AF (NOAA 12651)	–	1.7	–	Fig. 14
15	IF (NOAA 12652)	0.60	0.82	06:00	Fig. 9
16	QF	23	–	05:34	Fig. 4
17	IF (NOAA 12653)	0.60	0.63	02:36	Fig. 10

* The value with an asterisk (Phase-1 duration of Event 8 or 11) could be overestimated because of the absence of data.

Discussion

- In **9 events out of 12**, **Phase 1 was detected** prior to the disappearance of the filament, regardless of the filament types and whether the disappearance was associated with a CME or not.
- Our results reveal **wide variations in Phase 1 and Phase 2**, ranging from 0.18 to 42 h and 0.17 to 3.5 h, respectively.
  - Omitting the possibly overestimated durations of Phase 1 (Events 8 and 11), we observe that **a quiescent filament has a longer Phase-1 duration** than the other two types of filaments by one or two orders of magnitude.
- In **all** the cases of the **intermediate and quiescent** filaments, the **standard deviation** during Phase 1 **generally** changed **from 2–3 km s^{-1} to 4–5 km s^{-1}**.