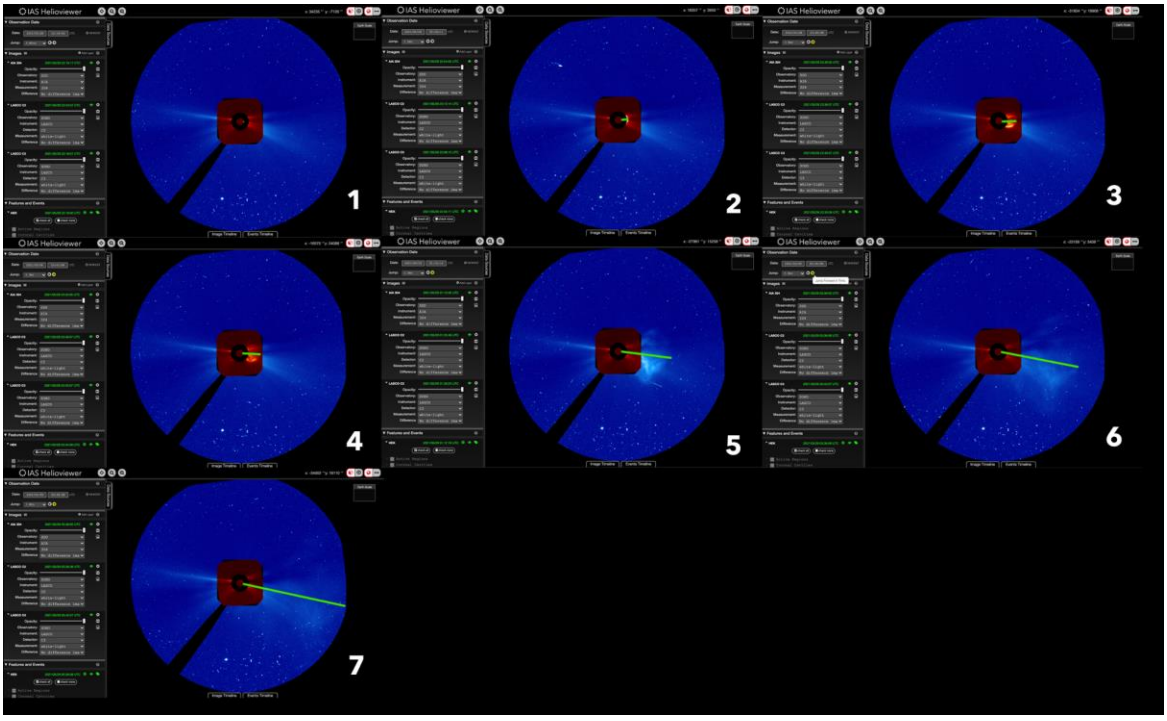
The solar slap

SOLUTION

1.
Data selection (selecting appropriate images showing the evolution of the CME) and identification of CME front.



A total of 7 time intervals are selected tracing the evolution of the CME

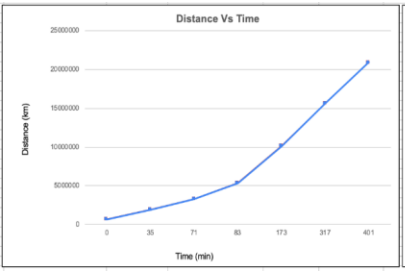
1. 2021/05/28 22:19:00 UT
2. 2021/05/28 22:54:11 UT
3. 2021/05/28 23:30:08 UT
4. 2021/05/29 23:42:08 UT
5. 2021/05/29 01:12:16 UT
6. 2021/05/29 03:36:08 UT
7. 2021/05/29 05:00:08 UT

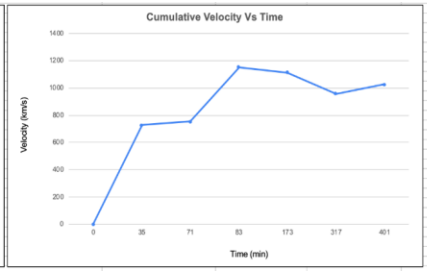
Summary of the information extracted from the images for all different selected intervals

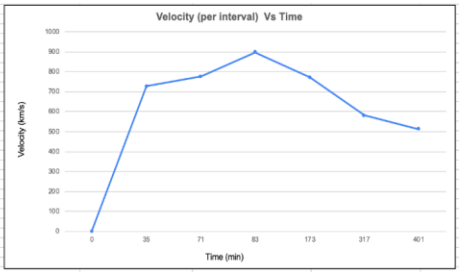
2. **Plotting the kinetic evolution of the CME**

Interval	Date and Time	Time interval (minutes)	Time from CME onset (minutes)	Coordinates of the CME fron x"	y"	Distance from disc center (arcsec)	Distance from disc center (km)	Distance from onset (km)	Cumulative velocity plane of the sky (km)	Deprojection of velocity towards ParkerSP (km/s)	Distance per time interval (km)	Velocity on plane of he sky (km/s)	Deprojection of velocity towards ParkerSP (km/s)
1	2021/05/28 22:19:00 UT	0	0	950	144	961	696617	0	0	0	0	0	0
2	2021/05/28 22:54:11 UT	35	35	2682	174	2688	1948538	1252198	596	728	1252198	596	728
3	2021/05/28 23:30:08 UT	36	71	4579	97	4580	3320520	2624180	616	752	1371982	635	775
4	2021/05/28 23:42:08 UT	47	83	7441	116	7442	5395380	4699040	944	1152	2074861	736	898
5	2021/05/29 01:12:16 UT	126	173	14000	-891	14028	10170535	9474195	913	1114	4775155	632	771
6	2021/05/29 03:36:08 UT	191	317	21048	-4570	21538	15615349	14919009	784	958	5444814	475	580
7	2021/05/29 05:36:08 UT	210	401	27922	-7126	28817	20892306	20195966	839	1025	5276957	419	511

Plots: distance vs time and velocity vs time







3. Calculating the velocity of the CME front reaching ParkerSP

The velocity corresponding to the last interval (up to reaching 30 solar radii) is **511 km/s** which, according to the considerations of the problem, would be the same velocity of the CME front once it reaches the ParkerSP.

Calculating the time spent by the CME front to reach the ParkerSP from it's onset.

The Sun-ParkerSP distance estimated from Figure 1 is approx. 0.66 AU = 9.9×10^7 km = 141 solar radii (given the information that 10 solar radii es approx. 7×10^6 km)

From the previous analysis, it is known that the CME front reaches a distance of 30 solar radii after 401 minutes (6.7 hours) from its onset (see Table). The distance that the CME travels at the constant speed of 511 km/s is expressed as 141-30=111 solar radii = 7.8x 10^7 km, and thus the time spent in that intervaled is 42.4 hours.

Finally, the total time it takes for the CME front to reach the ParkerSP from its onset is computed as: 6.7+ 42.4 = **49.1 hours**.

4. True and false statements

A larger number of selected images would give more precise information on the evolution of the CME and the calculated physical parameters. **TRUE**

B. The analysis and measurements of the CME evolution should consider the differential rotation of the Sun, and therefore the calculated velocities will be affected. **FALSE**

C. Any software (numerical) misalignment among the images when creating the mosaic will have direct effects on the precision of your calculations. **TRUE**

D. The different assumptions made in order to construct the model displaying in a heliospheric density map in Figure 1, may affect the estimation of the Sun-ParkerSP distance. **FALSE**

E. The interaction of the CME-front with the remnant dust left by the 2019 Borisov comet broadens and difuminate the images. This intensifies the lack of contrast in the images, increasing the uncertainty in determining the CME-front and its propagation. **FALSE**

5. Kinetic energy calculations

Proton:

$0.5 * (1.67262e^{-27}\ kg) * (511\ m/s)^2 = 1.4 \times 10^{-3}\ eV$

Alpha particle:

$0.5 * (6.64e^{-27}\ kg) * (511\ m/s)^2 = 5.4 \times 10^{-3}\ eV$

Marking scheme

75 points

1. Table

Give A TOTAL number of points following the possible situations (select only one option):

2 points: If the table includes information extracted from **a single image (1 frame)** for date/time and the corresponding size of the CME (distance measured from the solar limb to the CME front).

7 points: If the table includes information extracted from **two images (2 frames)** for date/time and the corresponding size of the CME (distance measured from the solar limb to the CME front).

9 points: If the table includes information extracted from **three images (3 frames)** for date/time and the corresponding size of the CME (distance measured from the solar limb to the CME front).

11 points: If the table includes information extracted from **four images (4 frames)** for date/time and the corresponding size of the CME (distance measured from the solar limb to the CME front).

13 points: If the table includes information extracted from **five of more mages (5 or more frames)** for date/time and the corresponding size of the CME (distance measured from the solar limb to the CME front).

Note: The tabulated data in a row is assumed to be extracted from a single JHelioviewer frame, that corresponds to a mosaic of solar images acquired with multiple telescope/instruments, in particular SDO/AIA, SOHO/LASCO1, SOHO/LASCO3.

6 points: For calculating the cumulative velocity over the tabulated data

6 points: For calculating the instantaneous velocity (in every time interval) over the tabulated data.

5 points: For considering the deprojection of velocities (from the plane of the sky into the direction towards the location of the ParkerSP).

2. Plots

5 points: Plotting the distance vs time for the tabulated data

5 points: Plotting the cumulative velocity vs time.

5 points: Plotting the velocities for all the different time intervals vs time.

3. Velocity and time of CME front

5 points: Estimating the distance (in km) from the Sun to the ParkerSP based on Figure 1 and the appropriate unit conversions.

3 points: Considering the velocity computed for the last interval (up to 30 solar radii) that should be around 500-600 km/s, as the velocity that impacts the ParkerSP.

2 points: Calculating the time it takes for the CME front to reach the ParkerSP from its onset (in hours), considering the time spend in the first 30 solar radii besides the time the CME is moving at constant speed (from 30 solar radii to the location of the ParkerSP).

4. True statements

2 points A. TRUE

2 points B. FALSE

2 points C. TRUE

2 points D.FALSE

2 points E. FALSE

5. Energy

4 points. Proton calculation

6 points. Alpha particle calculation