CUME 456
Total points:51

Overview:

CUME 456 is based on the manuscript: **A persistent quiet-Sun small-scale tornado I. Characteristics and dynamics** by K. Tziotziou et al 2018**.** To answer the Cume, kindly go through the Sections: Introduction, observations and discussion in details. If you have time, you can overview the result section.

To successfully complete CUME 456, you will need a basic understanding of solar physics, observational techniques and analysis.

There are three sections to the cume. First covers background and introduction to the topic. Second covers the observations and the third covers the results and discussions in the manuscript. The sections have 20, 15 and 20 points, totaling to **51** points, with a **passing mark of 38.25 at 75%.**

Related to the cume questions: Questions in the cume are in black font, sections are titled in bold. Marks corresponding to each question are in green. Categories of Bloom Taxonomy are in Orange.

Technical details: You will need pen, paper and calculator.

Contact: Via Zoom on Canvas or by provided Zoom link. Canvas chat is preferred.

PS: When I mention swirls or chromospheric swirl, I am referring to the same physical structures observed in the chromosphere. For photospheric vortex motions, the nomenclature used may be vortices or vortex. Solar physicists sometimes call the same things by different names!

Category: Introduction and background (21 points)

1.) What are the two ways in which the photospheric vortex motions are observed? (2 points) (Comprehension)
Ans: Motions of magnetic bright points (1 point), and vortical motions in granular and super-granular junctions (1 point).

2.) From the introduction: What chromospheric features are defined as chromospheric swirls? How may these features be observed? (3 points) (Comprehension)
Ans: Vortices observed in chromospheric Ca II 8542 line were called chromospheric swirls (1.5 points). The appear as circular rings in chromospheric, sometimes fragmented (1.5 points)

3.) From the introduction: What are the MHD waves that can be produced by swirling motion? (2 points)
Ans: Any two of the following Alfven, sausage and kink. (Comprehension)

4.) A chromospheric swirl would consist of plasma frozen in between twisted field lines. A swirl usesually has a centre and arms. Each plasma particle will follow a circular or spiral motion along the arms of the swirls. Compute the angular velocity of a plsma particle, around the centre of mass, if the swirl has a diameter of 2.0 Mm (the distance between two opposite ends of the swirl arms) and a linear velocity of 10 km/s. (2 points) (Application)
Ans: Using the relation w= v/ r = 0.01 rad/ s (1.0 point for right formula, 1.0 point for answer).

5.) Period with which a swirl rotates is 3 mins. What is the angular velocity of the swirl? (2 points)
Ans: Use the formula $\omega = 2 * \text{pi} / T = 0.034$ rad/s (2 points for both the steps) (Application)

6 a.) If a plasma is flowing across the solar atmosphere covering the height of 1 Mm, and a up flow velocity of 2-7 km/s. How long will it take to reach the height. (Please ignore all efforts due to gravity, pressure and buoyancy). Compare this time with the lifetime of the swirl, that is 10 – 15 mins. Can a swirl reach the height of 1 Mm in its lifetime? (5 points) (Application)
Ans: Use the formula time = distance / speed (1 point). Two unit conversions: 1 Mm to km, seconds to minutes (1 point). Compare the answer with lifetime and comment (1 points). Ignoring all the physical processes the time required for the up flows to reach the height of 1 Mm is, between 140 s to 500 s. It is shorter than the swirl lifetime. This means that the signal from the vortex motion would reach the chromosphere and be visible as a swirl (2 points). 2.5 points, if the conversions are wrong and they lead to wrong interpretations.

6 b.) What would be the main physical processes that could drive a swirl? (5 points) (Knowledge)
Ans: Small-scale vortices are driven by convective motions (1 point to mentions convective motions) and localized at the downdrafts of intergranular lanes. Vortex flows in the photosphere force the magnetic fields (1 point, relation to magnetic field) to rotate and as they are coupled with plasma (1point, coupling of plasma and magnetic fields), the penetrate from the photosphere upwards (1 point upward movements) they can produce co-rotating structures throughout the solar atmosphere (1 point, co-rotating structure).
(Anything on this line)

Category: Observations (13 points)

7.) Let's revisit Figure 1 from the paper. What is the size of this swirl circled in the yellow in kilometres? (1 point) (Application)
Ans: Conversion between arcsec to kilometres (750 km). (1 point)

8.) What would be the Doppler velocity ranges in Hα and Ca II 8542 Å covered by the observing campaign? (3 points) (Application)
Ans: Using Doppler Velocity formula (v=c * (del (lambda) / lambda). 1.5 point for each calculations. Answer is +/- 8 km/s. However, the authors mention this at multiple places in the paper. And students have noted that down. 2.75 points, if they plug in the values from the paper.

9. Major challenges in observations of small-scale events in the solar chromosphere is the spatial resolution of the instruments that are used. Identifying and resolving the chromospheric swirls, authors mention, is thus dependent on the spatial resolution of the instruments. In this paper, authors have used the CRISP instrument on a ground-based telescope, and few images from AIA and HMI instruments on the satellite SDO. The spatial resolutions of each instrument is mentioned in the observations. Use these values from the paper, to answer the next three sub-questions.

9a) Suppose I observe two swirls, swirl 1 is 200 km wide and swirl 2 is 500 km wide. Which of the swirls can be observed in the SDO AIA channels used in the paper? (3 points) (Analysis)
Ans: Swirl 1 - no. Swirl 2 - Yes (1 point for each of these). Comparison with AIA/HMI (1 point for reasoning).

9b.) Footpoints of the above swirls (swirl 1 and swirl 2) are generally magnetic concentrations observed in the photosphere, which are usually 100 km to 300 km in size. The paper uses low-resolution HMI channels for observations of swirl footpoints. Can the authors resolve these footpoints? Justify your answer. (3 points)
Ans: Swirl 1 - no. Swirl 2 - no (1 point for each of these). Comparison with HMI (1 point for reasoning).

9.c) How do the authors know if the swirls they observe have photospheric and magnetic origin from the data they observe? (5 points)
Ans: The authors are unable to resolve the footpoints of the swirls in HMI, which they use as a low-resolution magnetogram as a guide for magnetic field (1 point for identifying the observational technique). In addition, the authors use wings of Halpha and Ca II 8542 lines, however there are no signatures observed in either of these wavelengths (2 points for figuring it that there is no direct evidence of magnetic concerntrations). However, authors observe an un-resolved mangetic patch in HMI which indicates that the swirl can be formed within the mangetic canopy (1 point). The data is present at the coronal hole boundary this naturally creates a magnetic field canopy (1 point to figure this out).

Category: Results and Discussion (17 points)

10.) What is the advantage of multi-wavelength solar observations? (2 points) (Knowledge)
Ans: Multiple wavelengths correspond to different plasma dynamics corresponding to the different temperature, density and Doppler velocities (2 points for any 2 properties). 1 point if the answer is vague, such as different plasma dynamics of the magnetic field.

11.) Describe in 5 sentences, how do the authors use the multiple-wavelength observations to explore the dynamics of the chromospheric swirls? (Focus your answer on similarities and dissimilarities in the observations. (5 points) (Comprehension)
Ans: Descriptions of how the swirls appear different in both the wavelengths focusing the discussion on third row of Fig. 1, 4 and Fig. 5) (2.5 points). That describes a comparison between Halpha and Ca II (2.5 points). The paper has multiple descriptions, so the answer is a little varied.

12.) Swirls are thought to be rotating as rigid bodies. Does this statement agree with the observations reported by the authors? (5 points) (Analysis)

Ans: The authors report on swirls on the edge of coronal holes. The is one central swirl and multiple small swirls (2 points in identifying the different scenarios corresponding to swirls). There are three scenarios described by the authors. The central swirls is fragmented (1 point), which goes against the rigid body idea of a swirls. Furthermore the swirls seems to feed into or drive other swirls (1 point) in the observations. This interaction or relation corresponds to a complex scenario, very different from the simple rigid body idea (1 point, for conclusion).

13.) What can trigger oscillations in the reported swirls? How are they observed? (5 point) (Application)

Ans: Fragmented or complex appearance of the swirls indicates instabilities. These instabilities would lead to different types of MHD waves. These are often observed as alternating patterns in the intensity images (black to white) or Doppler images (red-blue). In addition, time-series analysis such as wavelength can be used to identify the oscillations. The authors are using time-distance plots (Fig 9, Fig 12, Fig 13)