

CUME 456

Total points:53

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 detail. 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 21, 15 and 17 points, totaling to **53** points, with a **passing mark of 39.75 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.

Technical details: You will need a pen, paper and calculator (do not use the stored formulae to solve the CUME).

Units: 1 arcsec = 750 km.

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)
- 2.) From the introduction: What chromospheric features are defined as chromospheric swirls? How may these features be observed? (3 points)
- 3.) From the introduction: What are the MHD waves that can be produced by swirling motion? (2 points)
- 4.) A chromospheric swirl consists of plasma frozen in between twisted field lines. A swirl usually 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 plasma 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)
- 5.) Period with which a swirl rotates is 3 mins. What is the angular velocity of the swirl? (2 points)
- 6 a.) A chromospheric swirl consists of plasma flowing upwards from the photosphere (the surface of the Sun) to the chromosphere. Suppose that a plasma is flowing across the solar atmosphere up to a height of 1 Mm. Throughout the flow, there is an upflow velocity of 5 km/s. How long will it take a parcel of plasma to rise to the top of the flow? (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)
- 6 b.) What would be the main physical process that could drive a chromospheric swirl? (Hint: This is related to how Wedemeyer-Bohm describe chromospheric swirl mentioned in the introduction, 5 points)

Category: Observations (15 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)
- 8.) What would be the Doppler velocity ranges in H α and Ca II 8542 Å covered by the observing campaign? (3 points)
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)

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)

9.c) How do the authors know if the swirls they observe have photospheric and magnetic origin from the data they observe? (5 points)

Category: Results and Discussion (17 points)

10.) What properties of the solar atmosphere can be probed by using multi-wavelength solar observations ? (2 points)

11.) Describe in 5 sentences, how do the authors use the multiple-wavelength observations to explore the dynamics of the chromospheric swirls? (Hint: Focus your answer on similarities and dissimilarities in the swirl observations in $H\alpha$ and Ca II 8542 Å, and the photospheric lines. How to the swirl appear at different wavelengths. (5 points)

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

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