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What can Observations of Comets Tell Us about the Solar Wind at the Maunder Minimum?

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Abstract. This paper discussed whether 17$^{\text{th}}$ Century observers left historical records of the plasma tails of comets that would be adequate to enable us to extract the physical parameters of the solar wind. The size of the aberration angle between a comet's tail and its radius-vector defines the *type* of the tail: plasma or dust. We considered Bredikhin's calculations of the parameters for 10 comet tails observed during the Maunder minimum (1645 – 1715). For those comets the angle between the tail's axis and the radius-vector on average exceeded the value of 10° that is typical for dust tails. It was noted that visual observations of the ion tails of comets are very difficult to make owing to the spectral composition of their radiation, confirming the conclusion that observations of comet tails made in the 17$^{\text{th}}$ Century are not suitable for deriving past values of the physical parameters of the solar wind.

Keywords. history and philosophy of astronomy, (Sun:) solar wind, comets: general, comets

1. Introduction

The fact that historical reports of comets contain observations of plasma tails indicates the persistence of the solar wind phenomenon. Even before the discovery of the plasma tails, Bessel (1836) suggested that a repulsive force ejects particles from the cometary nucleus. The larger this force, the lighter the elements composing the cometary tail, and the closer the tail to the anti-solar direction. This idea was exploited by Bredikhin (1879a, 1879b, 1880, 1886), who developed a classification of cometary tails. Although the theory of the shape based on mechanical arguments is not valid for plasma tails, a qualitative description ("straight and narrow") matches their type I tail. In the Maunder minimum $\sim$20 comets were reported, most of them with nearly straight tails.

2. Orientation of cometary tails

Fig. 1 illustrates the trajectory of a comet with straight plasma and curved dust tails, in relation to its orbit around the Earth. ε is the angle between the plasma tail and the radius-vector passing through the Sun and the comet's nucleus, V_c is the orbital speed of the comet, and γ is the angle between V_c and the anti-solar direction. However, there are circumstances in which the dust tail may appear to the observer to be straight; those include a non-stationary outflow of cometary particles, a short dust

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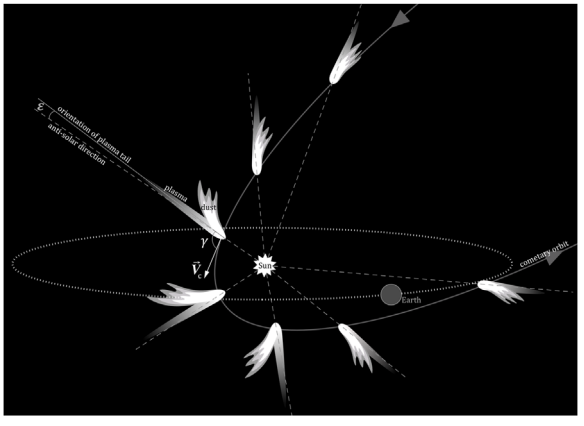
Table 1. Deviation ε of the cometary tail angle

Comet	Average ε	Comet	Average ε
C/1471 Y1	12° [1]	C/1664 W1	27°
C/1577 V1	12.5° − 33.5°	C/1665 F1	−2° − 12.9°
C/1580 T1	15°	C/1668 E1	Unknown
C/1582 J1	37.5°	C/1672 E1	Unknown
C/1618 W1	25°	C/1677 H1	Unknown
C/1652 Y1	11.7°	C/1680 V1	$\varepsilon > 10°$ [2]
C/1558 P1	10°	1P/1682 Q1	23° (Halley)
C/1661 C1	Unknown		

[1] 1472 Jan 20: $\varepsilon = 6°$, Feb 2: $\varepsilon = 18°$. [2] ε from 1° to 20°



tail (less than 6° – 7°), and the projection effect when an observer is close to the plane of the orbit. The latter also introduces an uncertainty in the calculation of the angle of aberration.

The reliable method (Mendis 2007) for defining the plasma tail is to evaluate ε, the ratio of the transverse component of the comet's orbital speed and the radial component of the solar wind flow: $\varepsilon \approx \arctan(|V_c| sin\gamma / |V_{sw}|)$. Typical values of the transverse velocity, ε, should be less than 6°. Larger deviations of the cometary tail from the anti-solar direction were recorded when an observer was able to report the dust tail. By applying the calculations by Bredikhin (1879a, 1879b, 1880, 1886), we can specify the type (dust or plasma) of the tails from the historical records. Tab. 1 lists the average angle of deviation of the tails from the radius-vector on dates before and during the Maunder minimum.

The orientation of tails is obviously not as accurate from drawings as from photographs. For four comets, the quality of observations proved to be too poor to determine the type of tail. For Great comet C/1665 F1, ε varied significantly, enough to prevent us from determining the type of its tail. According to Hevelius (1668), in 3.5 hours the orientation of the tail of Comet C/1652 Y1 changed by 18°, but a change of that amount is hardly possible even if the solar wind had storm-level gusts.

3. Conclusions

In spite of the poor quality of observations, the average deviation of tails from the anti-solar direction was found to exceed 10°, thereby suggesting that observers had actually reported dust tails rather than plasma tails. However, it is worth noting that plasma tails can be difficult to discern, because fluorescence of ionized gases is hard to detect by the unaided eye or even with a telescope.

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