Analysis of Comet Tails for Turbulence in the Solar Wind

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"Chaos is inherent in all compounded things. Strive on with diligence." – Buddha

Summary

The heliospheric imager on the STEREO spacecrafts (HI-1) shows the solar wind to have gusts of plasma with short periodicity. It is not well understood if these periodicities are from the driving force of the solar wind or from turbulent processing in the heliosphere. In-situ data suggests the presence of turbulent processes but cannot be explicitly determined without the ability to track specific wind currents for long periods of time. Sungrazing comets that pass through HI-1 have their ion tails carried by the solar wind and are subject to any processing of the wind. With better background subtraction techniques we tracked perturbations in the ion tails of comet Machholz, Lovejoy, ISON and Encke for multiple hours. We analyzed these test particles for turbulence with the structure function, a statistical test of particle memory. The structure function revealed evidence of confinement in motion which occurs in turbulent processes. With continued tracking the turbulence could be quantified and used in models of space weather in particular CME breakup predictions.

Comet Tail Tracking Tool

We wrote a tracking tool in Perl Data Language (PDL) to place test particles on disconnection events, knots, and other tail features caused by the solar wind.

Program's Abilities:

- Justify the comet head in the fame of view
- Toggle motion filter
- Adjust brightness
- Change the color scheme

The human eye is used for all data collection.

Allows us, in essence, to track a piece of solar wind for hours (~15-30)

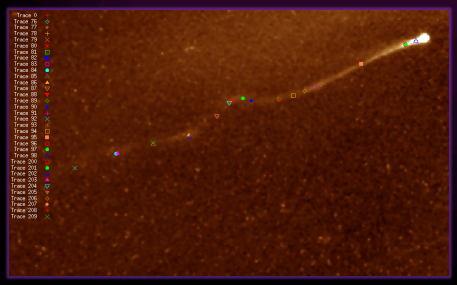
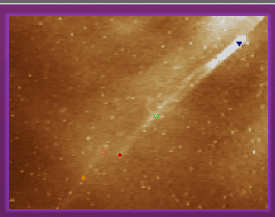


Figure 1. Comet Machholz with tracks found independently by D. Rice and C. DeForest overlaid. We are confident that the eye is a useful tool for this collection.

COMETS

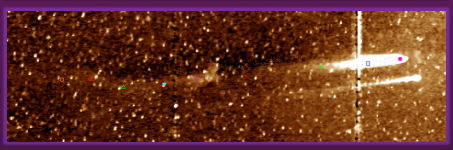


Lovejoy (C2/2011 W3) - December 2011

40 Traces — 12th – 22nd

Difficulties:

- Entry only 2 days
- Exits SUPER bright

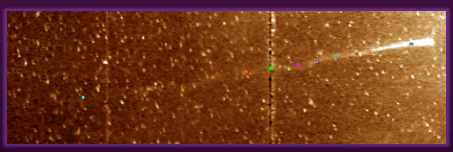


ISON (C/2012 S1) - November 2013

50 Traces — 20th – 29th

Difficulties:

- Projection Angle
- Straightens out after 5 days



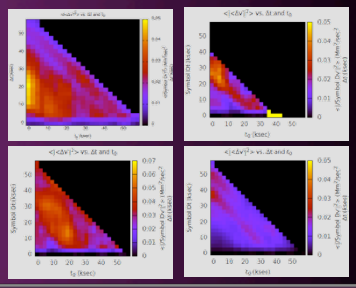
Encke (2P/Encke) - November 2013

44 Traces — 18th – 29th

Difficulties:

- Farther Away (faint)
- Solar Maximum

Velocity and Structure Function



1. Machholz
2. Lovejoy
3. ISON
4. Encke

Above A map of the evolution of the difference in relative velocity of two points.

The point at where t_0=0 peaks is when particles are fully entwined in the solar wind.

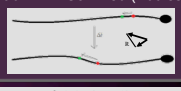
Any further change in the difference of velocities is attributed to turbulence.

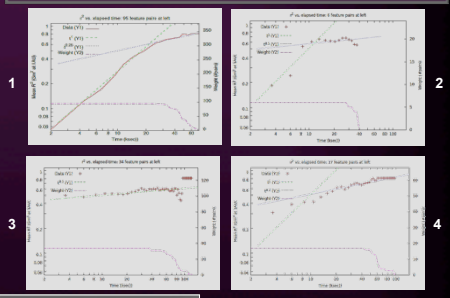
Below The structure function is a statistical test of particle motion and memory.

R^2 is the difference in the displacement vectors between two points for a given Δt.

Linear – Random walk

Sub Lin. – Confined (Eddies)





Conclusions

- Tracking tool and background subtraction allowed tracking of perturbations over multiple hours
- Qualified the existence of turbulence in the solar wind passing through Comet Machholz
- Other comets support that the results will be repeatable with stricter comet selection
  - Criteria: Fluctuations throughout HI-1, no fan tail, brightness comparable to max F-corona

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