Momentum Flux of a Comet Ionosphere

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Background

- Comet ionosphere is dominated by interaction between solar wind ions and cometary ions
- Pickup ions gyrate around the frozen in magnetic field lines and are accelerated
- This requires a momentum transfer from the solar wind ions, which are deflected -> mass loading
- Two cometary ion populations: energetic pickup ions and colder, newly ionized ions that still move with the neutral gas radially away from the nucleus

Rosetta Mission

- Orbited nucleus of comet 67P/ Churyumov-Gerasimenko (67P) from August 2014 to October 2016
- Heliocentric distance varied from about 3.8-1.2 AU
- Large change in comet activity -> change in comet ionosphere

Rosetta Instruments

- Rosetta Plasma Consortium:
  - Ion Composition Analyzer (ICA): ion mass spectrometer, flux and energy of H^+, He^+, He^{++}, and water ions
  - Langmuir Probes (LAP) and Mutual Impedance Probe (MIP): measure electron density, temperature, and spacecraft potential
- Magnetometer (MAG): triaxial magnetic field

Momentum Flux and Pressure

- Solar wind and pickup ions predominately antisunward -> 1D MHD approximation

$$\frac{\partial}{\partial x}\left(\rho u^2 + P + \frac{B^2}{2\mu_0}\right) = 0$$

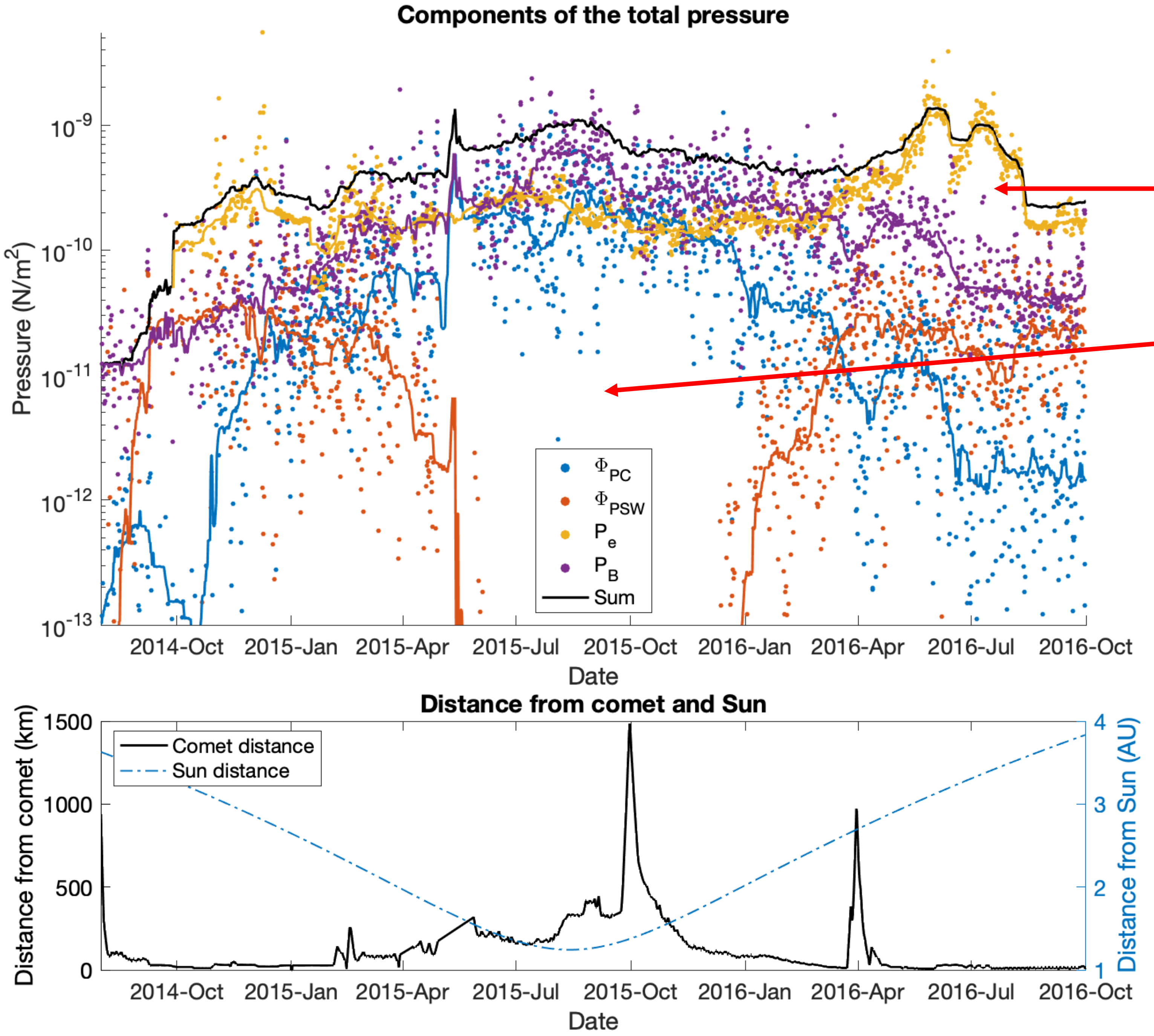
Dynamic pressure

Thermal pressure

Magnetic pressure

Momentum flux

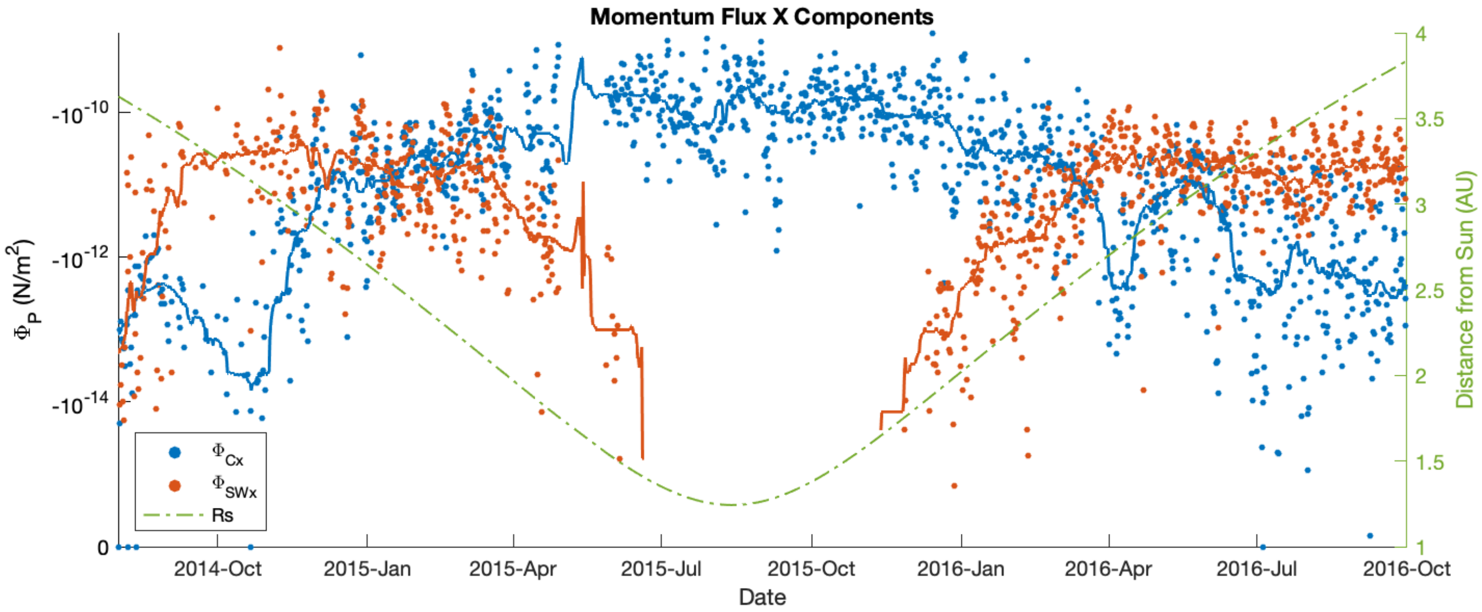
We can only get momentum flux for higher energy ions from ICA, so to include lower energy ions, we calculate thermal electron pressure (about 1 order of magnitude higher than ion thermal pressure)

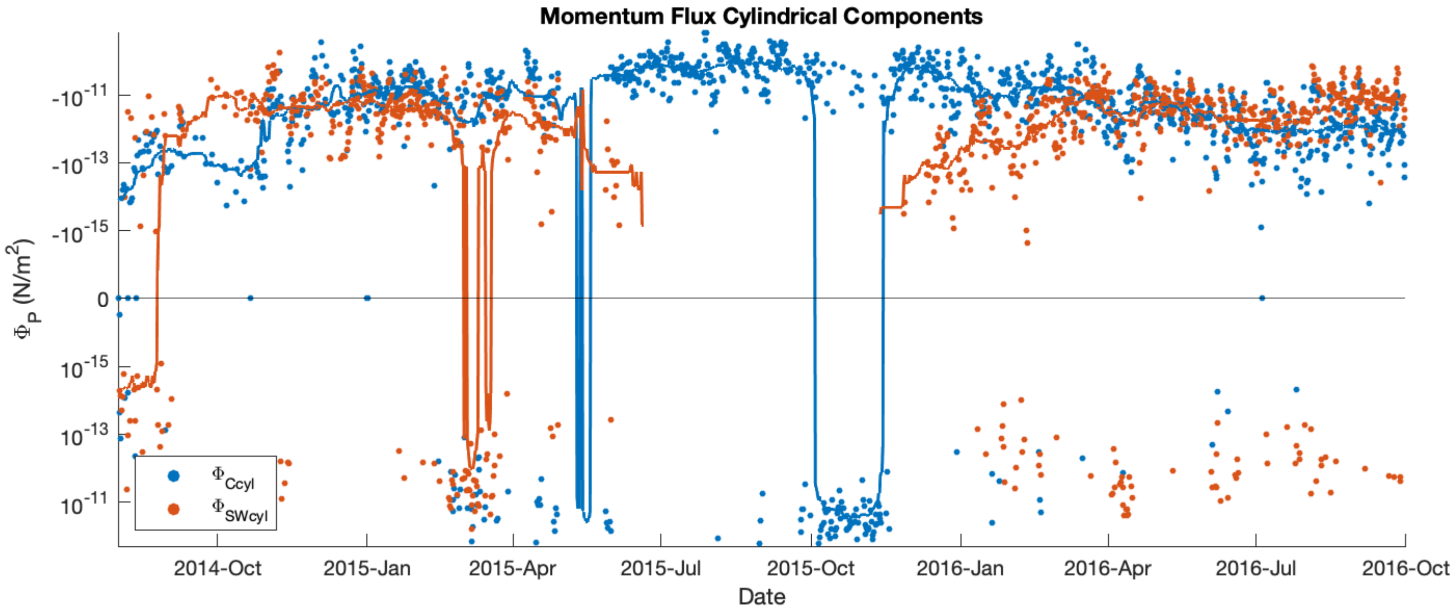


Spacecraft close to nucleus -> higher density cold ions -> higher electron pressure

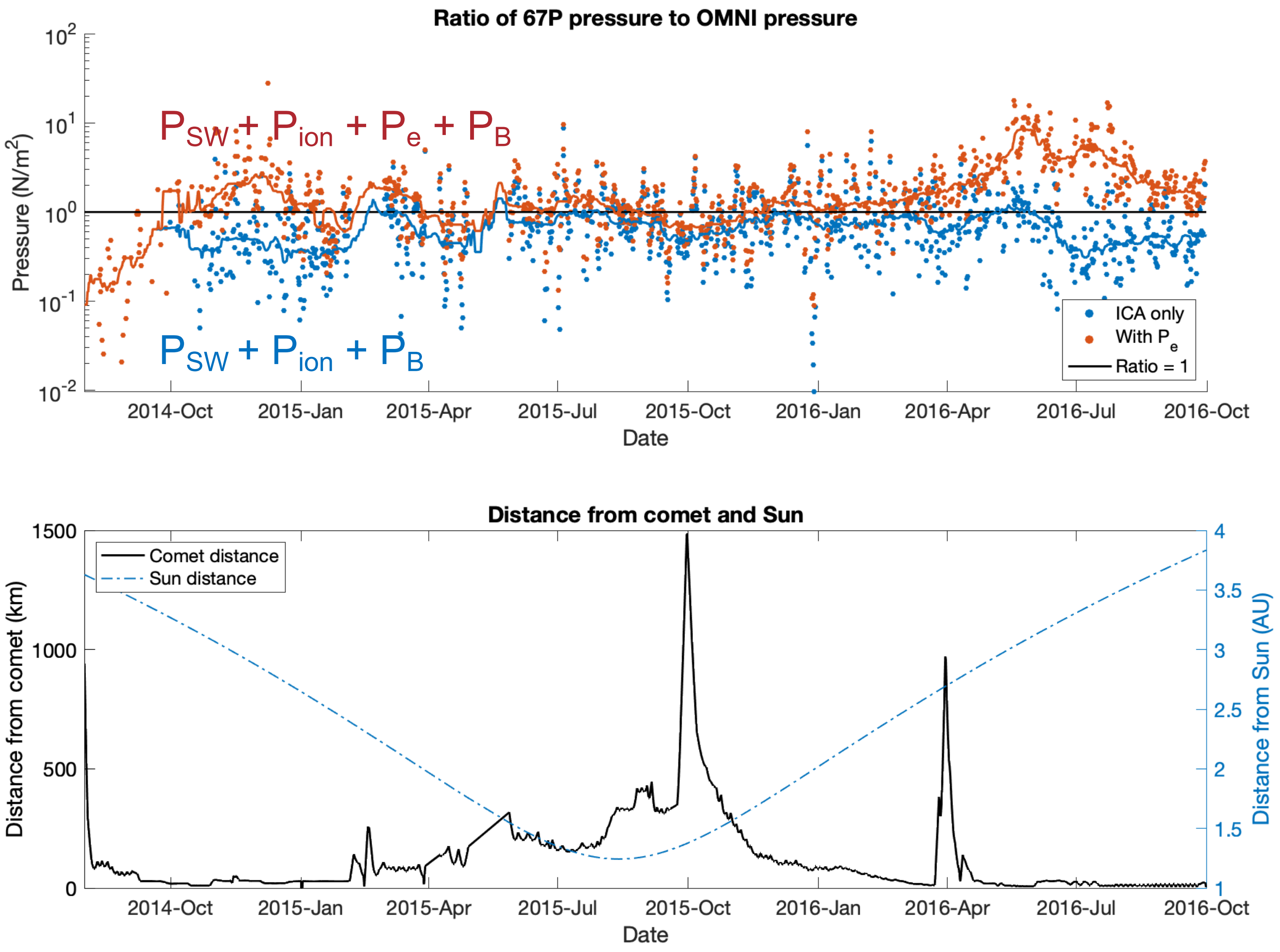
Solar wind ion cavity

- Points are 12 hour averages, lines are 30 day running medians.
- Total pressure is dependent on heliocentric distance.
- Electron pressure dominates
- Cometary ions dominate in solar wind ion cavity
- Magnetic pressure varies with the cometary ions (blue)





- Majority of ion momentum flux is antisunward
- Cylindrical components on average factor of 3-4 smaller
- Pickup ions act like solar wind ions in the solar wind ion cavity, as would be expected for mass loading
- Electrons (not shown) are presumed to be radial, so should have equal components in both dimensions



- OMNI momentum flux: Taken from OMNIWeb, upstream solar wind density and velocity scaled to the location of 67P
- Ratio stays constant, so change in total pressure is due to heliocentric distance
- Electron pressure adds extra momentum flux compared to the upstream solar wind

Conclusions

- The momentum flux changes consistently with heliocentric distance for the portion of the comet ionosphere seen by Rosetta
- The pickup cometary ions take up the bulk of the antisunward momentum flux in the ionosphere in the solar wind ion cavity as would be expected in a mass loading scenario
- Evidence of the ionosphere transitioning from being solar wind origin ion dominant to cometary origin ion dominant near perihelion
- The solar wind ion cavity is not a significant boundary in terms of energy input into the ionosphere system
- An additional transition region is seen after the solar wind ion cavity, where the electron pressure dominates the total momentum flux, including the magnetic pressure, by almost two orders of magnitude
- Here we do not expect local momentum balance to the upstream solar wind as we are inside an expanding and escaping ionospheric plasma