

New Horizons Encounter with the Pluto System: Solar Wind Parameters – Overview

Each file of this data set includes the time information for a given pair of sweeps in the original CODMAC level 2 raw data file, the solar wind proton density, proton speed, proton temperature, proton dynamic pressure, proton thermal pressure.

The Helio file of this data set has the spacecraft position in Heliographic Inertial (HGI), Heliocentric Aries Ecliptic (HAE-J2000), and Heliographic (HG).

The Pluto file of this data set has the spacecraft position in Pluto J2000, Pluto IAU, and Heliographic Inertial (HGI) coordinates systems.

SWAP Pluto Plasma Parameters

On July 14, 2015 the Solar Wind Around Pluto (SWAP) electrostatic instrument on the New Horizons spacecraft McComas, et al. (2008) detected a long tail of heavy ions extending at least 100 Pluto radii from Pluto. McComas et al. 2016 describes our methods for determining the plasma parameters for those heavy ion observations; this paper should be used as the citable reference for any further use or analysis of these data.

Our basic method is a numerical integration of the measured secondary count rate distribution. Heavy ions create a strong signal in the SWAP secondary detector and a weaker signal in the primary detector since the heavy ions produce a lot more secondary electrons on the side of the foil facing the secondary detector than on the primary side. Heavy ion observations were defined for any energy step where the ratio of the secondary to the primary count rate was 3.5 or greater. Energy steps where the ratio is below 3.5 have the count rate set to 0 for the heavy moments determination. The calibration information indicate that the heavy and light species are well separated at energies <3000 eV with this technique, but at energies > 3000 eV this technique does not work as well Ebert, et al. (2010), McComas, et al. (2016).

In our analysis we assume the peak of the distribution is in the SWAP instrument field-of-view (FOV), and that the distribution is isotropic. When the spacecraft is spinning, we do not need those assumptions because the spinning of the FOV sweeps out nearly the full sky. However, the tail observations occur when the spacecraft is in 3-axis mode and not spinning.

For the plasma parameters, we assume that the heavy ion species is methane (CH₄) as anticipated by atmospheric models (Strobel and Zhu, 2017, and references therein) and indicated as being most likely in the SWAP data as show by Zirnstein et al. 2016. The instantaneous SWAP FOV is 276 degrees by 10 degrees. We begin our analysis by assuming we fully measure the distribution within our FOV in order to estimate the number flux as first order numerical integration. Then we estimate the drift speed (v_{drift}) as the centroid speed of the measured count rate distribution. We use the width of the distribution to estimate the thermal speed (v_{th}). We use both the drift speed and thermal speed to estimate the angular extent of

the distribution ($\tan^{-1}(v_{th}/v_{drift})$). The angular extent is then used to determine the validity of our assumption that the full distribution was within the SWAP field-of-view.

We find that the heavy ion distributions in the Pluto space environment do not seem to be either really hot or really cold, but instead are warm. When the distribution was wider than the SWAP FOV in either dimension, we estimate what fraction we missed and correct our estimate of the flux and density. Additionally, we correct for the motion of the spacecraft, which was moving at 13.3 km/s during this timeframe.

To check the numerical integrations, we also use the cold beam analytic fitting procedure developed by Elliott et al. 2016. The only adaptations needed to the analytic Maxwellian fitting procedure were to change the mass from protons to methane and to use the effective area of the secondary detection rather than for the coincidence detection. The more complex comprehensive method by Elliott et al. 2016 requires knowing the direction of motion of the ions.

Since the solar wind is typically within 1 degree of the radial direction, we can assume the solar wind is radial, but for the Pluto ions we cannot make such a simplifying assumption. Therefore, we adapted the analytic Maxwellian fitting method for the Pluto ions, which does not account for the instrument angular response rather than the comprehensive fitting procedure and consequently does not require angular information. The bulk velocities from both methods are nearly identical, especially when the counting statistics are high (i.e., times with high flux). For the density and temperature, the numerical moments calculation generally results in a higher values. This is a result of the Maxwellian not capturing the wings of the distribution. In the McComas et al. 2016 paper we show only the numerical integrations since we find the distributions to generally be a warm beam and not a cold beam as we assumed in the Maxwellian fits. Therefore, we archive the numerical integration results.

Reference Frame

Heliographic Inertial (HGI)

This system is Sun centered with the X-axis along the intersection line of the ecliptic (zero longitude occurs at the +X-axis) and solar equatorial planes. The Z-axis is perpendicular to the solar equator, and the Y-axis completes the right-handed system. This coordinate system is also referred to as the Heliocentric Inertial (HCI) system.

Heliocentric Aries Ecliptic J2000 (HAE-J2000)

This coordinate system is heliocentric system with the Z-axis normal to the ecliptic plane and the X-axis points toward the first point of Aries on the Vernal Equinox, and the Y-axis completes the right-handed system. This coordinate system is also referred to as the Solar Ecliptic (SE) coordinate system. The label 'J2000' refers to the time at which one defines the Vernal Equinox. In this case it is defined at the J2000 date, which is January 1, 2000 at noon.

Heliographic (HG)

This system is similar to the Heliographic Inertial one except the zero longitude is fixed on the surface of the Sun and rotates with a period of 25.38 days. Specifically, the zero was defined as

the longitude at the ascending node of the equator in the ecliptic plane on January 1, 1854 at 12 UT. This system is also known as the Carrington system and is an intrinsic system to Spacecraft Planet Instrument C-matrix Events (SPICE) toolkit denoted as IAU_SUN where IAU stands for International Astronomical Union.

Pluto J2000

The J2000 coordinate system with the origin translated to the center of Pluto.

Pluto International Astronomical Union (Pluto-IAU)

This is a cartographic coordinate system centered on Pluto where the frame is fixed and does not move with respect to the surface of the planet. The International Astronomical Union (IAU) defines the orientation of the frame.

Summary

The reference frames above are based on SPICE defined reference frames and central bodies. See below for a summary of their definitions in terms of SPICE.

Description	SPICE Reference Frame Name	SPICE Central Body Name
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Heliogr. Inertial (HGI)	HCI	Sun
Heliocentr. Aries Eclip. J2000 (HAE-J2000)	ECLIPJ2000	Sun
Heliographic (HG)	IAU_SUN	Sun
Pluto J2000	J2000	Pluto
Pluto International Astronomical Union (Pluto-IAU)	IAU_PLUTO	Pluto

Epoch of Geometric Parameters

All geometric parameters provided in the data labels were computed at the epoch midway between the START_TIME and STOP_TIME label fields.

References

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