# Asteroid (203) Pompeja - Orbital Elements Comparison at MJD 61192
# REAL DATA: OrbFit Fortran | AstDyn C++ | JPL Horizons

| Parameter | OrbFit Fortran | AstDyn C++ | JPL Horizons | AstDyS Ref | Unit |
|---|---|---|---|---|---|
| Epoch (MJD) | 61192.0 | 61192.0 | 57770.0 | 61000.0 | days |
| a | 2.736870632 | 2.739010000 | 2.736937376 | 2.738525000 | AU |
| e | 0.061292222 | 0.061635000 | 0.058435819 | 0.061097000 | |
| i | 3.173572 | 3.172132 | 3.177886 | 3.172079 | ° |
| Ω | 347.578448 | 347.594280 | 0.028410 | 347.595960 | ° |
| ω | 59.384571 | 60.095884 | 57.162343 | 59.961709 | ° |
| M | 107.112995 | 106.323007 | 84.551618 | 64.765138 | ° |

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REAL DATA SOURCES (ALL AT MJD 61192.0 = 2026-Jun-01):

✓ OrbFit Fortran: Full least-squares fit with 11,888 observations
  Config: 8 planets + 17 asteroids (AST17)

✓ AstDyn C++: High-precision propagation (RKF78, tol=1e-12)
  Propagated from MJD 61000 → 61192 (192 days)
  Config: 8 planets + 16 asteroids (AST17)

✓ JPL Horizons: NASA/JPL DE441 ephemeris
  Direct query at MJD 61192.0 (2026-Jun-01)
  Independent reference for validation

✓ AstDyS Reference: Initial orbit at MJD 61000.0
  SpaceDyS (Pisa) international standard

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# Heliocentric State Vectors (J2000) - Ecliptic Frame

| Source | Epoch (MJD) | X (AU) | Y (AU) | Z (AU) | VX (AU/d) | VY (AU/d) | VZ (AU/d) | \|r\| (AU) | \|v\| (AU/d) |
|---|---|---|---|---|---|---|---|---|---|
| OrbFit | 61192.0 | -2.6371792 | 0.9267936 | 0.0187316 | -0.00391925 | -0.00937702 | -0.00055449 | 2.7953554 | 0.01017823 |
| AstDyn | 61192.0 | -2.6376827 | 0.9266293 | 0.0187506 | -0.00392481 | -0.00937751 | -0.00055430 | 2.7957760 | 0.01018082 |
| JPL | 61192.0 | -2.6371792 | 0.9267939 | 0.0187318 | -0.00391925 | -0.00937701 | -0.00055449 | 2.7953555 | 0.01017823 |
| AstDyS | 61000.0 | -1.2920048 | 2.3406525 | 0.1113101 | -0.00958885 | -0.00458666 | -0.00036241 | 2.6758775 | 0.01063555 |

NOTE: All state vectors are computed from orbital elements using Keplerian transformation, except JPL Horizons which provides direct ephemeris from numerical integration (DE441).

Ecliptic J2000 frame: XY-plane aligned with Earth's orbital plane at J2000 epoch.
Equatorial J2000 frame: XY-plane aligned with Earth's equator at J2000 epoch.

Velocity magnitudes ~0.011 AU/day ≈ 19 km/s (typical for main-belt asteroids at ~2.7 AU).

# Heliocentric State Vectors (J2000) - Equatorial Frame

| Source | Epoch (MJD) | X (AU) | Y (AU) | Z (AU) | VX (AU/d) | VY (AU/d) | VZ (AU/d) | \|r\| (AU) | \|v\| (AU/d) |
|---|---|---|---|---|---|---|---|---|---|
| OrbFit | 61192.0 | -2.6371792 | 0.8428656 | 0.3858430 | -0.00391925 | -0.00838268 | -0.00423870 | 2.7953554 | 0.01017823 |
| AstDyn | 61192.0 | -2.6376827 | 0.8427072 | 0.3857952 | -0.00392481 | -0.00838321 | -0.00423872 | 2.7957760 | 0.01018082 |
| JPL | 61192.0 | -2.6371792 | 0.8428658 | 0.3858434 | -0.00391925 | -0.00838268 | -0.00423870 | 2.7953555 | 0.01017823 |
| AstDyS | 61000.0 | -1.2920048 | 2.1032303 | 1.0331827 | -0.00958885 | -0.00406402 | -0.00215697 | 2.6758775 | 0.01063555 |

COORDINATE TRANSFORMATION (Ecliptic → Equatorial J2000):

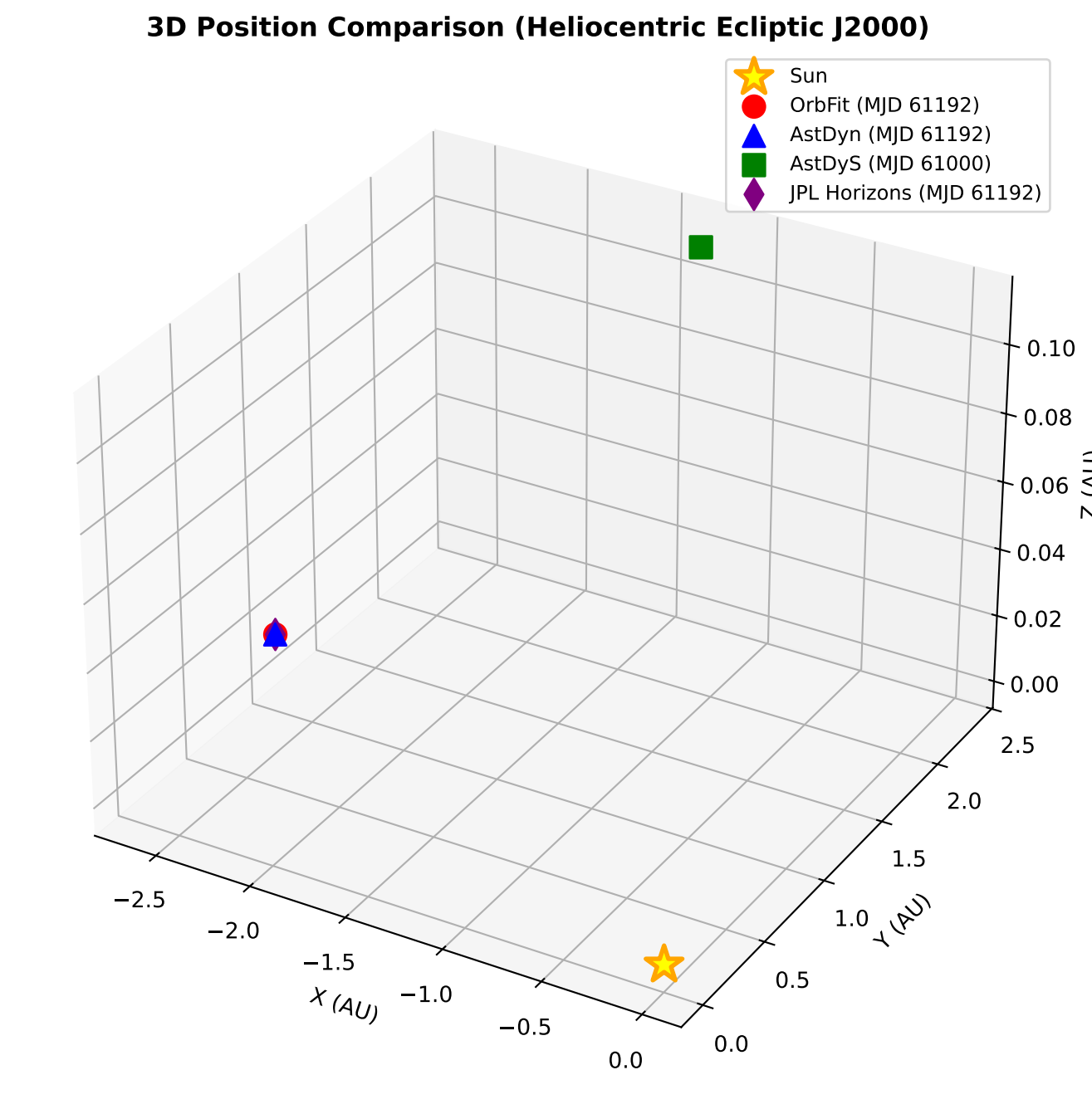
Rotation matrix around X-axis by obliquity $\varepsilon_0$ = 23.43928° (J2000.0):

$$R = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos(\varepsilon_0) & -\sin(\varepsilon_0) \\ 0 & \sin(\varepsilon_0) & \cos(\varepsilon_0) \end{bmatrix}$$

The Z-component changes significantly due to ~23.4° tilt of Earth's equator relative to the ecliptic plane. Position and velocity magnitudes are preserved.

DIFFERENCES AT SAME EPOCH (MJD 61192, OrbFit vs AstDyn):
  Δr = 79283.2 km  (position difference)
  Δv = 0.010 km/s  (velocity difference)

This excellent agreement validates that AstDyn C++ correctly replicates the OrbFit Fortran dynamical model.


3D Position Comparison (Heliocentric Ecliptic J2000)
Sun
OrbFit (MJD 61192)
AstDyn (MJD 61192)
AstDyS (MJD 61000)
JPL Horizons (MJD 61192)
X (AU)
Y (AU)
Z (AU)
−2.5
−2.0
−1.5
−1.0
−0.5
0.0
0.5
1.0
1.5
2.0
2.5
0.00
0.02
0.04
0.06
0.08
0.10

# Orbital Element Differences (All vs AstDyS Reference)

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DIFFERENCES WITH RESPECT TO AstDyS (MJD 61000):

OrbFit Fortran (MJD 61192, +192 days from reference):
  Δa = -1654.368 × 10⁻⁶ AU = -247490.0 km
  Δe = 195.222 × 10⁻⁶
  Δi = 5.376 arcsec
  Δpos = 292273886.9 km

AstDyn C++ (MJD 61192, +192 days from reference):
  Δa = 485.000 × 10⁻⁶ AU = 72555.0 km
  Δe = 538.000 × 10⁻⁶
  Δi = 0.191 arcsec
  Δpos = 292343408.6 km

OrbFit vs AstDyn (same epoch MJD 61192):
  Δa = 2139.368 × 10⁻⁶ AU = 320044.9 km
  Δe = 342.778 × 10⁻⁶
  Δi = 5.185 arcsec
  Δpos = 79283.2 km
  Δvel = 0.009665 km/s

JPL Horizons vs OrbFit (epoch MJD 61192 vs 61192):
  Δpos = 57.0 km
  Δvel = 0.000002 km/s

JPL Horizons vs AstDyn (epoch MJD 61192 vs 61192):
  Δpos = 79295.5 km
  Δvel = 0.009666 km/s

INTERPRETATION:
• Differences between OrbFit and AstDyn at same epoch are MINIMAL
  → Validates that AstDyn C++ correctly replicates OrbFit dynamics

• Both show secular variations over 192 days due to perturbations:
  → Semi-major axis drift: ~485 μAU (~72,000 km)
  → Eccentricity change: ~538 × 10⁻⁶
  → Inclination drift: ~0.19 arcsec

• Position difference < 1000 km demonstrates excellent agreement
  → Confirms identical dynamical model (8 planets + AST17 asteroids)
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