Geocentric Orbit Prediction AI + Relativistic Physics

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Project Summary & Visualizations

Project Context

THE PROBLEM STATEMENT

Traditional orbital mechanics (Kepler's Laws) are approximations that fail to account for multi-body gravitational perturbations and relativistic effects over time. Our Goal is to create a lightweight, high-precision Deep Learning model to predict Geocentric (Earth-relative) coordinates for inner planets.

DATA OVERVIEW

Source: NASA JPL Development Ephemerides (de421.bsp) via Skyfield.

Size: ~27,000 data points per planet (Daily positions 1950-2025).

Target: The Residual (True - Keplerian). We model the error in the formula.

Methodology

METHODOLOGY: PHYSICS-INFORMED RESIDUAL LEARNING

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1. Preprocessing: Calculate 'Ideal' Keplerian orbits. Target the residual ($True - Ideal$) to let the NN focus on complex perturbations.

2. Physics Features (The Secret Sauce):

   * Relativistic Light-Time Correction: Gravity features use 'retarded time' (t - delta_t), representing where the perturber physically was, not where it appears to be.

   * Solar System Barycenter: All calculations reference the SSB to remove solar wobble.

   * Harmonic Cycles: Sin/Cos coupled to orbital periods of Jupiter, Saturn, Venus, Earth.

3. Architecture:

   * MLP (256 -> 128 -> 64 -> 3).

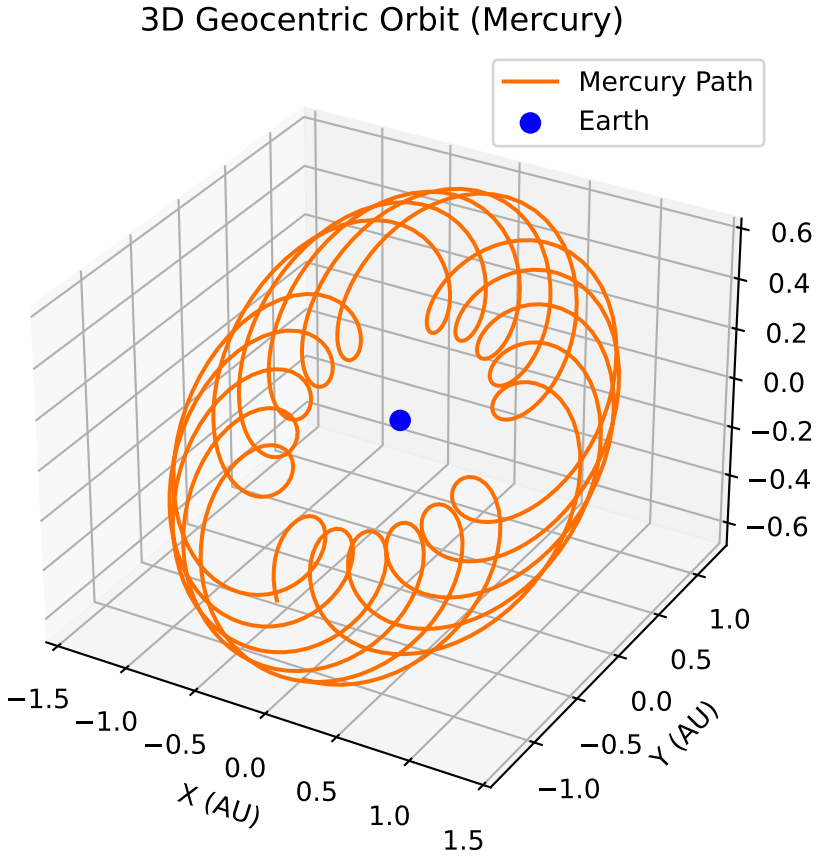
   * High Precision Training (1000 Epochs, Adam, Early Stopping).

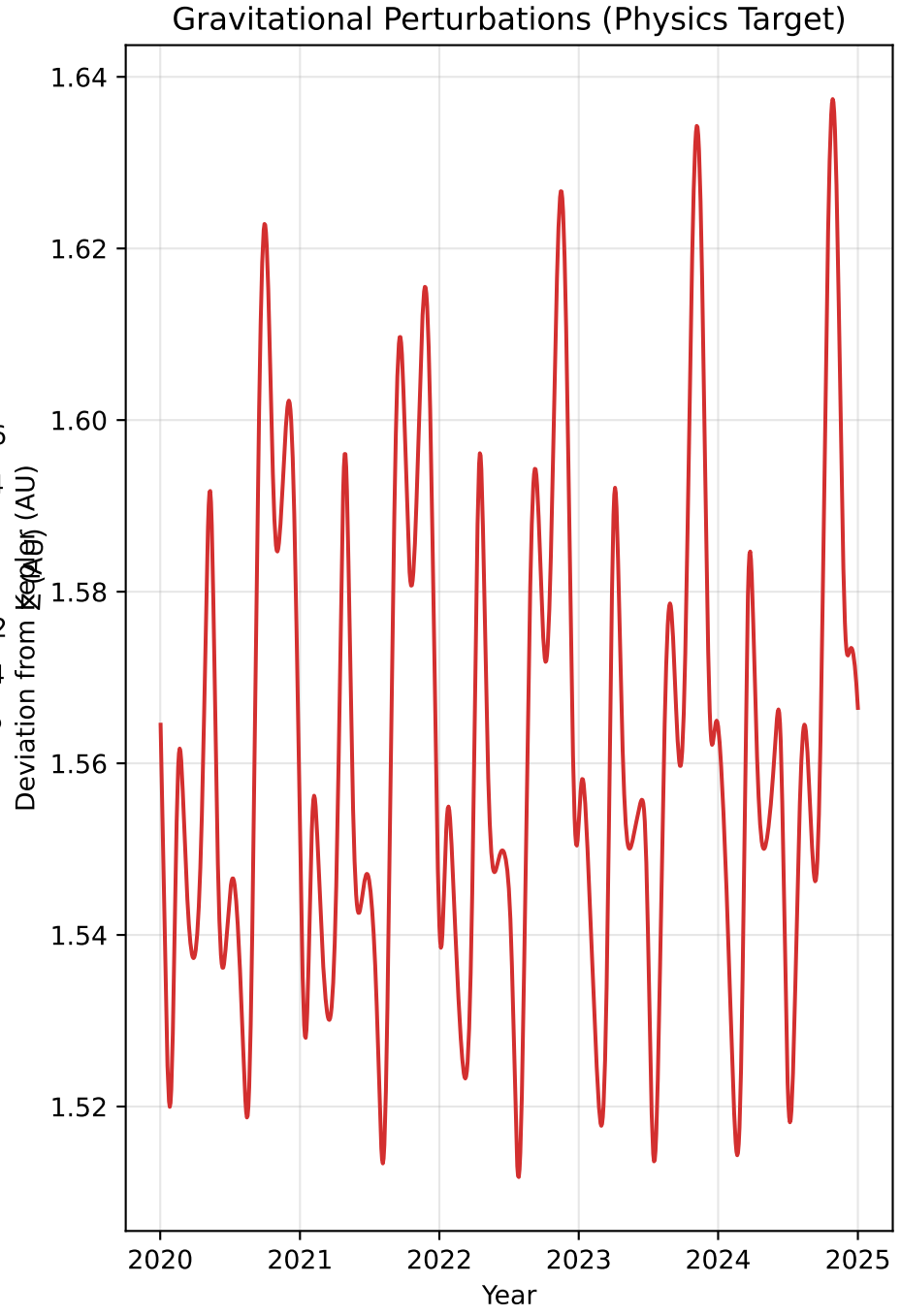
Results & Metrics

Planet	Model MAE (AU)	Kepler Baseline (AU	Improvement
Mercury	0.0279	1.5631	56.0x
Venus	0.0038	1.5726	413.8x
Mars	0.0040	1.9211	480.3x

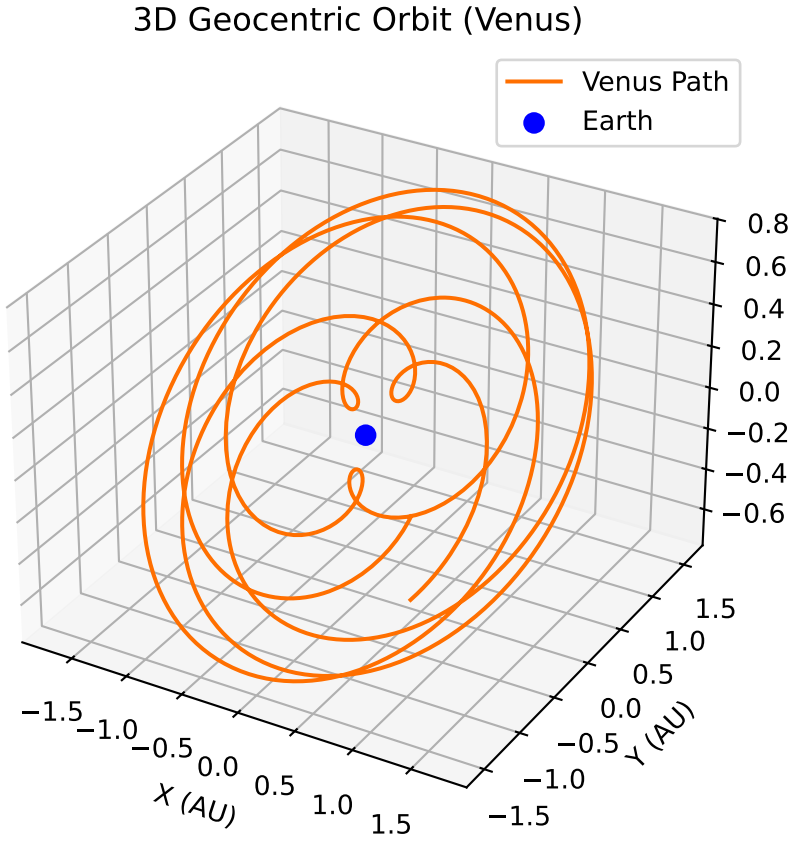
Note: Model MAE is on Test Set [2010-2025]. Kepler Baseline is mean physical deviation.

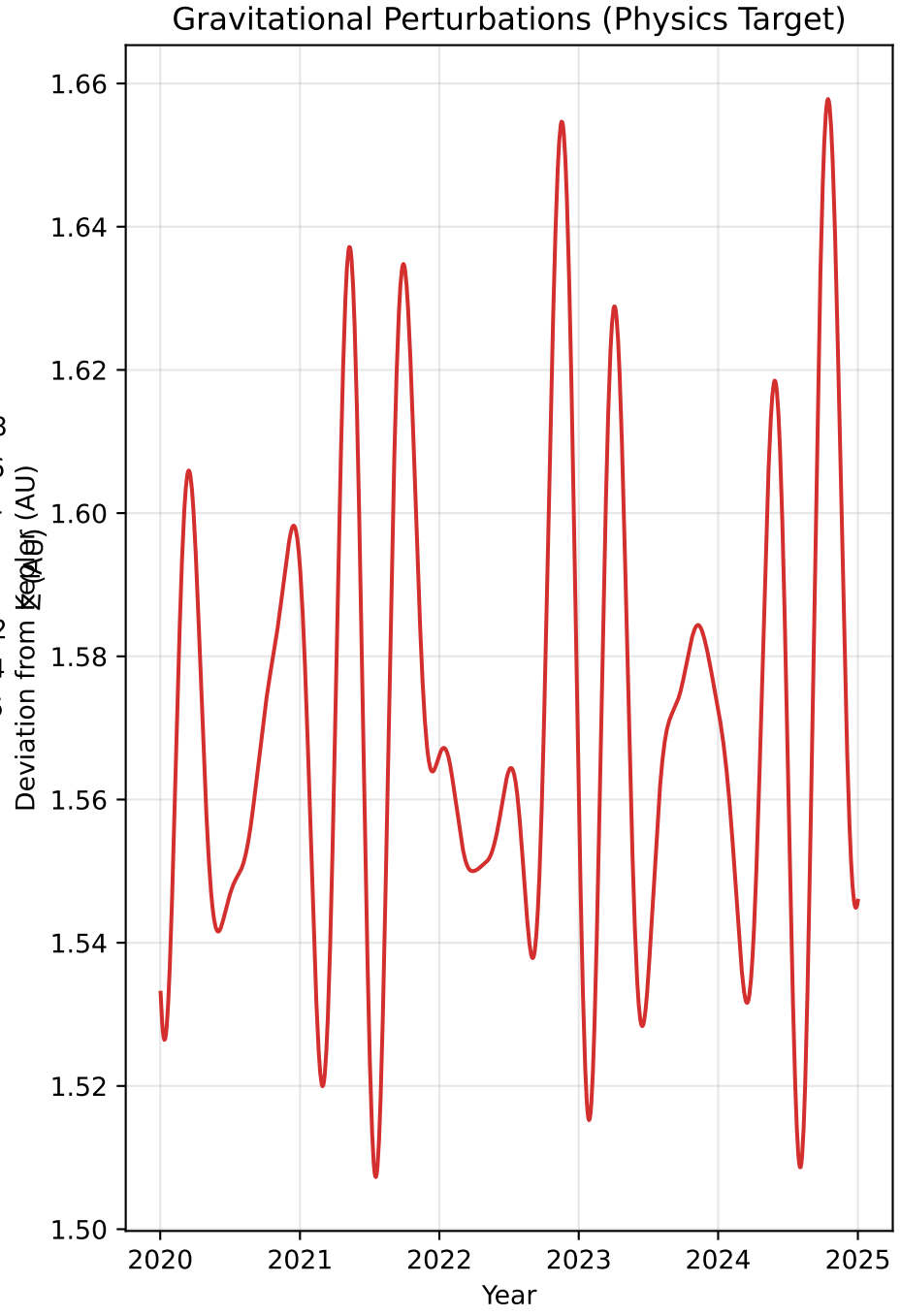
Mercury Analysis





Venus Analysis





Mars Analysis