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Geodesic motion of S2 and G2 as a test of the fermionic dark matter nature of our Galactic core

The anomalous perihelion precession of Mercury around our Sun led to the greatest change of paradigm of physics thanks to the conception of General Relativity by Albert Einstein. The multi-year, high-quality data recording the motion of the closest objects around the compact source at the Galactic center, Sgr A*, led to the verification of the predicted gravitational redshift, to the anomalous precession of S2, as well as to the anomalous fly-by of G2. This heralds a fermionic dark matter dense core interpretation of the nature of Sgr A*, traditionally interpreted as a black hole. A new neutral fermion of 56 keV, a dark matter "*ino*", for short a "*darkino*", is basic to this alternative approach. New perspectives are open 1) to the understanding of the predominance of dark matter in our Galaxy and in the large scale of the Universe, 2) to formulate a new paradigm for identifying the seed for the formation of ten-billion-solar-masses black holes in active galactic nuclei, and 3) to address the fundamental physics of the *darkinos* which, together with the *neutrinos*, appear to have a fundamental role in accounting for a large portion of the Universe mass-energy. These results are presented in the new article appearing on 9 September 2020, in Astronomy & Astrophysics, co-authored by E.A. Becerra-Vergara, C.R. Argüelles, A. Krut, J.A. Rueda, and R. Ruffini [1].

Harvesting the detailed analysis made possible by the Einstein Theory of General Relativity, the article shows that the motion of the S2 star and the G2 cloud around Sgr A*, traditionally interpreted as due to a black hole of about 4 million solar masses, is instead better explained by the fermionic dark matter dense core of nearly the same mass (see Figs. 1–4 on pages 2–5). The core is composed of *darkinos* of 56 keV rest mass-energy, roughly 9 times lighter than electrons. This dark matter component extends, from the core, to the entire Galaxy, creating the stable gravitational cradle where all the stars rotate. The dense core formed of these "*darkinos*" becomes unstable giving origin to a black hole when it reaches a mass of about 100 million solar masses. This represents the lowest black hole seed mass for the growth of supermassive ten-billion-solar-masses black holes in active galactic nuclei.

This discovery has been made possible thanks to some of the largest observational facilities ever achieved in the history of our planet. The data of S2 (see Fig. 1 on page 2 and Fig. 3 on page 4) are taken from the SINFONI (`http://www.icranet.org/telescopes/SINFONI-VLT.jpg`) and NACO (`http://www.icranet.org/telescopes/NaCo-VLT.jpg`) instruments of the Very Large Telescope (VLT) (`http://www.icranet.org/telescopes/VLT.jpg`), operated by the European Southern Observatory (ESO) located on Cerro Paranal in the Atacama Desert in Chile (`http://www.icranet.org/telescopes/potw2023a.jpg`), the Keck I (`http://www.icranet.org/telescopes/Keck_I.jpg`) and Keck II (`http://www.icranet.org/telescopes/Keck_II.jpg`) Telescopes, operated by the W. M. Keck Observatory located in Hawaii (`http://www.icranet.org/telescopes/Keck_ext.jpg`), the Gemini North Telescope (`http://www.icranet.org/telescopes/Gemini_int.jpg`), operated by the Gemini Observatory located in Hawaii (`http://www.icranet.org/telescopes/Gemini_ext.jpg`), as well as from the Subaru Telescope (`http://www.icranet.org/telescopes/Subaru_int.jpg`), operated by the National Astronomical Observatory of Japan at the Mauna Kea Observatory on Hawaii (`http://www.icranet.org/telescopes/Subaru_ext.jpg`). The observational data of G2 (see Fig. 2 on page 3 and Fig. 4 on page 5) are taken from the SINFONI and NACO instruments of the VLT.

This approach is rooted in the work of Enrico Fermi who introduced the fermions in particle physics. Remo Ruffini recalls: "Eugene Wigner, Nobel laureate colleague of Einstein and Fermi, often stated: *the Thomas-Fermi model works better than it should*. This model has been leading for 93 years the description of all atoms: a gas of electrons, negatively-charged fermions, attracted electromagnetically by a positively-charged nucleus. In 1973, in Princeton, I addressed the gravitational analog of a Thomas-Fermi atom. Many neutral self-gravitating fermions characterized by their mass and spin, kept in equilibrium by their collective self-gravitation [2]. This idea was developed for years in ICRA and ICRANet, leading to a new approach to neutron stars (see [3] and references therein), and to the dark matter distribution in galaxies in the RAR model [4, 5], here applied to the dark matter galactic cores".

[1] `https://doi.org/10.1051/0004-6361/201935990` (A&A forthcoming article).

[2] R. Ruffini and S. Bonazzola, Physical Review **187**, 1767 (1969).

[3] J. A. Rueda, R. Ruffini, and S. S. Xue, Nucl. Phys. A **872**, 286 (2011), 1104.4062.

[4] C. R. Argüelles, A. Krut, J. A. Rueda, and R. Ruffini, Phys. Dark Universe **21**, 82 (2018), 1810.00405.

[5] C. R. Argüelles, A. Krut, J. A. Rueda, and R. Ruffini, Phys. Dark Universe **24**, 100278 (2019).

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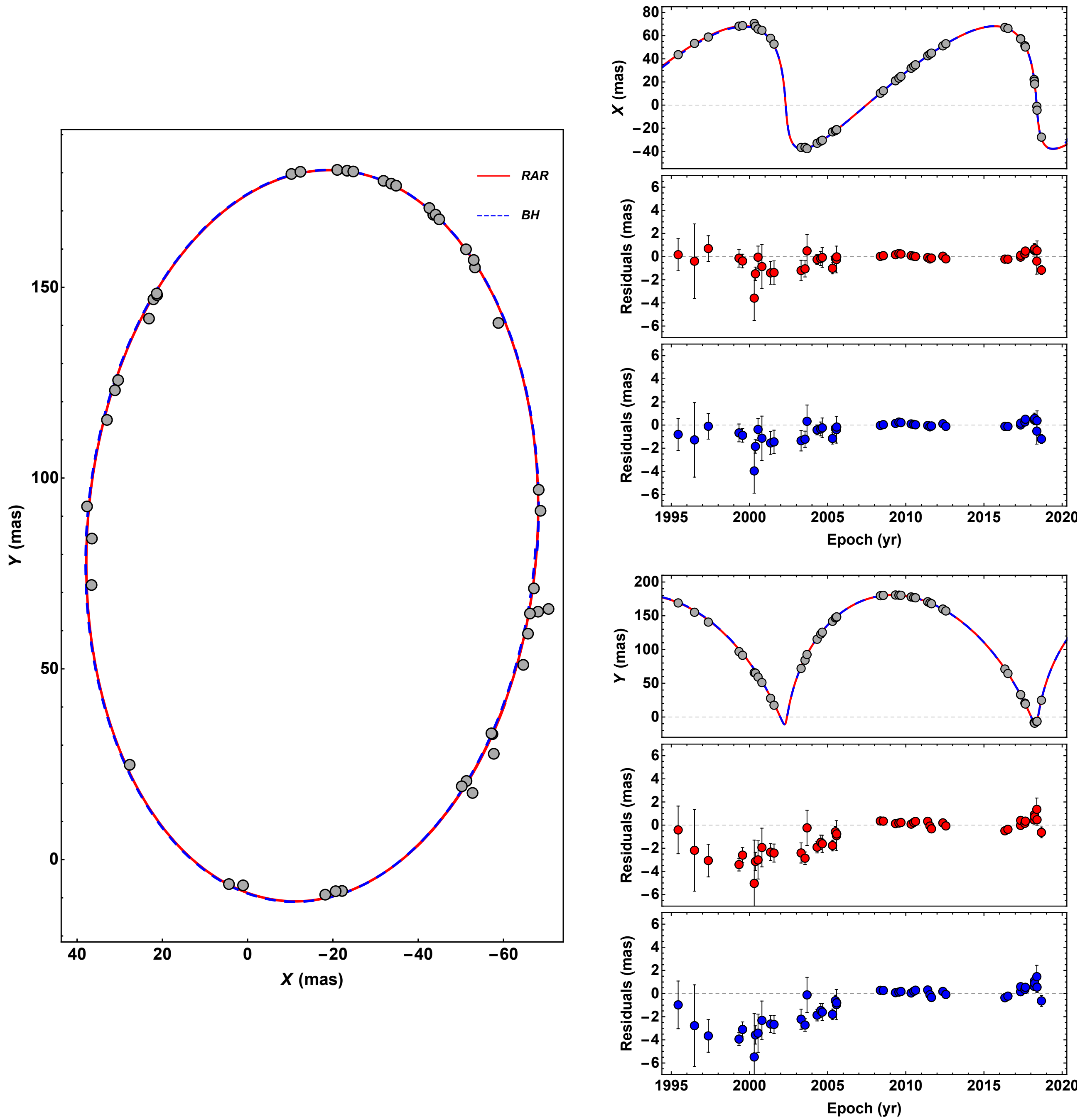

FIG. 1. Taken from [1]. Theoretical (central BH and RAR models) and observed orbit of S2 around Sgr A*. The left panel shows the orbit, i.e. the right ascension (X) vs. declination (Y) angular positions, and the right panel shows the X and Y positions as a function of the observation time, and the corresponding residuals of the best-fit for the BH (blue) and the RAR (red) models. The theoretical models are calculated by solving the equations of motion of a test particle in the gravitational field of: 1) a Schwarzschild BH of 4.075 million solar masses (blue-dashed curves), and 2) the DM distribution obtained from the extended RAR model for 56 keV-fermions (red curves). The mass of the quantum core in the RAR model is 3.5 million solar masses. Figure available at: http://www.icranet.org/orbitS2.pdf

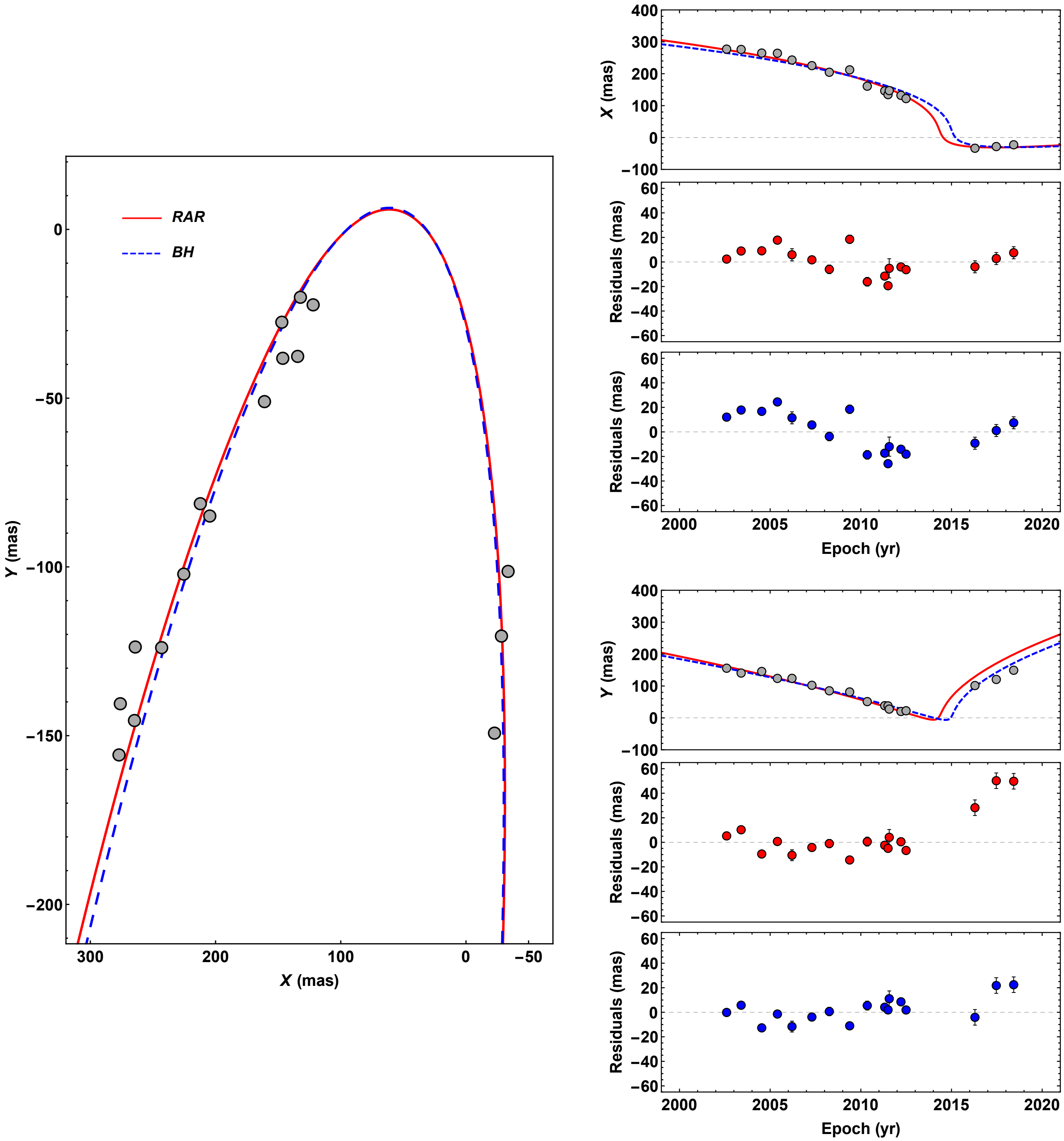

FIG. 2. Taken from [1]. Same as Fig. 1, but for G2. Figure available at: http://www.icranet.org/orbitG2.pdf

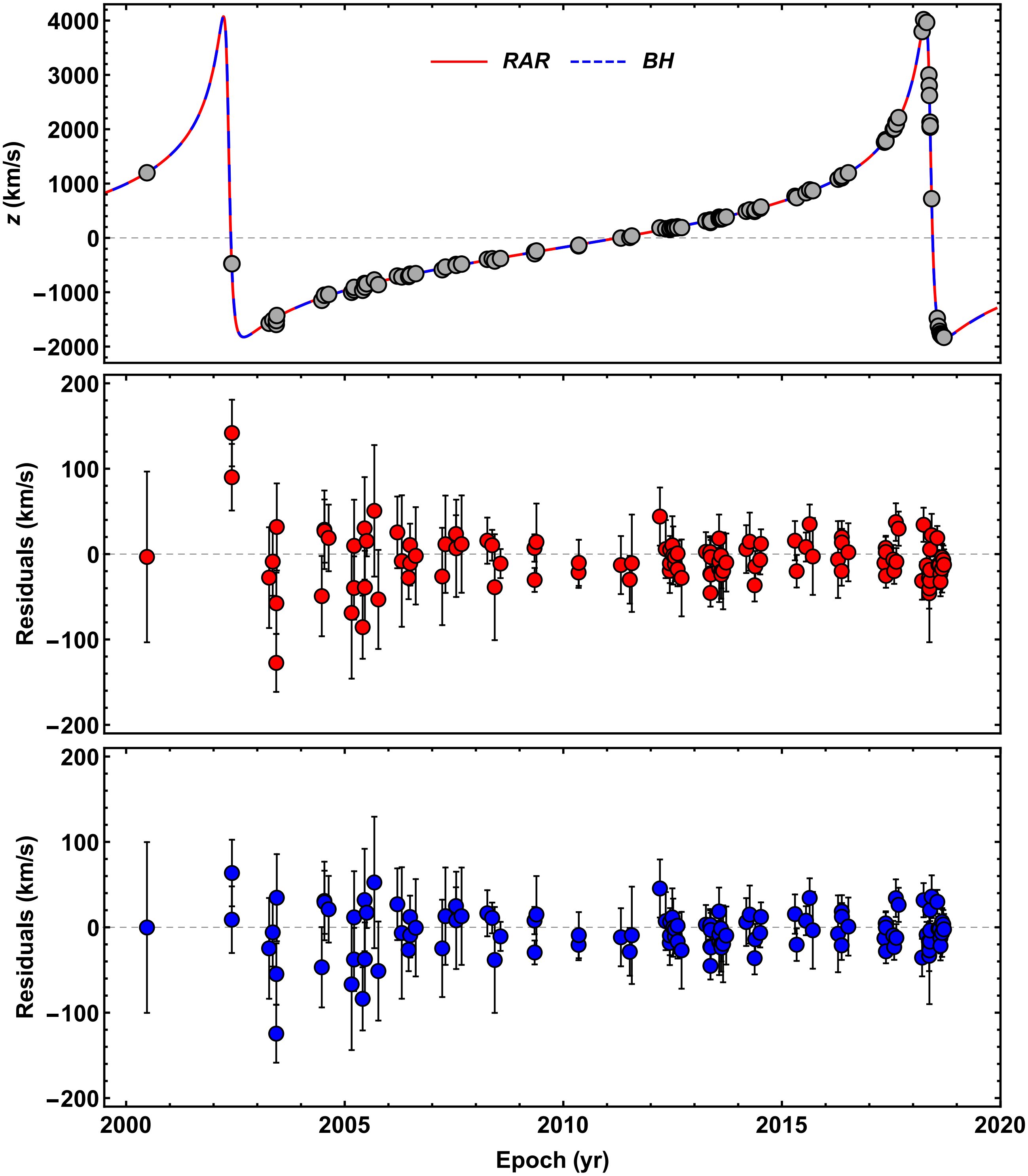

FIG. 3. Taken from [1]. Same as Fig. 1, but for the line-of-sight radial velocity of S2 (i.e. the redshift function z). Figure available at: http://www.icranet.org/velS2.pdf

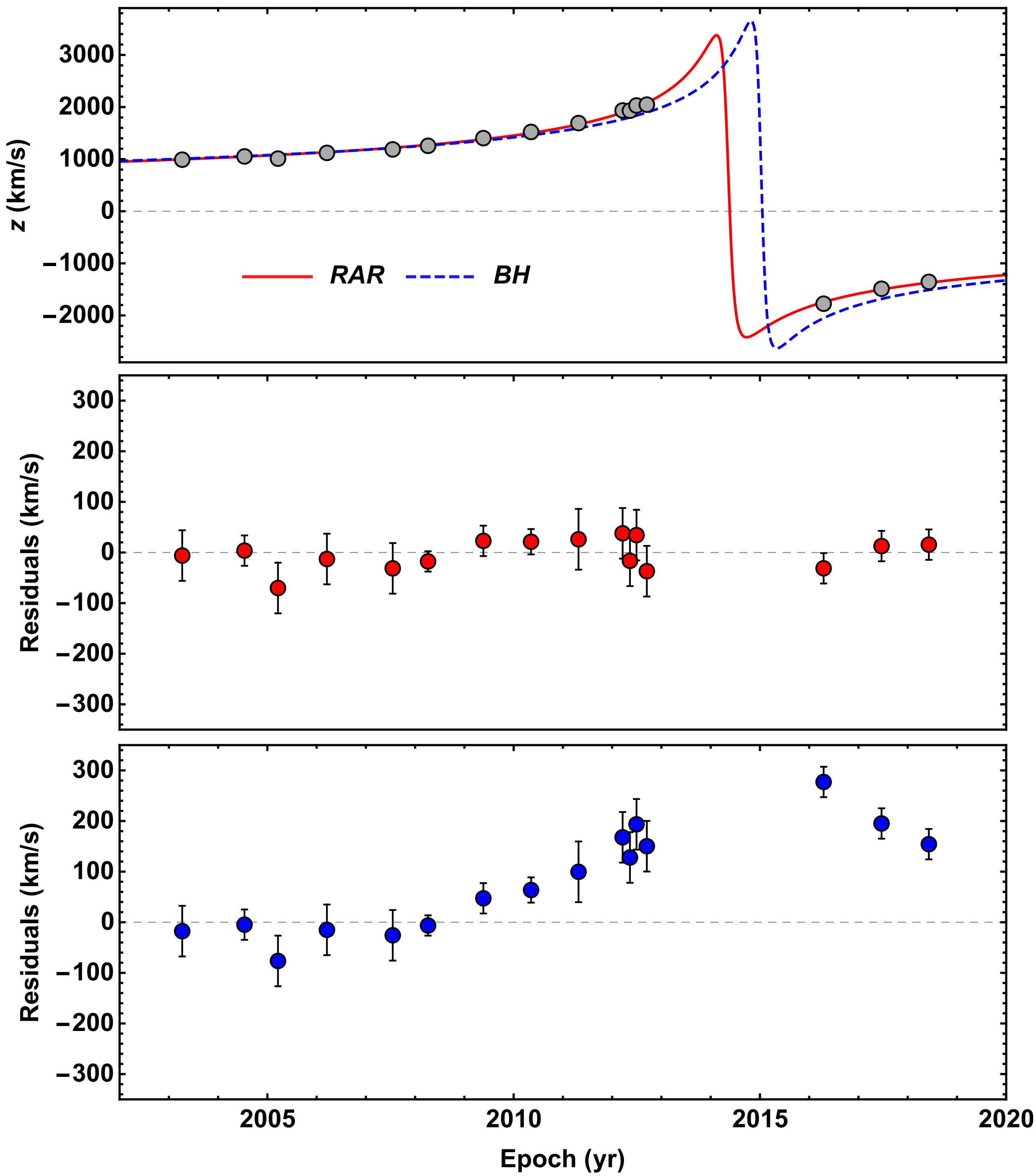

FIG. 4. Taken from [1]. Same as Fig. 3, but for G2. Figure available at: http://www.icranet.org/velG2.pdf