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Are "Little Red Dots" Dynamical Gravastars in Formation?

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We propose that the "little red dots" observed by the JWST are dynamical gravastars (a type of black hole mimicker) in formation. (Memo dated 8/3/2025.)

The aim of this short, qualitative, note is to tie together two ideas that have appeared in the recent literature. The first, reviewed in [1], is the suggestion that horizonless black hole mimickers termed "dynamical gravastars" form when matter under extremely high pressure undergoes a phase transition to a state with *negative* energy density, as is permitted when quantum effects are taken into account. The second is the suggestion [2], [3], [4] that the "little red dots" observed by the JWST are a new type of compact relativistic object, taking the form of an ultramassive black hole surrounded by an opaque atmosphere.

The dyamical gravastar model of [1] consists of solving the Tolman-Oppenheimer-Volkoff equations (which are a clever rewriting of the Einstein equations for a relativistic fluid source in a spherically symmetric metric) assuming an equation of state undergoing a phase transition at very high fluid pressure. For pressure $p \leq$ pjump the equation of state is taken as that of a relativistic fluid with energy density $\rho(p) = 3p$, while for pressure $p >$ pjump the energy density is taken as $\rho(p) = -p + \beta$, with β a small positive constant. The model exhibits a metric structure very similar to that of a Schwarzschild black hole in an exterior region dictated by the equations, whereas g_{00} becomes exponentially small, but remains always positive, in the interior region. The calculations of [1] are static, giving the equilibrium structure, but do not show what happens as this structure forms in a collapse.

Consider now the time-dependent dynamics of formation of a dynamical gravastar. Once the pressure pjump is exceeded in a collapse, the model postulates a first order phase transition to a state of negative energy density. There will be a large energy release in this collapse, leading to an exterior appearance of an extremely energetic object. However, the fact that g_{00} is exponentially small in the interior leads to a very large time dilation and red shift as the released energy leaks out. Hence the energy release will be highly red shifted, and the time span of the energy release could be of a cosmological scale of millions or billions of years. These characteristics can give an

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exterior appearance of a "little red dot" constituting an extremely large energy source, consistent with what is observed. It would be clearly of great interest, and well within current computer capabilities, to do a computer simulation of this time-dependent scenario.

The papers of [2], [3], and [4] are astrophysical analyses motivated in part by the quasi-star model proposed earlier in [5]. The essence of our suggestion in this note is that the dynamical gravistar mechanism reviewed in [1] gives a collapse dynamics that leads to a structure resembling a quasi-star, and can naturally accommodate the little-red-dot phenomenon currently being observed.

[1] S. L. Adler, Black hole mimickers as relativistic stars calculated from the Tolman-Oppenheimer-Volkoff equations, Mod. Phys. Lett. A **40**,No. 26 (2025) 253009, arXiv:2504.18690.

[2] The Discovery of Little Red Dots in the Local Universe: Signatures of Cool Gas Envelopes, arXiv:2507.10569 (2025)

[3] Exploring the Nature of Little Red Dots: Constraints on AGN and Stellar Contributions from PRIMER MIRI Imagina, arXiv:2411.12005.

[4] M. C. Begelman and J. Dexter, little Red Dots As Late-stage Quasi-stars, arXiv:2507.09085.

[5] M. C. Begelman, E. M. Rossi, and P. J. Armitage, Quasi-stars: accreting black holes inside massive envelopes. Monthly Notices ofthe Royal Astronomical Society, 387(4), 1649-1659 (2008), arXiv:0711.4078.