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The Effect of Gravitational Focusing on Annual Modulation

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The scattering rate at dark-matter direct-detection experiments should modulate annually due to the Earth's orbit around the Sun. The rate is typically thought to be extremized around June 1, when the relative velocity of the Earth with respect to the dark-matter wind is maximal. We point out that gravitational focusing can alter this modulation phase. Unbound dark-matter particles are focused by the Sun's gravitational potential, affecting their phase-space density in the lab frame. Gravitational focusing can result in a significant overall shift in the annual-modulation phase, which is most relevant for dark matter with low scattering speeds. The induced phase shift for light O(10) GeV dark matter may also be significant, depending on the threshold energy of the experiment.

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