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On the width-amplitude inequality of electron phase space holes

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Width-amplitude relations for one-dimensional and three-dimensional electron holes are derived to be inequalities that allow existence of the holes in regions to one side of a bound. The theoretical origin of the width-amplitude inequality is elucidated to show that the inequality nature is independent of specific functional forms of the solitary potential and ambient plasma distribution functions. Ion dynamics and effects of finite hole velocity and finite perpendicular size are subsequently included. Finally, we show that the electron holes measured by the Polar Plasma Wave Instrument populate an allowed region in the solution space that is significantly away from the bounding curve. These electron holes evidence that Nature can realize solutions far away from the bounding curve, and confirm the theoretically predicted inequality for the first time. The existence of these loosely constrained electron holes opens up the possibility that they may be easily accessed by turbulence or random fluctuations, and thus may play important role in transport and thermal conductivity in collisionless plasma processes such as magnetic reconnection and boundary formation.