Closer look reveals how deep ocean squid uses 'leaky' optical fibers to disappear into the background

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Ventral view of a specimen of Galiteuthis glacialis recovered from the Ross Sea of Antarctica (71°59'S, 173°24'E). Specimen has a mantle length of 321 mm. Photograph by Darren Stevens of New Zealand, International Polar Year and the Census of Antarctic Marine Life. Credit: Wikipedia/ CC BY 3.0

(Phys.org)—A pair of researchers with the University of Pennsylvania has discovered how a type of deep ocean squid is able to remain unseen by predators despite having clearly visible eyes. In their paper published in *Journal of the Royal Society Interface*, Amanda Holt and Alison

Sweeney describe their study of glass squid and how it has evolved to hide itself from predators that lurk in any direction.

Glass squid live in the deep ocean and every part of their body except their eyes is clear, which helps to avoid being seen and eaten by predators from below. Such predators look up to find animals that create silhouettes against the distant light striking the surface of the water. Prior research had shown that the squid use what is known as counter-illumination to keep their eyes from being seen as part of a silhouette—they have organs below their eyes (photophores) that emit just enough light to match the light that is broadcast from above, preventing the eyes from being seen from below. But what about prey that live at approximately the same depths?

That is what the research pair wanted to know, so they obtained some samples of the squid and put them under a microscope. They found that the photophores were actually made of cells that have a bend in them and that the walls were reflective—the two attributes together caused light to be channeled, like fiber optic cables. Looking even closer they discovered that the reflecting ability was not very efficient, which meant a lot of the light that was supposed to be channeled would leak out. At first, the researchers found this baffling, but then discovered that it actually served a very real purpose. In leaking small amounts of light, which turned out to be in many directions, the squid's eyes became invisible to creatures that were at or near the same water level.

The researchers confirmed what they had found by creating simulated leaking fiber cables that leaked in the amounts calculated from the squid, and by also reproducing the light levels in an experimental tank that simulated that in the environment where the squid lived—and found they matched. The end result, the researchers report was that the photophores were actually omnidirectional invisibility cloaks, noting that sometimes imperfections in a biological system might be producing better results than one that might seem perfect in other ways.

More information: Amanda L. Holt et al. Open water camouflage via 'leaky' light guides in the midwater squid, *Journal of The Royal Society Interface* (2016). DOI: 10.1098/rsif.2016.0230

Abstract
Galiteuthis, a midwater squid, has photophores on the ventral surfaces of its eyes. These photophores emit bioluminescence to counter-illuminate the shadows cast by the eyes in downwelling sunlight, thereby hiding the eyes from upward-looking predators. The photophores consist of laminated fibre-like cells with semi-coaxial protein-dense layers around axial cytoplasm. These cells have been suggested to function as light guides: bioluminescence is an isotropic process used to hide in an anisotropic light environment, so any emission must be reshaped to be effective. We found a wide variation in cross-sectional geometries of photophore cells; some were more efficient at light guiding than others. We used a set of optical models to place these photophores in the context of the radiance where Galiteuthis lives and discovered a possible adaptive reason for this variation. In Galiteuthis's horizontal and vertical range, ocean radiance is also quite variable. For complete camouflage, photophores must reproduce this variation in radiance using an isotropic source. Our models show that variation in the geometry of the photophore light guides reproduces the predicted variation in ocean radiance experienced by this species. By selectively activating geometrically distinct populations of photophore cells, the animal may reproduce the angular distribution of light at all positions in its habitat.