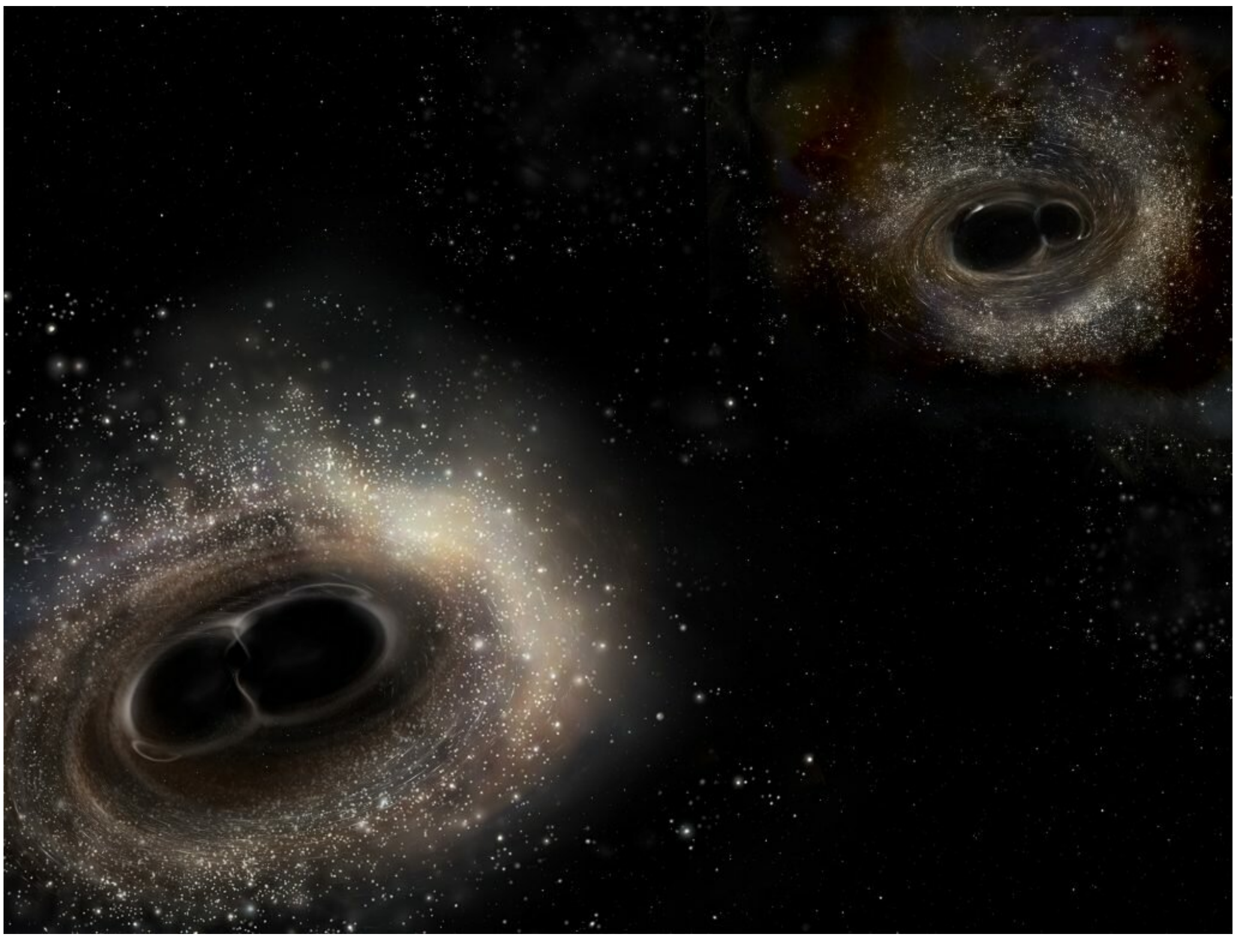
Using black holes to conquer space: The halo drive

March 14 2019, by Matt Williamsmatt Williams



Artist's impression of merging binary black holes. Credit: LIGO/A. Simonnet

The idea of traveling to another star system has been the dream of people long before the first rockets and astronauts were sent to space. But despite all the progress we have made since the beginning of the Space Age, interstellar travel remains just that – a dream. While theoretical concepts have been proposed, the issues of cost, travel time and fuel remain highly problematic.

A lot of hopes currently hinge on the use of directed energy and lightsails to push tiny spacecraft to relativistic speeds. But what if there was a way to make larger spacecraft fast enough to conduct interstellar voyages? According to Prof. David Kipping, the leader of Columbia University's Cool Worlds lab, future spacecraft could rely on a halo drive, which uses the gravitational force of a black hole to reach incredible speeds.

Prof. Kipping described this concept in a recent study that appeared online (the preprint is also available on the Cool Worlds website). In it, Kipping addressed one of the greatest challenges posed by space exploration, which is the sheer amount of time and energy it would take to send a spacecraft on a mission to explore beyond our solar system.

Kipping told Universe Today via email: "Interstellar travel is one of the most challenging technical feats we can conceive of. Whilst we can envisage drifting between the stars over millions of years – which is legitimately interstellar travel – to achieve journeys on timescales of centuries or less requires relativistic propulsion."

As Kipping put it, relativistic propulsion (or accelerating to a fraction of the speed of light) is very expensive in terms of energy. Existing spacecraft simply don't have the fuel capacity to get up to those kinds of speeds, and short of detonating nukes to generate thrust à la Project Orion, or building a fusion ramjet à la Project Daedalus, there are not a lot of options available.

In recent years, attention has shifted toward the idea of using lightsails and nanocraft to conduct interstellar missions. A well-known example is Breakthrough Starshot, an initiative that aims to send a smartphone-sized spacecraft to Alpha Centauri within our lifetime. Using a powerful laser array, the lightsail would be accelerated to speeds of up to 20 percent of the speed of light – thus making the trip in 20 years.

"But even here, you are talking about several terra-joules of energy for the most minimalist (a gram-mass) spacecraft conceivable," said Kipping. "That's the cumulative energy output of nuclear power stations running for weeks on end... so this is why it's hard."

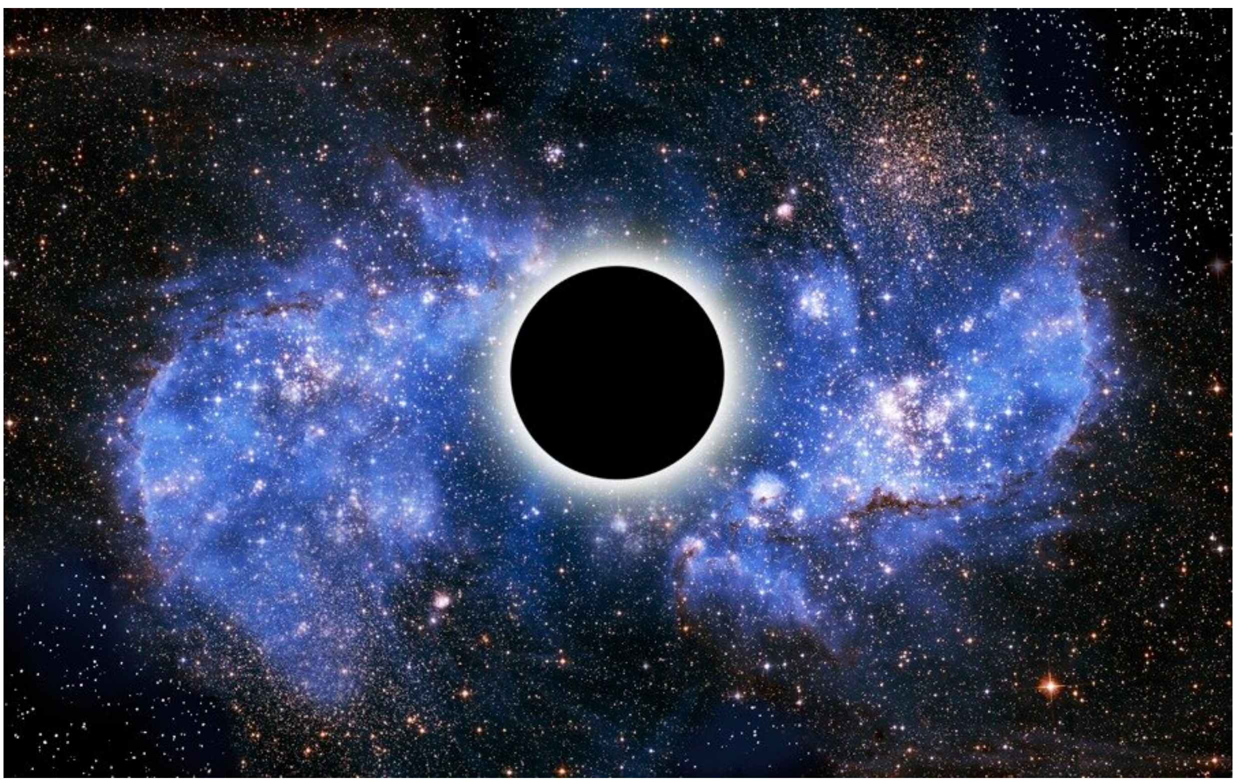
To this, Kipping suggests a modified version of the "Dyson Slingshot," an idea proposed by venerated theoretical physicist Freeman Dyson, the theorist behind the Dyson Sphere. In the 1963 book Interstellar Communications (Chapter 12: "Gravitational Machines"), Dyson described how spacecraft could slingshot around compact binary stars in order to receive a significant boost in velocity.

As Dyson described it, a ship would be dispatched to a compact binary system where it would perform a gravity-assist maneuver. This would consist of the spaceship picking up speed from the binary's intense gravity, adding the equivalent of twice their rotational velocity to its own, and is then flung out of the system.

While the prospect of harnessing this kind of energy for the sake of propulsion was highly theoretical in Dyson's time (and still is), Dyson offered two reasons why "gravitational machines" were worth exploring:

"First, if our species continues to expand its population and its technology at an exponential rate, there may come a time in the remote future where engineering on an astronomical scale may be both feasible and necessary. Second, if we are searching for signs of technologically advanced life already existing elsewhere in the universe, it is useful to consider what kind of observable phenomena a really advanced technology might be capable of producing."

In short, gravitational machines are worth studying in case they become possible someday, and because this study could allow us to spot possible extraterrestrial intelligences (ETIs) by detecting the technosignatures such machines would create. Expanding upon this, Kipping considers how black holes, especially those found in binary pairs, could constitute even more powerful gravitational slingshots.



Artist’s conception of the event horizon of a black hole. Credit: Victor de Schwanberg/Science Photo Library

This proposal is based in part on the recent success of the Laser Interferometer Gravitational-Wave Observatory (LIGO), which has detected multiple gravitational wave signals since 2016. According to recent estimates based on these detections, there could be as many as 100 million black holes in the Milky Way galaxy alone.

Where binaries occur, they possess an incredible amount of rotational energy, which is the result of their spin and the way they rapidly orbit one another. In addition, as Kipping notes, black holes can also act as a gravitational mirror – where photons directed at the edge of the event horizon will bend around and come straight back at the source. As Kipping put it:

"So the binary black hole is really a couple of giant mirrors circling around one another at potentially high velocity. The halo drive exploits this by bouncing photons off the "mirror" as the mirror approaches you, the photons bounce back, pushing you along, but also steal some of the energy from the black hole binary itself (think about how a ping pong ball thrown against a moving wall would come back faster). Using this setup, one can harvest the binary black hole energy for propulsion."

This method of propulsion offers several obvious advantages. For starters, it offers users the potential to travel at relativistic speeds without the need for fuel, which currently accounts for the majority of a launch vehicle's mass. And there are many, many black holes that exist throughout the Milky Way, which could act as a network for relativistic space travel.

What's more, scientists have already witnessed the power of gravitational slingshots thanks to the discovery of hyper-velocity stars. According to research from the Harvard-Smithsonian Center for Astrophysics (CfA), these stars are a result of galactic mergers and interaction with massive black holes, which kick them out of their galaxies at one-tenth to onethird the speed of light – around 30,000 to 100,000 km/s (18,600 to 62,000 mps).

But of course, the concept comes with innumerable challenges and more than a few disadvantages. In addition to building spacecraft that can endure being flung around the event horizon of a black hole, a tremendous amount of precision is required – otherwise, the ship and crew (if it has one) could be pulled apart in the maw of the black hole. Additionally, there's simply the matter of reaching one:

"[T]he thing has a huge disadvantage for us in that we have to first get to one of these black holes. I tend to think of it like a interstellar highway system – you have to pay a one-time toll to get on the highway, but once you're on, you can ride across the galaxy as much as you like without expending any more fuel."

The challenge of how humanity might go about reaching the nearest suitable black hole will be the subject of Kipping's next paper, he indicated. And while an idea like this is about as remote to us as building a Dyson Sphere or using black holes to power starships, it does offer some pretty exciting possibilities for the future.

In short, the concept of a black hole gravity machine presents humanity with a plausible path to becoming an interstellar species. In the meantime, the study of the concept will provide SETI researchers with another possible technosignature to look for. So until the day comes when we might attempt this ourselves, we will be able to see if any other species have already made it work.

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