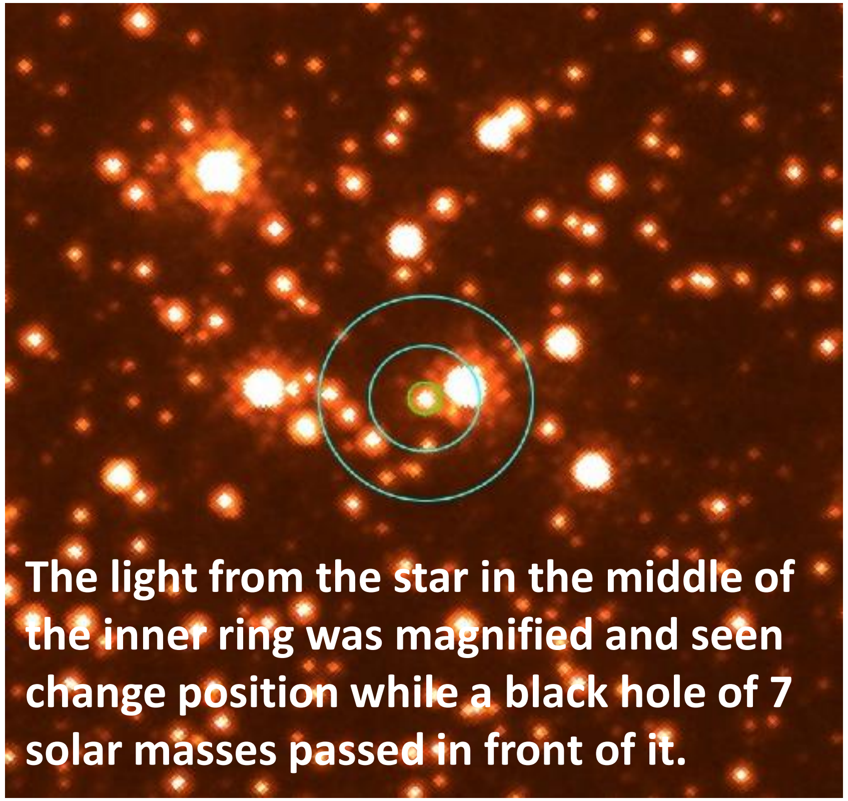
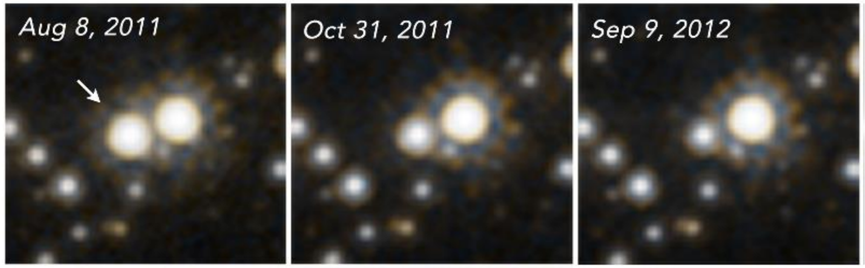
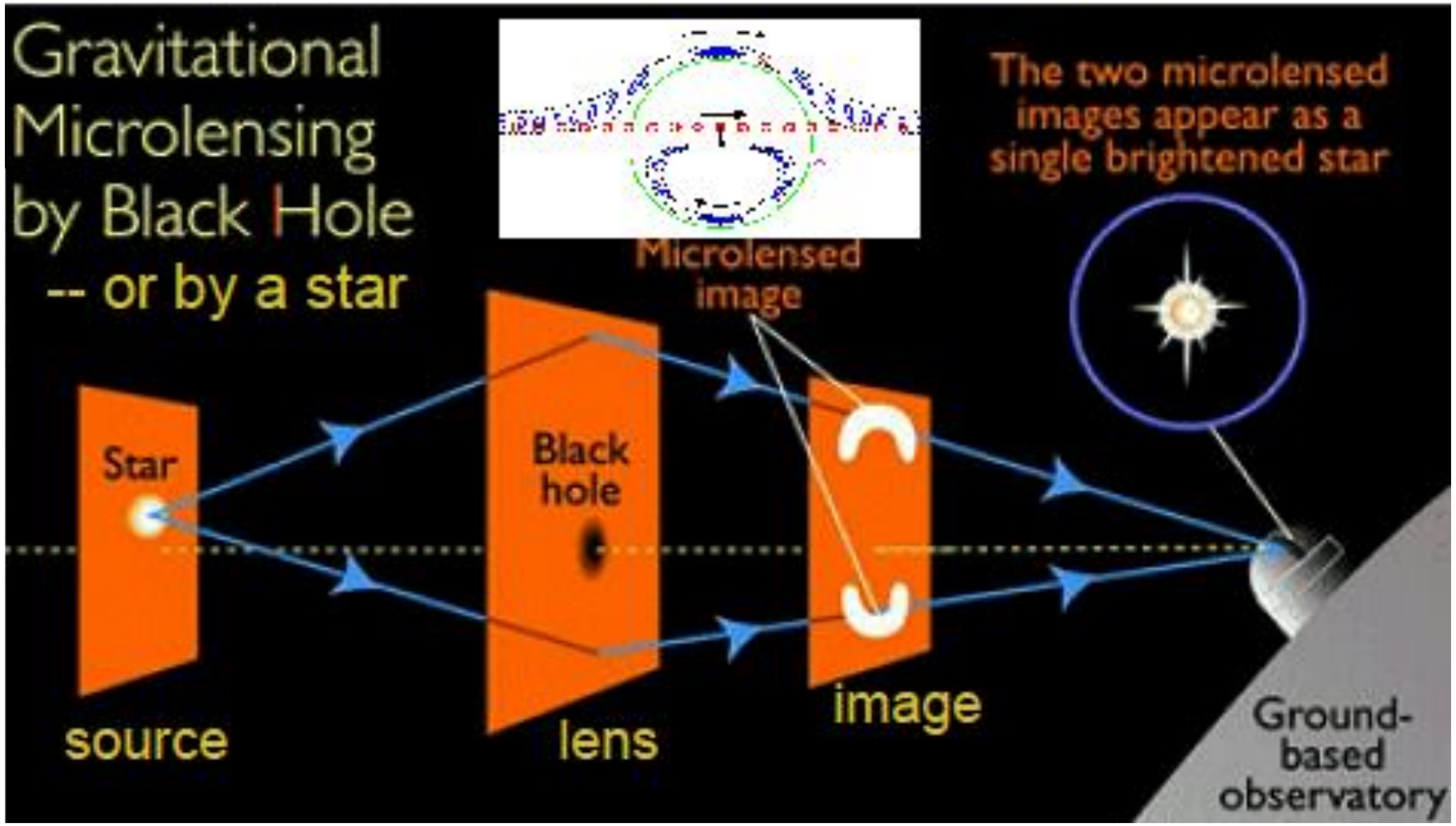
Stars like the Sun end their life as white dwarfs. Stars of 8 solar masses or somewhat more ends in a supernova explosion and leaves behind a neutron star. Even larger stars, of 20 solar masses or more, also ends in a super nova explosion, but leave behind a black hole - - a strange object that has no size, but still is a few times the mass of the Sun. The gravitational field of a black hole is so strong that it stops time and not even light can escape from it. There are less than one such explosion per century in the entire Milky Way galaxy , but since the Milky Way is 10 billion years old, many atoms in our body were made during these explosions, and many million of the produced black holes are floating alone around in the galaxy. Yet nobody has ever seen any such one – until now.

By combining observation done over a period of seven years, from the Hubble space telescope and from observatories on the ground, including the Danish 1.54m telescope in Chile, it has for the first time ever been possibly to "see" one of these 100 million free floating black holes we expect as remnants of large super nova explosions. The work is in press for publication in Astrophysical Journal as: Kailash Sahu et al, "An isolated stellar mass black hole detected through astrometric microlensing", and is available on the web as https://arxiv.org/abs/2201.13296

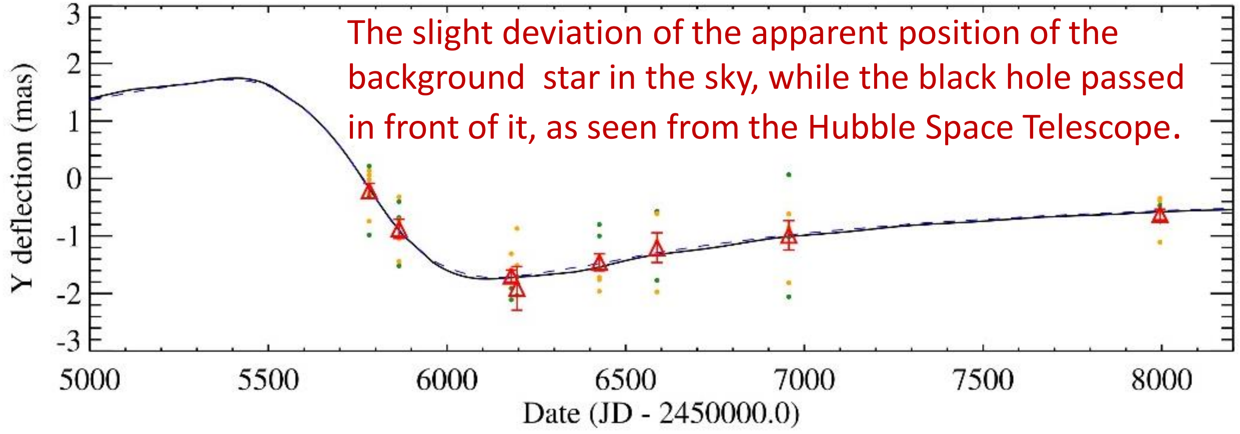


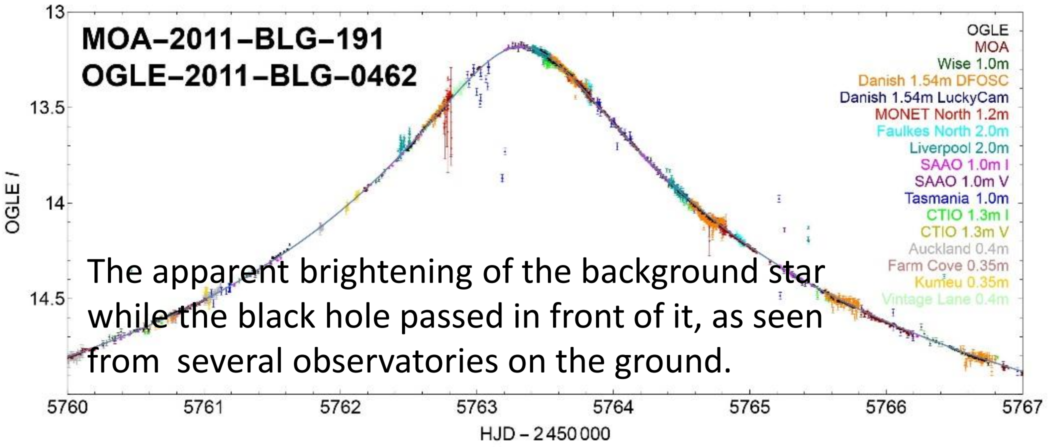


Observations of how a background star (to the left among the two stars in the centre of the images) was first brightened (left image) when the invisible black hole was in front of it, and then faded again as the black hole moved away.

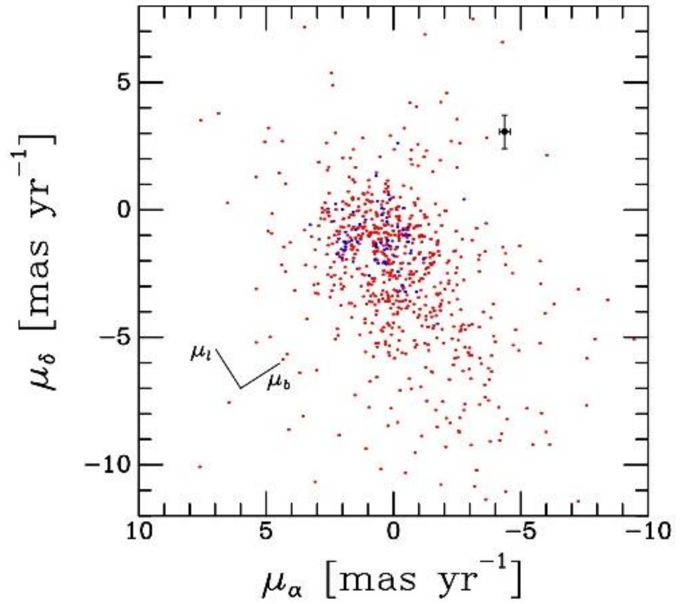


Black holes emit no light, but if they pass in front of a bright background star, their strong gravity will distort the light from the background star (illustration left) . This will magnify the stellar light as well as shift its position a slight amount.
Measuring the shift is best done from space (lower left) because it requires extreme accuracy in the determined position. Measuring the change in brightness is best done from observatories on the ground, because it requires many observations (lower right). Combining the two set of observations allowed us to calculate the mass, distance, and movement of the invisible black hole.





More than 2000 distant stars in the direction of the centre of the Milky Way are annually seen to temporarily brighten up because smaller (lensing) stars passes in front of them and focuses their light toward us – this is called a microlensing event. We monitor such events from the Danish 1.54m telescope in Chile because they will reveal if exoplanets orbit the lensing star. Most events take a few weeks, but some can last months or even years. A long event time can be because the lens move slowly, but it can also be because the lens mass is unusually large. Observing, from space, the precise movement of the distant star will reveal if the slowness is due to a high mass of the lensing object. Observing a particular slow event during several years from 2011 showed that the lens was 7 times the mass of the Sun, but yet was invisible. This can only be a black hole left over from a large supernova explosion. Detailed analysis show that the hole is on its way through the Galaxy with a speed of 150,000 km per hour, caused by an asymmetric explosion that accelerated it like a rocket. The lower left figure show its speed away from the surrounding stars. The black hole is 5,000 light years (1.58kpc) away, and caused the light from the distant star to brighten with a factor of almost 400. It's the first detection of a black hole from a supernova.



Right: summary of the main results.
Left: velocity of the black hole relative to the surrounding stars. μ*l* and μb are the directions along and perpendicular to the galactic plane.

Mass, $M_{\rm lens}$	$7.1 \pm 1.3\, M_\odot$
Distance, D_L	1.58 ± 0.18 kpc
Einstein ring radius, $\theta_{\rm E}$	5.18 ± 0.51 mas
Proper motion, (μ_α, μ_δ)	$(-4.36 \pm 0.22, +3.06 \pm 0.66)$ mas yr^{-1}
Galactic position, (X, Y, Z)	$(-4, -1580, -45)$ pc
Space velocities, (V, W)	$(+3, +40)$ km s^{-1}
Peak magnification, $A_{\rm max}$	369
Date of peak magnification, t_0	2011 July 20.825
Timescale, $t_{\rm E}$	270.7 ± 11.2 days