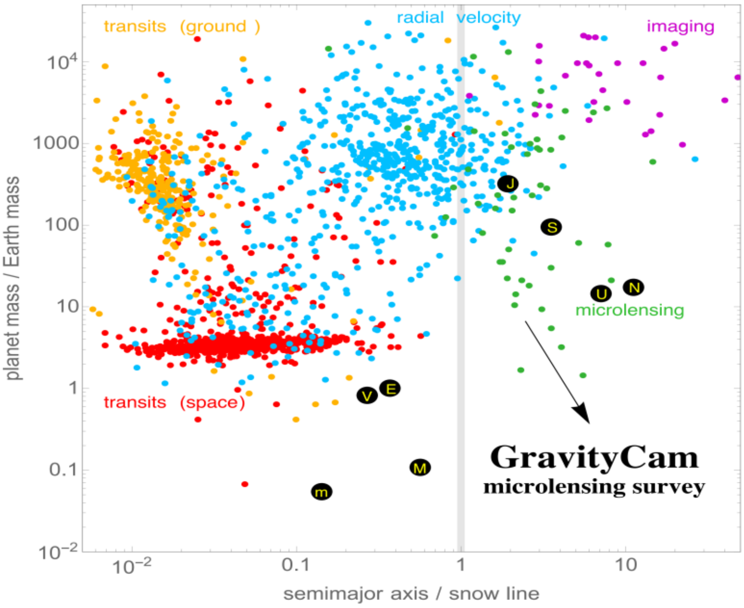
GravityCam: Project Summary. **23 June 2017.**

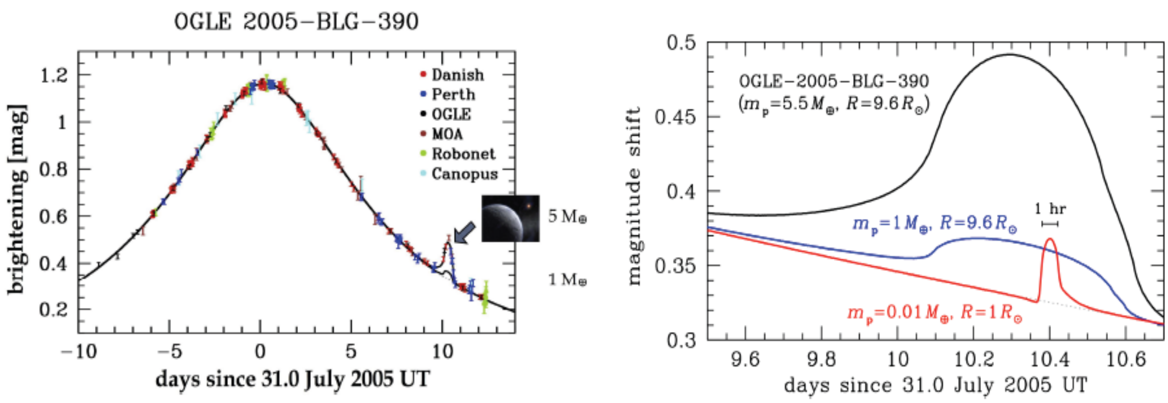
Abstract: GravityCam will allow wide-field visible surveys at high angular resolution and high time resolution for the first time. It will detect large numbers of Earth-mass exoplanets as well as an exceptionally sensitive survey for Kuiper belt and Oort cloud objects. It will also allow detections of bright pulses of light across wide fields of view.

GravityCam is an entirely new instrument designed to image large areas of the sky in the visible with angular resolution much better than normally possible with ground-based instruments. It does this by taking images at high-speed, typically 25 Hz. Each image is then shifted and added to give the output image. This technique, known as Lucky Imaging, improves the resolution by a factor of 2.5-3 over that normally obtained from the ground. Even higher resolution comes from post-processing.



GravityCam will detect planets that are virtually undetectable by other methods. This figure shows the planets detected to date where we see that for planets of Earth-mass and below detections are very few though we expect there are vast numbers of them.

There are a number of scientific programs that GravityCam is particularly well-suited to. The detection of planets the mass of the Earth and below is extremely difficult by normal radial velocity or transit methods. GravityCam will allow up to 90 million stars in the bulge of the Galaxy to be tracked night after night looking for gravitational microlensing events.



Gravitational microlensing profile showing planet detection. On the right are simulated profiles for an Earth-mass planet (blue line) and a moon-mass object (red line).

Should the lensing star have a planet in orbit around it, the microlensing brightness profile is affected allowing the mass, diameter and distance of planet from the lensing star to be determined. We predict we will detect several thousand new microlensing events over the six-month period when the bulge of the galaxy is in the sky, and expect to detect very many low mass planets in the region of 0.3–3 AU. The sensitivity allows planets down to the mass of the moon to be detected.

Other programs use the capacity of GravityCam to build statistics on the fluctuations of each and every star in the field. Microlensing events are selected by abnormal brightening characteristics. They are then followed accurately for many weeks.

We will simultaneously survey for Kuiper belt and Oort cloud objects with great efficiency. We will see stars blink off and on again for very short periods of time. The length of the occultation indicates the size of the object. If the occultation produces only a 20% reduction in brightness then we know that the occultation duration was only 20% of the frame rate or 8 ms. These data are produced in parallel during the above microlensing survey.

The total number of star-hours of observations searching for such objects is around 1 million at present. Within six months we expect to have approximately 100 billion star-hours and so should be able to detect very large numbers of Kuiper belt and Oort cloud objects. Good statistical coverage of the incidence and size spectrum of such objects is key for assessing the risks of interstellar travel.

The high time resolution of GravityCam also allows parallel surveys of the sky for bright optical flashes, such as those from lasers. The brightness produced by phased laser arrays can be extremely high and GravityCam has the capacity to detect those. The high frame rate allows detection of pulses with high signal-to-noise even on at very great distances.

The high angular resolution means that GravityCam has application in many other imaging areas such as the detection of dark matter by the distortions of Galaxy shapes at high redshift.

GravityCam would use the New Technology Telescope 3.6 m ESO telescope on La Silla in Chile. This is a high-performance telescope well-suited to mounting a wide area detector array in the Naysmith focal plane. The instrument will include an atmospheric dispersion corrector to maintain angular resolution when observing well away from the zenith.

The instrument will use wide area CMOS imaging detectors with very high quantum efficiency and low read-out noise. These are currently under development by E2V Teledyne. They are the manufacturers of most of the visible detectors for projects such as Hubble, Gaia, the LSST and the dark energy survey. The instrument will produce ~ 500 TB of data per night. Real time processing reduces that data rate dramatically.

The technical challenges of building GravityCam are not particularly severe. The detector manufacturer will probably build the main camera cryostat. Much of the effort will be focused on software development to make an efficient and reliable data pipeline. Our estimates are that the total project might cost in the region of $20 million including operations for two years after the end of commissioning. It should take about 2.5-3 years to substantially complete and begin to take data.

In order to take GravityCam forward, the next step is to undertake a Phase A study to develop a more detailed and properly costed plan for the instrument. That study should be completed in about 6-9 months and we estimate that it will cost about $200,000. The main costs here are travel to Chile and to ESO headquarters in Germany, outline design and costing of the optical components plus a relatively detailed plan for the software development. The software structure must allow easy reconfiguration for a variety of future programs. Both optical and software design would be done by well-qualified consultants.

GravityCam is a project between the Institute of Astronomy of the University of Cambridge, UK, the Open University STEM Faculty with Colin Snodgrass, the Centre for Electronic Imaging under Prof Andrew Holland, and the University of St Andrews under Dr Martin Dominik.

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