Our ERC Consolidator grant proposal will radically improve our understanding of one of the two fundamental energy sources available to galaxies; that of accretion onto the compact object in the central engine. We will achieve this by leveraging several of the new, large-scale surveys that are coming online in the next few years. The scope and remit of an ERC Consolidator grant will allow us to combine these data products in a manner that will not only establish the new state-of-the-art in extragalactic variable science, *it will establish and kickstart the new field of extragalactic variable science itself*. The P.I. is a world-leader in observational quasar astrophysics, both in terms of survey work and individual object study. Our proposal takes astrophysics into the 2020s, going from single objects samples, to surveys and samples of millions of objects leveraging these multi-billion Euro/dollar/pound next generation missions, telescopes and their subsequent datasets.

Quasars are ideal probes... etc.

Overview of Surveys related to this propopsal

The **Sloan Digital Sky Survey (SDSS):** An ongoing project, currently in its fourth phase, SDSS-IV. The P.I. was a leading member of the SDSS-III: Baryon Oscillation Spectroscopic Survey (BOSS). The fifth generation of Sloan Digital Sky Surveys: SDSS-V will be an all-sky, multi-epoch spectroscopic survey, yielding spectra of over 6 million objects during its lifetime. Data taking is due to start in 2020. Access would be through a USD $230,000 'buy-in' (which allows access for the P.I. and one PDRAs). . *Data Products: Repeat spectra in the North and Southern Hemisphere for 500,000 bright QSOs.*

The **Dark Energy Spectroscopic Instrument (DESI) Survey:** is a 5 year cosmology survey that will be conducted on the Mayall 4-meter telescope at Kitt Peak National Observatory starting in 2019. It uses the 5,000 fiber Dark Energy Spectroscopic Instrument and will obtain optical spectra for $\approx$20 million galaxies and quasars. The DESI Survey is starts in late 2019 and data access is through a USD $250,000 'buy-in' (which allows access for the P.I. and two PDRAs).
Data Products: Spectra of 1e6 quasars across 14,000 deg^2 of the Northern Sky.

Euclid is an ESA Medium Class mission to map the geometry of the dark Universe. It aims to understand why the expansion of the Universe is accelerating and what the nature of the source responsible for this acceleration

("dark energy") is. The mission will investigate the distance-redshift relationship and the evolution of cosmic structures by measuring shapes and redshifts of galaxies and clusters of galaxies out to redshifts $\sim$2, or equivalently to a look-back time of 10 billion years. In this way, Euclid will cover the entire period over which dark energy played a significant role in accelerating the expansion. *Euclid* is planned for launch in mid-2021. *Data Products: Very broadband optical and 3 filter near-infrared space-based imaging for 15,000 deg^2.*

The **Large Synoptic Survey Telescope (LSST)** project will conduct a 10-year survey of the sky, imaging the full Southern Sky every 3 nights. The LSST survey is designed to address four science areas (Understanding the Mysterious Dark Matter and Dark Energy; Hazardous Asteroids and the Remote Solar System; The Transient Optical Sky; The Formation and Structure of the Milky Way) and is an absolutely unique facility as far as areal, temporal and wavelength coverage.
Data Products: ugrizY broadband optical and near-infrared imaging for 20,000 deg^2. Images the full Southern Sky every 3 days.

The **4-metre Multi-Object Spectroscopic Telescope (4MOST):** is a fibre-fed spectroscopic survey facility on the VISTA telescope with a large enough field-of-view to survey a large fraction of the southern sky. The facility will be able to simultaneously obtain spectra of 2,400 objects distributed over a field-of-view of 4 square degrees. The initial Galactic and Extragalactic surveys will operate over a five-year period delivering spectra for $\geq$25 million objects over $\gtrsim$15,000 deg. 4MOST will commence science operations in mid-2021 (**TO BE CHECKED!!!**. *Data Products:*

Notes:: 4MOST has full access to the full LSST footprint. LSST will overlap half (7,500 deg^2) of the *Euclid* footprint.

The *Extended Roentgen Survey with an Imaging Telescope Array (eROSITA)* is the main instrument on the Spektr-RG (Spectrum-X-Gamma; SRG, SXG), an international high-energy astrophysics observatory.

The **Wide-field Infrared Survey Explorer (WISE)** is a NASA infrared-wavelength astronomical space telescope launched in December 2009 and is still operation (in its "NEOWISE-R" mission phase as at the time of writing). WISE performed an all-sky astronomical survey with images at 3.4, 4.6, 12 and 22μm using a 40cm (16 in) diameter infrared telescope in Earth orbit.

The **James Webb Space Telescope (JWST)** is a space telescope developed in coordination among NASA, the European Space Agency, and the

Canadian Space Agency.[5] It is scheduled to be launched in 2019. The telescope will offer unprecedented resolution and sensitivity from 0.6 to 27μm.

Gaia

eROSITA

sizes and timescales::
10^8 MBH to Jupiter,
speed at which we send a probe there...

Black holes are omnipresent in our Universe, and black holes that are millions to billions of times the mass of our Sun, are ubiquitously found at the centers of galaxies, including our own Milky Way. Initially consider physical oddities, we now strongly suspect that these (central, "supermassive") galactic black holes have a profound affect on the galaxies that they live in. This is not surprising since the potential energy associated with mass accretion onto a supermassive black hole is comparable to that generated via the nuclear fusion in the galaxy's stars.

However, the interaction and the physical processes involved in how this energy escapes the inner most regions of the galaxy and then interacts with the gas, dust, stars and dark matter, is currently very poorly understood theoretical, with very few observational data giving insight on how to make key progress.

The field is poised for a fundamental and rapid change. The first data are now in hand that show *changes on human timescales* in external galaxies, with these new field defining studies including lead projects by the P.I.

This proposal has two broad but well-posed goals. First, we aim to elucidate, for the first time, how the energy directly associated with a supermassive black holes impacts the universal galaxy population.

Second, will open up and explore the Variable Extragalactic Universe, bringing to bear the slew of CLQs, TDEs, Binary BHs, binary SMBHs... Things will go "bang in the middle of the night"; we just don't know what they are yet.

NS-NS merger (EM signatures in the blue...) ... Unify the four fundamental forces of nature...

We ask for the personnel to accomplish these vey ambituous, but achievable goals, along with the 'buy-in' to the facilites we need access to. The timing could not be better; the first data "firehose" turns on in late 2019, with the full datastream from our key sources fully online around 2021.

The P.I. has bulit their career on this science case, and has already been a P.I. of a Working group team (as part of a collaboration) with prodigious scientific output (400 published, peer-reviewed papers and counting).

0.1 Contemporary Galaxy formation theory