Proposal FS2100a-1: Observing nano-second variability with unprecedented precision

: Request: One Lunar Night

Background

Variability has long been of importance in astronomy. Many classes of objects vary on timescales of years, days, hours, minutes and even seconds.

How short do the variability timescales go? Several sources, including gamma-ray bursters, Gravity wave chirpers and ψ-stars, are known to vary on millisecond timescales, though only at the level of 0.2 mMag. These variability measurements have been crucial to our understanding of these sources. Nothing is currently known of variability on shorter timescales still.

Proposed Observations

We have built a camera called RVC (Rapid Variability Camera), using a BHP mega-Qbit arrays cooled to pico-kelvin temperatures. This camera, combined with the light-gathering power of the far-side telescope, will give us unprecedented sensitivity to extremely rapid variations. For sources brighter than $R = 24$, we should be sensitive to nano-second variability at the 0.03 mMag level. This is three orders of magnitude in timescale, and one order of magnitude in sensitivity better than any previous observations.

Nothing is known about variability on these timescales, and few theoretical predictions are available. These observations will allow us to explore a whole new regime of variability. As usual with such observations, we expect that the most important results will be ones that could not possibly have been predicted in advance.

We request time to observe a variety of sources which are known to vary on millisecond timescales. These sources will include Gamma-and X-ray bursters, GW Chirpers and ψ-stars. Allowing for set-up time and instrument commissioning, we will require a full lunar night to get the instrument working and to measure a wide range of sources.

Proposal FS2100a-2: Spectroscopic Monitoring of the Unique Gamma-Ray Pulsar GAM2139−4434

: Request: One Lunar Night

Background

TeV Gamma-ray pulsars (TGPs) are among the most enigmatic objects known. Their repeated gamma-ray bursts, complex mix of pulsation frequencies, and broad-spectrum gravity wave emission all suggest that they bear little resemblance to conventional radio pulsars. Literally dozens of models have been proposed for them, ranging from kinked Mor-strings to binary Charm stars.

Roughly 7% of TGPs emit strong, highly variable optical emission lines (so-called ELTGPs). The Balmer series line profiles in particular can vary on timescales of seconds. Line widths as small as 0.3 km/s and as large as 20,000 km/s have been measured. It is hypothesised that these lines originate in some temporary accretion disk, or in an out- or in-flowing wind.

Proposed Observations

GAM2139−4434 is the nearest and best studied ELTGP. We have obtained two weeks of time with NNNNGST (the Next Next Next Next Generation Space Telescope), to obtain Gamma-ray through radio monitoring of GAM2139−4434. In this proposal we request time to simultaneously monitor the optical emission-lines of the source.

The combination of multi-wavelength photometric monitoring with time and phase resolved spectroscopy should help discriminate between the many models for these sources. Space precludes a detailed description of how each of the twenty currently favored models can be tested by this dataset, but we should be able to rule out at least 17 of the models, and strongly constrain the remainder.

GAM2139−4434 is magnitude $R = 29.3$. We require a signal-to-noise ratio of 100 with a resolution of 0.03 km/s (to fully resolve the lines even at their narrowest). To obtain this with one second time resolution, we thus need the collecting area of the Lunar Far-Side Telescope.

The pulses from GAM2139−4434 are modulated on timescales from seconds to days. Thus a week is required to study this source in all its various states. This week must lie within the NNNNGST monitoring campaign. We thus request one lunar night.

Proposal FS2100a-3: Deep Imaging of SNR in Fornax Galaxies.

: Request: One Lunar Night

Supernovae are a crucial ingredient in the energetics and chemical enrichment of the universe, as well as being amongst the most energetic events known. Their remnants are a vital phase of the interstellar medium, and provide otherwise unobtainable data on the structure of the interstellar medium, and on the geometry of winds from giant stars. Detailed mapping of SNRs in our own galaxy has shown a large diversity in morphologies and sizes. More recently, SNRs have been mapped with nano-arcsecond resolution in Virgo cluster galaxies. The distribution of SNR shapes in Virgo is a strong function of galaxy type (Methuselar et al. 2089), and of location within the cluster. It is hypothesized that this diversity is caused by the different ISMs of cluster galaxies.

We request time to image SNR remnants in the Fornax cluster. Using the VWFI camera on the farside telescope, we will obtain narrow-band Hα, [O III] and S II images with nano-arcsec resolution of the central square degree of this cluster. No comparable observations currently exist: the best current data (Laurel & Hardy 2067) has only Hα observations, and was only sensitive enough to detect the top of the luminosity function. Our proposed observations will go a factor of 17 deeper, in addition to obtaining two other lines.

Extrapolating from the Virgo luminosity function, and allowing for the larger early-type galaxy population in Fornax, we expect to detect over 20,000 SNRs. For each SNR, our imaging will allow us to measure the ionisation state and morphology. These measurements will strongly constrain theories of SNR formation and evolution.

To map the central square degree to our proposed sensitivity will take 50 pointings, with an exposure time of three hours per pointing. We therefore request one lunar night.

Proposal FS2100a-4: Ionisation Shells around Redshift Fifty Population III stars

: Request: One Lunar Night

Background

It has been know for over 100 years that some primordial population of stars must have switched on before redshift ten, to reionise the intergalactic medium and produce the first metals. The first such stars were found in 2023 (Huynh & Drake 2023a), and since then the study of their properties has become an important part of astrophysics. The formation of Pop III stars is quite different from that of later stars, due to the lack of metals and neutrality of the infalling gas.

It has recently become clear that feedback processes are crucial in determining the positions and types of the first stars. They have long been known to drive winds of shocked gas into the surrounding IGM, but it is only with the advent of the far-side telescope that the true significance of these winds has been realised. The FST has allowed absorption-line spectroscopy of these winds, which has revealed that they are very stratified, but also that dense inhomogeneities form within them, which may be the sites of dwarf star formation.

Proposed Observations

The HTS (Humungous Throughput Spectrograph) allows us to obtain mid-IR spectroscopy of the redshifted Lyman series absorption of these stars, with resolutions approaching 100,000. The best current data have resolutions of only $\sim$10,000. At this lower resolution, the absorption is only marginally resolved, and no velocity sub-structure can be measured. Modelling of the ionisation state (eg. Austin & Dickens 2097) strongly suggests that velocity sub-structure is present: the observed strength of the low ionisation absorption is too strong to be reproduced by an homogeneous outflow. This sub-structure would be closely related to the density inhomogeneities described above.

We request time to obtain HTS spectroscopy for a small sample of Pop III stars at redshift 50. These spectra will tell us whether velocity sub-structure is really present, and if it is, will allow us to infer the amplitude of the density fluctuations, using the Coleman-Stanford method (Coleman & Stanford 2034). This will tell us whether the density is sufficient for the formation of dwarf stars in these winds.

A signal-to-noise ratio of 100 is required to measure weak absorption lines such as O I, which are crucial to determining the ionisation state of any velocity subcomponents. This requires an exposure time of 100 hours per source. We will do three sources, so we require one lunar night.

Proposal FS2100a-5: A Survey for Oxygen in the Atmospheres of Earth-mass planets

: Request: One Lunar Night

Background

All planets down to the mass of Pluto have now been found around stars within 100pc of the Earth. Measuring the properties of these planets has, however, proven much harder that finding them. Of most interest are the 450 planets with Earth-like masses and temperatures suitable for liquid water. Do these planets have have life-forms on their surfaces? One clue would be the presence of oxygen in their atmopheres, as oxygen is too reactive to remain present in the absence of some analogue of photosynthesis.

The spectral signatures of oxygen have now been found in four such planets, all lying within 30pc of the Earth (Bach & Handel 2099). These planets are clearly of enormous interest, and NASA are considering diverting the alpha-cen probe to visit one such planet.

Proposed Observations

We are engaged in a long term survey to find more Earth-like planets with oxygen atmospheres. Current surveys have only targetted planets within 30pc. Using the far-side telescope, we will extend the survey out to 100pm. We expect to find around 100 planets with oxygen, if the success rate of the near-by surveys is maintained.

We have already been awarded three lunar nights to this project, over the last two years, and have observed 154 planets. Twelve of these have the signatures of oxygen, though follow-up NNNGST spectroscopy is required to confirm this (time allocated for Jan 2101). In this proposal we ask for one lunar night, to do another 50 candidate planets.

Our experience suggests that exposure times of around 5 hours are needed for each target.

At our current rate of completion, the survey will require another six lunar nights in upcoming semesters.

Proposal FS2100a-6: Host Galaxies of GW Chirpers, Merging or Isolated?

: Request: One Lunar Night

Background

Tens of thousands of gravity wave chirpers have been detected over the last fifty years. They are believed to be produced by the in-spiral and merger of stellar mass black holes, or black-hole/neutron star binaries.

In 2083, Cornelius et al. claimed that GWCs are preferentially found in merging or interacting galaxies. If true, this would imply a connection between the merger process and the formation of binary compact objects in close orbits, as predicted by McDonald & Saunders (2081). The Cornelius result, however, was only based on a sample of ten GWCs.

Wells et al. (2087) disputed the Cornelius result, based on mid-IR measurements of the hosts of GWCs. Their sample was also small, however.

Since then, the issue has remained unresolved, despite over ten subsequent surveys. The largest current survey (Eyre 2099) contains 100 host galaxies, and found a 2σ excess of interactions over field samples.

Proposed Observations

The unique 20dI (Twenty-Degree Imager) on the far-side telescope allows high resolution imaging to be obtained for up to 400 objects simultaneously, spread over the 20 square degree prime-focus field. We propose to use this system to image a sample of 1000 GWC host galaxies. The images will be used to look for signatures of recent interactions, such as tidal tails, shells or double nuclei. In addition, a search will be made for close companions to these galaxies. A control sample of equal size will be selected from the faint galaxy catalogue, taking care to match morphologies and magnitudes.

If the amplitude of the effect tentatively detected by Eyre continues, we should detect or rule-out an excess of mergers and interactions with 99.99% confidence.

An exposure time of 50 hours per pointing is required, as the images must be sensitive to low surface brightness features in the outer regions of the galaxies. We thus require one lunar night.