



WP

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Agenda Item:

2.1.3

Person Responsible: Representative
from Thailand

**XXXIV SCAR Delegates Meeting
Kuala Lumpur, Malaysia, 29-30 August 2016**

Application of Thailand for Associate Membership

Executive Summary

Title: Application of Thailand for Associate Membership

Authors: Thailand authorities

Important Issues or Factors: From the SCAR Rules of Procedure:

Applications for Associate Membership:

- 1.3.1 are usually expected to precede application for full membership; and*
- 1.3.2 shall be accompanied by a statement of what the applicant hopes to contribute to and/or gain from the Charity.*

Recommendations/Actions and Justification: Delegates are requested to consider Thailand's application for Associate Membership of SCAR.

Budget Implications: \$5,000 annual membership fee for Associate Membership.

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No. 0002/1557

29 February B.E. 2559 (2016)

Dear Dr. Baeseman,

Please consider the current letter to certify that the National Research Council of Thailand (NRCT), a National Organization adhering to the International Council for Science (ICSU), appointing the National Astronomical Research Institute of Thailand (NARIT) to represent the Kingdom of Thailand as a Member of the Scientific Committee on Antarctic Research (SCAR) and to coordinate all activities related to scientific research in the Antarctic. A copy of the summary of activities by NARIT and Thailand relevant to Antarctic research is enclosed herewith for your kind perusal.

We would appreciate your cooperation in informing us of the outcome at your convenience.

Yours sincerely,

(Miss Sukunya Theerakullert)
Deputy Secretary-General
Acting Secretary-General of NRCT
& Chair of the National Committee on Coordination
between ICSU and Thailand

Dr. Jenny Baeseman
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Encl.

SUMMARY OF ACTIVITIES BY NARIT AND THAILAND, RELEVANT TO ANTARCTIC RESEARCH

NARIT (the National Astronomical Research Institute of Thailand) has been officially established in 2009, with the goal to develop Astronomy and Astrophysics in the country to international standards and with a mission to establish a leading astronomical institute in the Southeast Asian region. In the few years since its creation, these goals have been largely fulfilled.

NARIT employs over 100 Thai and international staff, and has a successful track record both in the area of education and public outreach – having organized many tens of schools, teacher training courses, and other public-oriented activities – and in the area of professional research. NARIT has developed the national 2.4-m telescope, which is equipped with state-of-the-art instrumentation and is being used since 3 years by researchers from Thailand and around the world, with an excellent output of publications. NARIT has also developed a number of smaller telescope in the 50-70 cm class, some of them for robotic operation, in collaboration with other countries such as China, Australia, USA. NARIT is also strongly engaged in the development of a national Radio telescope with a 40-45 m dish, and is collaborating with other institutes around the world in various fields such as astroparticle physics, atmospheric research, space weather, solar physics, etc.

Coming to the context of Antarctic Research, two recent activities are especially worthy of mention.

- Firstly, NARIT has proposed a collaboration with the University of Svalbard in Norway, to pursue joint research in the area of Aurorae Borealis and Ionosphere Physics. While this activity is taking place in the Arctic, it is also perfectly applicable to the same area of research in the South and it is likely that, once that Thailand's presence is established there, it could be extended to include Antarctic studies.
- Secondly, NARIT has actively pursued a direct involvement in Antarctic astronomical research since about two years, and its researchers have participated in various workshops and conferences on the topic (eg the "International Collaboration Meeting on Antarctic Survey Telescopes" in Hong Kong March 2015, and the "Third Workshop of the SCAR AAA" in Hilo, Hawaii, USA, August 2015). Initial contacts were established both with the Kunlun chinese station at Dome A, and with the Concordia french-italian station at Dome C. More recently however, since mid-2015, a successful collaboration has started with the University of North Carolina (USA), the University of Sydney (Australia) and the University of Toronto (Canada) to develop a so-called Evryscope and eventually deploy it at the Amundsen-Scott station at the South Pole. This project is dubbed EVA and some details of this collaboration are copied verbatim below from its Executive Summary.

The EVA project aims at developing a unique instrument, which will provide an almost complete coverage of the full sky, with 2 minutes cadence and reaching about 16th magnitude (or about 10,000 times fainter than the faintest stars visible by naked eye). One such instrument has already been developed by the American partner in this collaboration and is located in Chile. With EVA, however, we will be able to take advantage of the polar night and record continuous data for –in principle, apart from weather conditions- months and months. This would be a ground-breaking, unique capability which is not available anywhere else. It is worth mentioning that EVA foresees both an Arctic and an Antarctic deployment: if run in parallel, we would obtain uninterrupted operation alternating between the

northern and southern winters. Some science cases included in the original EVA Project Description are copied at the end of this document.

Clearly, the scope of this endeavour is extremely fascinating from the point of view of the scientific possibilities. It is also already largely demonstrated technologically (a few remaining tests for the extreme weather and environmental conditions in Antarctica are planned to be executed in the first part of 2016). The budget for EVA is shared between the partners, but the hardware costs are mainly the responsibility of NARIT and it is anticipated that formal approval will be obtained soon. Barring unexpected problems, we think that EVA could obtain first light in the Arctic in late 2017, and in the Antarctic in mid-2018 or mid-2019, depending on project funding.

With this prospect, NARIT would be posed to set a strong foothold in Antarctic research within the next few years. It is thus highly desirable that the Kingdom of Thailand could become a formal member of SCAR, and be represented by NARIT. NARIT has already offered its candidacy to host the next SCAR AAA meeting planned in mid-2017. If this bid is successful, the location would not only offer an opportunity for NARIT to showcase its interests and commitments to Antarctic Research, but also offer a convenient and economical possibility for many other less developed countries in the region to learn about science in Antarctica.

While the NARIT activities are focused mainly on astronomy, Thailand as a country has a general interest in other Antarctic-based research as well. Here we mention two recent collaborations which involved Thai scientists.

1) In 2014, Faculty of Science, Chulalongkorn University sent 2 Thai researchers to Antarctica by joining the People's Republic of China's Antarctic exploring team N.30. The first researcher was involved in studying the impacts of global warming to ocean life and environment. The second researcher was involved in studying the diversity and activities of underground micro-organisms. The studies were carried out at the Great Wall Station between 1 January - 10 February 2015.

2) In 2015 the Faculty of Science of Burapha University sent one Thai researcher to Antarctica by joining the People's Republic of China's Antarctic exploring team N.31, studying the effects of global warming to changes in water mass and ice melting in the Antarctic continent and ocean.

These collaborations were organized between the National Science and Technology Development Agency (NSTDA), Ministry of Science and Technology, and the Chinese Arctic and Antarctic Administration (CAA) as a bilateral cooperation between Thailand and the People's Republic of China. Clearly, if Thailand was an official SCAR member such activities could be coordinated at a wider level and receive access to more funding possibilities.

[Attach: EVA executive summary \(2 pages\), and EVA science cases \(about 7 pages\)](#)

Executive Summary

We propose to construct the Evryscope for the Arctic and Antarctic (EVA), the first ultrawide-field synoptic sky survey to be conducted from either Pole. The system is based on the successful Evryscope concept (see Section 2), already installed and operating since 2015 at Cerro Tololo in Chile with the following characteristics: robotic operation, $\sim 8,000$ square degrees simultaneous sky coverage, 2-minute cadence, milli-mag level photometric accuracy, pipelined data processing for real-time analysis and full data storage for off-line analysis.

The science goals enabled by this unique combination of almost full-sky coverage and high temporal cadence are several, and include among others ground-breaking forays in the fields of exoplanets, of stellar variability, of asteroseismology, of supernovae and more. In addition, the EVA polar location (first in the High Arctic at the PEARL station on Ellesmere island, and then at the South Pole at the Amundsen-Scott station) will enable unprecedented time coverage during the polar night, with uninterrupted observations lasting in principle over weeks and months depending on the weather conditions. Some of the specific EVA science goals are described in Section 3, but many more remain open to the imagination of the astronomical community.

While a polar location is certainly challenging in terms of environment and serviceability, we are confident that we can contain the costs and minimize the risks by building upon the proven Evryscope design already working at CTIO, by using off-the-shelf components for the bulk of the hardware and by benefitting from our wide experience of logistics and operation at the PEARL station. For the South Pole deployment, we will seek NSF funding to cover the potentially very expensive logistics costs. Details of the proposed deployment sites, design, previous experience, and the specific technical challenges for a polar environment are described in Sections 4 and 5.

This is a multi-national effort, which will involve institutes in North America and South-East Asia, with a need to enforce a strict timeline due to the fact that the seasons for shipment and operation in the polar regions are limited and even small delays in the project could result in large delays in the first light and science. With this in mind, we have dedicated a considerable effort in our project to define a reliable timeline and structure, which are described in Section 6. We believe that we can build an operational EVA which will have first light at the PEARL station in the winter of 2017-18, for a cost of about 350 kUSD in hardware and employing human resources mainly already existing in our different institutes. The position of a dedicated Project Manager working at UNC will need additional funding, for about 150 kUSD over 2 years. Further, if our application to NSF shall be successful, we plan to either a) disassemble this first EVA, refurbish it and ship to Antarctica for a first light in the summer of 2019, or b) build a second EVA and ship it to Antarctica for parallel operation. Option b) would be more expensive but would of course enable a much-increased scientific return. The choice between a) and b) will be made at a later stage, presumably in 2017. The scheme of EVA funding is also described in Section 6.

Finally, we describe in Section 7 our view on the policy for the EVA scientific collaboration and concerning data sharing with the community. We foresee to involve about 10 scientists directly in the project starting in 2016, with the potential for a much larger group from 2018. Eventually, we plan to make the EVA data public after a proprietary period.

Science drivers for an Evryscope in the Arctic and Antarctic

In this section we highlight the reasons for building an Evryscope for the Arctic and Antarctic (EVA), enabling a wide range of science that cannot effectively be performed with the current mid-latitude system.

Optical time-domain astronomy programs can achieve uninterrupted coverage of their target fields by observing from space, constructing multiple observing sites spanning the globe, or by observing from near the North or South poles. Already developed Polar sites can perhaps offer the most attractive combination of ease of access and maintenance, at the cost of the hardening required for equipment to survive the extremely cold conditions. The continuously dark winter sky at the Poles offers an opportunity to build a new type of sky survey: one that continuously images half of the entire sky at minute timescales with no day-night window interruptions.

Advantages of observations from the polar regions

An EVA system will have many advantages compared to a similar system at mid-latitudes. In the following we list some of them in the context of exoplanet studies, but in fact they are applicable also to many other areas such as stellar variability, asteroseismology, microlensing, supernovae and more, as described in the following subsections. Some of them are:

- achieve a factor-of-five increase in sensitivity to habitable exoplanets because of the continuous winter darkness (Figure 4; Law et al. 2013),
- have the ability to detect exoplanet transits from long-period systems because of the lack of day-night window interruption,
- reach much smaller exoplanets than the current system because of reduced systematics, see below,
- achieve truly-continuous observations which are the only way to attain a near-certainty of detecting and following rare transients before, during and after the events,
- achieve better photometric systematics due to zero diurnal airmass variation, to generally low scintillation levels, and to other factors such as very low aerosols, water vapor, etc.

Here we list some science cases where EVA can play a key role, but clearly more are possible which will no doubt become clear as the science data will come in. The fact that continuous (i.e. days and weeks, as opposed to hours) observations of regular as well as transient variability have never been performed until now, certainly opens the door to the possibility of new, exciting discoveries. Each partner of the EVA consortium has its own science cases of interest, but much more will be available also to external collaborators, see Section 7.

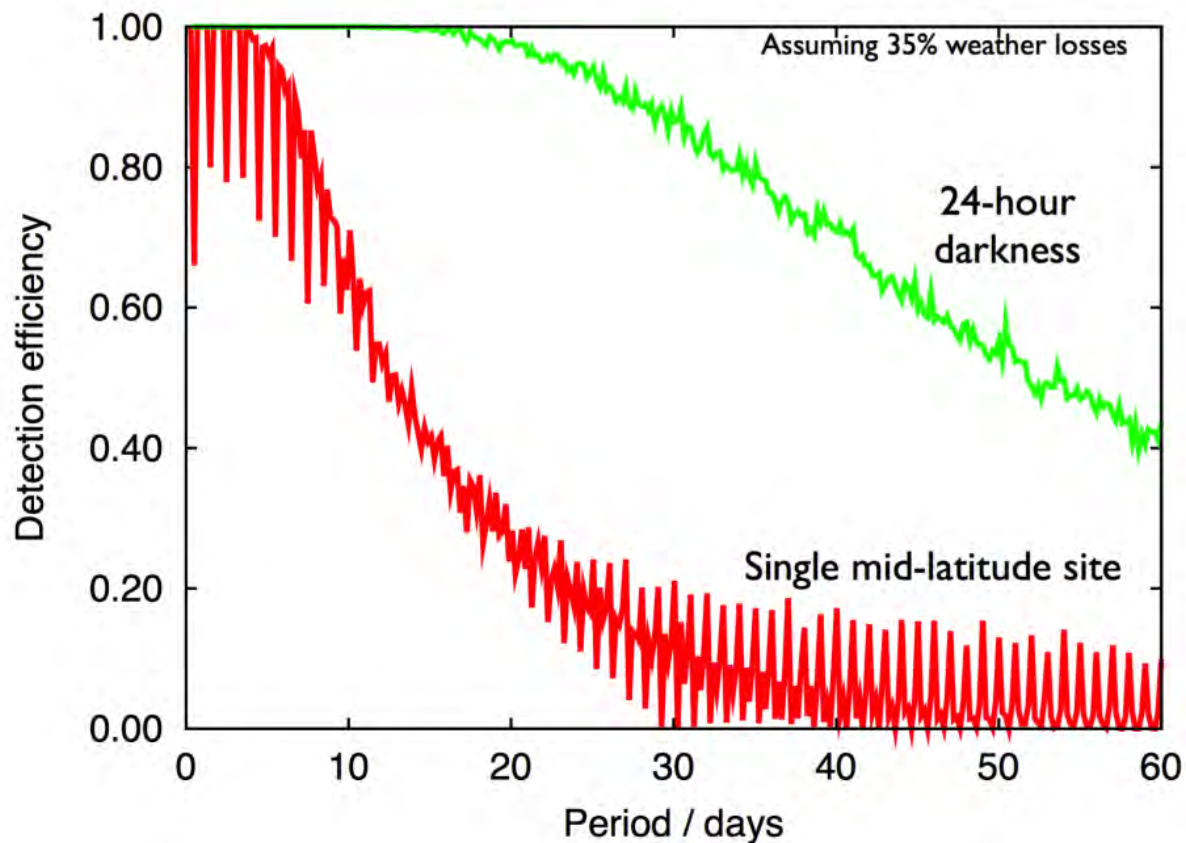


Figure 4: Factor-of-five increase in detection sensitivity to habitable exoplanets from a continuous winter darkness site with respect to a mid-latitude site.

Exoplanet surveys

Current exoplanet transit surveys are limited to fields of view of 100-1000 square degrees and so cannot effectively search for transits around large samples of stars that occur rarely in the sky. EVA would have an order-of-magnitude larger field of view than the next-largest current exoplanet surveys, along with an improved detection sensitivity of up to five times in long period exoplanets because of the continuous winter coverage. This would enable the following exoplanet key projects:

First Arctic and Antarctic Large-Scale Survey for Habitable Planets Transiting White

Dwarfs: At least 1/3 of WDs have metal contamination in their atmosphere suggesting that there could be small rocky bodies around them (e.g. Raddi et al. 2015). Recent theoretical work has suggested that rocky debris could be indicative of migration processes that would bring rocky planets close enough to the WDs for transit detection (Veras et al. 2015). The detection of a transiting planet around a WD gives us insights into the characteristics of planets in this exotic environment; the planetary system evolution during the star's red giant phase; and constraints on the properties of very small rocky bodies. White dwarfs (WDs) are attractive transit-search targets because their small size enables the detection of extremely small objects: rocky planets can occult the star, moon-sized objects give 10%-range transit signals, and large asteroids, groups of smaller objects (planetesimals) or dust clouds have been very recently detected around a metal polluted WD by Vanderburg et al. 2015 ; Croll et al. 2015, and may be a common scenario (Drake et al. 2010, Agol 2011, Law et al. 2015).

The small WD diameter reduces the transit time to minutes rather than hours for solar-type stars. Surveys thus require a very high observational duty cycle on each target to have a reasonable

chance of detecting the transits. Since bright white dwarfs are rare, it has been very difficult to monitor more than one target at a time at the necessary cadence with conventional telescopes, let alone the 1,000+ targets required for a reasonable chance of detection. EVA gives us the field of view required to monitor the few-thousand brightest WDs at rapidly enough to detect transits; these are also the WDs bright enough ($g < 16.5$) to feasibly follow-up exoplanet detections.

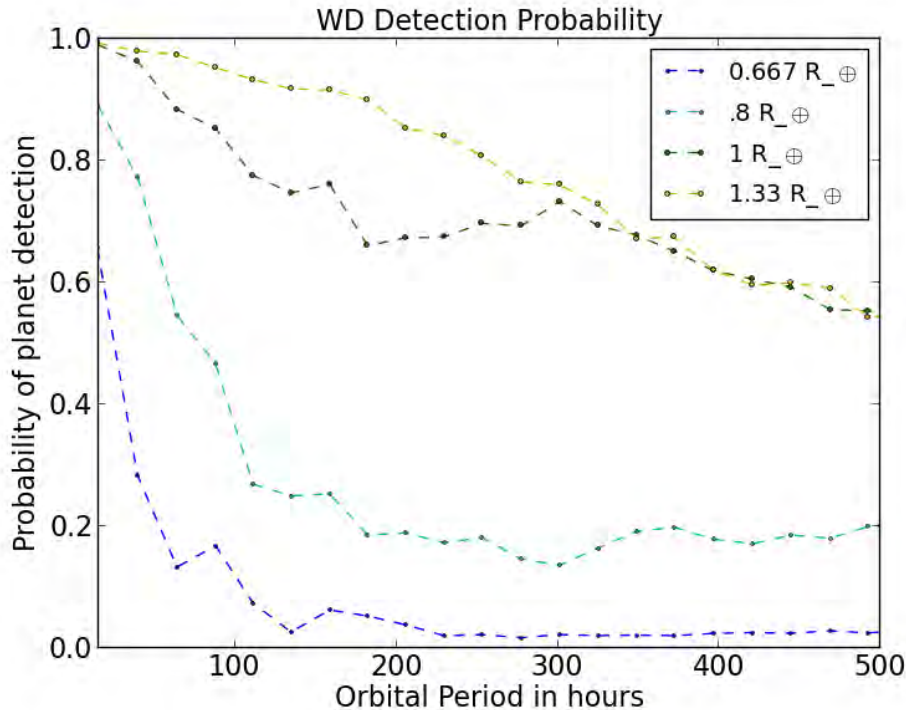


Figure 5: The probability of detecting a transiting rocky planet around a white dwarf in one month of EVA data, based on detailed simulations of our detection efficiency, detection algorithms and correlated noise.

EVA will be able to simultaneously and without daily interruption observe hundreds of WDs with better than 10% photometric precision in each two-minute exposure, and will cover more than 1000 WDs each night (Law et al. 2015). This will enable us to place limits on the populations of – or even discover – Mercury-sized objects in the \sim day-orbital-period habitable zone of the WD (Figure 5). The geometric transit probability for habitable-zone planets around WDs is approximately 1%, so our initial 1000-white-dwarf survey will place the first 30%-level constraints on the fraction of habitable planets around WDs, even with no detections (Agol 2011). During this search, the EVA will also detect new eclipsing WD binaries and periodically variable WDs.

As our survey continues, we will expand to longer-period planets and to much larger target lists. Because the WDs are so small, even faint targets can be effectively searched for rocky-planet transits by searching for drop-outs where the white dwarf disappears for a few minutes. In a later stage of our search we will greatly expand our target list by searching for Earth-sized transiting planets around WDs too faint to be detected at high significance in each EVA exposure. Standard transit search algorithms like BLS (Kovács et al. 2002) search for significant drops in period folded light curves. We will develop an equivalent algorithm that period-stacks the EVA images themselves, allowing us to search for periodic drop-outs of white dwarfs as faint as $g=18$.

Furthermore, spectroscopically-confirmed WD catalogs are still incomplete even at relatively bright magnitude limits, but here the rapid transit timescale assists us: a periodic two-minute long flux reduction of a candidate white dwarf leaves very few possible false positives. In the final stage of our survey, we will search for repeated rapid dropouts, still further expanding our target list.

This WDs survey from the polar regions is perfectly complementary to the mid-latitude southern version we are currently conducting with Evryscope at CTIO.

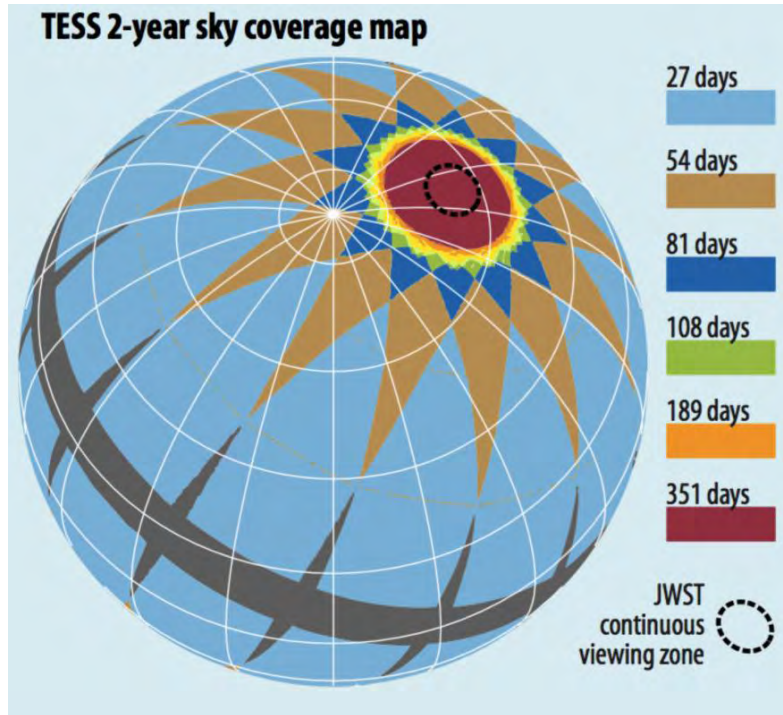


Figure 6: TESS 2-year sky coverage map. The JWST continuous viewing zone is overlapping with EVA continuous FoV.

TESS synergies: the TESS exoplanet-survey mission, the follow-up to the Kepler mission, will cover the entire sky in 2,000 square-degree chunks, starting in 2017. TESS will cover the majority of the sky for ~27 days, allowing the detection of planets with periods up to ~two weeks (Ricker et al. 2014). The JWST continuous viewing zone partly overlaps with EVA continuous FoV during the winter (Figure 6). Given these unique TESS-EVA continuous viewing overlapping zones conditions, EVA can play a key role in TESS planetary yield enhancement. The planet population increases towards longer periods (e.g. Howard et al. 2012) and so a large fraction of the transit events TESS discovers will be single events from long-period planets that cannot be confirmed within the standard 27-day or 54-day stare periods (Figure 6). EVA's longterm dataset will provide the time baseline required to find multiple transit events from these planets, and the system's homogenous dataset across the entire Northern sky will enable a comprehensive search for transit events. The very-high-SNR TESS single transit events will allow us to pick out single targets and shorter lengths of EVA data to search for transits. This will greatly decrease the required significance of individual detections in EVA data, and allow

the detection of much smaller planets than we can achieve with our untargeted surveys. Compared to other surveys, EVA's much higher cadence and longer-term coverage on each part of the Northern sky (as opposed to selected fields observed in sequence) will allow us to co-add hundreds or thousands of data points per phase-folded transit on even long-period planets – moving long-period planets as small as Neptune from unconfirmed single dips to confirmed planets, and thus greatly enhancing the TESS planet yield.

Bright Stars: Follow-up observations of transiting exoplanets, by either emission spectra during secondary eclipse or transmission spectroscopy, have revealed direct measurements of albedos, atmospheric composition, chemistry, and even phase curves showing features on the planetary cloud layers. These observations have been performed for only a very few planets, however, because they require a star which is significantly brighter than most narrow-field transit searches can currently monitor in their relatively narrow fields of view. Pushing to extremely bright naked-eye stars with EVA will require stacking reduced exposure-time images (to recover scintillation limited performance without saturation); we will perform test surveys to evaluate the feasibility of this search, which will be sensitive to long-term planets not accessible to the TESS mission (Figure 7).

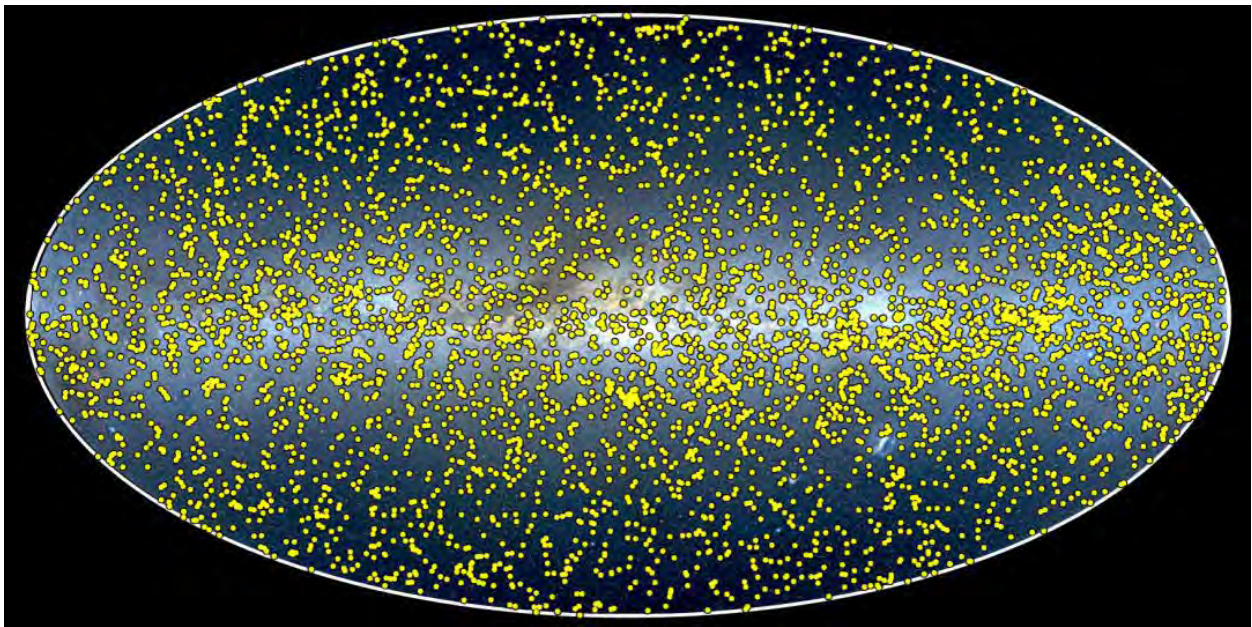


Figure 7: EVA survey will monitor 70,000 stars $g < 10$ for increasing planetary yield around very bright stars, which will be amenable to follow up atmospheric characterization.

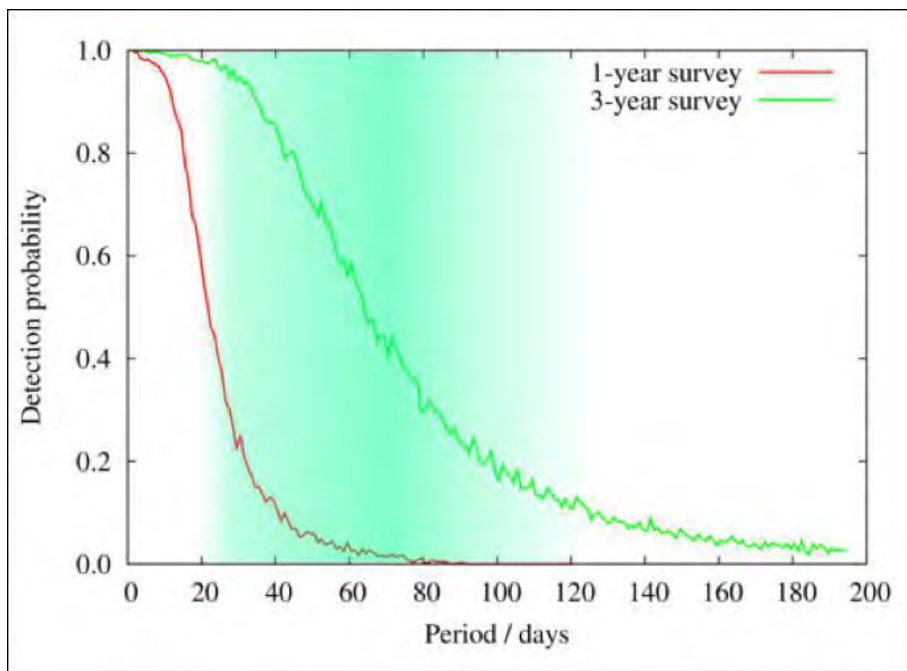


Figure 8: The probability of detecting a transiting rocky planet around an M-dwarf in 1 and 3 years of EVC data, based on detailed simulations of our detection efficiency, detection algorithms and correlated noise. Detection probability for EVA will be larger due to its 5× improved detection sensitivity to long-period exoplanets because of the continuous winter coverage.

Ms dwarfs: Despite being the most common stellar type in our galaxy, the transiting planetary population around M-dwarfs has not yet been explored in detail because of their extreme faintness compared to solar-type stars. Recent Kepler planetary population statistics suggest that the nearest transiting rocky planet in the habitable zone of an M-dwarf is less than 9pc away from us (Dressing et al. 2013). However, to have a chance of finding these planets around dwarfs bright enough and nearby enough to use for characterization, a large sample of nearby, bright M-dwarfs must be covered. In turn, their random and sparse distribution across the sky means we must cover a very large sky area to reach a significant number of targets. Kepler can only cover a few faint thousand targets in this mass range (Dressing et al. 2013) and individually-targeted surveys like MEarth are also limited to a few thousand bright M-dwarfs at most (Berta et al. 2013), while TESS can only reach the habitable zone for the targets in its relatively small continuous viewing zone. EVA is capable of simultaneously monitoring all bright, nearby late K stars and M-dwarfs (>5000) over years for transiting rocky planets. With few-millimagnitude photometric precision for all targets, and the ability to reach month-period objects in the habitable zones of those stars (Law et al. 2015), EVA is sensitive to planets as small as a few Earth radii around mid-M-dwarfs (Figure 8). In addition, EVA is also sensitive to giant planets around ~30000 M-dwarfs.

Nearby-star microlensing: Typical galactic exoplanet microlensing events occur as much shorter timescale bumps in week-scale stellar events. Most microlensing surveys (for example, OGLE; Udalski et al. 2008) have been performed with larger telescopes observing relatively the large population of background stars in small fields towards the galactic plane. However, occasional spectacular events around relatively nearby stars (Han 2008 ; Gaudi et al. 2008) have demonstrated that a sufficiently large-area survey has the opportunity to detect much closer events – and detect planets smaller than Earth in habitable-zone orbits (Figure 9). EVA’s few minute temporal resolution and high photometric precision mean that planetary signatures will be

directly detectable in the light curves (this has recently been demonstrated in smaller fields by Shvartzvald et al. 2014). We expect to detect several near-field microlensing events per year.

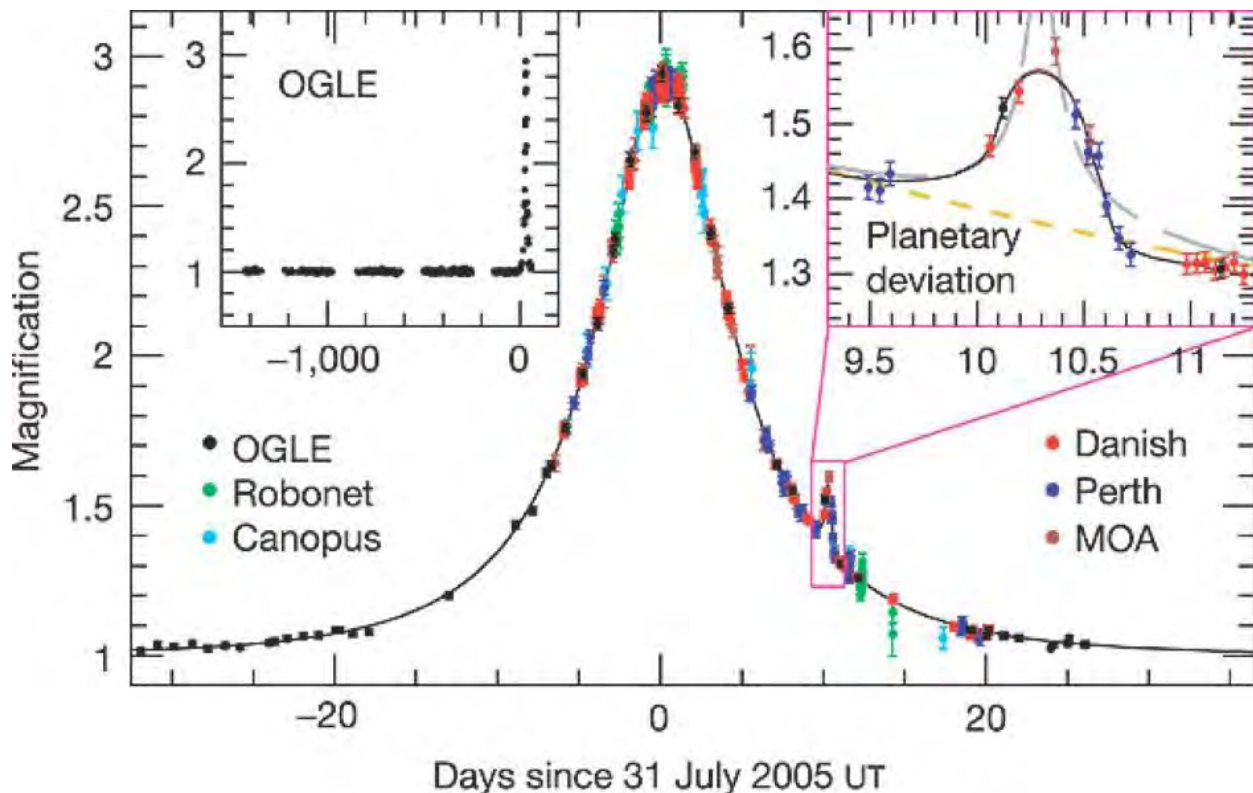


Figure 9: Rocky planet in 2.6AU orbit around M-dwarf ($i=14.2$) (Beaulieu et al. 2006).

Stellar variability

EVA will monitor the brightness of millions of stars across the sky each night, building up a multi-year, two-minute-cadence database of stellar activity for every star brighter than $g=16.5$ visible from the polar regions. This will enable the detection and characterization of unprecedented numbers of young and active stars, long-period eclipsing binaries that can be used to constrain the mass/radius relation, as well as the detection of a wide variety of other types of stellar variability (flares, stellar merger events, accreting compact objects, and exotic pulsators).

Exoplanet detection from eclipsing and pulsating stars: Transit, eclipse and pulsation timing variations allow us to measure the influence of other bodies in a system on the transiting/eclipsing/pulsating body's orbit. Current surveys must target individually-interesting systems (e.g. Marsh et al. (2013)). EVA will monitor tens of thousands of eclipsing binaries and pulsating stars simultaneously, including minute-precision timing of every eclipse and pulse cycle. Performing this search from the polar regions will allow a push to much longer-period systems, much more comprehensive eclipse monitoring, and thus a much higher probability of planet detection.

Prominences and flares in white dwarf binaries: Prominences and flares are two of many atmospheric activities exhibited by our Sun. During these events, large amounts of material are released from the Sun's surface, often thousand of kilometres up from the Sun's photosphere. Prominences are arcs of gas, held above the surface of the Sun by a strong magnetic field. This gas, which contains cool and dense material, will appear as dark filaments against the Solar disk. Typical prominences erupt quickly and last several minutes to hours, but the quiescent ones can persist for weeks or months. Prominences are also observed in other stars such as in the young

T Tauri stars, where the eruptions are thousand times more energetic and frequent than the ones of our Sun (Aarnio et al. 2012). In close binaries, evidences of slingshot prominences have been recorded spectroscopically by several authors, e.g. QS Vir (Parsons et al. 2011) and SDSS J0039+0054 (Southworth et al. 2010). The eruptive events in these binaries are known to originate from the active M dwarf companions.

A more complex and long-lived profile was recently found in another eclipsing WD binary, SDSS J1021+1744 (Irawati et al. 2016). This system has an unusual light curve (Figure 10), believed to be caused by large prominences and the ejected materials which are trapped close to the Lagrangian L5 point in this binary. Using EVA, we will monitor other WD systems to detect the signature of prominences, as well as other variabilities in these binaries. The polar location of EVA will allow us the unprecedented ability to monitor a large number of successive eclipses, thus following in detail the temporal evolution of the prominences.

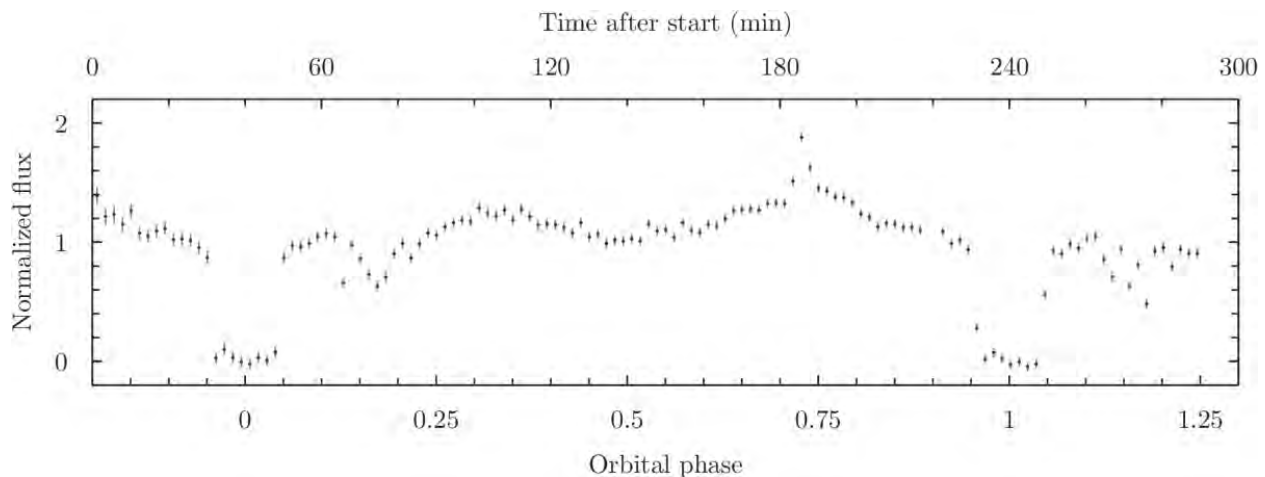


Figure 10: The light curve of SDSS J1021+1744 showing a flare and two consecutive eclipses with dips at orbital phase 0.18 and 1.15 (adapted from Irawati et al. 2016). The data is binned to match the EVA exposure time of ~ 120 s.

Asteroseismology of oEA stars

The EVA project will provide, during the long polar night, millions of well sampled, long timespan, nearly continuous, gapless light curves of all types of pulsating stars across the H-R diagram. This will be a treasure trove for asteroseismology, which is based on the analysis of continuous, well sampled, uninterrupted light curves. This kind of data have determined, e.g., the great success of the KEPLER space mission, but in the case of EVA we will be monitoring a sample of stars larger by many orders of magnitude. The excellent spectral windows function of the EVA data will greatly simplify multiple period search and will provide the detection and deep study of oscillation spectra. We will then be able to generate accurate asteroseismic models for an unprecedented number of pulsating stars.

An example is the asteroseismic study of the semi-detached (Algol-type) eclipsing binaries with the mass-accreting pulsating components (so called oEA stars, Mkrtichian et al., 2007). A typical continuous light curve of the Algol-type system WUMi obtained by AWCams in the Arctic is shown in Figure 21 of this document. We will use pulsation variations extracted from the binary photometric curve.

Figure 11 shows the 3-D hydrodynamic simulation of mass transfer in RZ Cas - a typical Algol-type system with oEA component. The unique peculiarity of these objects among other type of pulsating stars is the influence of cyclic variations of the magnetic activity of the Roche lobe-filling cool component on the generation of the high-mass transfer events.

These transfer/accretion events influence the pulsational properties of mass-accreting stars and the forced pulsation amplitude and frequency variations. This physical process makes it possible to apply asteroseismic methods to study the short-term dynamical evolution of binary system, and the accretion- and tidal-driven acceleration or breaking of the components. We will be able to generate 3-D models of the mass transfer for different systems and determine the geometry of interaction of gas streams with the atmospheres of oEA stars.

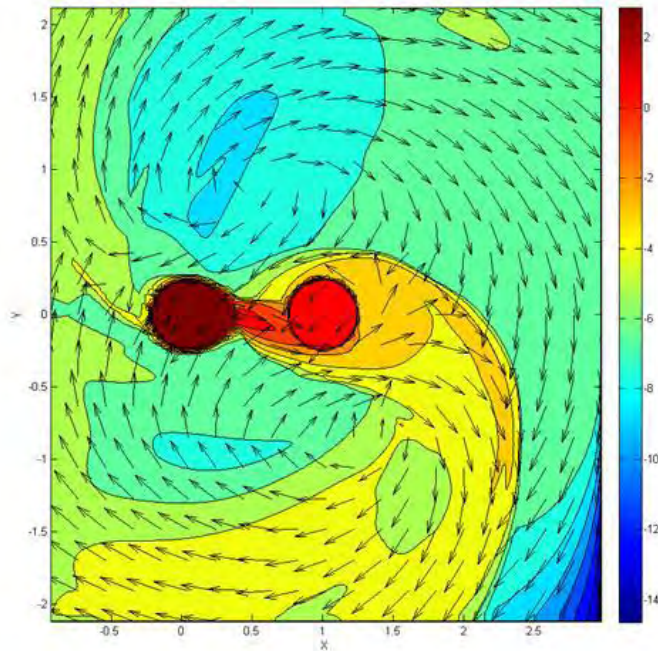


Figure 11 The 3-D gas-dynamic simulation of the mass-transfer in the Algol-type system RZ Cas having a rapidly pulsating (~ 22 min) mass-accreting component. The gas streaming via the L1 point strikes the atmosphere of the oscillating star, causing strong differential rotation that could be measured by asteroseismic methods.

Asteroseismology of hot stars

The asteroseismic potential of wide-field surveys is rapidly being realised, with the use of pulsating red giants from Kepler/K2 data to map stellar populations being just one recent example. Of all the asteroseismic data available, it is the hot, massive stars that have received the least attention, yet these stars play a dominant role in the luminosity function and gas kinematics of the galaxy. Despite this, state-of-the-art contemporary photometric missions are ill-equipped to observe them. The Kepler Space Telescope has a narrow field of view, and is restricted to relatively bright targets. The part of the galaxy that the original Kepler mission hosts few young, massive stars. Its successor mission, K2, looks instead along the ecliptic, however nearby O stars will be too bright to be observed. On the other hand, the upcoming TESS mission has greater sky coverage, but with the exception of small regions near the poles, it will only observe each patch of sky for 27 days, and most of the targets will have only 30-minute sampling.

However the key science drivers for the asteroseismic study of hot stars require both longer monitoring (to explore pulsation period and amplitude stability) and ideally higher cadence to properly Nyquist sample the variations. EVA offers both, with high quality photometric data on these important stars at high cadence, and for long periods of time. There are three (inter-related)

science drivers. Firstly, pulsations in high-mass stars can probe the extent of the convective core and allow us to measure the amount of overshoot. This is important because it can give important observational constraints on some poorly understood aspects of stellar evolution. Second is the exciting possibility of measuring internal rotation from its effects on pulsation frequencies; also an important aspect of stellar structure that is currently not well constrained by observations. Finally, the extent of diffusive mixing can be obtained, which for these stars is more important than convection in mixing material over the core boundary.

Extragalactic Transients and Supernovae

Supernovae and GRBs: The highest impact supernova discoveries have resulted from the most nearby events (distance $< \sim 20$ Mpc). The detailed multi-wavelength studies enabled for these sources more than compensates for their relative rarity; the most prominent example is SN2011fe in M101 (Figure 12), which for the first time provided direct evidence of a white dwarf progenitor for a type Ia supernova (Nugent et al. 2011). EVA will obtain high-cadence light curves even from before the supernova explosion, enabling a search for pre-outbursts and earlytime shock breakout. Co-adding will push the depth to up to $V=19$ on hour timescales, sufficient to monitor nearby supernovae as they occur. The dataset will also provide imaging of prompt optical emission from ~ 10 GRBs per year on minute time scales, not only immediately following GRB triggers, but pre-imaging those fields on minute cadences before the explosion. Compared to mid-latitude sites, the continuous coverage available in the Arctic will greatly increase the probability of covering an event while the system is operating (also important for intrinsically rare events such as searching for gravitational wave electromagnetic counterparts), as well as allowing the first uninterrupted high-cadence light curves for all bright transients.

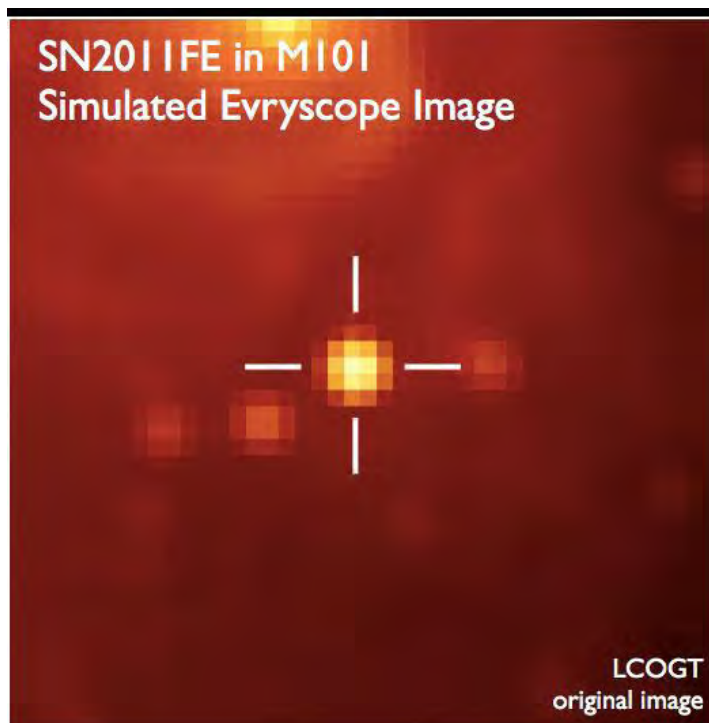


Figure 12: A simulated EVA image of SN2011fe, a very nearby bright supernova detected by the Palomar Transient Factory (Law et al. 2009). Based on an LCOGT image of the supernova soon after discovery (Nugent et al. 2011), with simulated EVA's $13''/\text{pixel}$ sampling and camera-lens point-spread-functions applied. The supernova is clearly distinguishable from the background structure of even this nearby, bright galaxy.

SN-rates in nearby galaxy clusters and implications for galaxy evolution and ICM metal

enrichment: A conservative extrapolation of previous results by e.g. Gal-Yam et al. (2008), based on a redshift-cut of $z \approx 0.1$ (corresponding to a mag-cut of $V \approx 19$), results in an estimate of ~ 100 SNe to be detected by EVA during one observation period (i.e. arctic/antarctic winter). In both fields-of-view (North & South) there are >30 Abell clusters with a robustly determined redshift below 0.1.

It is hence feasible to obtain statistically relevant samples of SNe in nearby cluster and field galaxies. Given that the redshifts/radial distances of these SNe can be determined either by prompt follow-up spectroscopy or by a restriction of the sample to standard-candle Type-Ia SNe, these samples can be used to:

a) derive SN-rates as functions of local/global environment (field vs. cluster, position within the cluster, cluster richness, cluster BM-type, galaxy type and stellar mass where known). The results will contribute to further constrain the SN-rate in different environments in the local Universe. This figure is crucial for models of metal enrichment in the IGM and ICM (see e.g. Aguirre et al. 2001, Tornatore et al. 2004).

b) correlate SN-rates and star-formation rates and derive SFR-histories in low- z galaxy clusters. SN-rates for differently dense regions of galaxy clusters will facilitate more accurate studies of the correlation between SNe and star-formation activity (see Figure 13). In a wider context, the EVA findings will contribute to answering the general question of the correlation between the spectro-photometric and morphological evolution of galaxies and their environment.

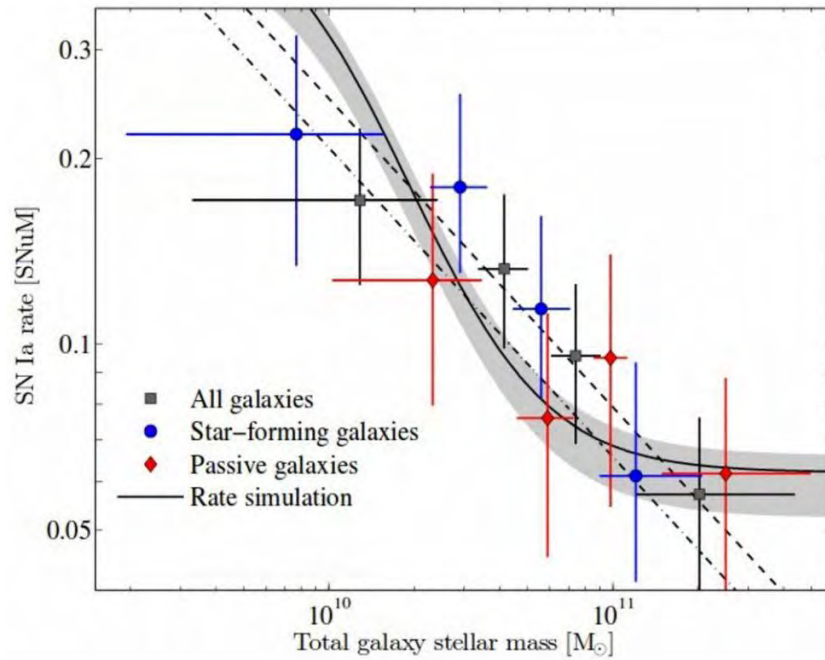


Figure 13: Rate of Type-Ia SNe vs. galaxy stellar mass for star-forming and passive galaxies (from Graur & Maoz, 2013)

c) derive rates/properties of intergalactic ("hostless") SNe in low- z galaxy clusters. Several studies published in the recent years describe robust detections of intra-cluster light (e.g. Lin & Mohr 2004, Coccato et al. 2011, Presotto et al. 2014). Consequently, the ubiquitous Type-Ia SNe are supposed to occur also outside galaxies but within clusters. Such rare events could be detected by EVA in a hitherto unmatched number, facilitating the first statistically robust study on the chemical history of intra-cluster light.

In addition, high-cadence photometry of SNe detected by EVA will allow to split up (at least the closer part of) the SN sample into sub-samples (beyond the established SN classification scheme), according to specific characteristics, e.g. the early onset phase of the SNe. These specific characteristics themselves will already be interesting to study. Moreover, they can again be set in context with the large-scale environment in order to search for correlations between properties at SN scale and larger scales.

Type Ia SNe at redshifts below 0.01 reach mags beyond 14. Based on the previous estimate for the number of SNe to be detected by EVA it is justified to expect at least a dozen of these events per polar winter.

Unknown or unexpected transients: EVA's very rapid cadence, extremely large field of view, and large étendue explores a new region of survey parameter space and may therefore reveal new unknown optical transients that would be rejected as cosmic rays or single-detection asteroids in longer-cadence surveys. For example, extreme millisecond radio transients with currently unknown origins have recently been discovered (e.g. Thornton et al. 2013 ; Coenen et al. 2014) (Figure 14). Due to their rarity and millisecond-scale speed, there is currently no way to get useful constraints on their optical brightness. EVA dataset will allow us to obtain simultaneous optical brightness limits (or even detections) on a minute-by-minute basis. This mode will also

allow confirmation of transients detected in archival data taken at other wavelengths in new allsky surveys such as the LWA (Hallinan 2014) and LOFAR (van Haarlem 2013).

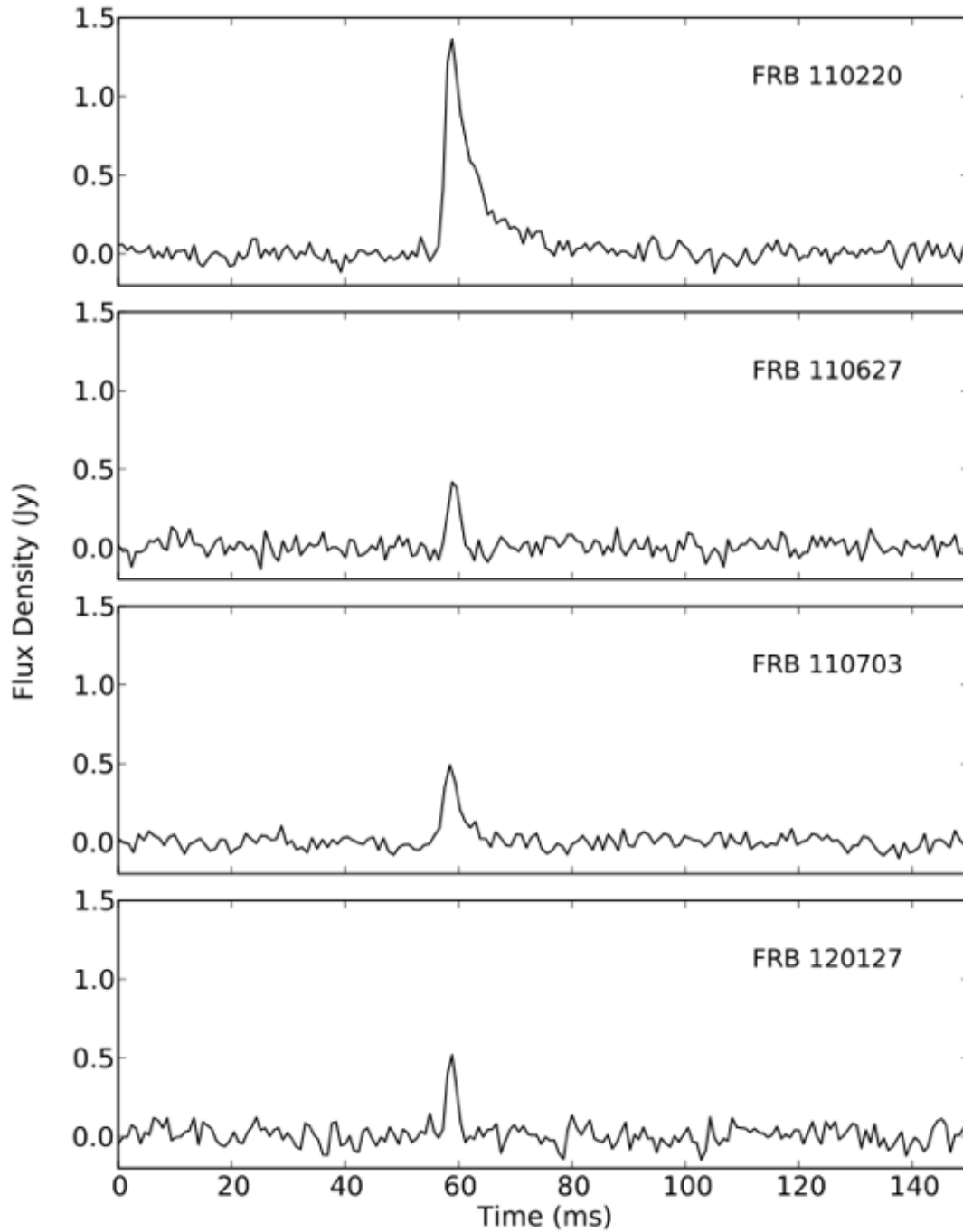


Figure 14: An example of millisecond radio transient detected by Thornton et al. (2013). EVA's very rapid cadence, extremely large field of view will allow to detect optical counterparts of such events