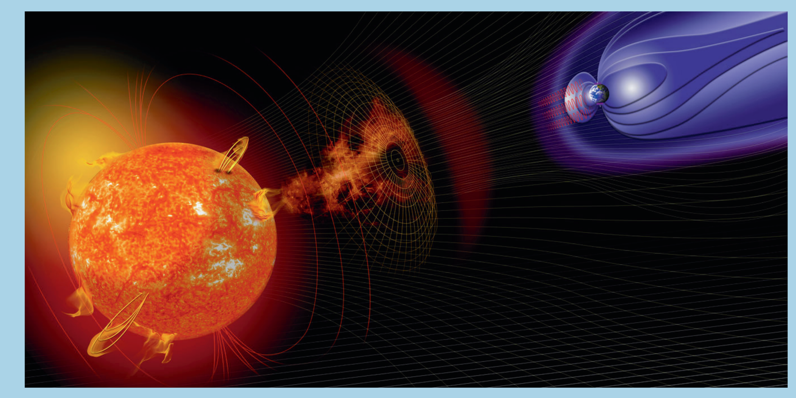
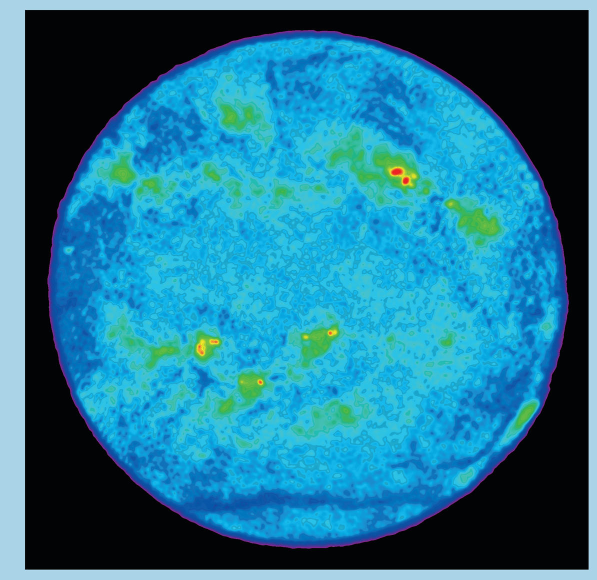
Meter- to Millimeter Emission from Cool Stellar Systems:

Latest Results, Synergies Across the Spectrum, and Outlook for the Next Decade

A **Tuesday** splinter session

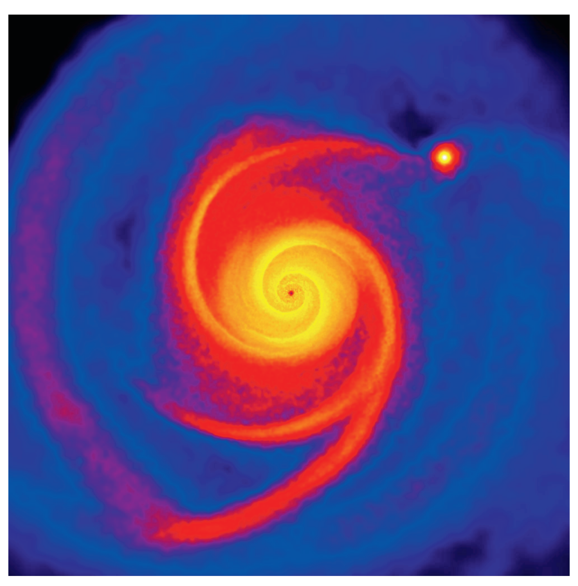


Lead organizers: Jan Forbrich (Hertfordshire), Peter K. G. Williams (Harvard CfA).
Co-organizers: Edo Berger (Harvard CfA), Manual Güdel (Vienna), Rachel Osten (STScI).



Radio observations of cool stellar systems provide unique information on their magnetic fields, high-energy processes, and chemistry. Buoyed by powerful new instruments (e.g. ALMA, JVLA, LOFAR), advances in related fields (e.g. the Gaia astrometric revolution), and above all a renewed interest in the relevant stellar astrophysics, stellar radio astronomy is experiencing a renaissance. In this splinter session, participants will take stock of the present state of stellar radio astronomy and chart a course for the field's future.

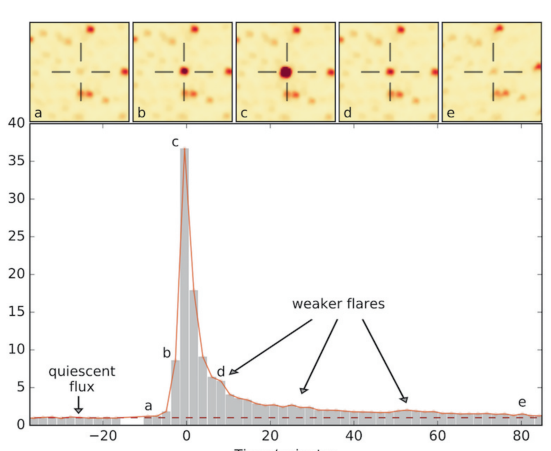
Speakers



Emily Drabek-Maunder · Cardiff University

Planet formation inside 10 AU: the disc of DG Tau A observed with the Planet-Earth Building-Blocks Legacy eMERLIN Survey

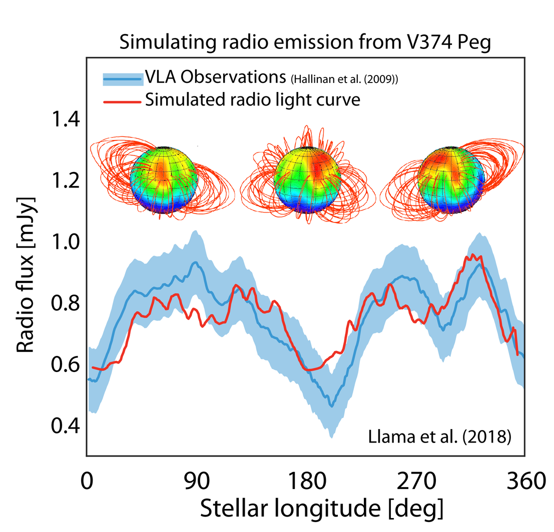
Planet Earth Building-Blocks - a Legacy eMERLIN Survey (PEBBLeS) is mapping 'pebbles' (cm-sized dust grains) at 5 cm wavelengths for protostars at a range of evolutionary stages and masses. The survey focuses on nearby star-forming regions to systematically study discs with a high potential for planet formation. The 40 mas resolution (5-9 AU) allows us to separate disc zones comparable to where terrestrial and gas giant planets form in our Solar System. The ability to image grain growth within a few AU of young stars is a unique eMERLIN capability, allowing the investigation of how planetary cores are made and the search for protoplanet candidates. We present observations of DG Tau A (Class I-II, low-mass) at 4-6 cm, where the disc is resolved and easily distinguished from jet emission. The extended source flux is significantly higher than predicted, suggesting a pile-up of dust grains with sizes ~1 cm. We compare the disc environments of DG Tau A and TW Hya, focussing on exploring the pebble-sized grain surface densities between 0.1 to ~16 AU from the star. We discuss the benefits of follow-up observations in near-IR wavelengths necessary to understand planet formation in these systems and how future SKA observations will further revolutionise our understanding of pebble formation.



Ward Howard · UNC Chapel Hil

Evryscope detection of the first Proxima superflare

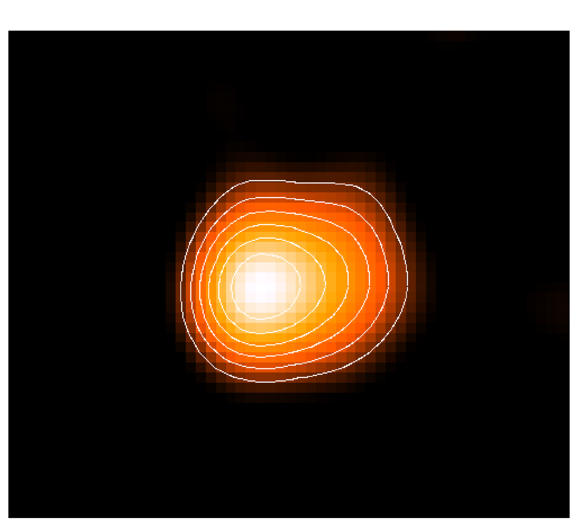
In March 2016, the Evryscope observed the first naked-eye-visible superflare from Proxima Centauri. The Evryscope array of small optical telescopes recorded the superflare as part of an ongoing survey of all bright southern stars, monitored simultaneously at 2 minute cadence since 2015. In light of large Proxima flares observed in the X-ray and sub-mm, we explore the contributions that continuous Evryscope monitoring bring to multi-wavelength studies of M-dwarf flare morphology and evolution, and the impacts on space weather environments of planets such as Proxima b. By modeling the photochemical effects of particle events accompanying large flares in a recently-accepted letter, we find repeated flaring is sufficient to reduce the ozone column of an Earth-like atmosphere at the orbit of Proxima b by 90% within five years and 99.9% over geologically-short timescales. Assuming complete ozone loss, surface UV-C levels during the Evryscope superflare reach ~100× the intensity required to kill simple UV-hardy microorganisms, suggesting that life would struggle to survive in the areas of Proxima b exposed to these flares. With the launch of TESS, multi-year Evryscope monitoring will help constrain both the emission mechanisms and habitability impacts of stellar flares for all the bright stars in the TESS field. In conjunction with Evryscope's long-wavelength radio counterpart, we discuss how simultaneous monitoring of the visible sky by Evryscope and the LWA may localize radio flares and potentially exoplanet auroral radio bursts. Furthermore, simultaneous Evryscope and ALMA observations of large sub-mm flares could constrain any associated thermal energy release, providing insight into the currently-unknown emission mechanism and habitability impacts of these events.



Moira Jardine · University of St. Andrews

Simulating Radio Emission from Low Mass Stars

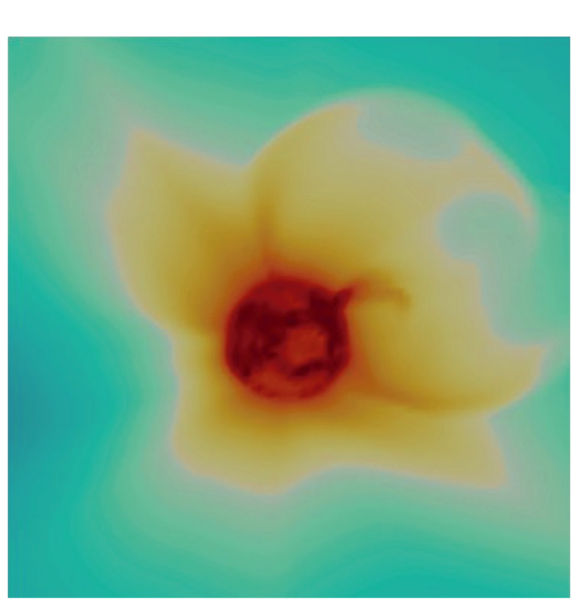
The radio emission from low mass stars has been a puzzle for some time, both in its magnitude, which greatly exceeds that expected from the star's X-ray emission, and in its rotational modulation, which shows a smooth background modulation with superimposed spikes. For one such star (v374 Peg) we combine information from two different wavelength regimes to study the nature of this emission. In the optical, we have maps of the surface magnetic field obtained using the spectropolarimetric technique of Zeeman-Doppler imaging, while in the radio we have simultaneous VLA observations at 4 and 8 GHz. Using information from the X-ray luminosity and these magnetic maps, we model the structure of both the coronal field and plasma density. From this we predict the dynamic radio spectrum that would be produced by the electron cyclotron maser instability and show that it reproduces the magnitude and smooth background modulation of the observed radio emission. This demonstrates the role of the field geometry in determining the nature of the radio emission and provides a new technique for studying the radio emission from low mass stars.



Lynn Matthews · MIT Haystack Observatory

Resolving the Radio Surfaces of AGB Stars

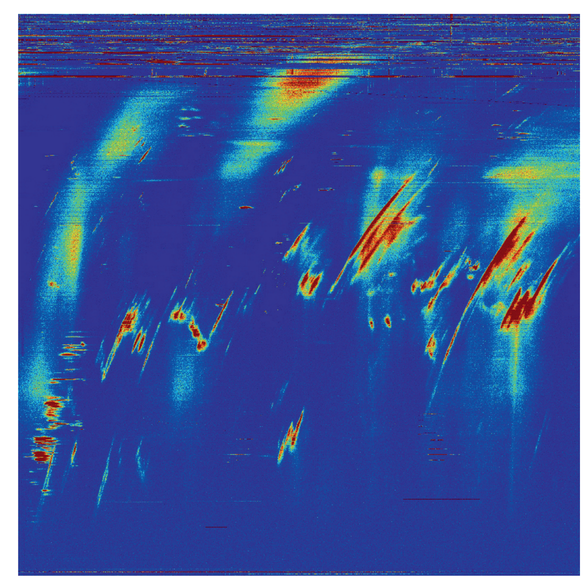
Stars on the asymptotic giant branch (AGB) have detectable "radio photospheres" that lie at roughly twice the classic photospheric radius measured at optical wavelengths. Radio continuum studies of AGB stars therefore provide a means to probe the atmosphere just inside the critical region where dust formation occurs and the stellar wind is launched. For the nearest AGB stars ($d < 200$ pc), it is possible to resolve the radio photosphere at millimeter wavelengths using the long-baseline configurations of the VLA and ALMA, thereby enabling the deviation of fundamental stellar parameters and the direct imaging of surface features. We will showcase recent findings from high-resolution imaging observations of the radio surfaces of several AGB stars, including results from a new sparse model image reconstruction algorithm. We find evidence that the shapes and other parameters of the radio photosphere vary over time. In addition, the data reveal signatures of brightness asymmetries and non-uniformities. Together these trends are consistent with manifestations of large-scale irregular convective flows on the stellar surfaces, although effects from non-radial pulsations cannot be excluded.



Sofia Moschou · Harvard-Smithsonian CfA

Examining stellar CME candidates: Does the solar flare-CME relation extend to other stars?

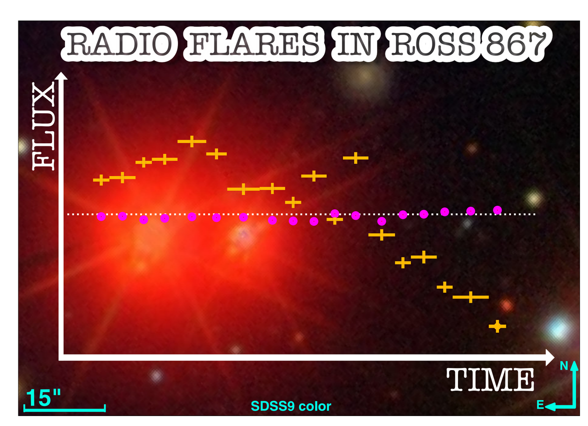
A well established relation between solar CMEs and flares has been revealed due to decades of direct observations. Strong flares are associated with faster and more massive CMEs and their correlation increases with increasing respective energies. The continuously growing number of confirmed extrasolar systems, particularly around M-dwarfs, requires the evaluation of the impact that stellar CMEs might have on habitability. However, direct imaging of stellar CMEs is currently impossible, so indirect observational methods need be employed. The three main observational techniques for capturing stellar CME signatures are measuring a) Type II radio bursts, b) Doppler shifts in UV/optical lines, and c) continuous absorption in the X-ray spectrum. We examine the most probable CME candidates up to date together with their kinematics and energetics. Finally, we discuss the extension of the solar CME-flare relation towards the high-energy limit for active stars and assess the uncertainty levels of the different observational methods utilized.



Robert Mutel · University of Iowa

Scaling laws for election cyclotron maser emission: How CMI emission characteristics differ in planetary and stellar magnetospheres

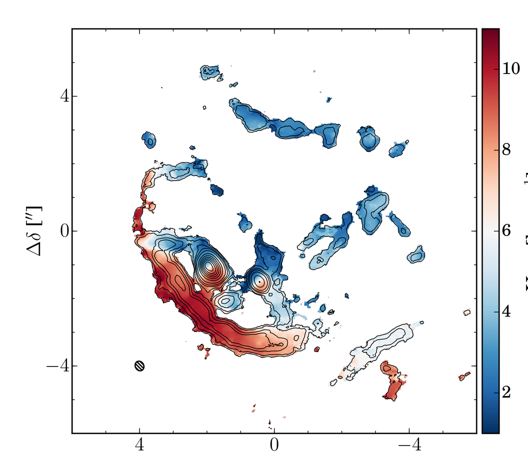
I will discuss scaling laws for ECMI radio emission, and how radiation characteristics such as angular beaming, strength of second harmonic emission, and dominance of RX vs LO mode are affected by the very different plasma environments of stellar vs. planetary magnetospheres.



Luis Henry Quiroga-Nuñez · Leiden Observatory / JIVE

Serendipitous discovery of variability at low radio frequencies: the case of M-dwarf star Ross 867

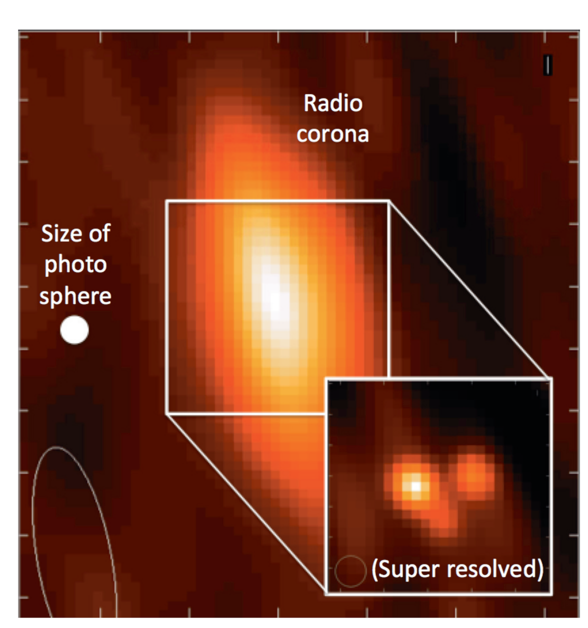
We have serendipitously discovered strong radio variability from M-dwarf star Ross 867 while studying a nearby galaxy cluster at sub-GHz radio observations. In this talk, we present an analysis of archival radio observations from GMRT, VLA and LOFAR, spanning several decades to reveal a history of radio flaring of Ross 867 on hour time scales. Further studies will include a radio circular polarization measurement and a comparison of the positions of the optical and radio emissions using Gaia DR2 data and (proposed) EVN VLBI observations.



Joseph Rodriguez · Harvard-Smithsonian CfA

Occultations as a Window into Circumstellar Architecture: RW Aurigae

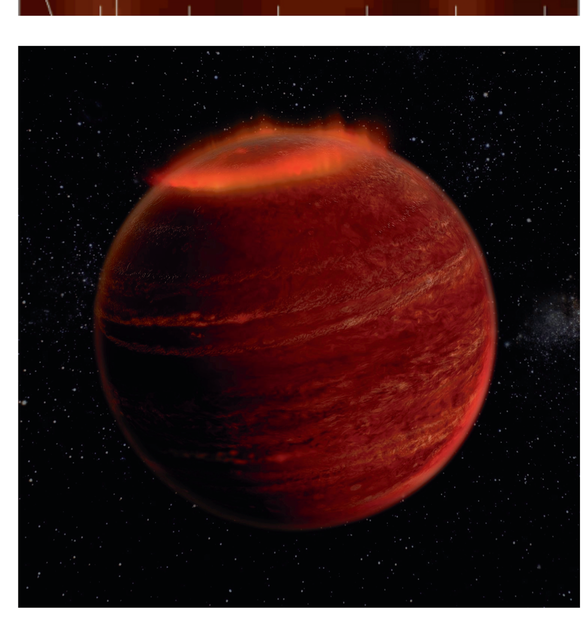
It is known that planets form from the gas and dust in the protoplanetary disks surrounding young stellar objects (YSOs). What is not clear is what governs the large diversity of planet types and of planetary system architectures that are now being discovered by the thousands. The differences in the outcome of planet formation and the vast range in planetary system architectures are directly influenced by disk substructures and stellar companions. The archetype for the impact of binary interactions on disk evolution and possibly planet formation is the classical T Tauri star, RW Aurigae. With ongoing surveys like the AAVSO accumulating a century of photometric observations on RW Aurigae, we are now able to search for periodic phenomena on spatial scales of up to ~20 AU. With recent ALMA observations of RW Aurigae, we are now able to resolve circumstellar features down to a few tens of AU, with future observations being able to resolve down to a few AU. This overlap in spatial scale between photometry and interferometry allows a unique opportunity to link photometric occultation events to specific architectural features seen from ALMA. I will present our combined analysis of over a century of photometric observations and the new ALMA millimeter data for RW Aurigae, and discuss how we are beginning to link the observed occultations to specific architectural features.



Jackie Villadsen · NRAO

Resolved imaging of the quiet and flaring radio corona of active M dwarfs

Very long baseline interferometry (VLBI) provides the resolution to image the radio-emitting corona of nearby low-mass stars. Past VLBI observations of active M dwarfs have provided evidence that the radio source(s), and the associated high-energy electron populations, often occupy a significantly larger area than the stellar photospheric disk. I will briefly review these past observations and present my current work comparing the locations of coherent and incoherent flares to the quiescent radio corona of two active M dwarfs, UV Ceti and AD Leonis. Time permitting, I will also discuss the prospects for detecting stellar eruptions in ngVLA long baseline observations of stellar radio coronae.



Andrew Zic · University of Sydney

Low-frequency GMRT observations of ultra-cool dwarfs

The quiescent and bursty radio emission observed in about 10% of Ultra-Cool Dwarf stars (UCDs; spectral class > M7) indicates the presence of strong, persistent magnetic fields. Radio frequency observations have been key to characterising the radio emission mechanisms as well as the magnetospheric structure for some radio-loud UCDs. However, important questions remain unanswered, including the generation, structure, and evolution of UCD magnetic fields; and how the UCD magnetosphere is populated with non-thermal electrons responsible for the radio emission. The majority of studies of UCDs at radio frequencies have been in the 4-8 GHz band. Hence the nature of UCD radio emission at low frequencies (<~ 1.4 GHz) remains relatively unexplored, and could provide key insights into these questions. In this talk, I will present the results of GMRT observations of 10 UCDs taken at ~610 and 1300 MHz. These are the first observations of UCDs in this frequency range to be published in the literature. Using these observations, we are able to constrain the shape of the spectral energy distribution for the detected UCDs, LSPM J1314+1320 and 2MASS J0746+20. We are also able to determine if there is a low-frequency counterpart to the bursty and pulsed radio emission observed at higher radio frequencies. These results provide new insights to the physical conditions in UCD magnetospheres.

Image Credits. Sun/earth: NASA Goddard Space Weather Center. Radio sun: NRAO/AUI and Stephen White (University of Maryland). Very Large Array: NRAO/AUI, Kelly Gatlin (photographer), Patricia Smiley (digital composite). Protoplanetary disk simulation: Greaves, Richards, Rice & Muxlow 2008. Radio dynamic spectrum: Diana E. Morosan, Peter T. Gallagher, and The Solar and Space Weather KSP Team. Brown dwarf artist's conception: Chuck Carter & Gregg Hallinan/Caltech.