Stars, Milky Way and the Local Volume

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with material from

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RAS LSST discussion meeting

12th May 2017

Outline

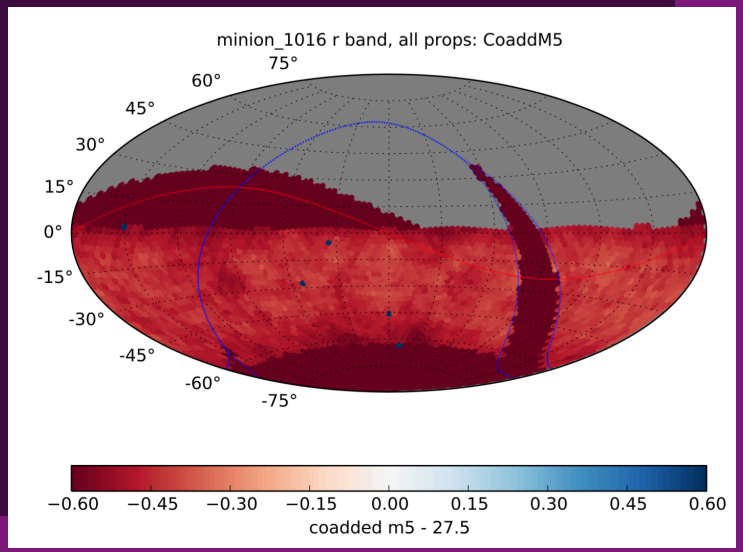
- Out-of-plane observations – fairly well catered for at present
- In-plane observations – current plan is silly

Milky Way Sub-groups

- Solar neighborhood: brown dwarfs, white dwarfs
- Milky Way halo ("Galactic Structure & ISM")
- "Magellanic clouds" and Local Group galaxies ("Near Field Cosmology")
- Variable stars
- Clusters
- Galactic Bulge:
  - TBD (LSST UK meeting in Preston next week)

Also

- Exoplanets
- Transients



Solar Neighborhood (d<100 pc)

- Parallax-based census of nearby space
  - brown dwarfs (and planets), white dwarfs, IMF, formation history
- Astrometry is key
  - Parallax precision of 0.6 (bright) to 8 mas (*r* = 24), DCR-corrected.
  - Pipeline will do shift and stack to detect nearby, high proper motion cold BDs.
  - Velocities allow statistical determination of population ages.
  - Young Moving Groups and clusters provide co-eval populations.
  - Caution: allow for movement of Galactic populations.
- Weather on brown dwarfs
  - Need to sample 1 day rotation periods.
- White dwarfs
  - Discover the coolest white dwarfs. Measure WD luminosity function.
  - Variable WDs (pulsators, dichroic magnetism, circumstellar matter). Need to sample periods of hours.

Milky Way Halo

Science Goals

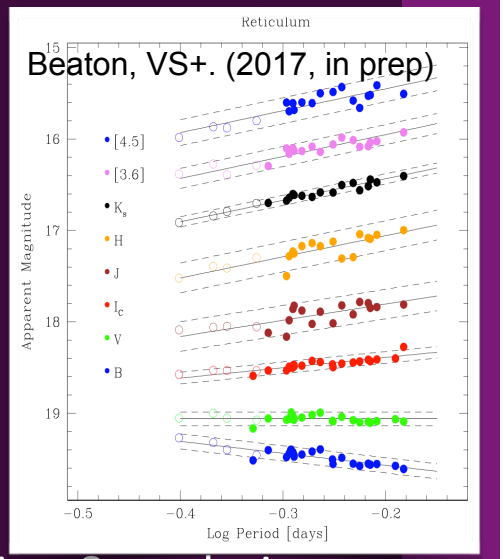
- Milky Way formation and evolution
- Astrophysics of dwarf galaxies (formation)
- First stars
  - IMF from faint main sequence stars
- Dark matter physics

Observables (with good PMs and star/galaxy separation)

- 1D halo density profile to 200 kpc
- 3D shape to 100 kpc
- Velocity ellipsoid to 100 kpc
- Clumpiness to 30 kpc
- Halo substructure
  - Dwarf spheroidal galaxies
  - Stellar streams and stream perturbations – a handle on the dark matter

Magellanic Clouds/Local Group

- Resolved stellar populations – stellar astrophysics
  - Wide range of star cluster metallicities
  - Different age-metallicity relation than the MW → breaks model degeneracies
- Need to take account of 3D structure of the Clouds
  - 6% LMC distance spread → 12% apparent luminosity spread.
  - RR Lyraes distances & extinctions calculated with aid of 6 filters.
- Magellanic survey extension likely (Dec < -60°).
  - LSST complements OGLE-IV and DES/DECam
- Other LG galaxies: many science cases, e.g. galaxy formation & evolution



<u>Key Technical Requirement</u>

- Precise DIA photometry for variable stars in LG galaxies and MC globulars.

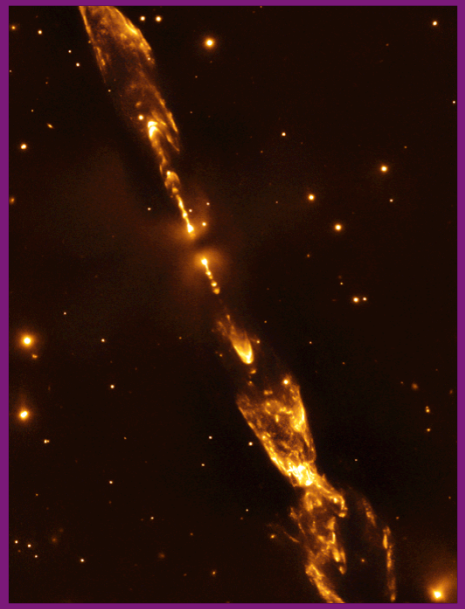
Variable Stars

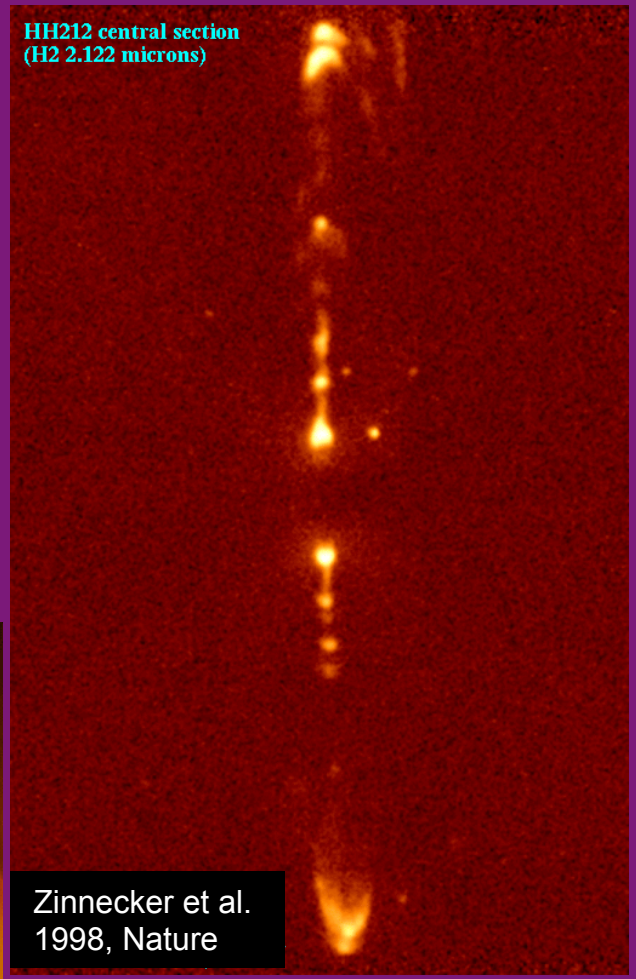
- Galactic structure (bulge, far side of Milky Way) using RR Lyraes, Cepheids
  - Complements VVV & VVVX by measuring structure GAIA cannot see.
  - Proper motions → 5D structure. LSST precision = 0.17 mas/yr.
  - Dark matter content of Galactic bulge from proper motion catalogue.

- Eruptive YSOs driven by episodic accretion
  - A key problem in the formation of normal stars – not understood.
  - VVV has shown it is common in embedded YSOs, burst durations of years
  - LSST depth needed for long term monitoring.

- X-ray binaries
- Milky Way transients
- CVs as type SN type Ia progenitors
- Magnetic cycles in normal main sequence stars
- The new and unknown

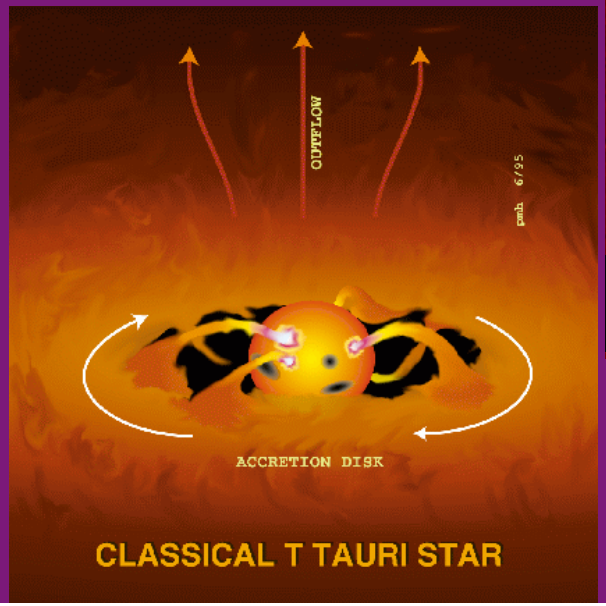
Variability in Young Stellar Objects (YSOs)



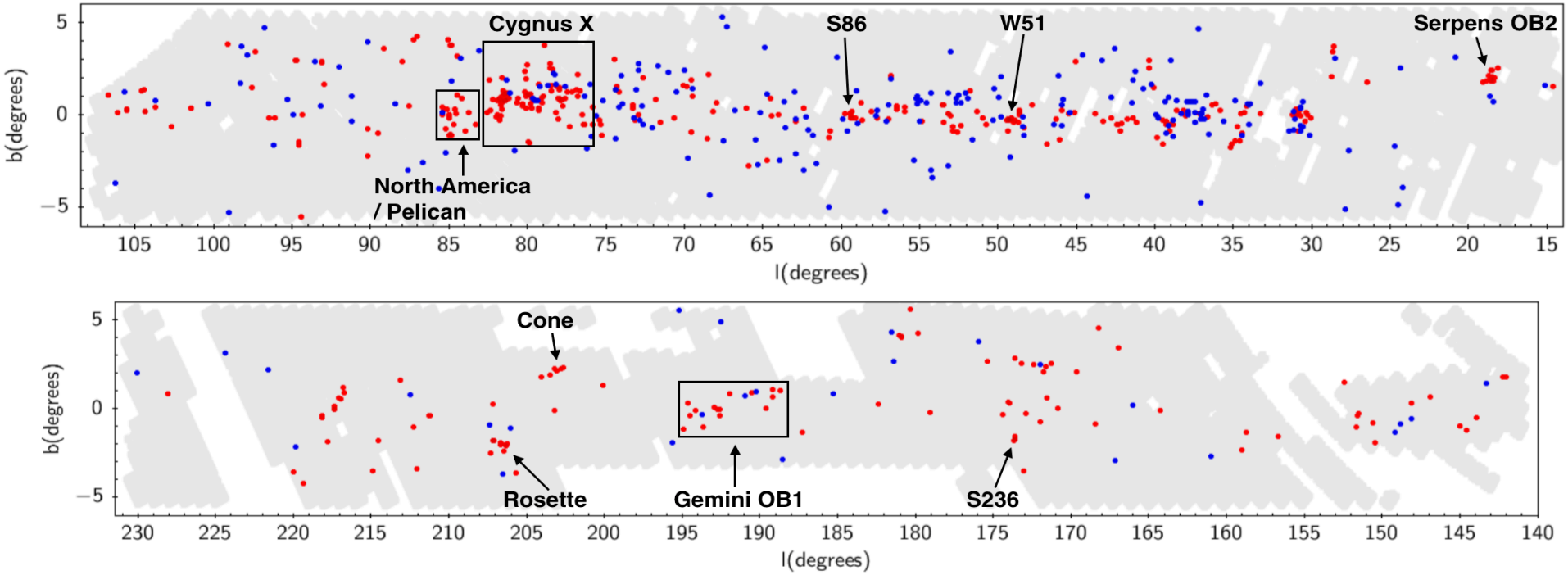


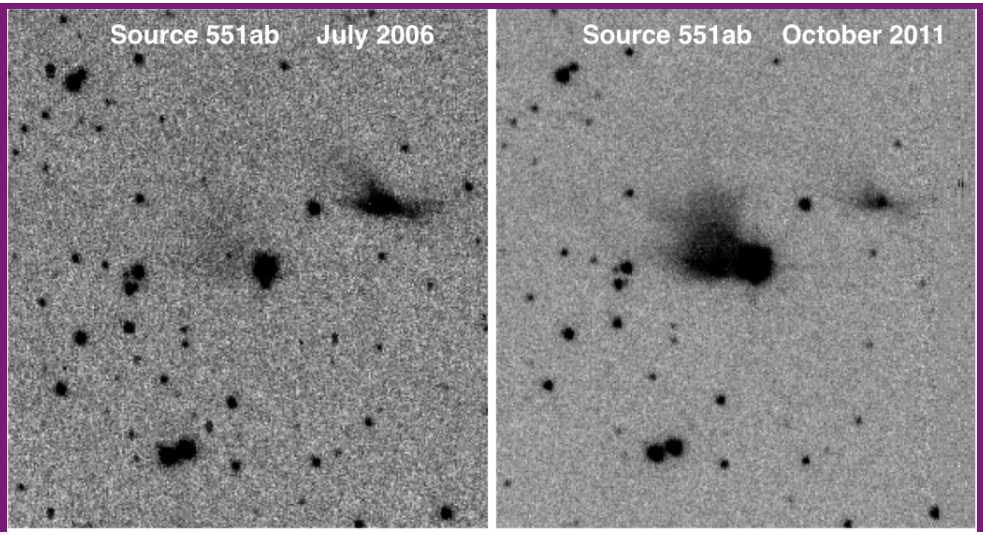
Zinnecker et al.
1998, Nature

HL Tau, Brogan et al.2014, ALMA



UKIDSS 2 epoch catalogue:
618 high amplitude IR variables: 60% are YSOs (red points)

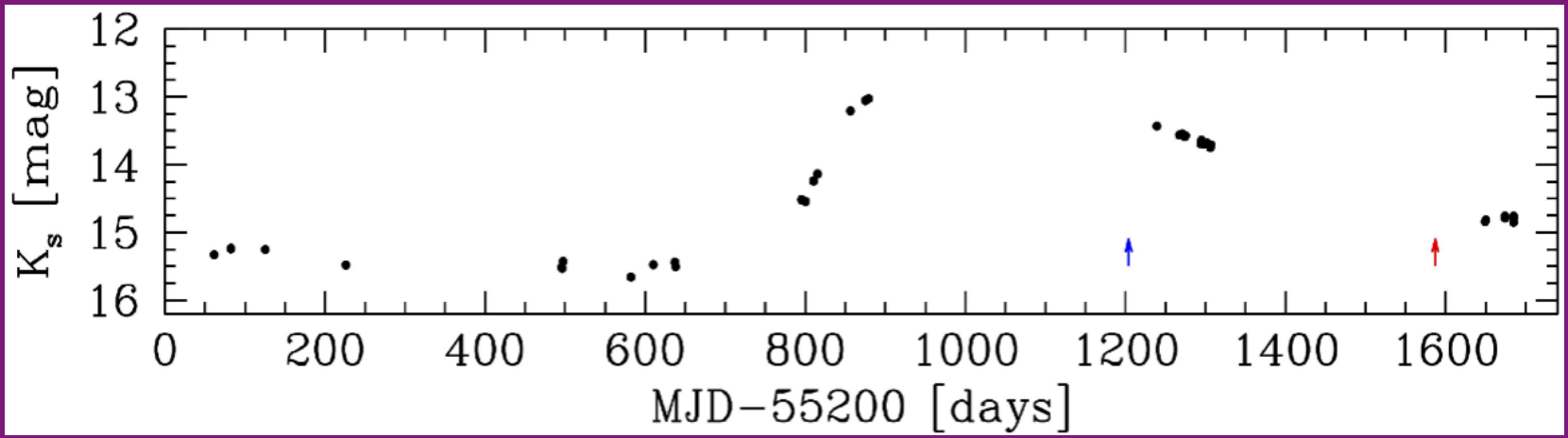


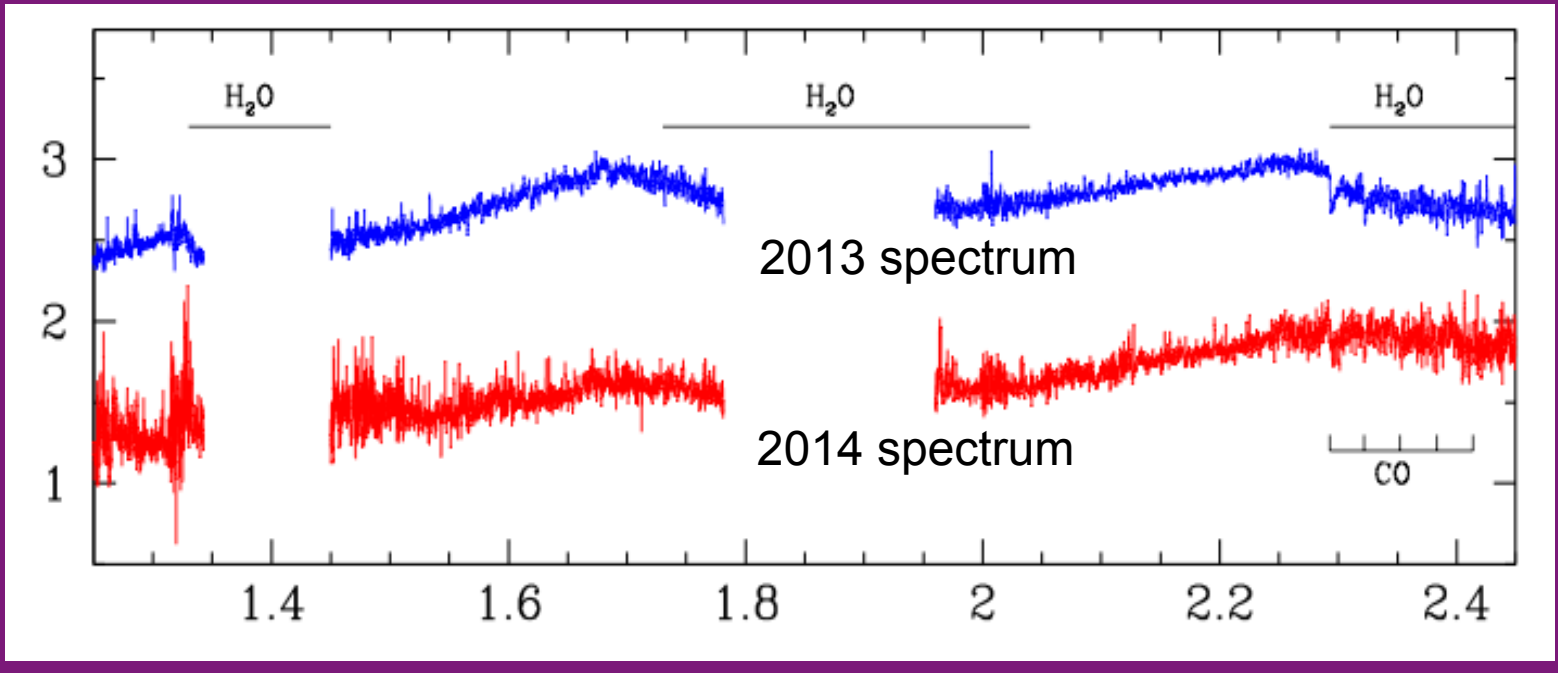


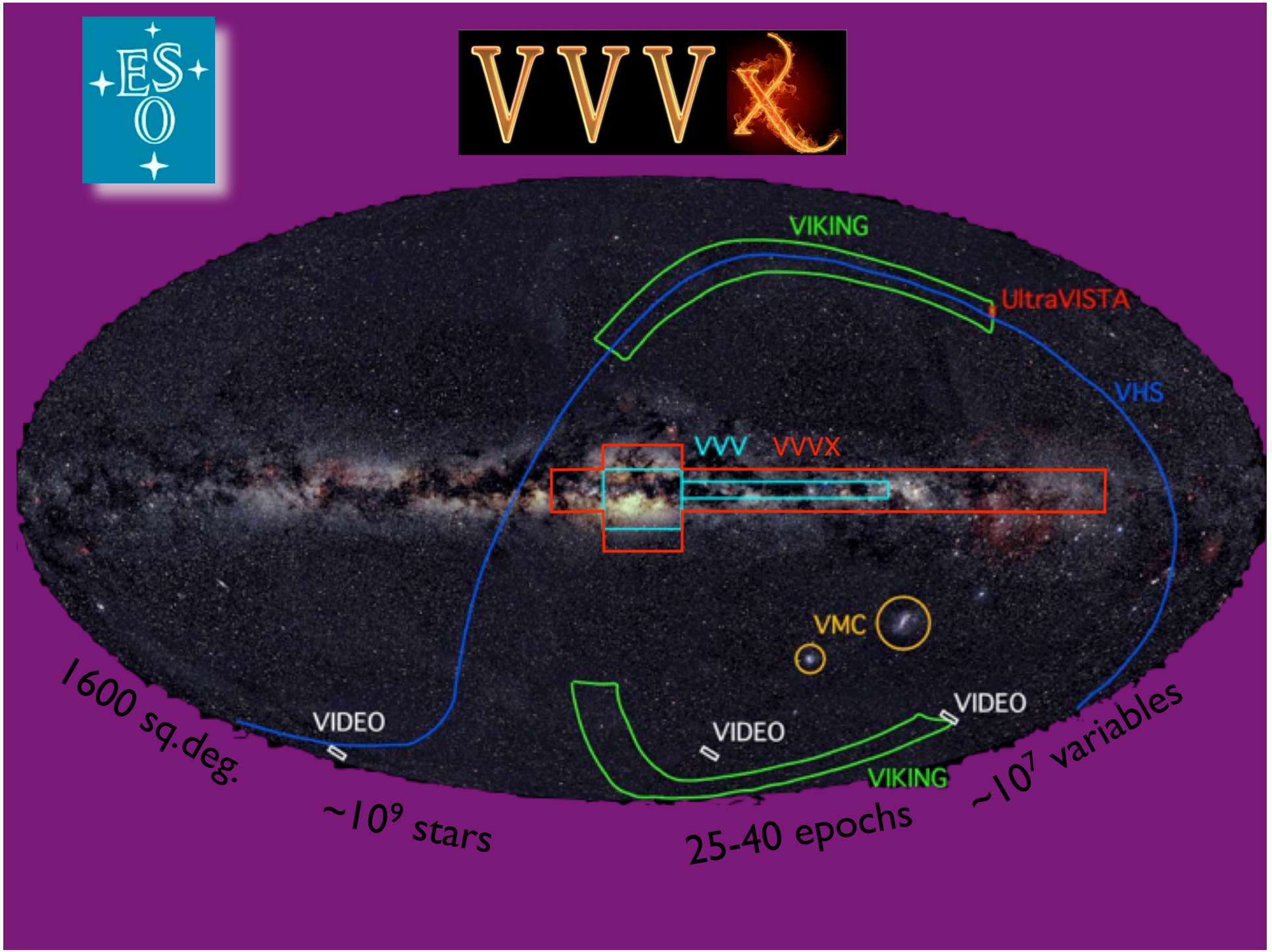
(Lucas et al.2017, submitted)

Eruptive variable protostars found in regions at d = 0.3 to 10 kpc, $L = 0.1 - 10^3\ L_\odot$

V322, a fast Fuor from VVV






VIKING
UltraVISTA
VHS
VVV
VVVX
VMC
VIDEO
VIDEO
VIDEO
VIKING
1600 sq.deg.
~10⁹ stars
25-40 epochs
~10⁷ variables

Clusters

- Laboratories for stellar evolution, common distance, age, metallicity
  - LSST can measure rotation periods for cluster members and field stars
  - Gyrochronal ages - a tool for stellar ages, calibrated by clusters
  - Comparison with asteroseismic ages (Kepler, TESS, PLATO).
  - Age – activity relation.

- Old metal poor clusters: Milky Way assembly
- Kinematics of embedded YSOs
  - too faint for GAIA, synergy with VVVX will help to get to 0.1 mas/yr.

Technical Issue

- Cadence of 3 days needed
- Targeted observations of mature clusters and pre-MS clusters?

Exoplanets - microlensing

- Short duration microlensing events probe low mass exoplanets at 1-10 au.
- Target inner Milky Way disc every 3 days → statistics at 5-10 au.
- LSST triggers high cadence follow up (OGLE-IV, MOA, KMTnet).
  - Triggers down to greater depth → order of magnitude increase in events.
- Space-based observation also needed for microlensing parallax.
  - E.g. EUCLID, WFIRST at L2.

Technical Issues

- Universal LSST wide, fast, deep cadence ok
- but multiple colours not needed.

Conclusions

- The lion's share of Milky Way science requires more time/higher cadence
  - LSST needs to be an actual time domain survey!
- E.g. universal wide, fast deep cadence (800 times in 10 years) **BUT**
  - Cadence should cover a range of time baselines.
- Filter strategy would have to be different in the plane.
  - Contemporaneous colours
  - More observations in redder filters
- **LSST UK Milky Way Science Workshop at U Hertfordshire, 26-27 June**
  - https://sites.google.com/site/lsstukstars1/