(Incomplete) review of inner Milky Way science drivers

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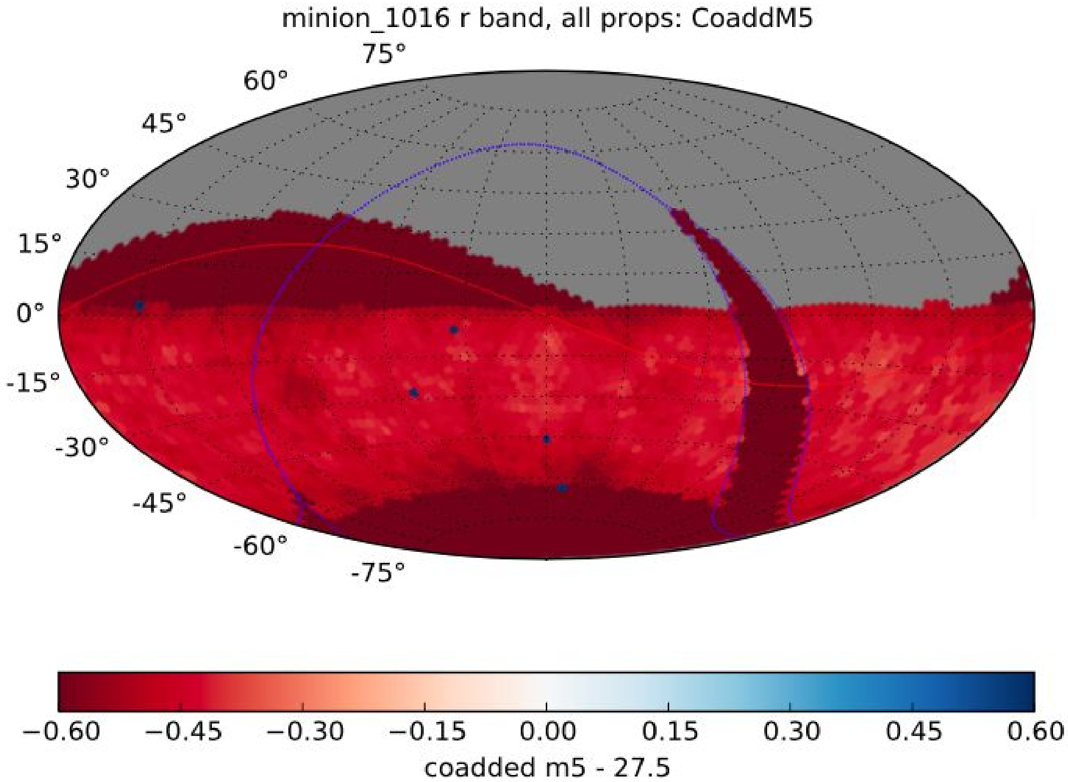
University of Michigan-Dearborn

LSST 2017 Project & Community Workshop
Milky Way and Microlensing Breakout
Tuesday August 15th, 3:30pm

(Note none of the approved DDFs are in the Plane.)



Deep-drilling fields (4 approved)

Mini-surveys, *currently*:

- Galactic Plane
- South Celestial Cap and Magellanic Clouds
- Northern Ecliptic Spur

Additional “Special programs,” e.g.

- Twilight Survey
- Mini-moons
- Meteor-sized impactors

(Incomplete) summary of inner-MW science

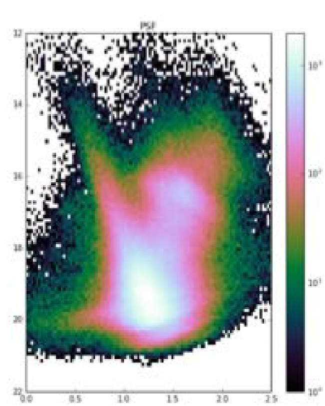
	"Static science"	**(Photometric) Variability**
Select field(s)	Astrometric and Photometric calibration for the main survey	Planetary microlensing Red-giant variability Transiting extrasolar planets New short-timescale transients
Many-fields	Extend Gaia-type investigations to the Bulge Optical-waveband constraints on the ISM (synergy with NIR) Kinematic sample of Red Clump Giants in the inner MW for Galactic Structure	Accretion/outflow in X-ray binaries Dwarf Novae and Type Ia SNe Microlensing constraints on black hole Dark matter Thick-disk structure (RR Lyrae) ISM (RR Lyrae)

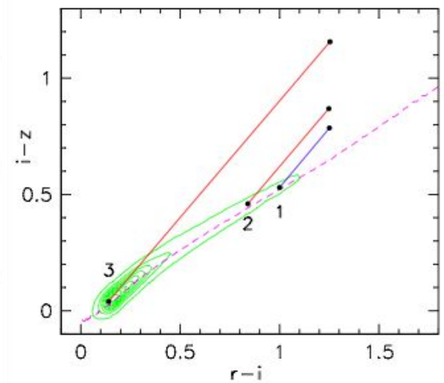
“Many-fields,” static: ISM and Bulge structure

- DECam shows that a seeing-limited imager ***can*** reach the Bulge MS turn-off even in highly crowded regions. *Berry et al. 2012*

Example: Reddening - With a few exposures per field, can use the {r,i,z} color-color method of [Berry et al. (2012 ApJ 757, 166)]() to estimate reddening from static photometry

(This {r,g-r} CMD from <10 images of a single DECam field, by UM-Dearborn undergrad Mike Conrad, from the Blanco DECam Bulge Survey, PI Mike Rich)

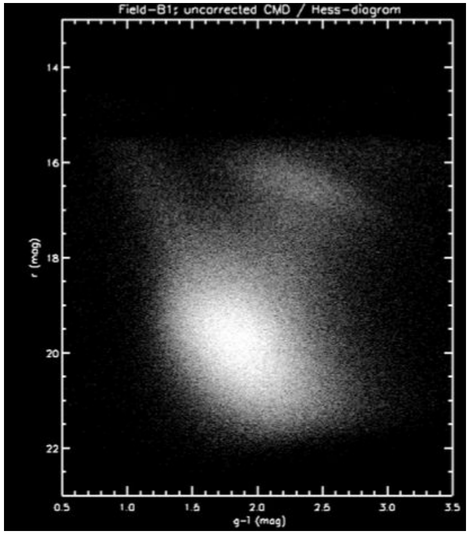


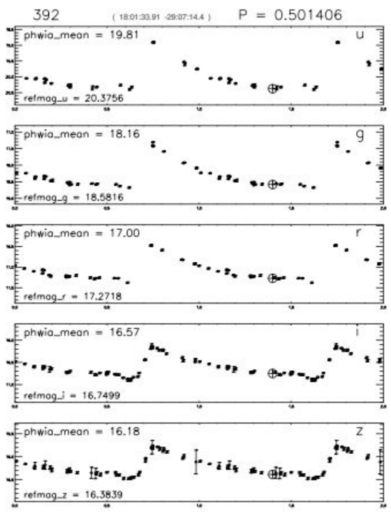


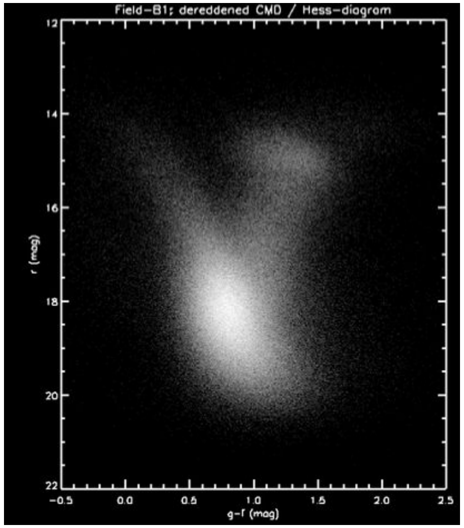
With a more WFD-like allocation , can use RR Lyrae to estimate reddening.

(From Saha et al. 2017 in prep)

Can imagine doing this all over the Bulge...





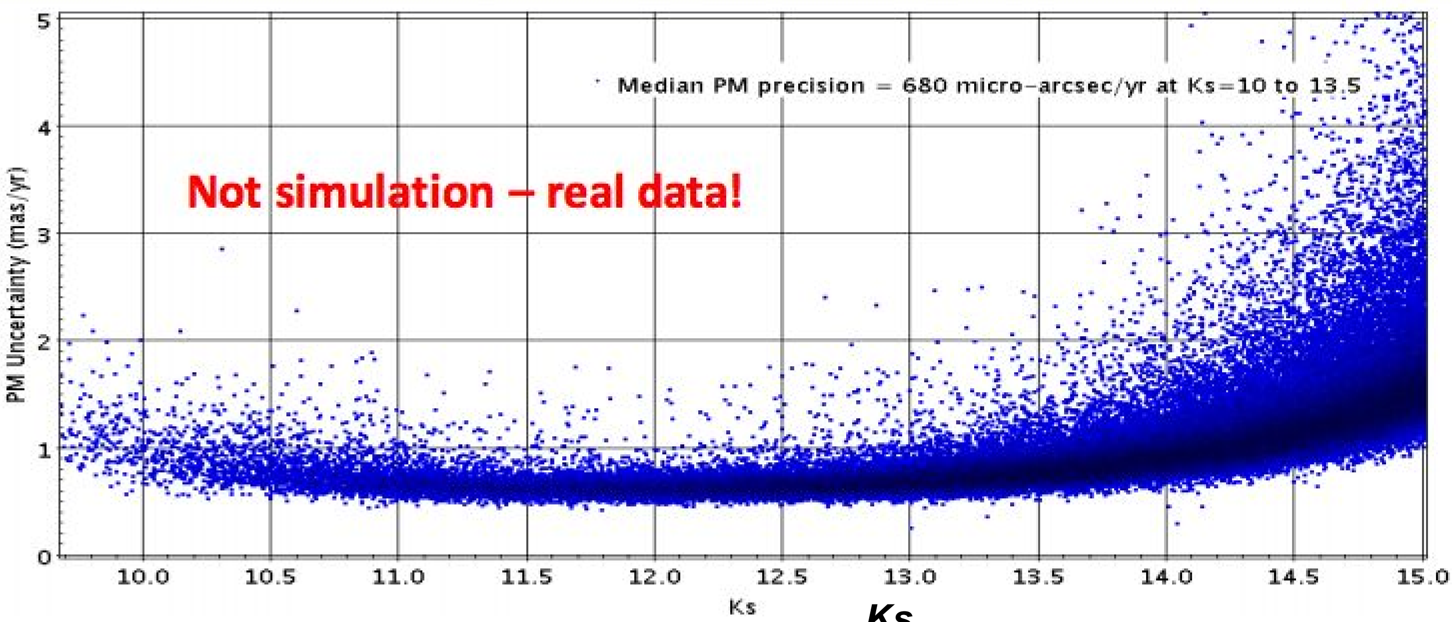


“Many-fields,” static and variables: synergy with external surveys

- Example wide-field surveys:
  - VPHAS+ (u,g,r,i,Ha, 2011-ongoing); http://www.vphasplus.org/)
  - VVV (Z,Y,J,H,Ks, 2009-2014); https://vvvsurvey.org/
    - (and its extension, VVVX, observations ~2016-2019)

- **With 9 year baseline VVV+VVVX should provide a proper motion precision of ~200 μas/yr: 1) the longer baseline; 2) benefit of more epochs**

From a 2015 talk by Radostin Kurtev; see, e.g. here:



PM precision (mas/yr; scale runs from 0 to 5 mas/yr)

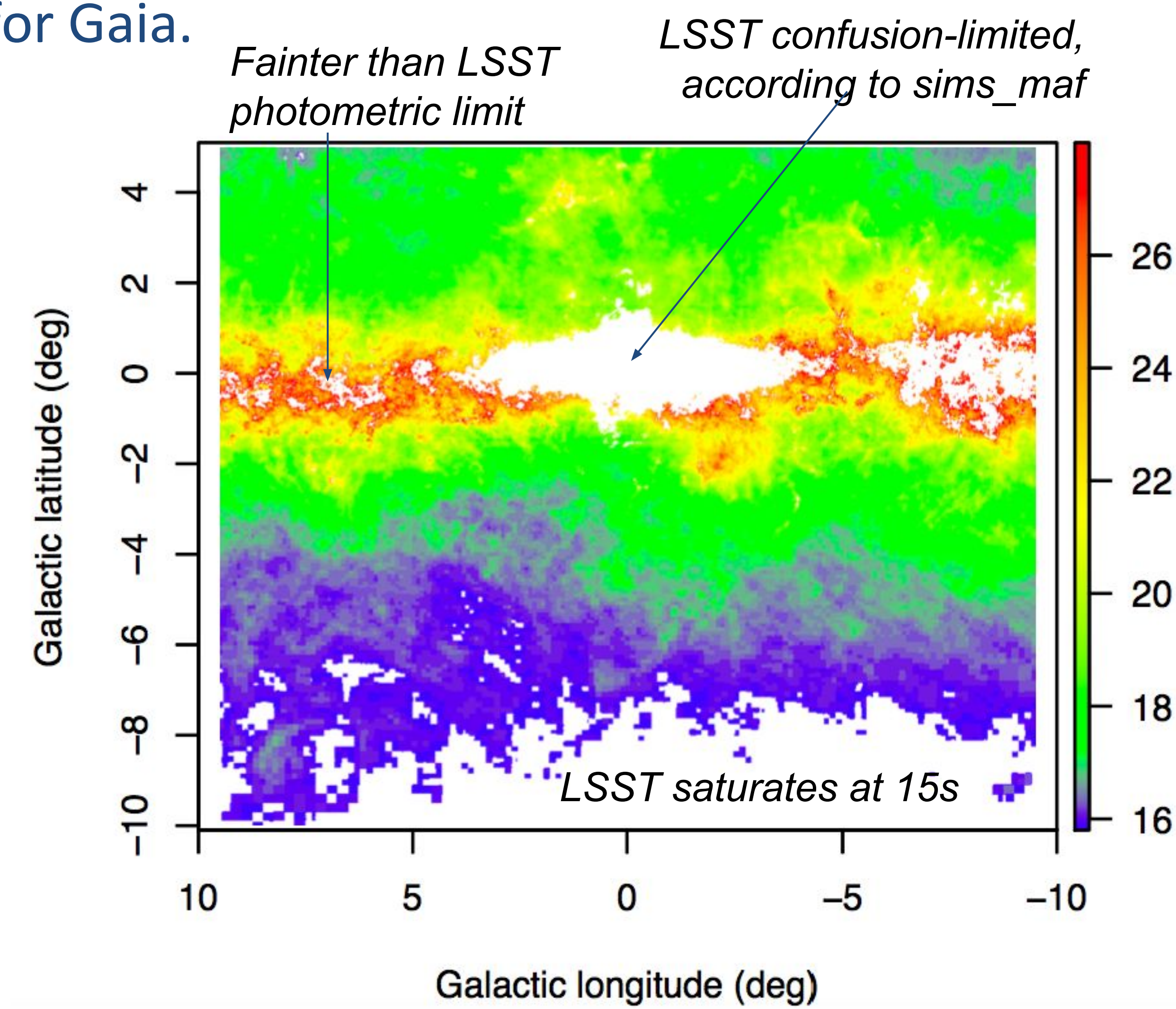
Ks

“Many-fields,” static and variables: synergy with external surveys

- Galactic Structure (e.g. RR Lyrae, Cepheids, RCGs); observe regions difficult for Gaia.

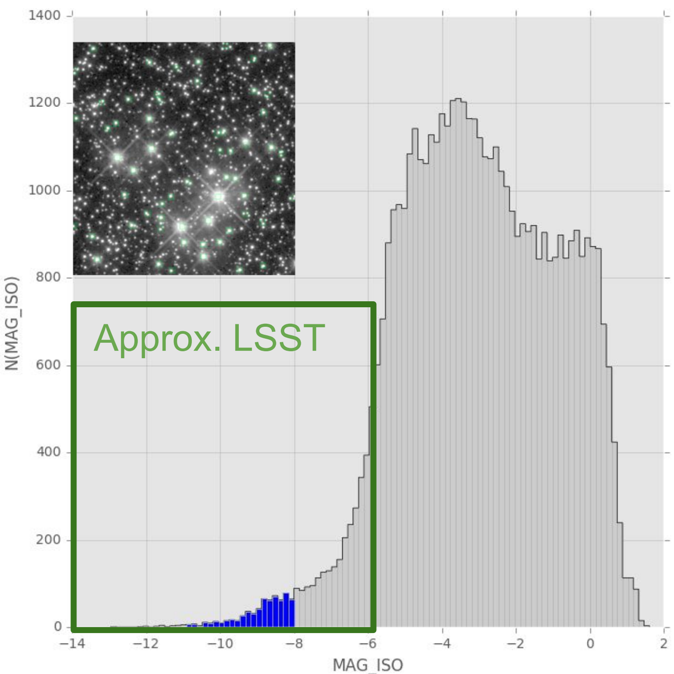
Right: prediction for r-band apparent magnitude of Red Clump Giants (RCGs) in the inner 20x15 degrees of the Milky Way, using the VVV extinction model. RCG in the white regions are either confusion-limited, depth-limited or are brighter than LSST’s expected saturation limit at 15s.

Figure prepared by Oscar Gonzalez, STFC



"Many-fields," static: Kinematics and (inner-) Galactic structure

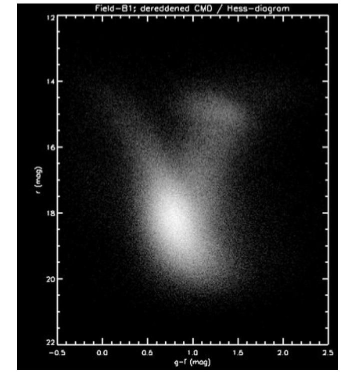
- Enable LSST to extend the Gaia uncertainty curve to fainter magnitudes in the inner Plane

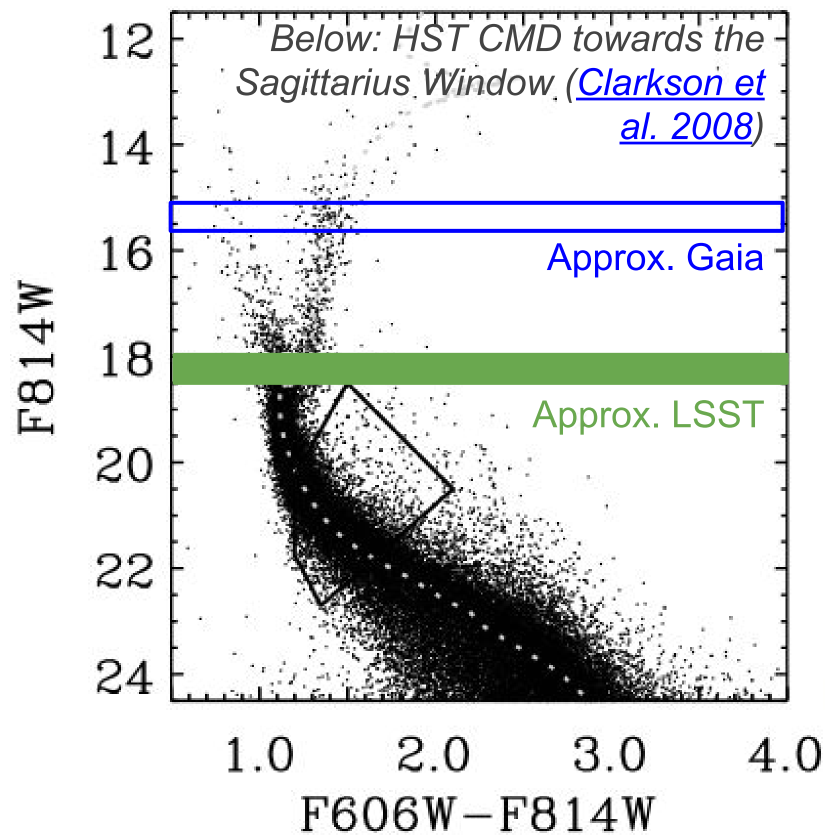


*Above: example cross-match between HST and Gaia in the Sagittarius Window (in F625W). Gaia/HST **candidate** cross-matches are in blue. The approximate regime of LSST sensitivity in the presence of confusion, is shown in green.*

Based partly on work by UM-Dearborn undergraduate Emily Aufdemberge

Right: DECam (g,r) CMD in Baade's Window (Saha et al. 2017 in prep)





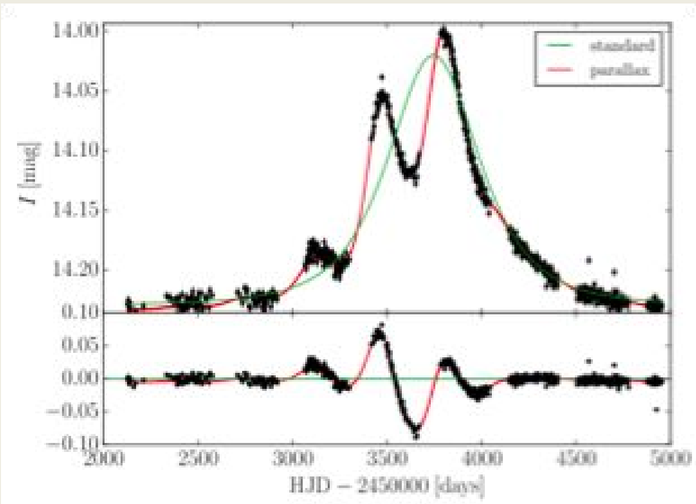
Below: HST CMD towards the Sagittarius Window ([Clarkson et al. 2008](#))

"Many-fields," variability: Long timescale variations

- Variability on months-years; transient outbursts, microlensing (of various types of object)

Events rare → wide-field
Long-term → photometric stability
Want to push to fainter objects → sensitivity → all LSST

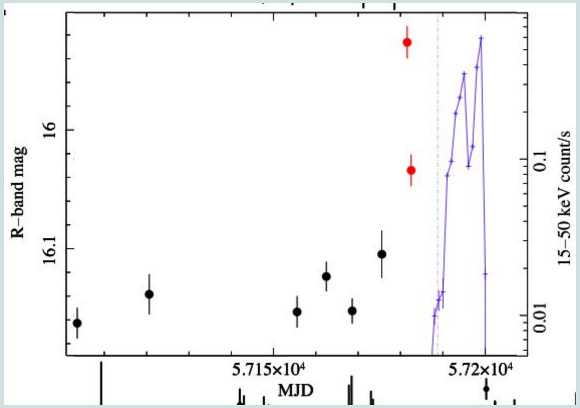
"Slow"-microlensing by nearby compact objects (Wyrzykowski et al. 2016 MNRAS 458, 3012)

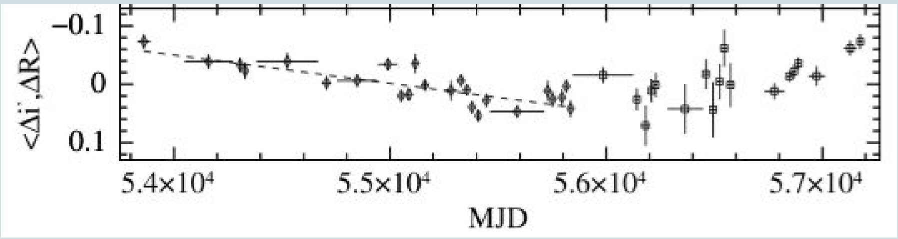


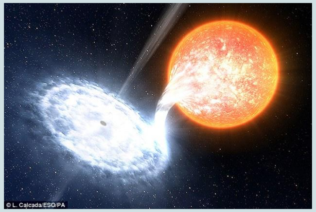
- Can trace the compact object mass function and thus stellar evolution

Optical ***precursor*** rise for (black hole) X-ray transient outbursts?

(E.g. V404 Cyg, Bernardini et al. 2016)

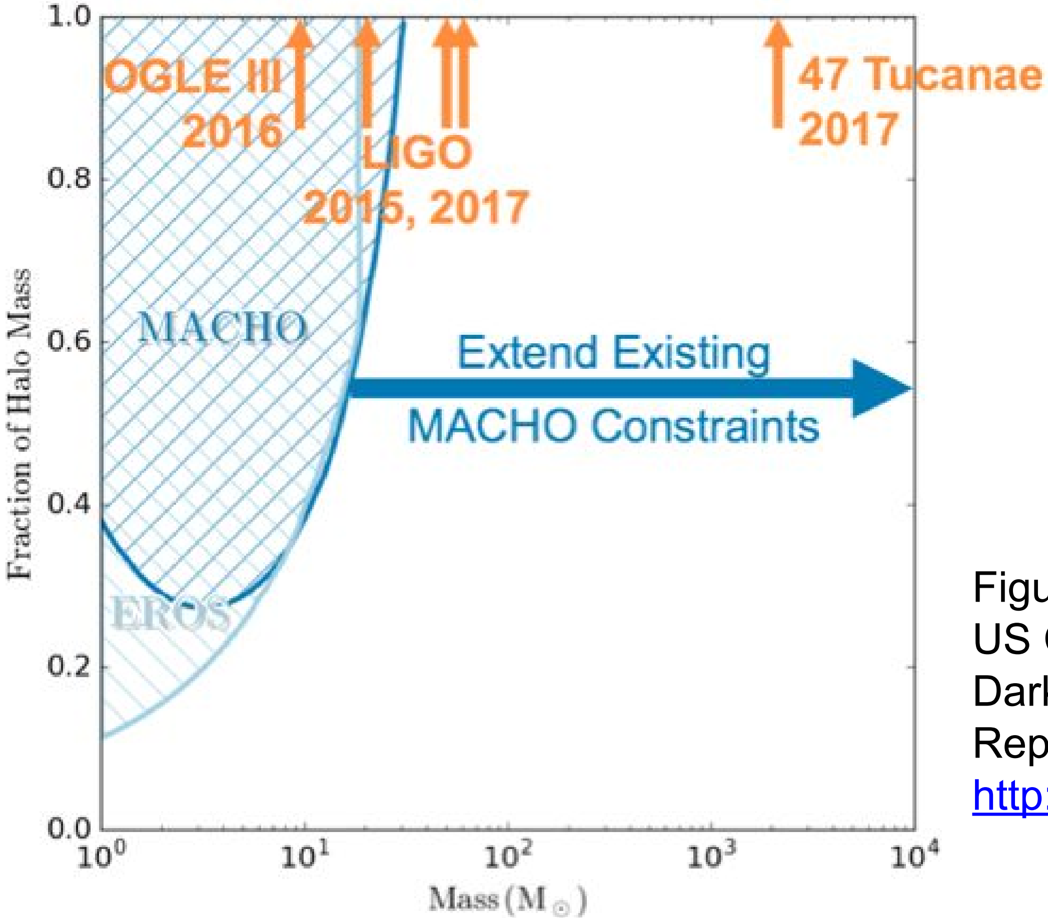






“Many-fields,” variability: Long timescale variations

- Constraints on intermediate-mass black hole Dark Matter through microlensing



See the “Dark Matter” breakout:
Weds Aug 16th 1:30pm
[Agenda link]

Figure from Battaglieri et al. 2017: US Cosmic Visions: New Ideas in Dark Matter 2017: Community Report
http://lanl.arxiv.org/abs/1707.04591

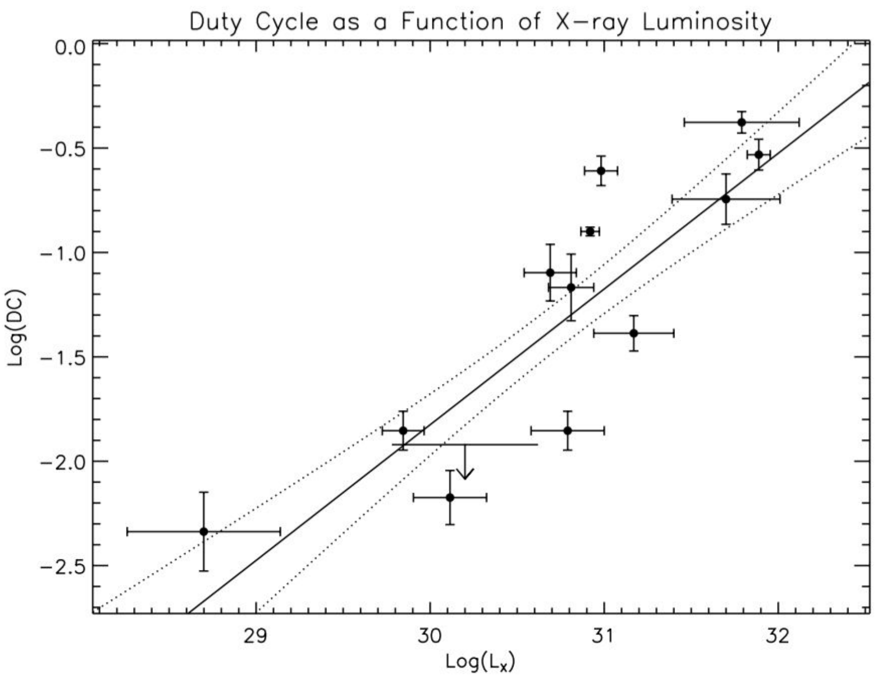
"Many-fields," variability:
Long timescale variations

- Dwarf Novae duty cycles (fraction of time in a bright state) as a probe of the stellar luminosity function

0.0

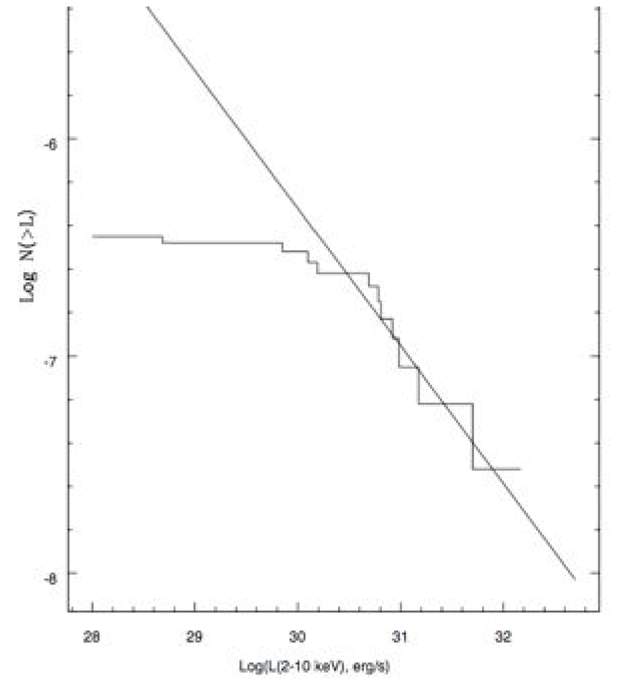
log_10 (Duty cycle)

-2.5



X-ray luminosity
(log scale)

log (N)



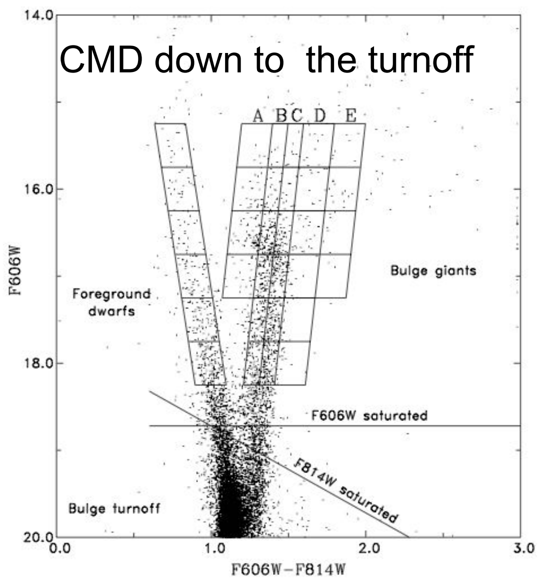
X-ray luminosity
(log scale)

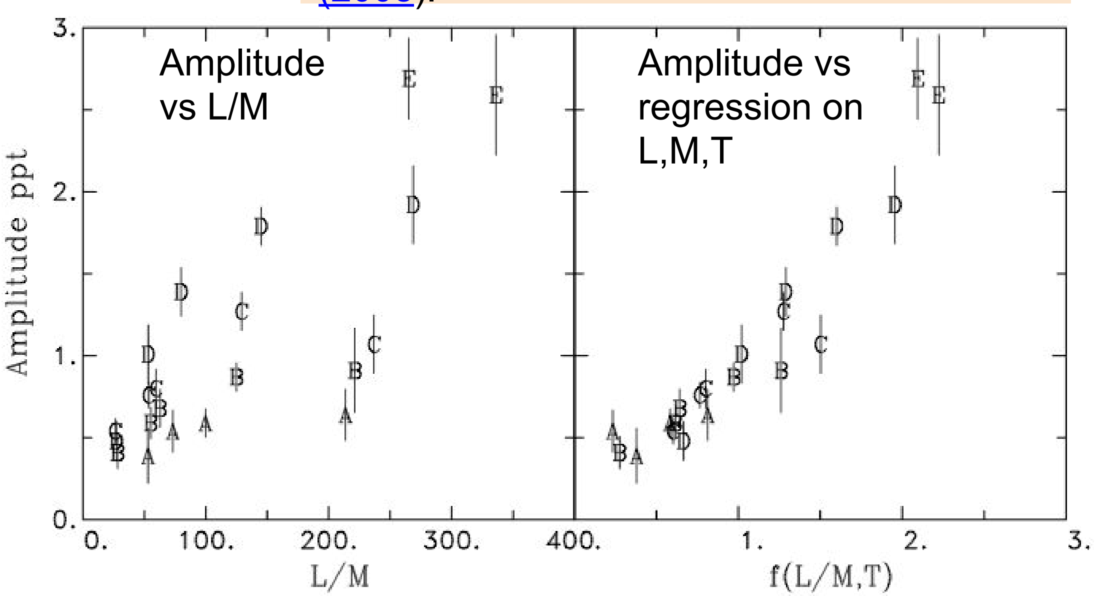
Figures from Chris Britt, Michigan State University; see also [Britt et al. (2015 MN)]

Deep-drill, Variability

- Examples of short-timescale variability in the Szkody et al. (2011) DDF whitepaper (Magellanic clouds and select Galactic globular clusters)
  - Compact objects and the accretion/outflow process
    - Cataclysmic Variables and AM CVn systems
    - Supersoft X-ray sources
  - RGB variability

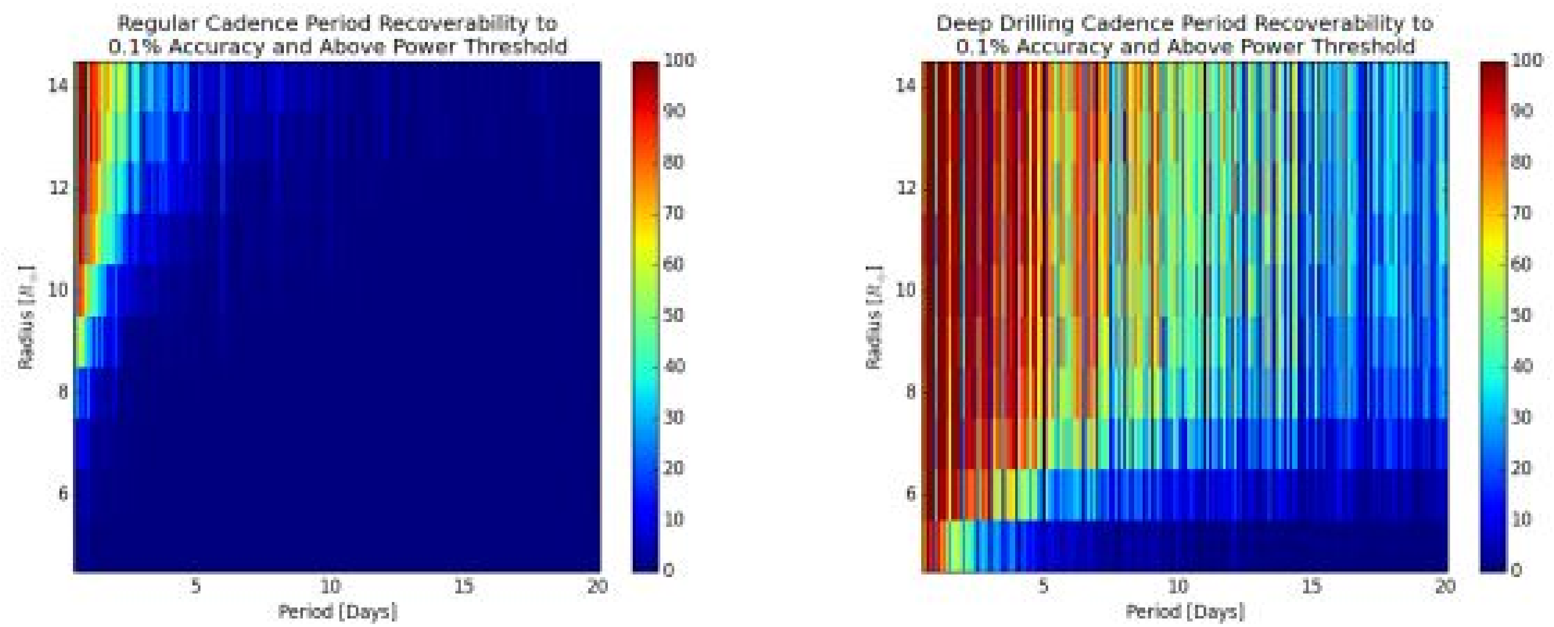
This example of red giant photometric variability on hours-days from Gilliland (2008).





Deep-drill, Variability: Short-period Transiting extrasolar planets

- E.g. Jacklin et al. (2015) comparison of transit recovery in Baseline (left) to Deep drilling (right; also Jacklin et al. 2017);:

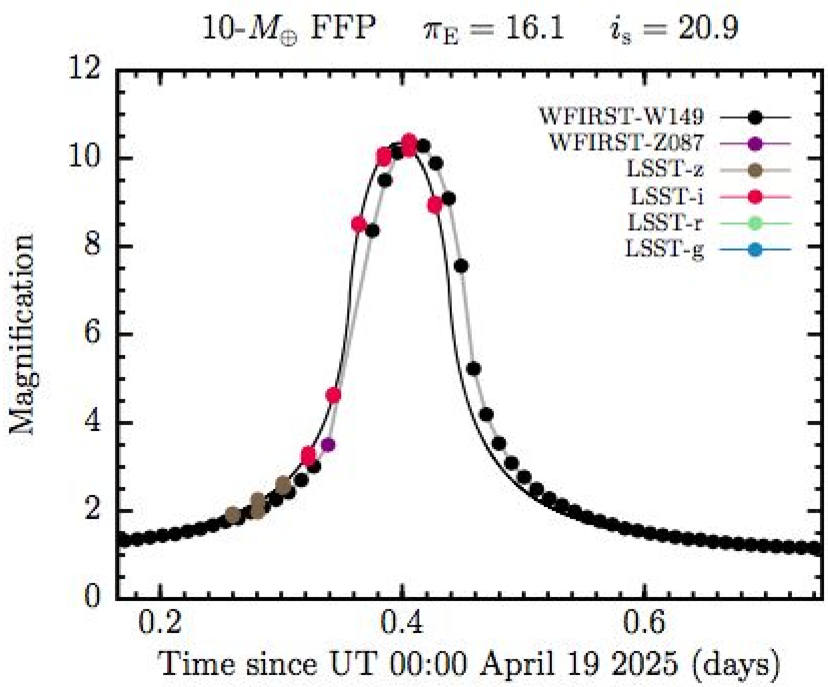


(a) Regular Cadence (b) Deep Drilling Cadence

"At the same time, we find that the LSST deep drilling cadence is extremely powerful: the BLS algorithm successfully recovers at least 30% of sub-Saturn-size exoplanets with orbital periods as long as 20 d, and a simple BLS power criterion robustly distinguishes ~98% of these from photometric (i.e. statistical) false positives."

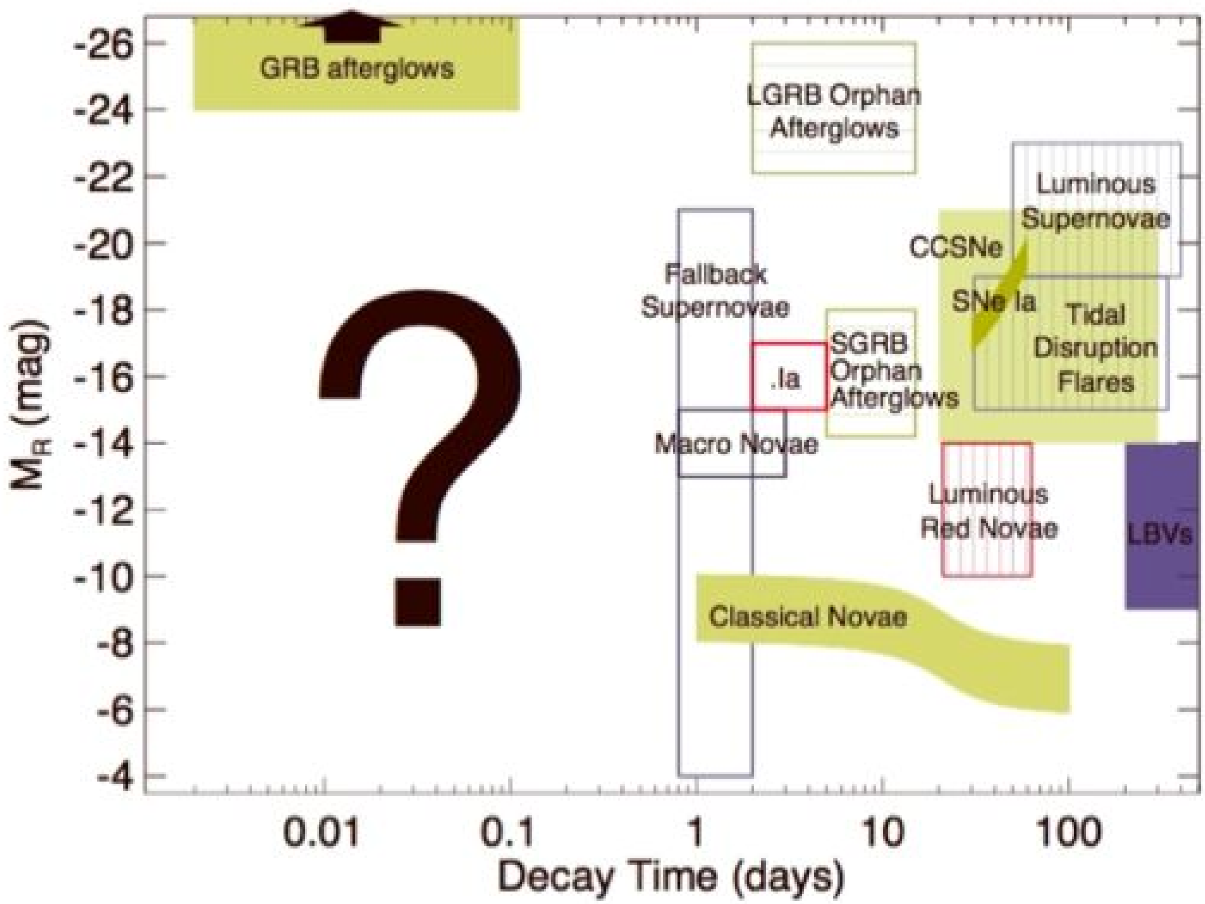
"Deep-drill," variability: Mass function of Free-floating and wide-orbit extrasolar planets

- Example from the Observing Strategy Whitepaper chapter 10.3:
  - 15-30min cadence with LSST simultaneous with WFIRST
  - 1-day cadence with LSST 1 year before and after WFIRST



Category	100 $M_\oplus$	10 $M_\oplus$	1 $M_\oplus$	Total
WFIRST-events	417	127	33	577
$i \leq 23$	88	30	13	131
π_E measured	22	8.2	2.7	32.9
M_L measured	5.9	3.4	1.5	10.8

- Figure 8.6 from the LSST Science Book: Discovery timescales for luminous optical transients and variables



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Legacy datasets for new discoveries