The Kunlun Infrared Sky Survey (KISS)

Jeremy Mould (Swinburne)

Michael Burton (UNSW)

Kilauea August 2015

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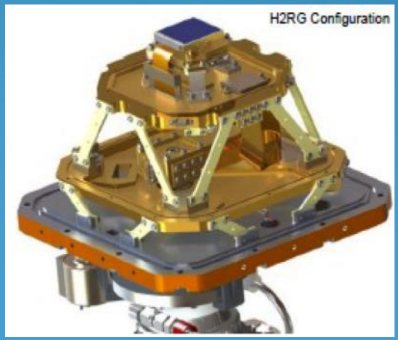

Australian Research Council Infrastructure Grant (LIEF)

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Michael Burton	UNSW
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Lifan Wang	Purple Mountain + Texas A&M
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Michael Ireland	Australian National University
Ji Yang	Purple Mountain Observatory

Australian Government
Australian Research Council

Summary of KISS (AST3-3 – IR)

- **The first exploration of time varying Universe in the IR.**
- Located at Kunlun Station
  - Southern sky available for the duration of the Antarctic winter
- Primary science:
  - Supernovae & the Equation of State
  - Reverberation Mapping and the Physics of AGN
  - Gamma Ray Bursters (super-supernovae)
  - Terminal phases of Red Giants (Miras)
  - Dynamics and Variability in Star Formation
  - Discovery of exo-planets (esp. Brown Dwarfs & Hot Jupiters)
  - Power spectrum of the Cosmic Near-Infrared Background
- KISS is complementary to SkyMapper in that it is infrared.
- KISS is complementary to 2MASS in that it is time sensitive.

An IR camera for AST3-3

- We have demonstrated that the Antarctic plateau is the best site on Earth for infrared and submillimetre astronomical observations.
- By establishing Kunlun Station (Dome A), our Chinese colleagues have presented us with the opportunity to exploit this scientifically.
- ARC LIEF funds allow us to build an infrared camera for their AST3-3 wide field telescope.

Builds on China – Australia Collaboration in Astronomy

- 2012: Astronomy Australia Limited (AAL) signed an MoU on Antarctic astronomy with the Division for Basic Research of the Chinese Academy of Sciences.
- 2013: Australian Government signed an MoU with Chinese Academy of Sciences.
- 2013: An implementation plan agreed on to progress the scientific opportunities offered by:
  - Chinese telescopes at Dome A +
  - Complementary observations using Australian telescopes.
- 2015: Launch of ACAMAR, Australia China Consortium for Astronomical Research

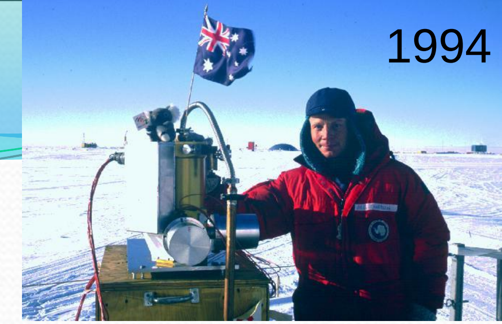
Science Working Groups

- Established in 2013.
- Met first in Australia, then in China that year
- Joint science leaders appointed
- Draft science plans written:
  - Supernovae - Fang Yuan + Xiaofeng Wang (Supernovae), Xuefeng Wu (GRBs)
  - Exo-planets - Chris Tinney + Jilin Zhou
  - Variable Stars - Charles Kuehn + Jianning Fu
  - Synoptic Universe - Paul Hancock + Zhaohui Shang
- Updates at Hong Kong University meeting in March 2015
  - Lifan Wang and Jeremy Mould co-Directors of KISS

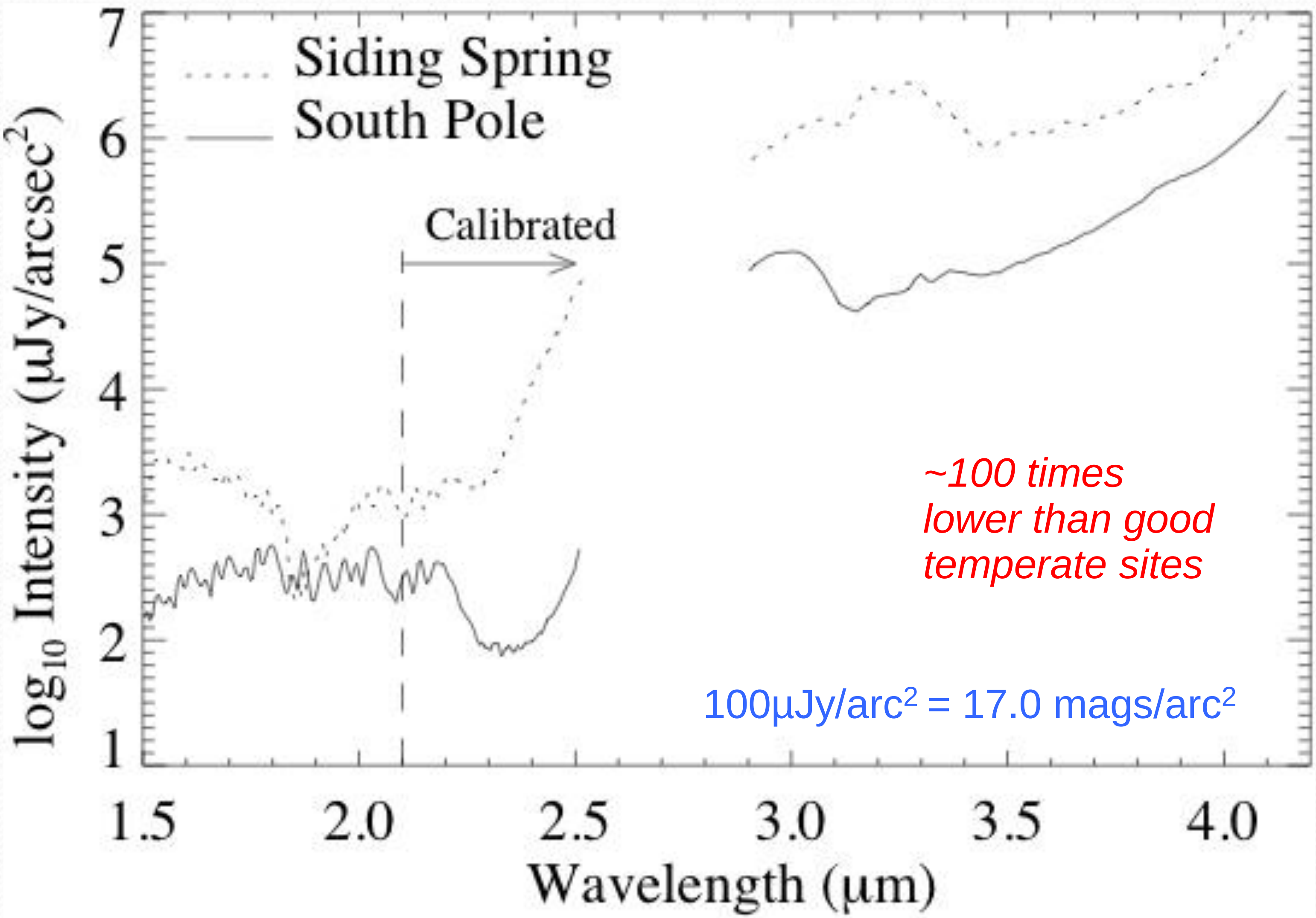
AST3–3–IR Capabilities
(thanks to Jon Lawrence & Xiangyan Yuan)

Parameter	Value
λ ($\Delta\lambda$)	2.36 (0.18) µm (K_{dark})
Diameter	68cm
Image Quality	1.9″ (1.1 x diffraction limit)
Array	2048 x 2048, 18µm pixels H2RG Teledyne preferred
Sampling	1″
Field of View	30´ x 30´
Achieving:	
Background limited integration time	25 secs
1σ 25 seconds	18.0 mags.
10σ 1 hour	18.5 mags.
Saturation limit (in 25 sec)	K_{dark} = 11.1 mags.
With Background Sky [South Pole]	K_{dark} = 17.0 mags/arc^2=100µJy/arc^2

Why K_{Dark}?



IRPS mgb



Ashley et al. 1996, Phillips et al. 1999

Exploits several key Antarctic Advantage

- Low background (~100 x lower than temperate sites)
- High photometric precision
- **High time cadence**

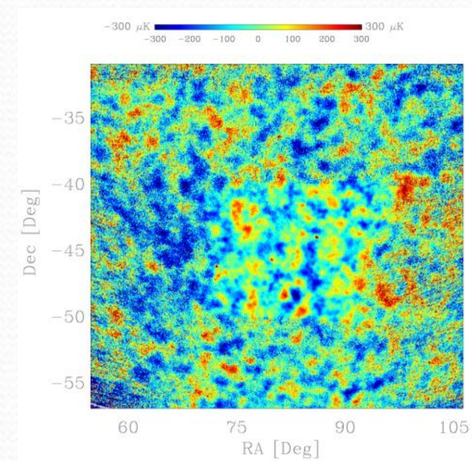
⇒Deep, wide field, high cadence, high precision imaging at the diffraction limit

2.4μm is the longest wavelength that truly deep imaging can be undertaken from the Earth

Sample Science for KISS

The Equation of State for the Universe

But we now also know that the Universe is accelerating?!

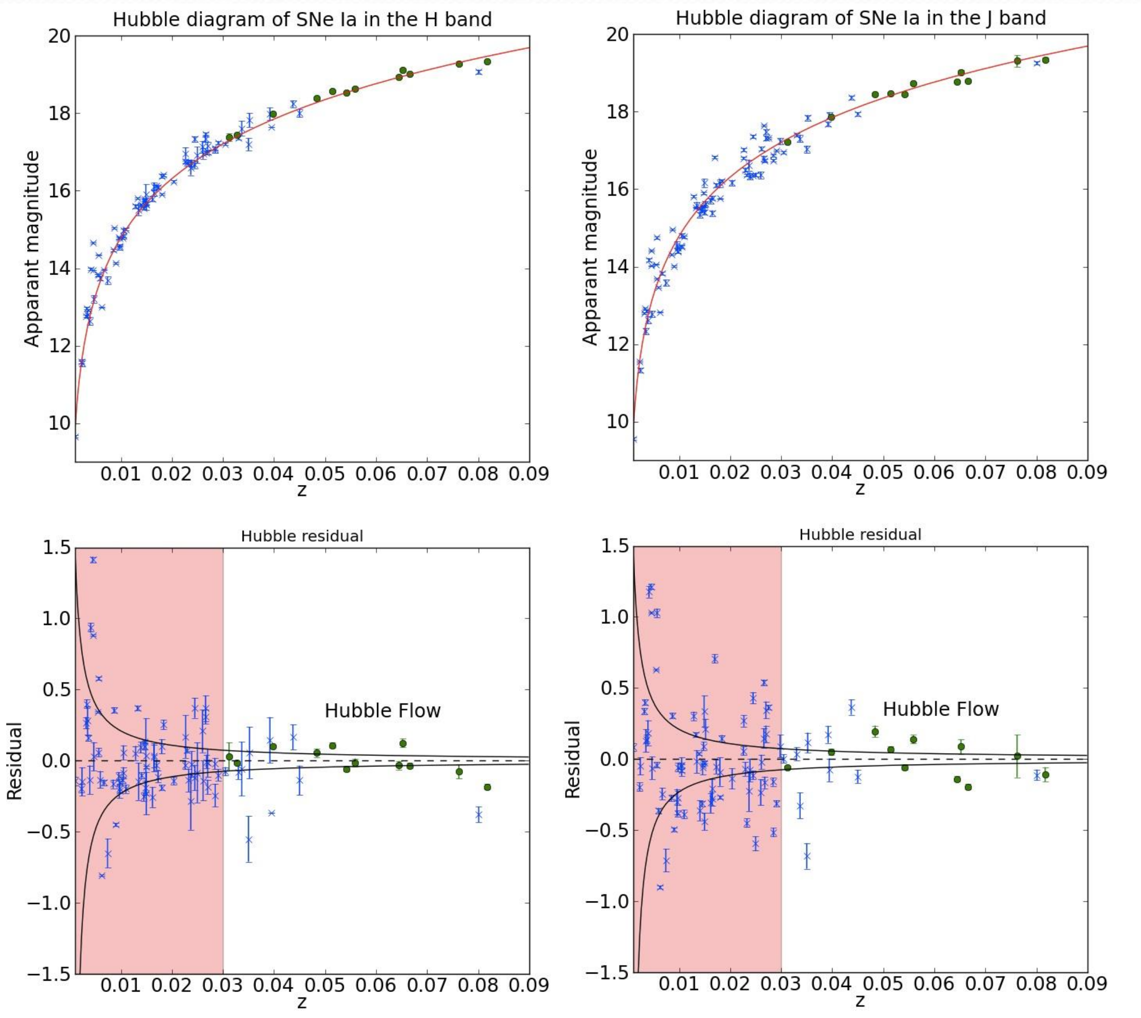


de Bernardis
et al 2000

Supernovae and the Distance Scale

- Demonstration that Universe is flat was a flagship radio astronomical observation from Antarctica (de Bernardis et al. 2000)
- Vacuum energy density responsible and acceleration of the Universe used SN standard candle at optical wavelengths (Perlmutter et al. 1999, Riess et al. 1998)
  - $\Rightarrow$ 2012 Nobel Prize for Physics.
- SNIa standard candle is more accurate in the NIR (Barone-Nugent et al. 2012).
- Race is now on to distinguish Einstein vacuum energy from other possible equations of state.
- Requires accumulation of hundreds of accurate SNIa measurements.
- SkyMapper (Schmidt et al. 2005) is devoted to this.
  - But ill-equipped for IR follow-up of these SNe.
- AST3-3–IR will fill this gap, and supplement SkyMapper SN discoveries with its own detection of transients within a few hundred Mpc.
  - SNIa peaks at $K = 17.5$ at 200 Mpc.
  - ~200/yr Ia SNe detectable from the South Pole with $K < 17.5$ mag based on SDSS statistics

IR SN are best!



Barone-Nugent et al. 2012

Reverberation mapping: AGN

- A technique for measuring the radius of a region very close to the central SMBH that echoes its activity.
  - In IR the dust morphology of the AGN is probed.
- Schnulle et al. (2013) measured NGC 4151 monthly and modelled a static distribution of central (~0.1pc) hot dust
  - Associated stars have central velocity dispersion measurable with ANU's WiFeS and ESO's SINFONI, together with the radius, this yields the mass of the Black Hole.
- Goal of infrared reverberation mapping is to characterise dust in central disk or torus as a function of BH mass and galaxy dynamics.

GRBs – Super-supernovae

Ultra-high redshifts (e.g. z~20) require the Infrared to be found

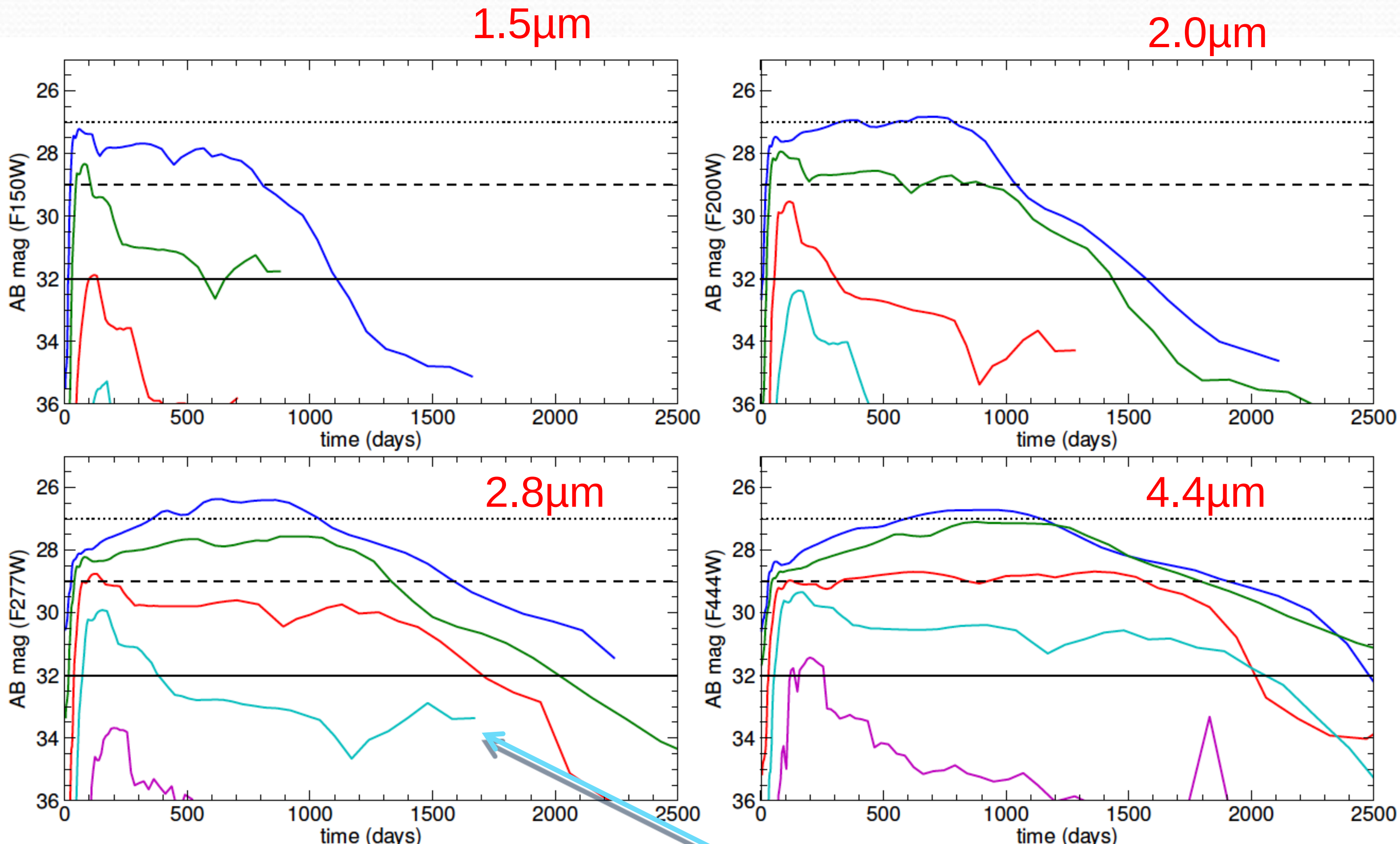


FIG. 4.— PPI SN NIR light curves at $z = 7$ (blue), 10 (green), 15 (red), 20 (cyan) and 30 (purple). The horizontal lines are photometry limits for WFIRST (dotted), WFIRST with spectrum stacking (dashed), and *JWST* (solid).

Whalen et al. 2014

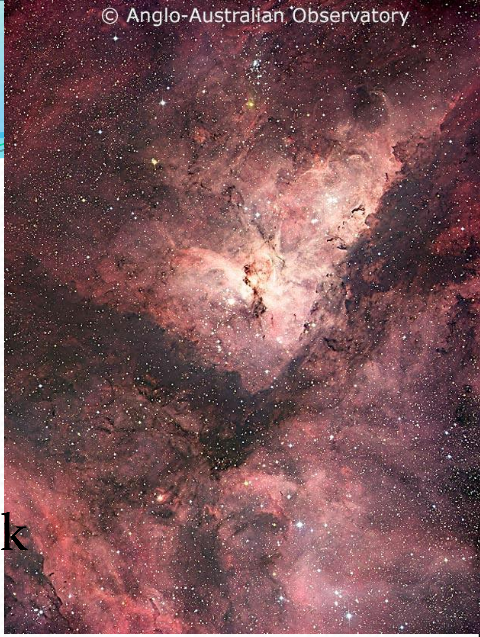
Supernovae in Starbursts

- Should have ~100 x the SN-rate of Milky Way
  - But buried within dusty nuclei – hard to see
- Need optical to define light curve of AGN variability
- Then IR to find the SN signal
- ⇒Uses both AST3-1/2 & AST3-3
  - i.e. a parallel survey program in the optical and IR

Terminal Phases Stellar Evolution Variable Stars – Miras

- Terminal phase for intermediate mass stars is Miras
  - Heavy mass loss surrounds ~10^5 $L_\odot$ star ➔ optically thick dust.
- Precursor optically thin phase well studied: Magellanic Clouds
  - e.g. Wood et al (1999), Bessell et al (1996), Aaronson & Mould (1982)
- Cadence of the DENIS survey (Cioni et al. 2000) insufficient to discover the dustiest cases
- Only OH/IR stars (Wood et al. 1992) discovered at radio wavelengths have been available to elucidate the terminal phase before the star becomes a PN.
- With K < 17.5 AST3-3IR can survey LMC/SMC to tip of RGB.

Star Formation: the gains



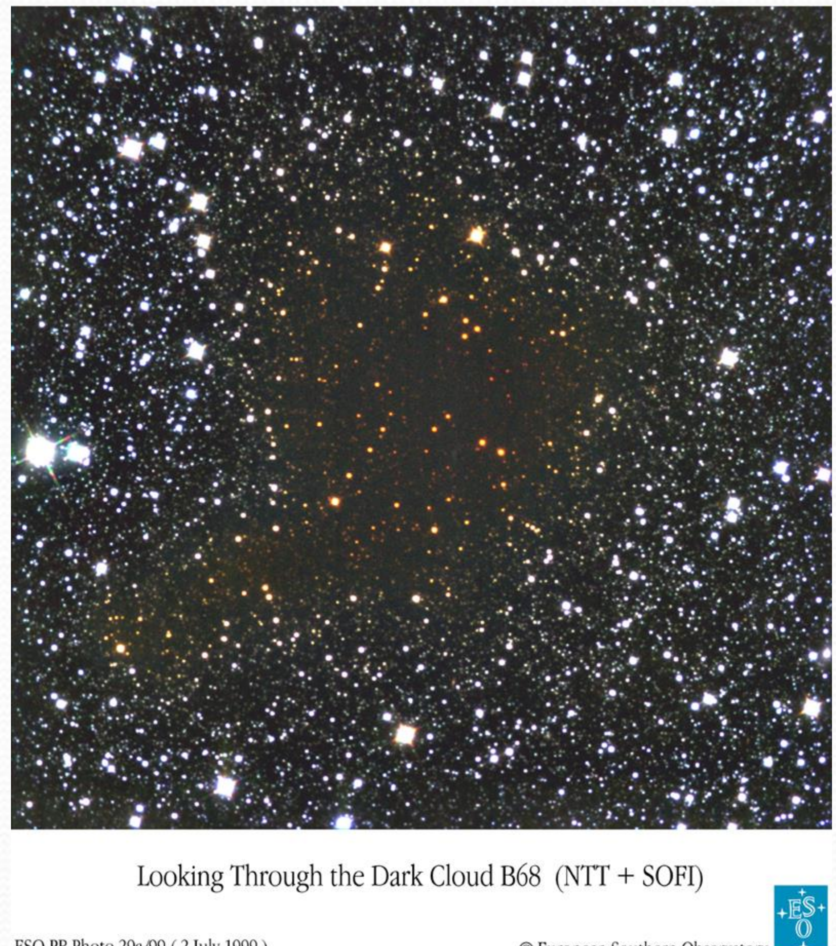
- Extinction is one-tenth of the optical at K_{dark}
  - Ability to peer inside molecular clouds
- Wide-field for a small telescope & large-array
  - Star clusters generally spread of tens of arcminutes
- High cadence
  - Allow searches for variability

$\Rightarrow$ *KISS opens a new regime in time exploration of stellar variability associated with star formation in the infrared*.

An example: Barnard 68

Optical

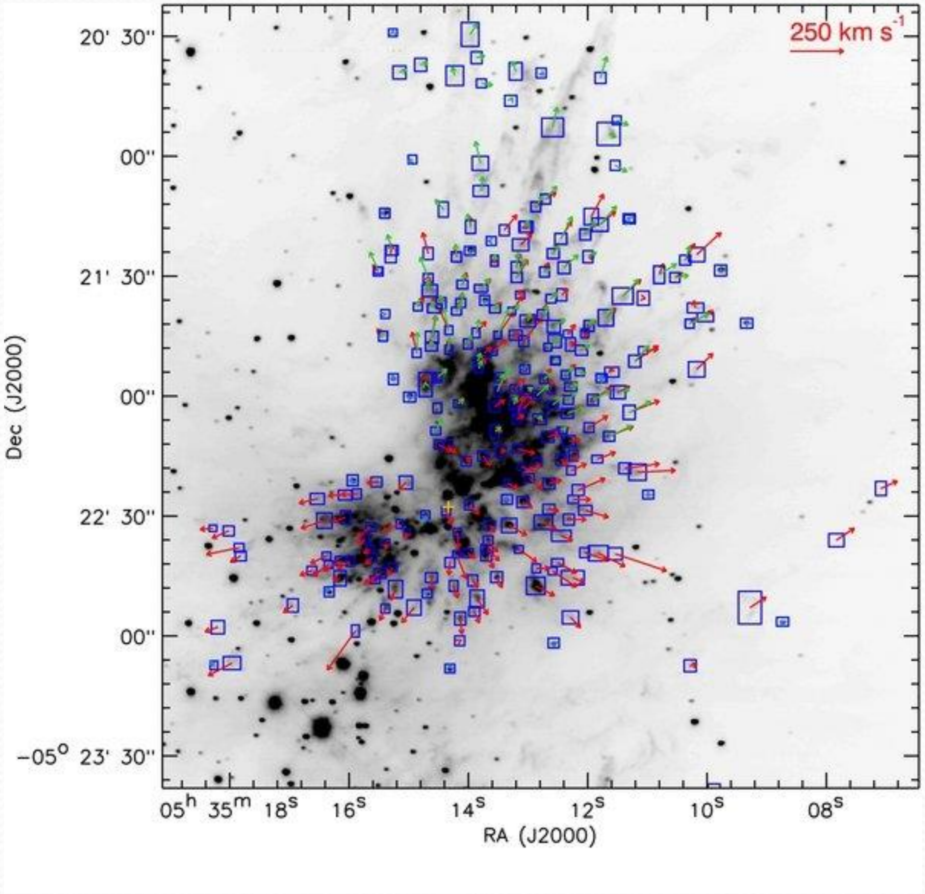
Near-infrared



Dynamical Interactions in Massive Star Formation

The Bullets of Orion **in motion**

Allen & Burton, 1992



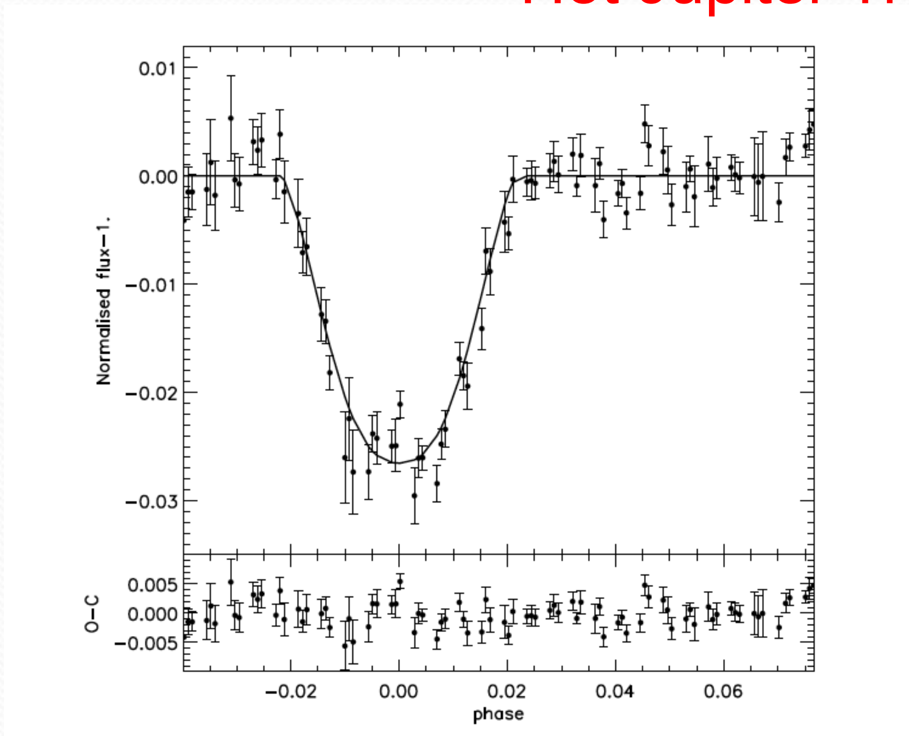
Bally et al. 2011

Brown Dwarfs and Hot Jupiters

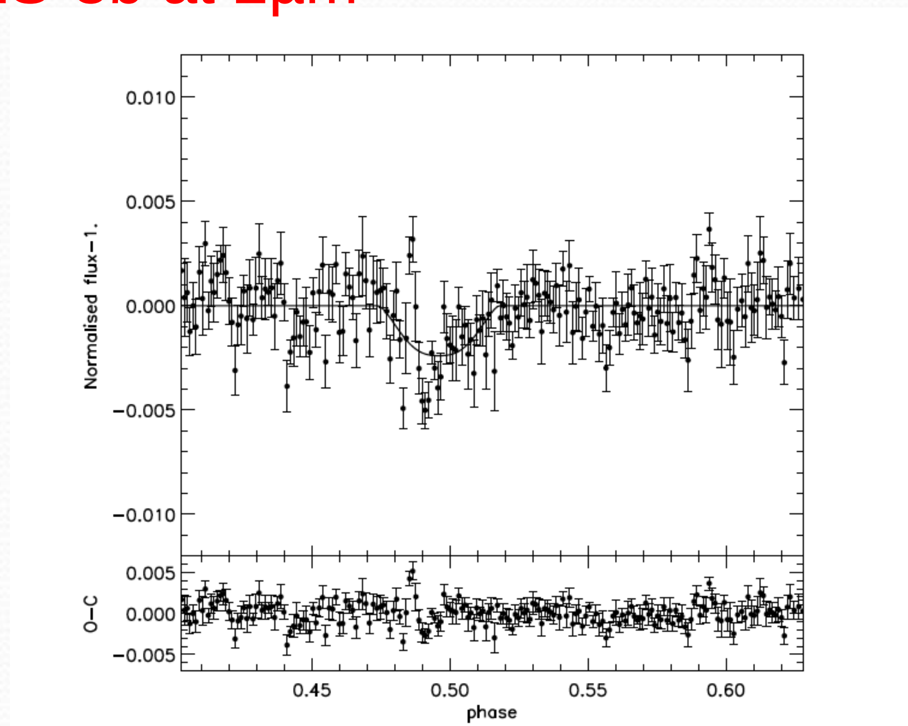
- At 2.4μm spectrum peaks for T~1,000-1,500K
- Use the transit technique

de Mooij & Snellen, 2013

Hot Jupiter TrES-3b at 2μm



Primary Transit

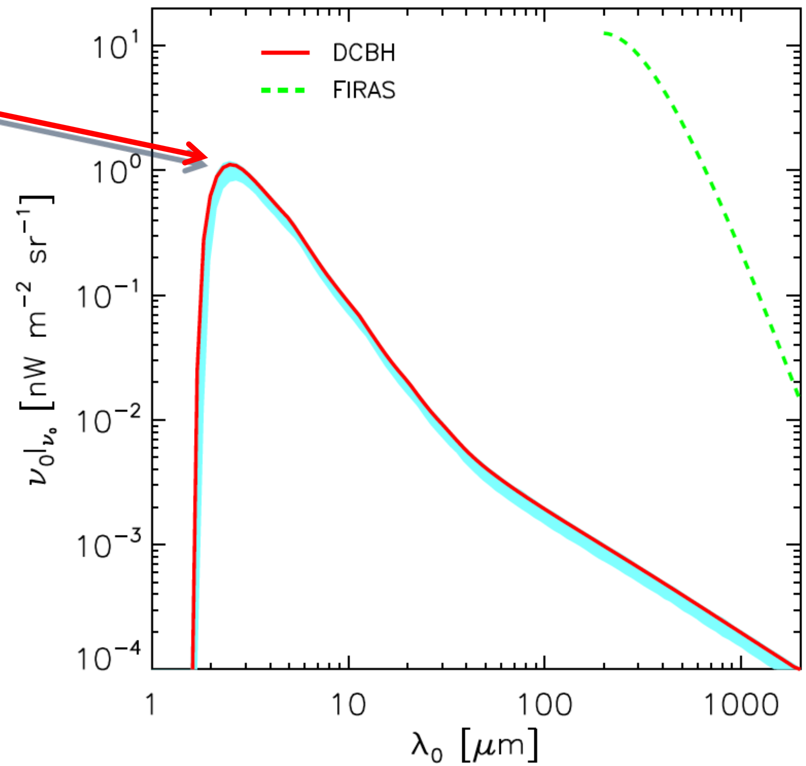


Secondary Eclipse

Cosmic Infrared Background
Signatures of first black holes?

~10^{-2} µJy/arc^2
c.f. Sky @ 10^{+2} µJy/arc^2

K_{dark} the best place to search



Yue et al. 2013

Fig. 4.— The contribution (solid) of DCBHs to the CIB with our best-fit parameters and the measured Cosmic Far-IR Background at 200-2000 μm (dashed) fitted by Gispert et al. (2000). Colored areas indicate regions corresponding to 1σ dispersion around the mean values of $(z_{\rm end}, M_{\rm BH,seed}, t_{\rm QSO})$.

Cosmic Infrared Background

Power spectrum of fluctuations on galaxy halo to LSS scales

- Epoch of reionization models make predictions about spatial scales of bursts of star formation that drive process
- These models predict an anti-correlation with 21 cm maps of the EoR (neutral vs ionized)
- These maps will become available from MWA and LoFAR by the time of KISS deployment
- After point source masking, maximizing anti-correlation will allow us to remove terrestrial thermal foreground, leaving variance and power spectrum for analysis

Timeline

ID	Milestone Completion	Due Date
5	Contract Negotiation (Detector)	September 2015
6	Purchase Order (Detector)	October 2015
7	PDR (De-Scope Option)	December 2015
8	SAIL Readiness Review at SUT	July 2016
9	Procurement Lead-time (Detector)	November 2016
10	SCAR AAA can hold an international KISS user needs mtg	
11	AIT	Feb. – June 2017
12	Camera Pre Delivery Review	Late 2017
13	Shipping to Antarctica	Nov. 2017
14	Commissioning	Jan. 2018
15	Science Survey commences	Feb. 2018