Infrared Background, Anisotropies & Spectral Line Intensity Mapping

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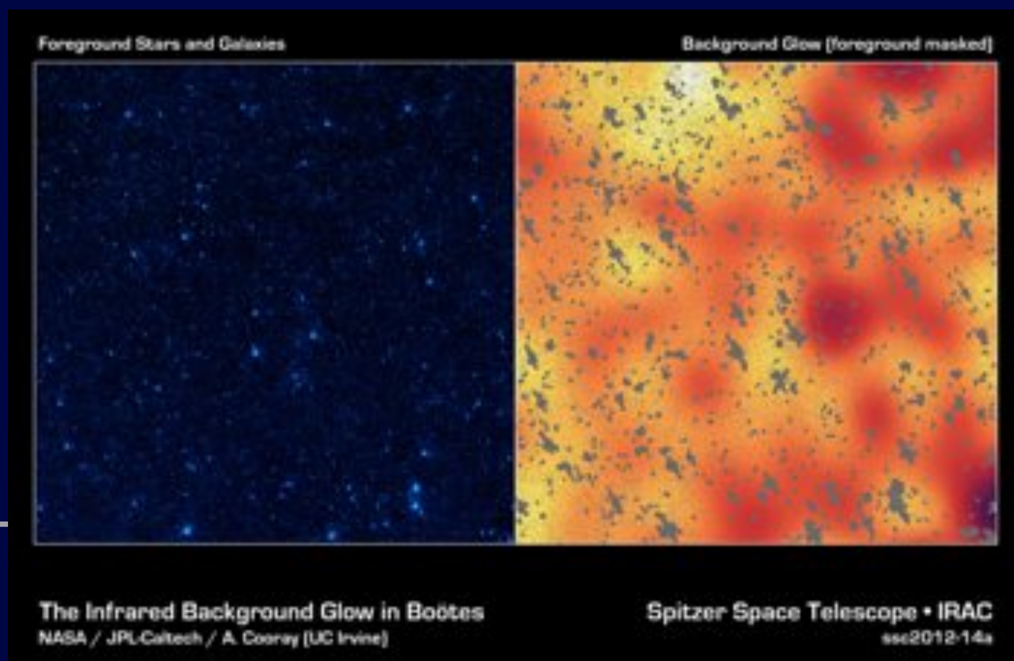
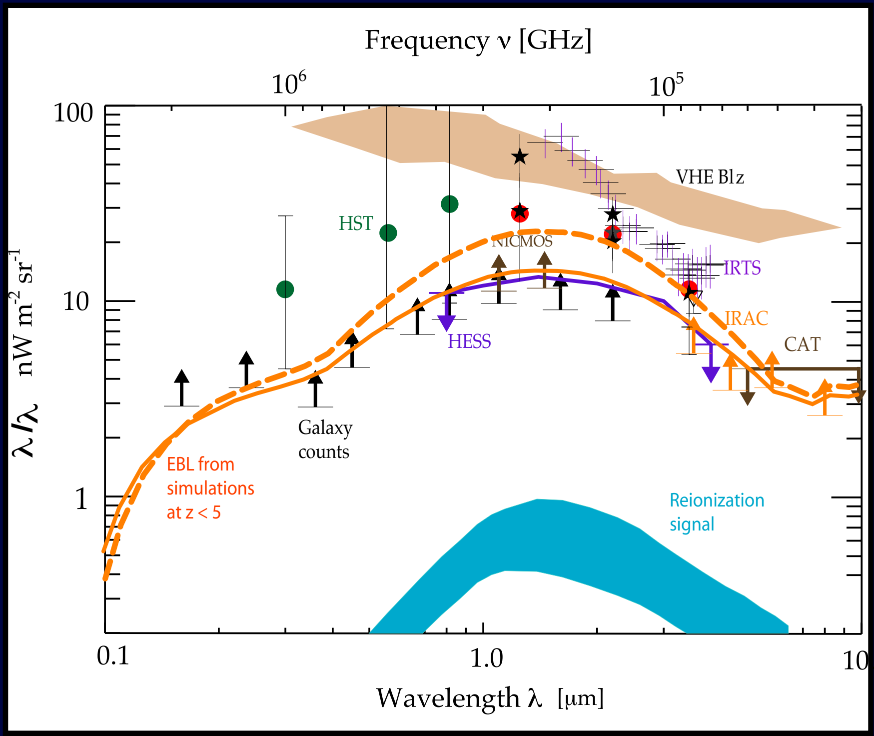
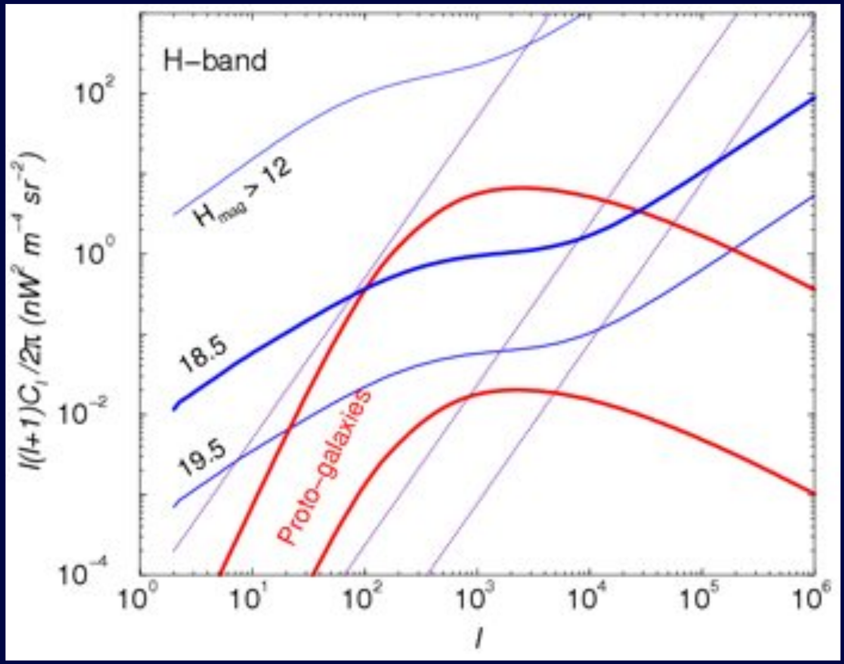


Outline

- Fluctuations in the near-IR background with Spitzer and Hubble, and CIBER
- Spectral Line Intensity Mapping in near-IR (expanding the science case of WISH and WISHspec)



High-z galaxies? Study IRB anisotropies.

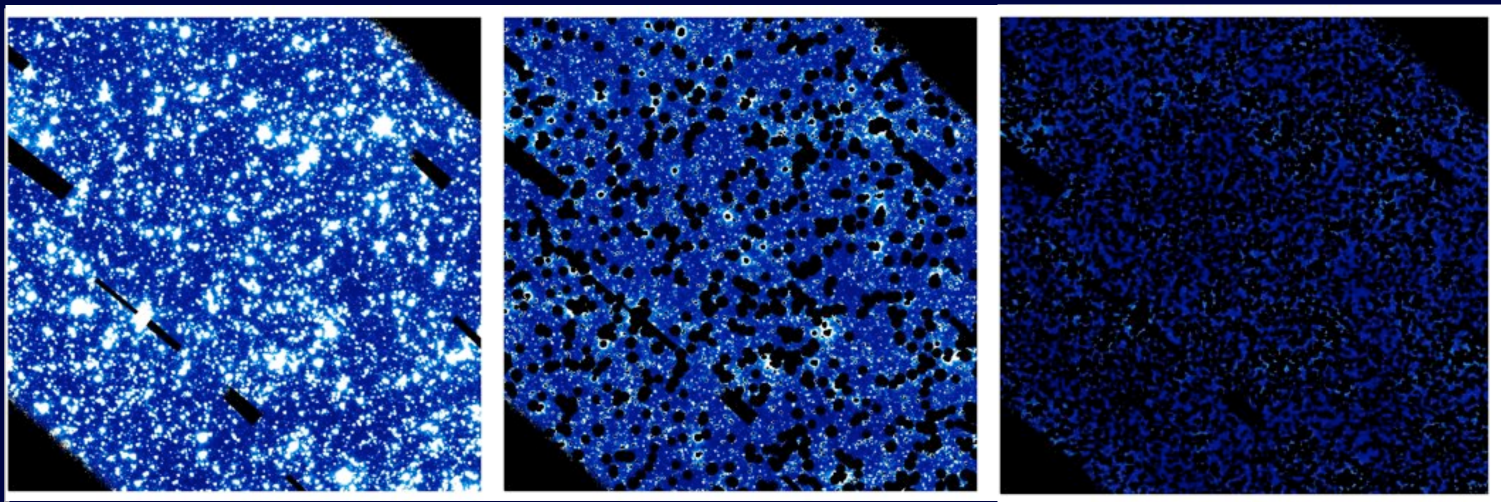


Total IR EBL intensity uncertain by at least a x10 at 1-2 microns

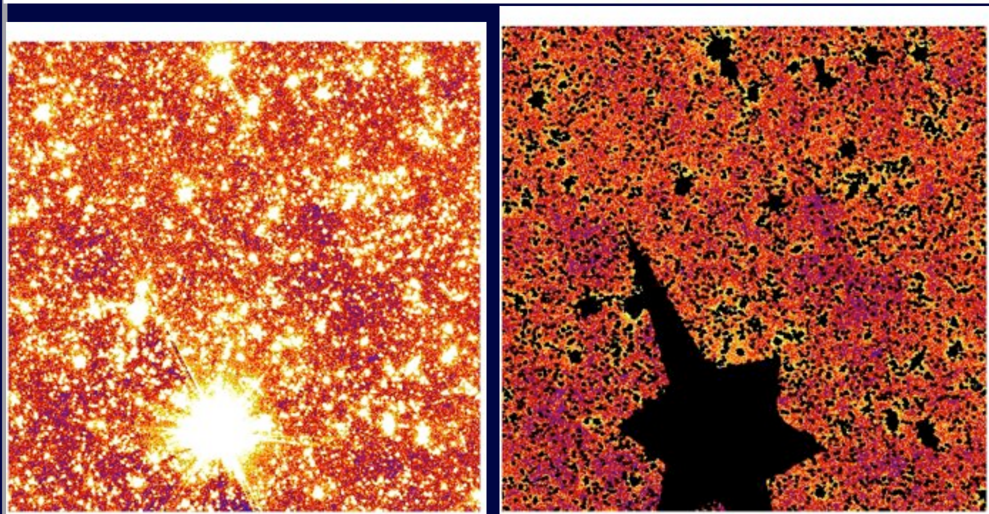
Instead of absolute EBL, study IR background anisotropies as a probe of faint galaxy populations.

(Cooray, Bock, Keating, Lange & Matsumoto 2004, ApJ)

IR Background Fluctuations Measurements



GOODS
CDF-S



COSMOS

What do we do?

Measure statistics of “empty” pixels.

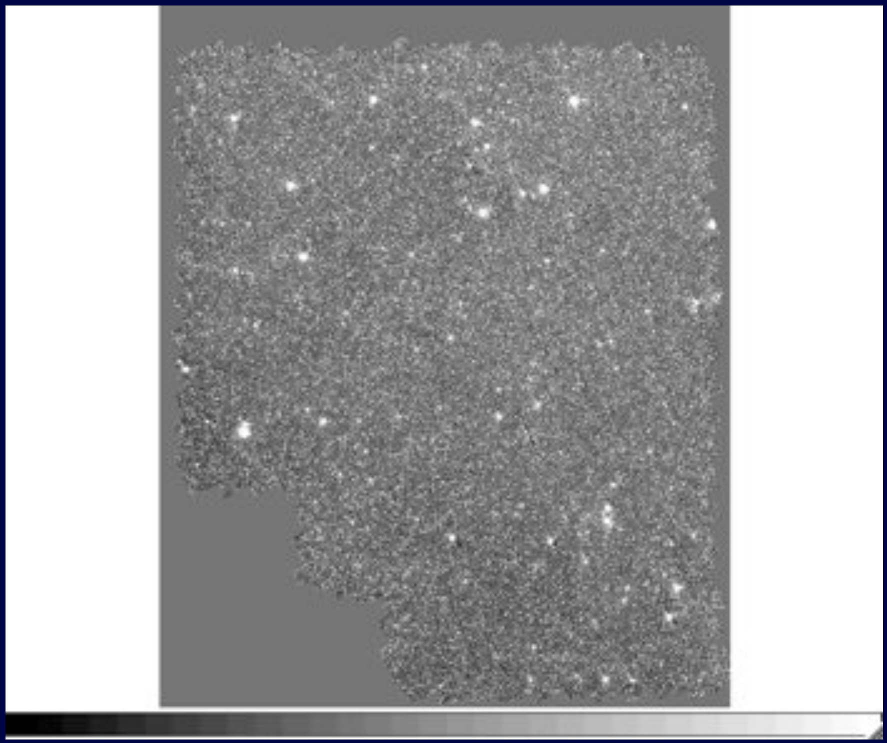
If unresolved faint galaxies are hidden in noise, then there is a clustering excess above noise

Challenges: > 10 million of pixels (higher complexity than analyzing CMB data.)

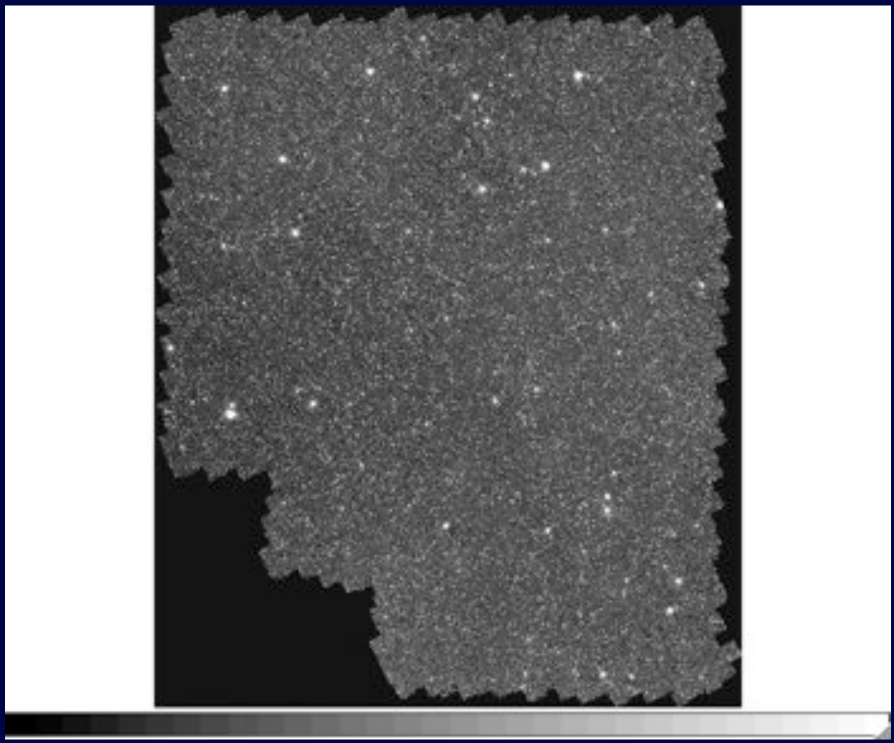
We also mask > 50% of pixels (GOODS we masked 70% of pixels).

Techniques to handle mask - borrowed from CMB analyses.

IR Background Fluctuations Measurements



Standard *Spitzer* software, MOPEX

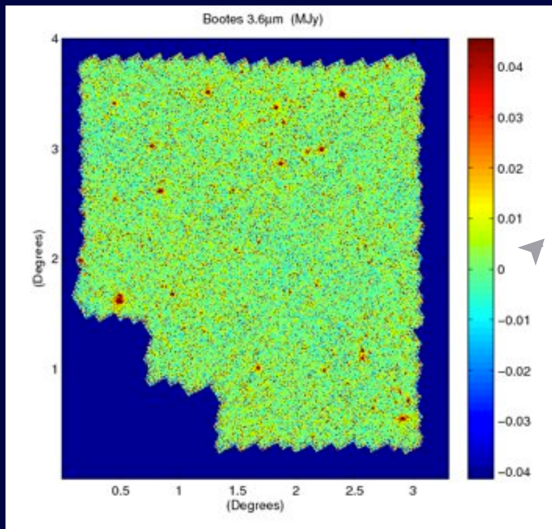


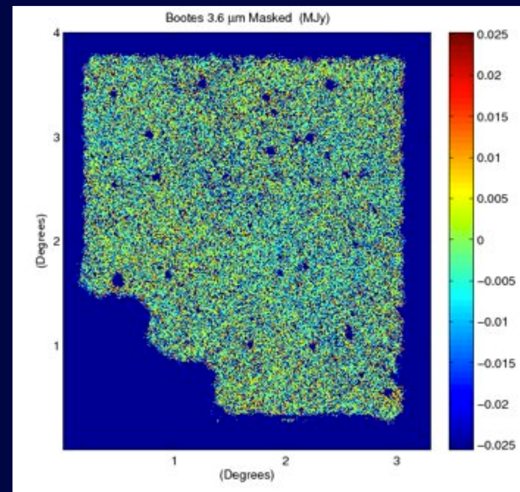
Our self-calibrated mosaic

Self-calibrated mosaics are aimed at preserving the background, unlike MOPEX and HST multi-drizzle for WFC3. Based on works by Fixsen et al. 1998 & Arendt et al. 2010 (Our internal code is cross-checked against Rick Arendt's routines).

Spitzer Background Fluctuations in SDWFS

Cooray et al. 2012, Nature, 490, 514

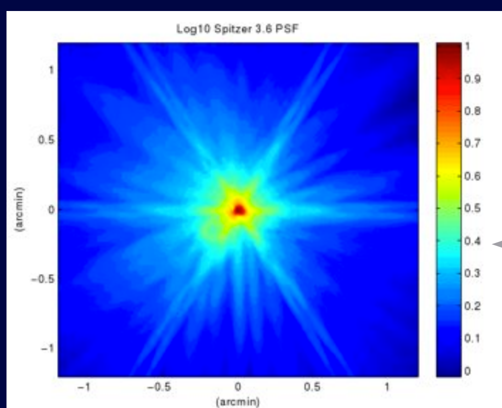




Mask map. (Sextractor)

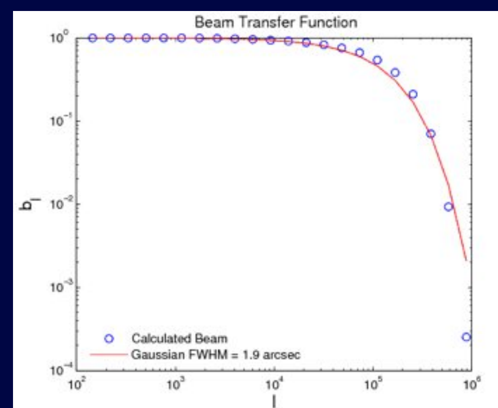
(Epoch 1 + Epoch 2) X (Epoch 3 + Epoch 4)

Cross-Correlate Coadded Epochs



Fourier Transform

PSF



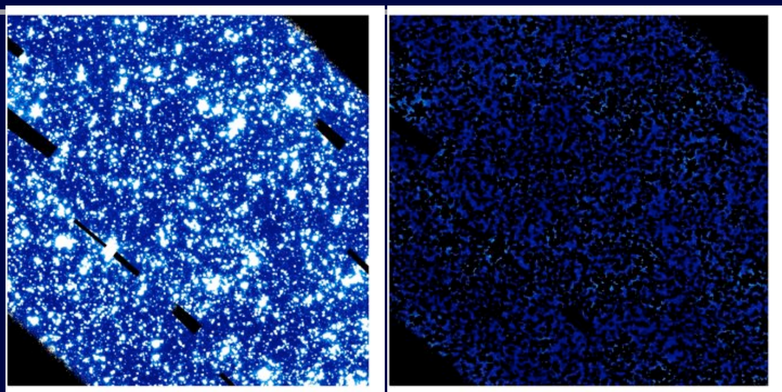
BEAM TRANSFER FUNCTION

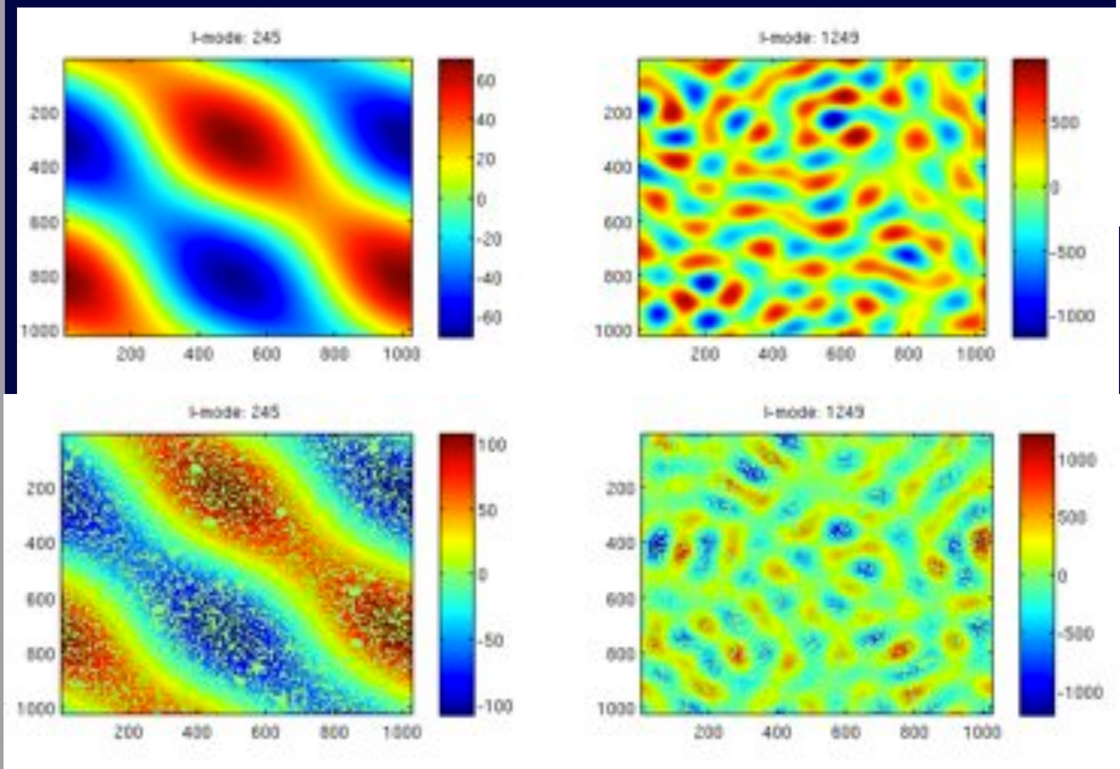
(Epoch 1 - Epoch 2) X (Epoch 3 - Epoch 4)

Jackknife For Noise Errors

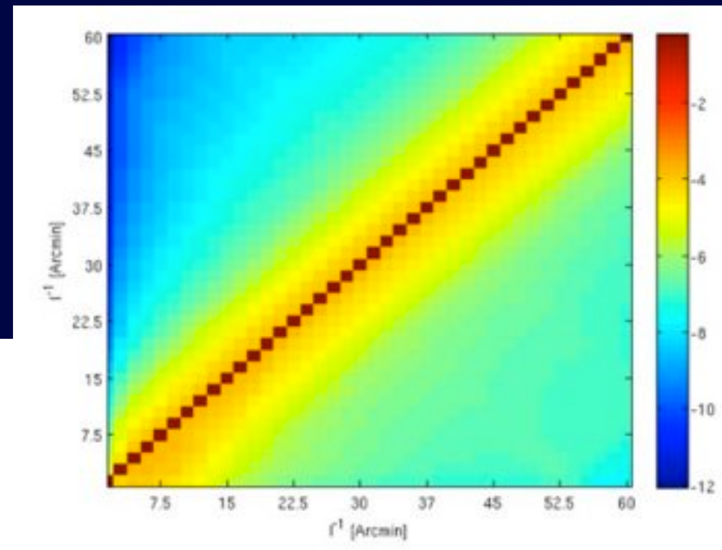
Spitzer Background Fluctuations in SDWFS

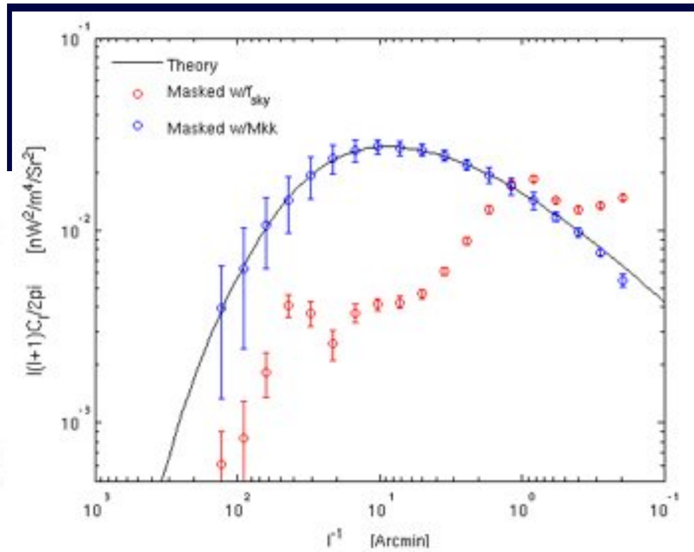
Cooray et al. 2012, Nature, 490, 514





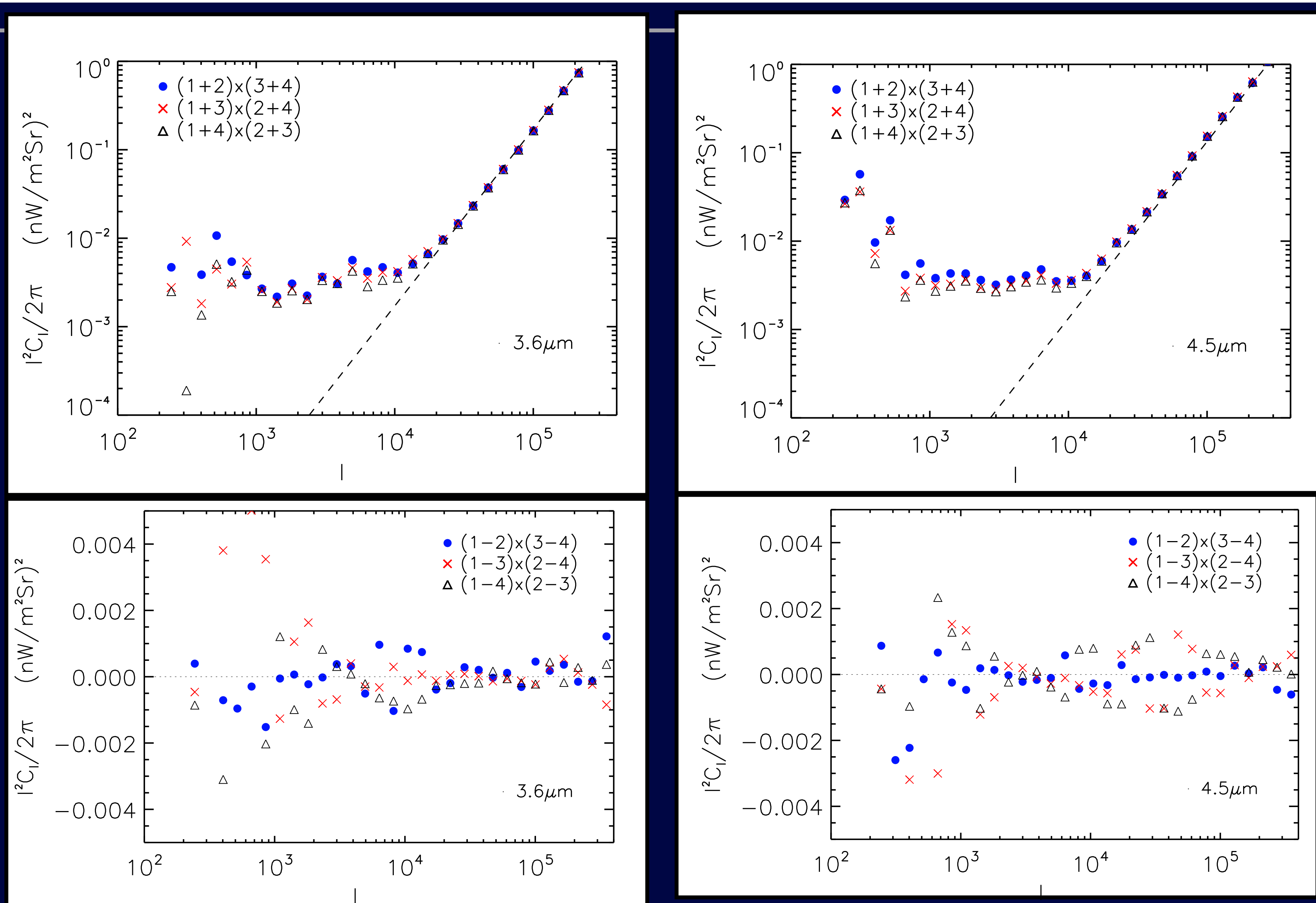
The Matrix itself.





Mode-coupling due to masked sources

Cooray et al. 2012, Nature, 490, 514

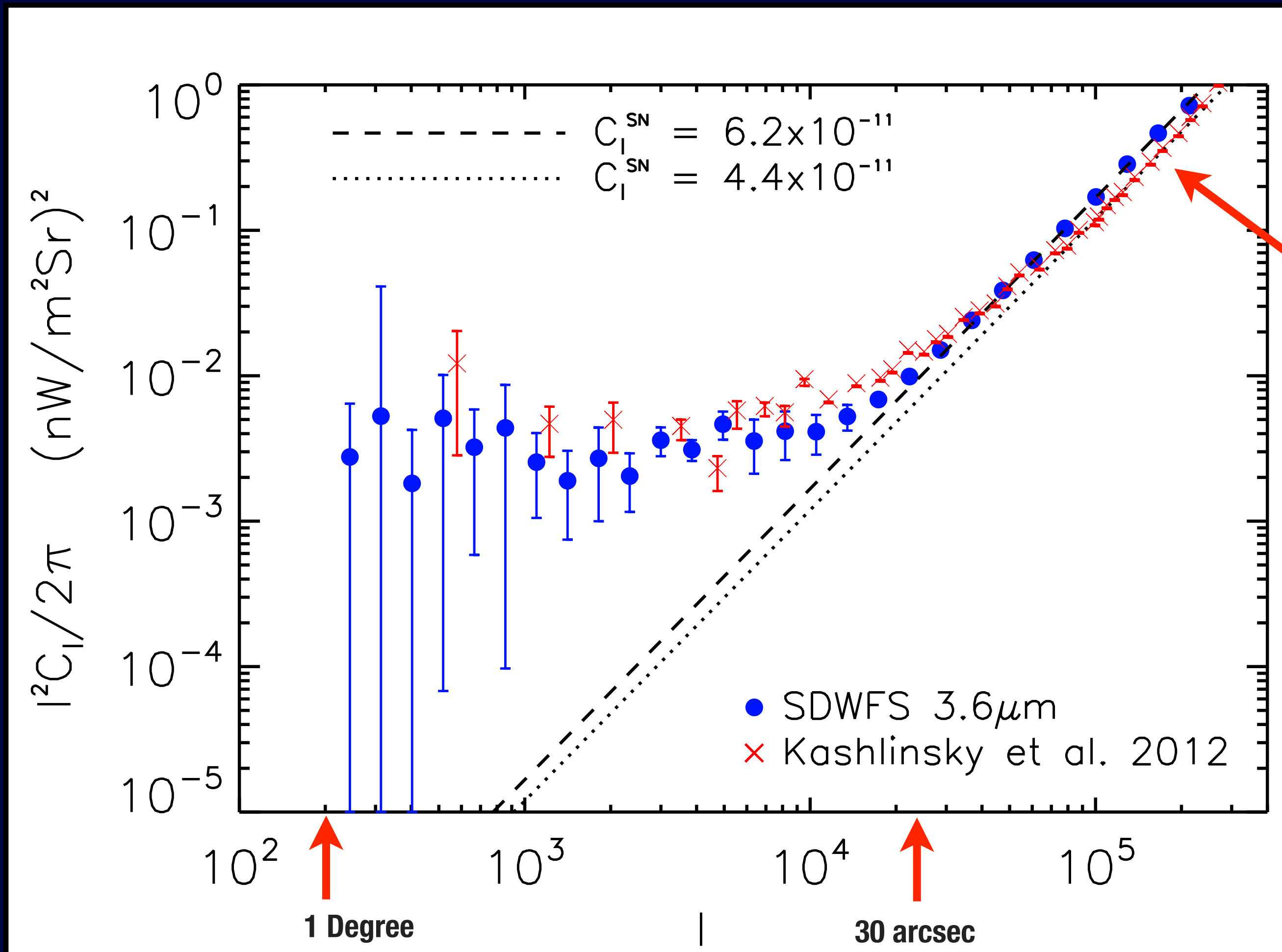


Spitzer Background Fluctuations in SDWFS

Cooray et al. 2012, Nature, 490, 514

Spitzer fluctuations are real! *Not an instrumental systematic nor zodiacal light*

Its extragalactic, repeatable, time-independent.

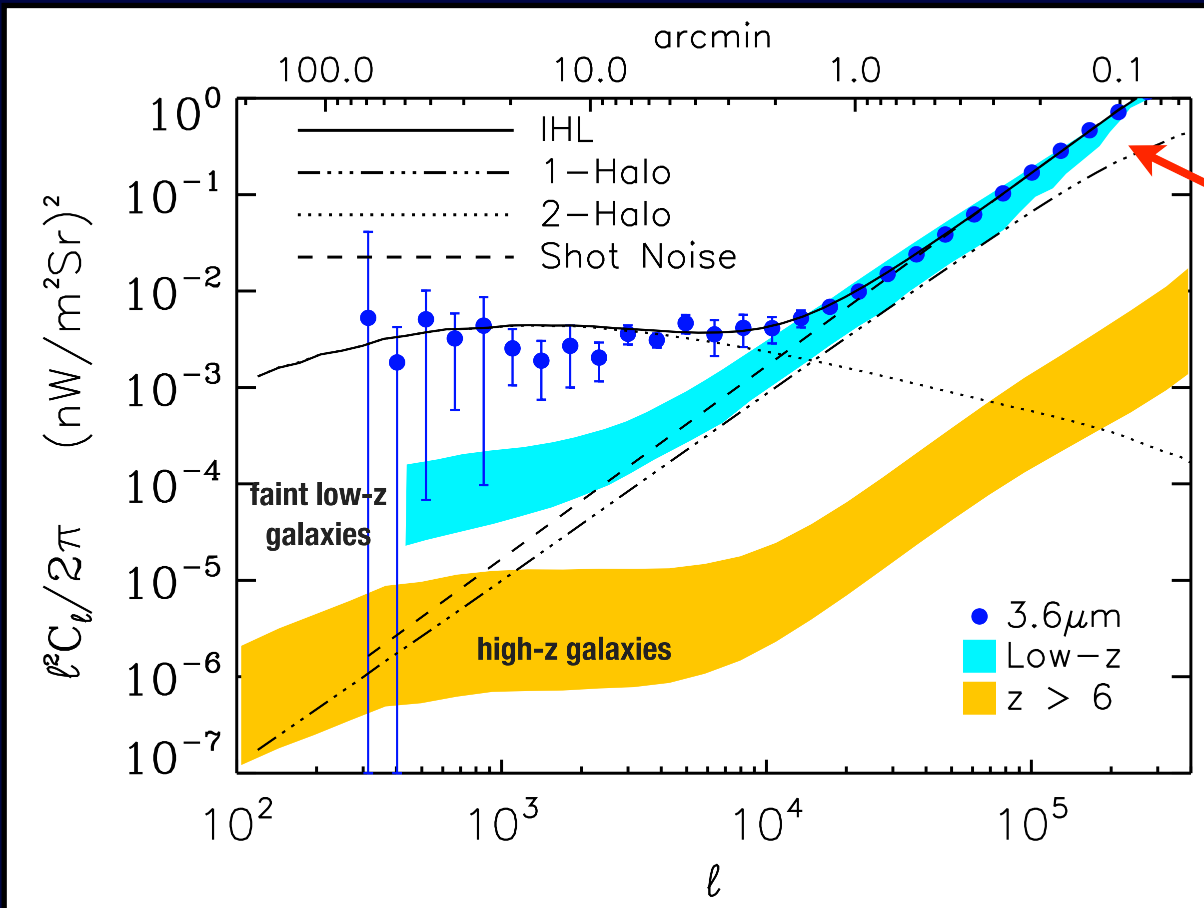


Kashlinsky et al. SEDS data are deeper than SDWFS (so more point sources are masked)

Spitzer Background Fluctuations in SDWFS

Cooray et al. 2012, Nature, 490, 514

What is the origin of these IR fluctuations?



Measured shot-noise agrees with prediction for faint galaxies below the detection threshold (Helgason et al. 2012)

Argues against a new source population to explain the observations

Spitzer Background Fluctuations in SDWFS

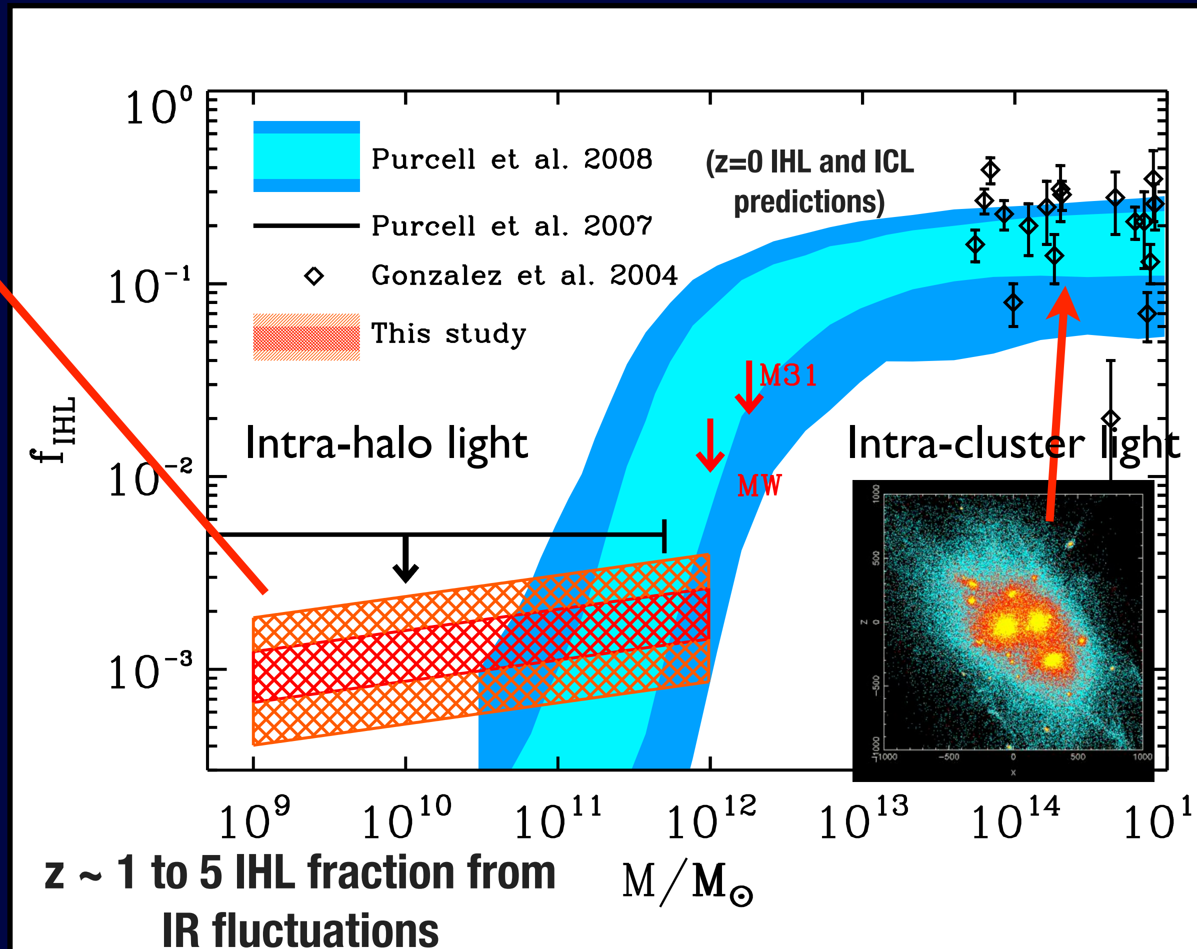
Cooray et al. 2012, Nature, 490, 514

What is the origin of these IR fluctuations?

Intra-halo light

Intrahalo light:
stars outside of the galactic disks and in the outskirts of dark matter halos due to tidal stripping and galaxy mergers.

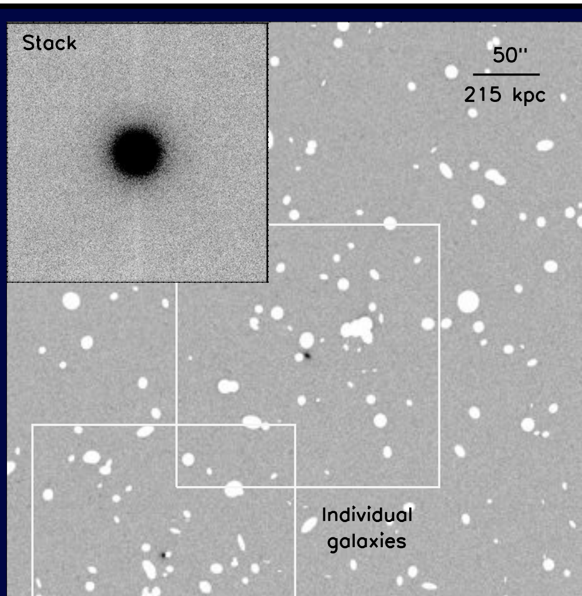
Simulation/theory predictions:
Purcell et al. 2007
Watson et al. 2012

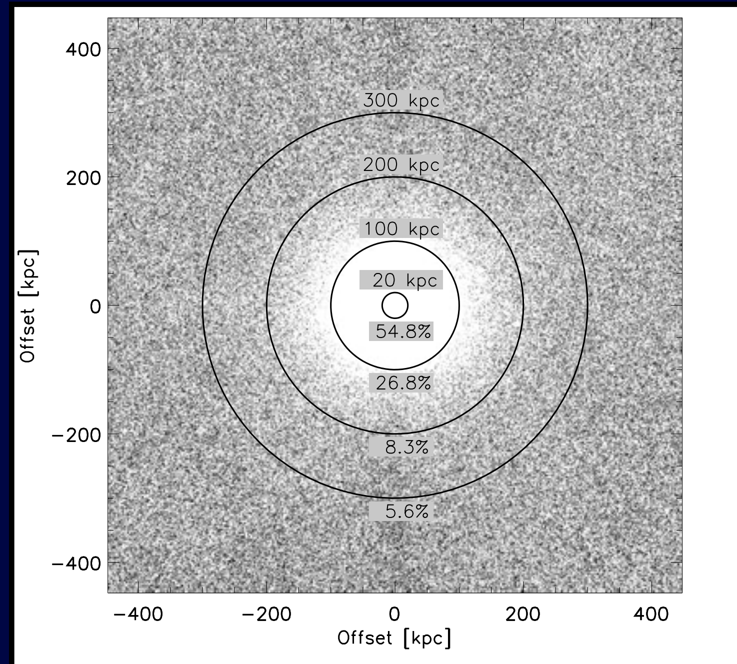


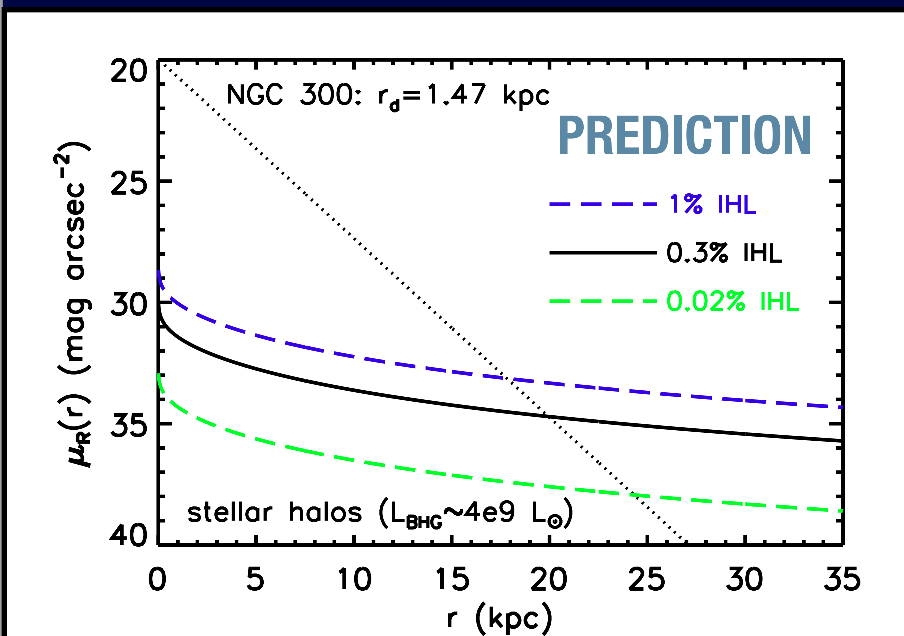
Intra-halo light in galaxy-scale dark matter halos

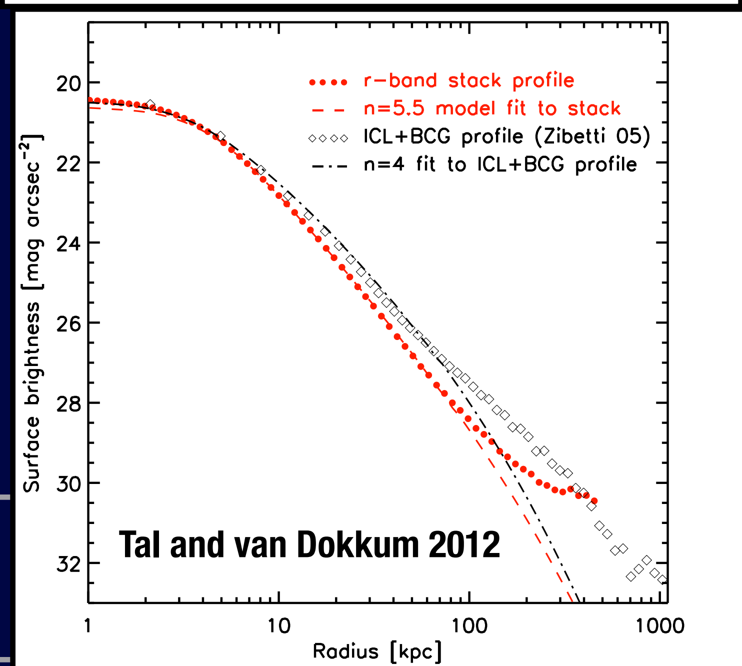
Cooray et al. 2012, Nature, 490, 514

SDSS stack of 40,000 galaxies at z=0.3



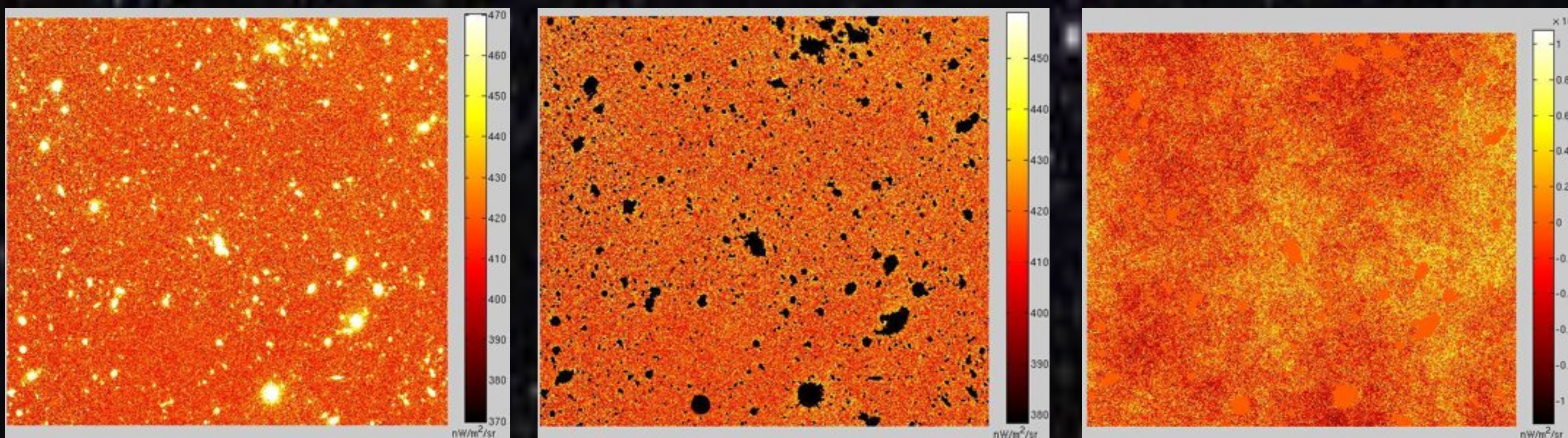






Reionization signal in IR fluctuations?

CANDELS, a multi-cycle program with Hubble Space Telescope.
WEBSITE: CANDELS.UCOLICK.ORG



Field	Area	Program ID	Dates
UDS	210 sq arcmins	12064	11/08/10-11/25/10
		12064	12/27/10-01/10/11
EGS	90 sq arcmins	12063	04/02/11-04/08/11
		12063	05/22/11-06/02/11
COSMOS	210 sq arcmins	12440	12/06/11-02/25/12
		12440	01/23/12-04/16/12
COSMOS	1.8 sq degrees	9822/10092	10/03-5/04

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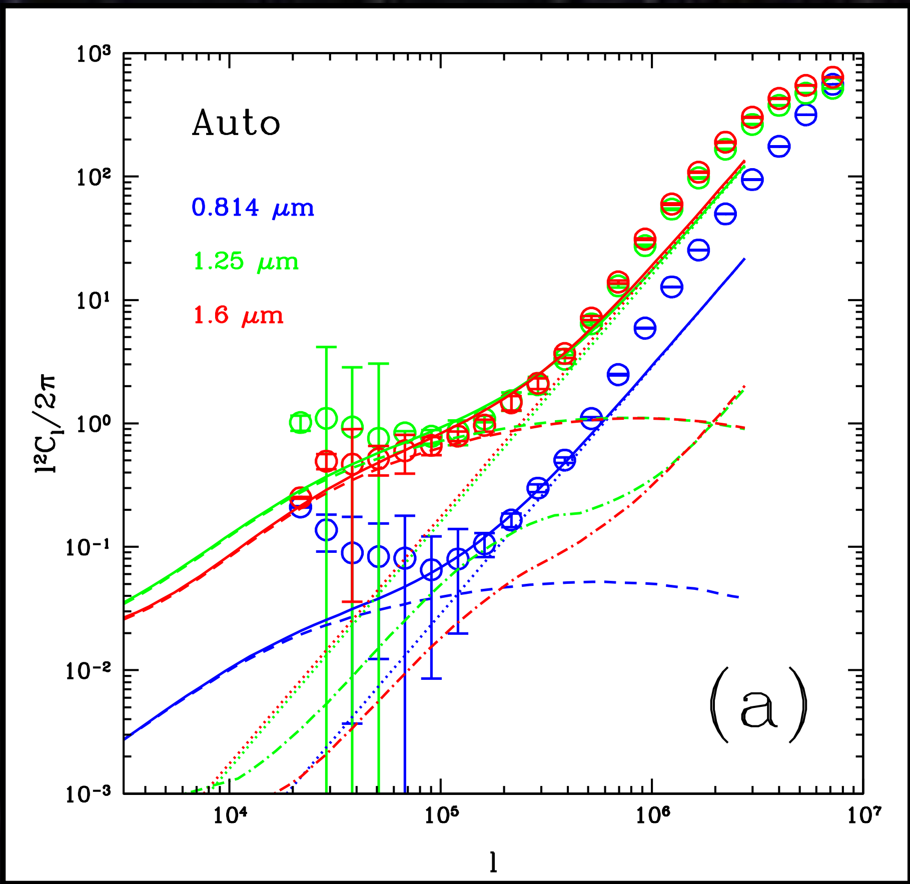

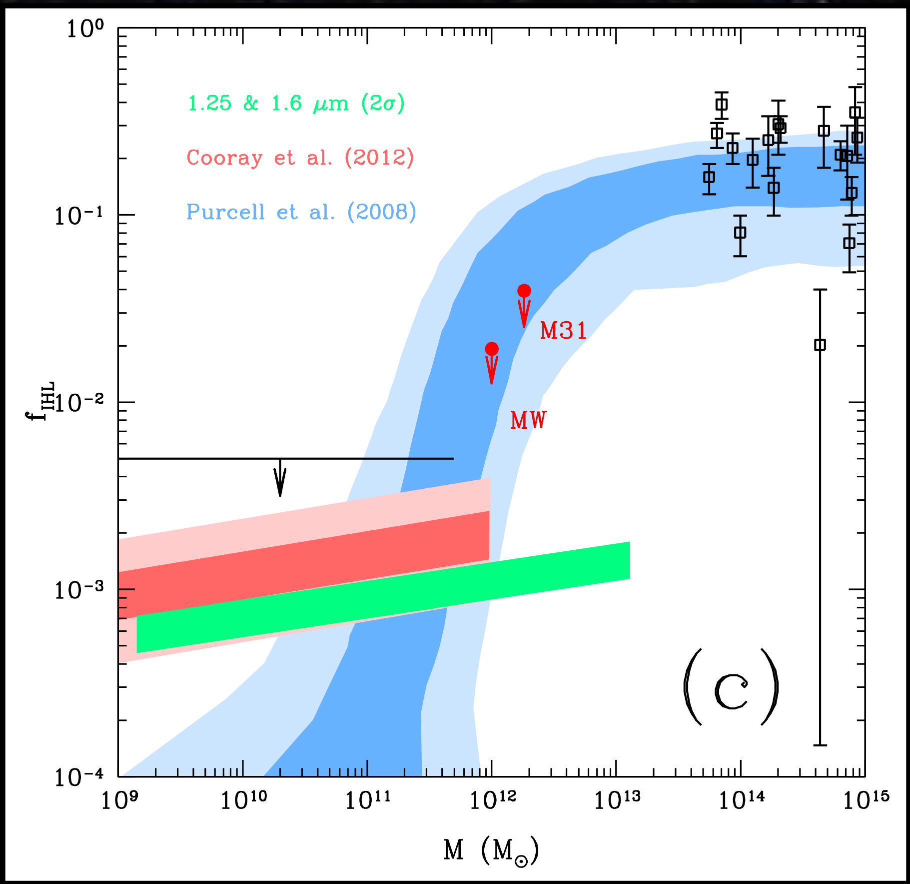

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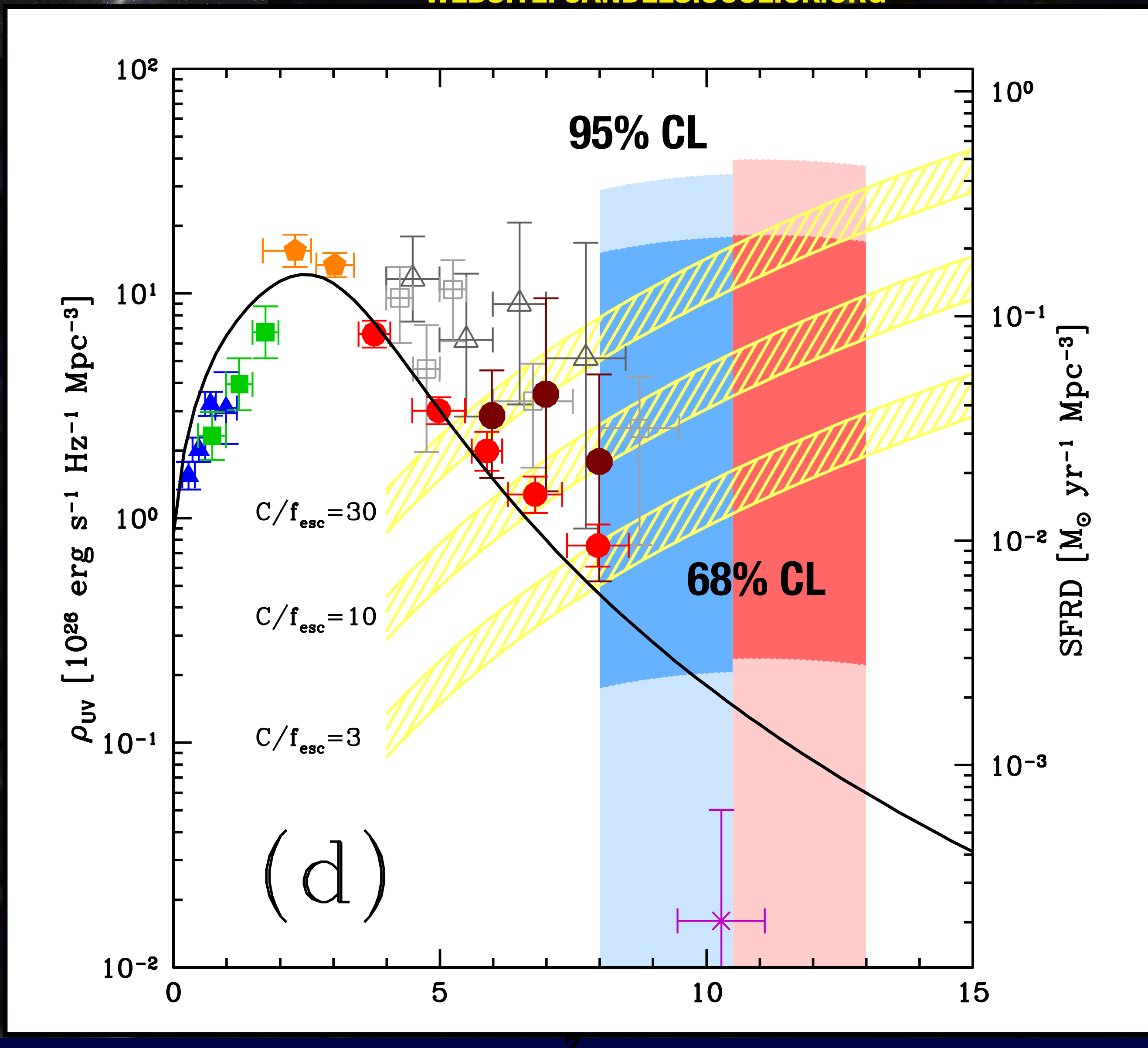


Cooray et al. in prep

CIBER
Cosmic Infrared Background ExpeRiment

CIBER1:

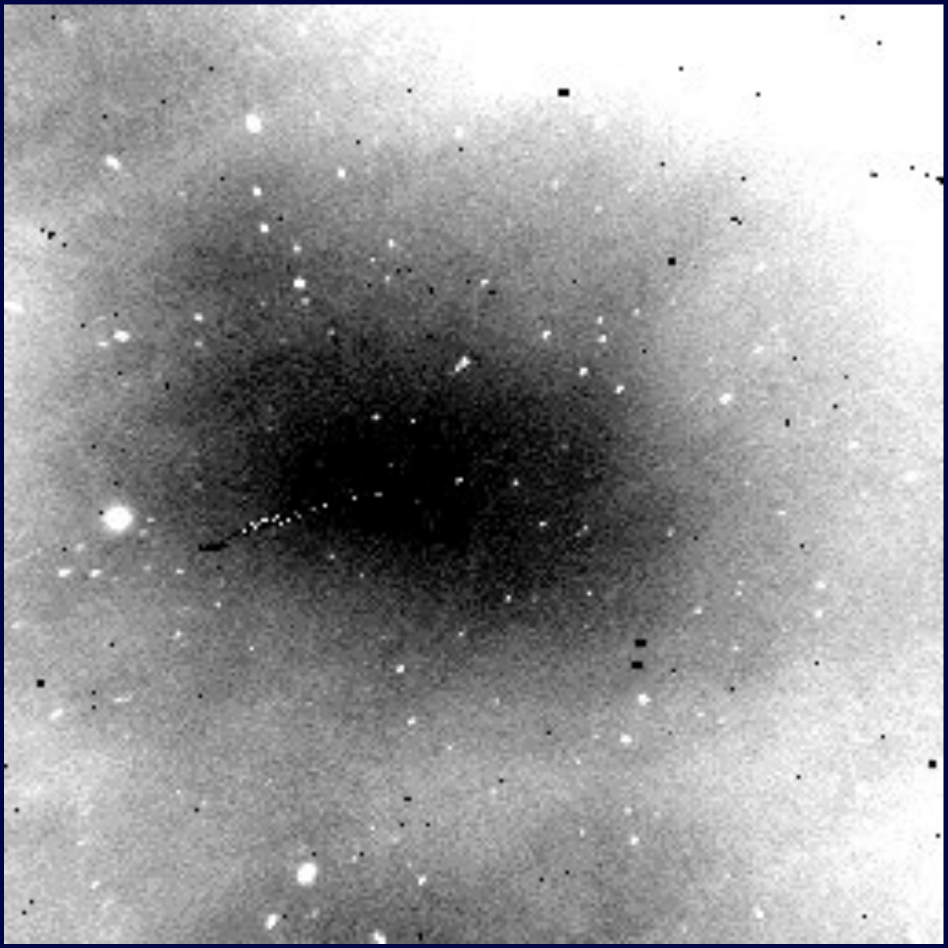
First flight February 2009, second July 2010. Third flight February 2012 (all from White Sands, NM). Fourth June 2013.

Fourth flight was a non-recovery longer flight from Wallops, VA; CIBER1 payload dumped in Atlantic.

Upgrade to CIBER2 completed; pending four additional flights from NASA 2015-2020.

Results paper (Zemcov et al. 2014) in final review with Science

THE CASE FOR SPACE



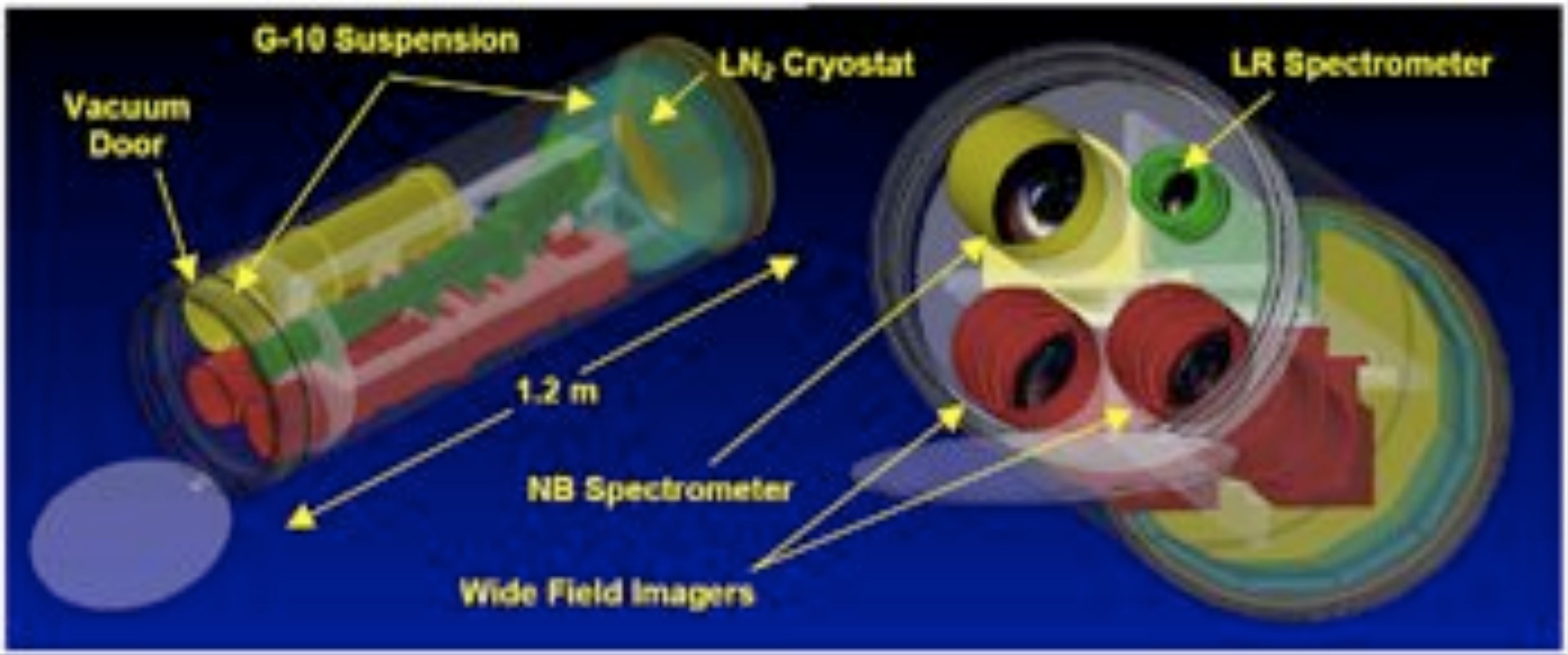
H-BAND 9º X 9º IMAGE OVER 45 MINUTES FROM KITT PEAK
WIDE-FIELD AIRGLOW EXPERIMENT: HTTP://PEGASUS.PHAST.UMASS.EDU/2MASS/TEAMINFO/AIRGLOW.HTML

Airglow Emission

- Atmosphere is **500 – 2500** times brighter than the astrophysical sky at 1-2 μm
- Airglow fluctuations in a **1-degree** patch are **10^6** times brighter than CIBER's sensitivity in 50 s
- Brightest airglow layer at an altitude of **100 km**… can't even use a balloon

CIBER
Cosmic Infrared Background ExpeRiment

CIBER-1



Dual Wide-Field Imagers
λ = 0.8 μm & 1.6 μm λ/Δλ = 2
2° x 2° FOV 7" pixels

Measure power spectrum from 7" to 2 degrees

Low-Resolution Spectrometer
λ = 0.8 – 2.0 μm λ/Δλ ~ 20
4° x 4° FOV 60" pixels
- Search for Ly cutoff feature in 0.8 – 1.2 μm region

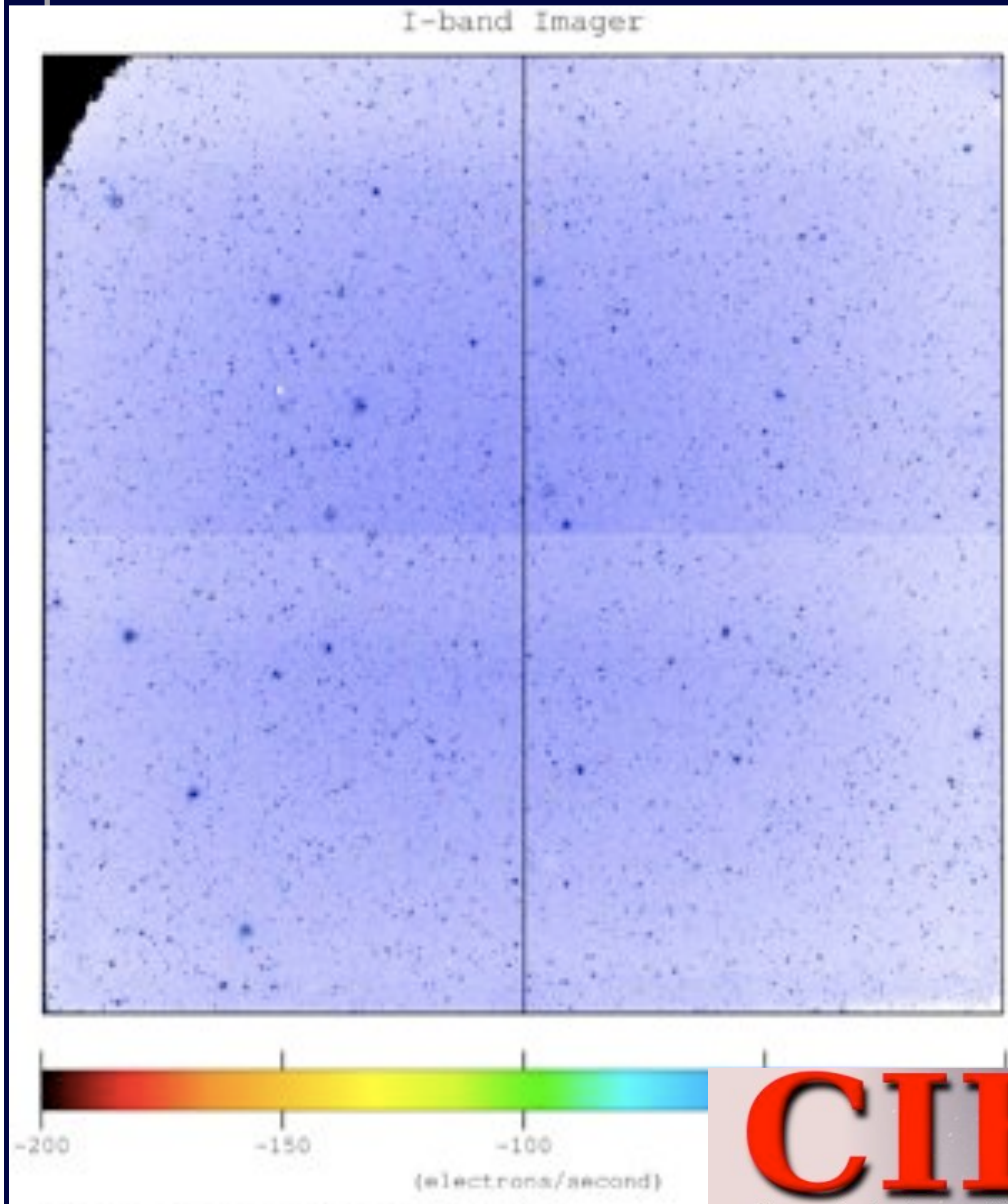
Narrow-Band Spectrometer
λ = 0.8542 μm λ/Δλ = 1000
8° x 8° FOV 120" pixels
- Use Fraunhofer lines to measure absolute Zodiacal intensity

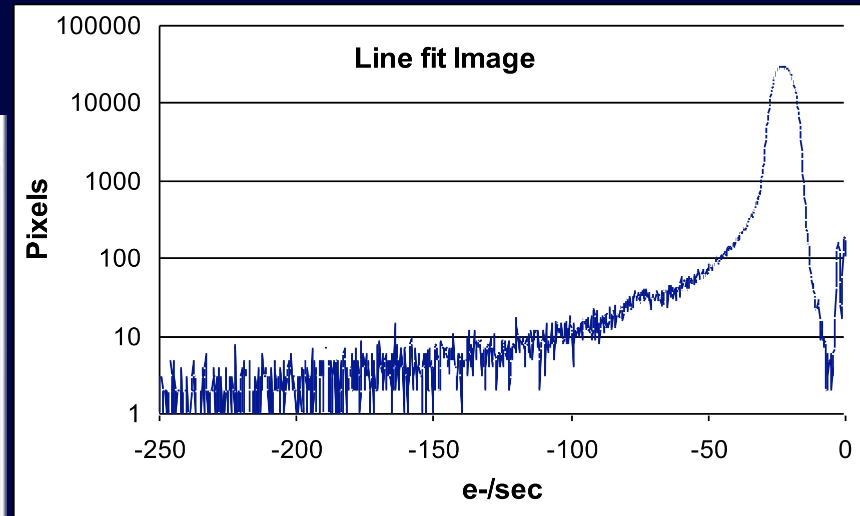
ApJ Supplement Special Issue on CIBER Instruments, September 2012, 5 papers

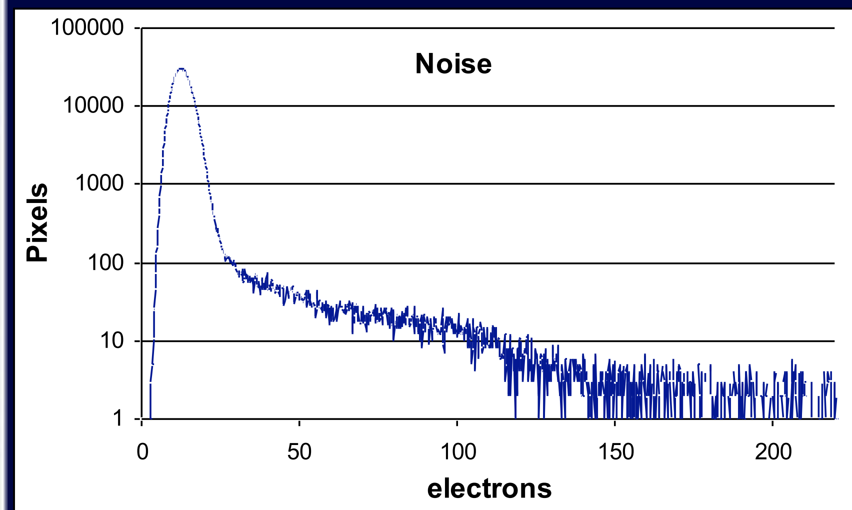
CIBER-1: before third flight

CIBER: Does exist! Recovery after flights

0.9 μm Imager Data



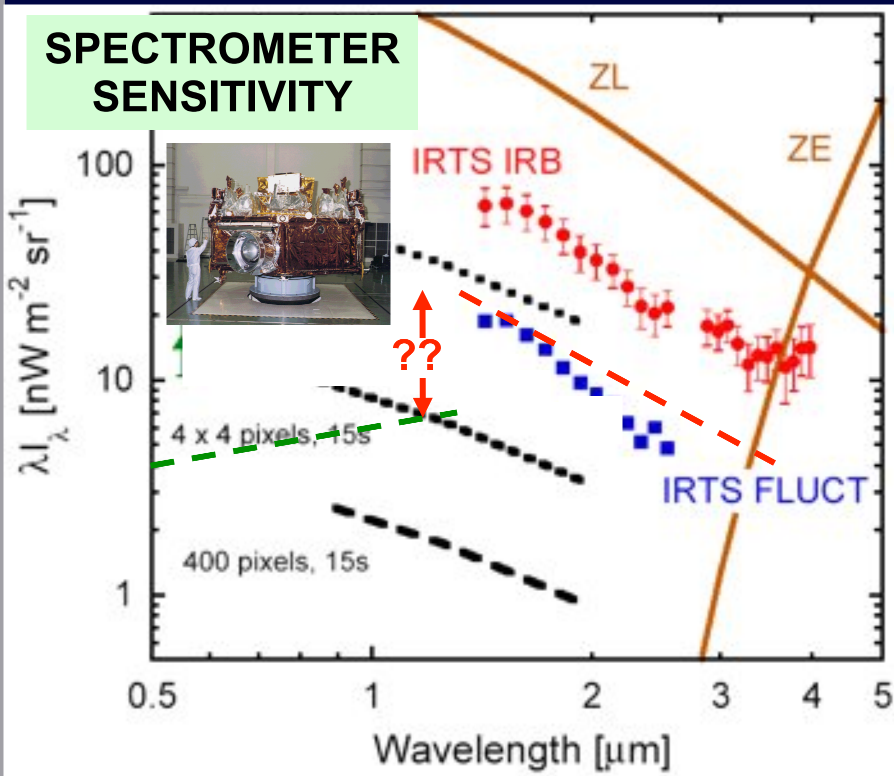


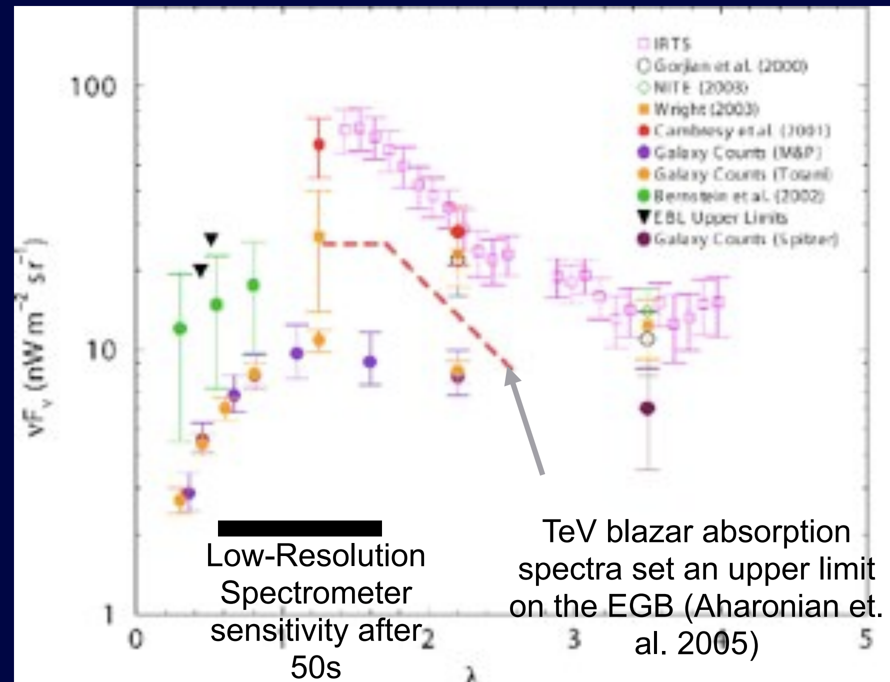


Median photocurrent = 22 e-/s
Median read noise = 12.6 e-

CIBER
Cosmic Infrared Background ExpeRiment

LOW-RESOLUTION SPECTROMETER SCIENCE





Is the gap between IRTS/DIRBE and HST real?

CIBER would see it easily, *without any* Zodiacal subtraction

Precisely measure Zodiacal color, link with narrow-band spectrometer

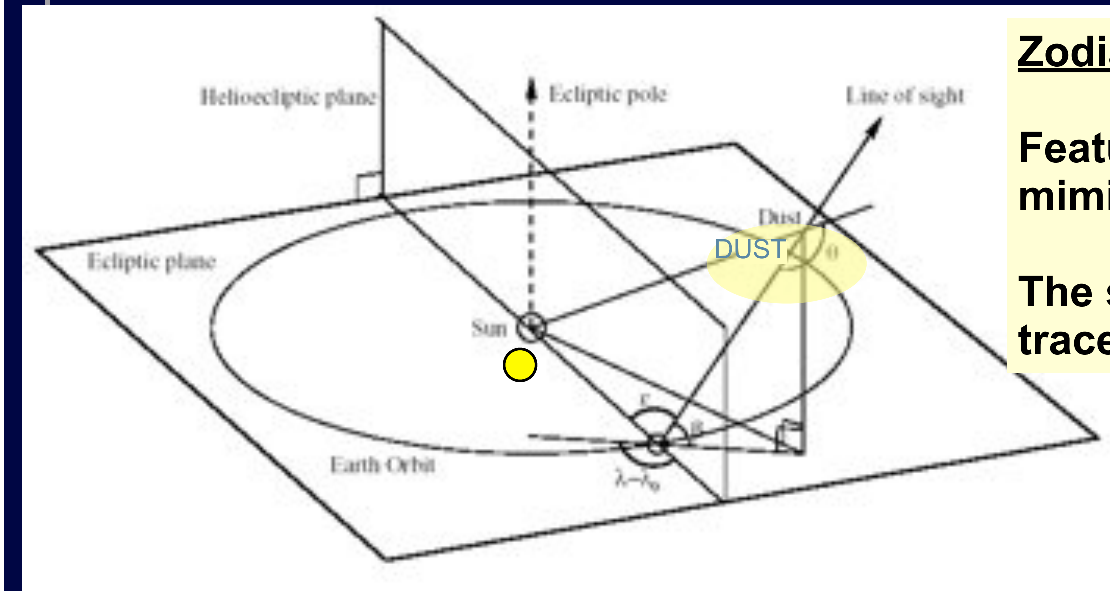
Low-resolution spectrometer sensitivity is 1-2 nW m^{-2} sr^{-1}

NB Spectrometer Zodiacal zero point is 3 nW m^{-2} sr^{-1} at 0.85 μm

Controversy at J-band is ~30 nW m^{-2} sr^{-1}

CIBER
Cosmic Infrared Background ExpeRiment

USING FRAUNHOFER LINES TO TRACE ZODIACAL INTENSITY



<u>Zodiacal Light is just scattered sunlight</u>

Features in the solar spectrum are mimiced in Zodiacal light

The solar spectrum gives a precise tracer of the absolute Zodiacal intensity

<u>But reality is messy</u>

Atmospheric scattering, emission, and extinction

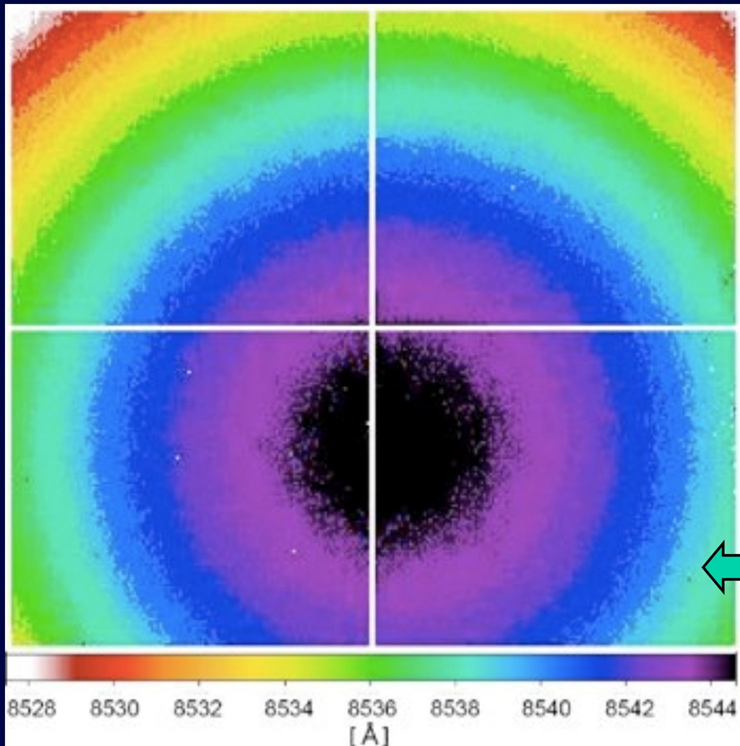
- **scattered ZL**
- **scattered starlight**
- **airglow**
- **etc**

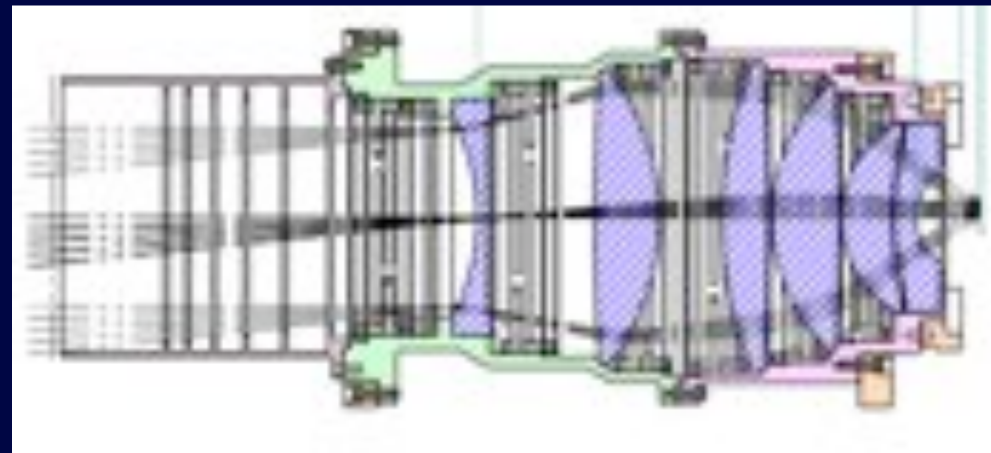
Calibration on diffuse sources

FOR DETAILS SEE: DUBE *ET AL*. 1979
BERNSTEIN *ET AL*. 2002
MATILLA 2003

CIBER
Cosmic Infrared Background ExpeRiment

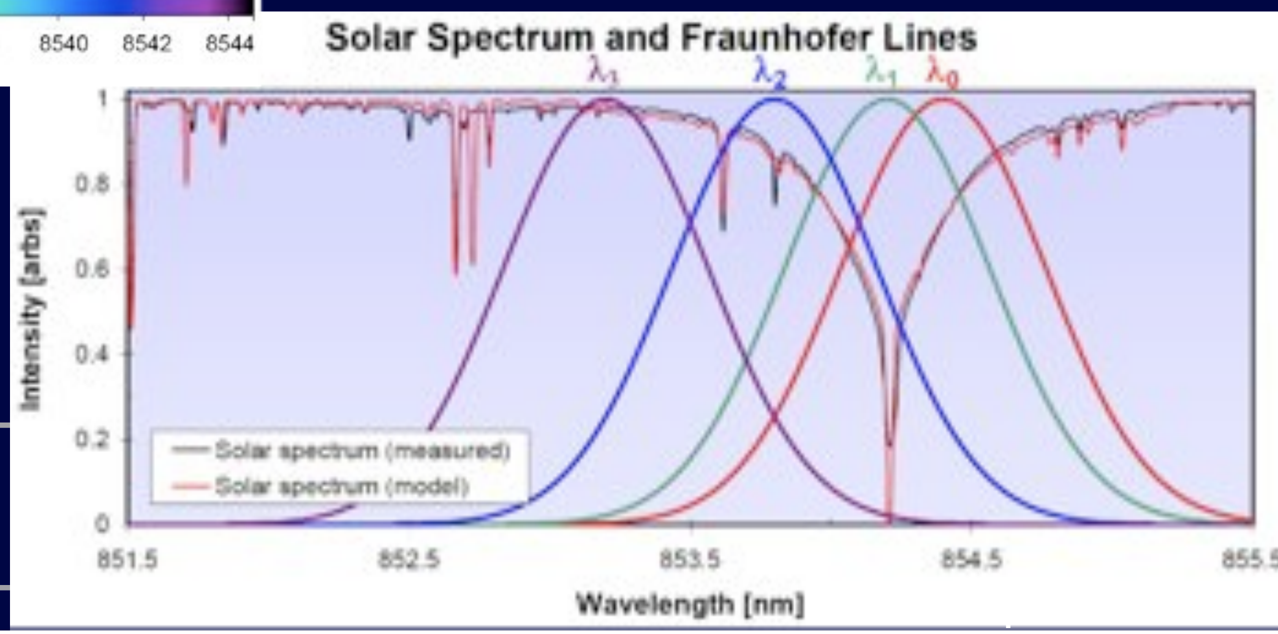
NARROW-BAND SPECTROMETER





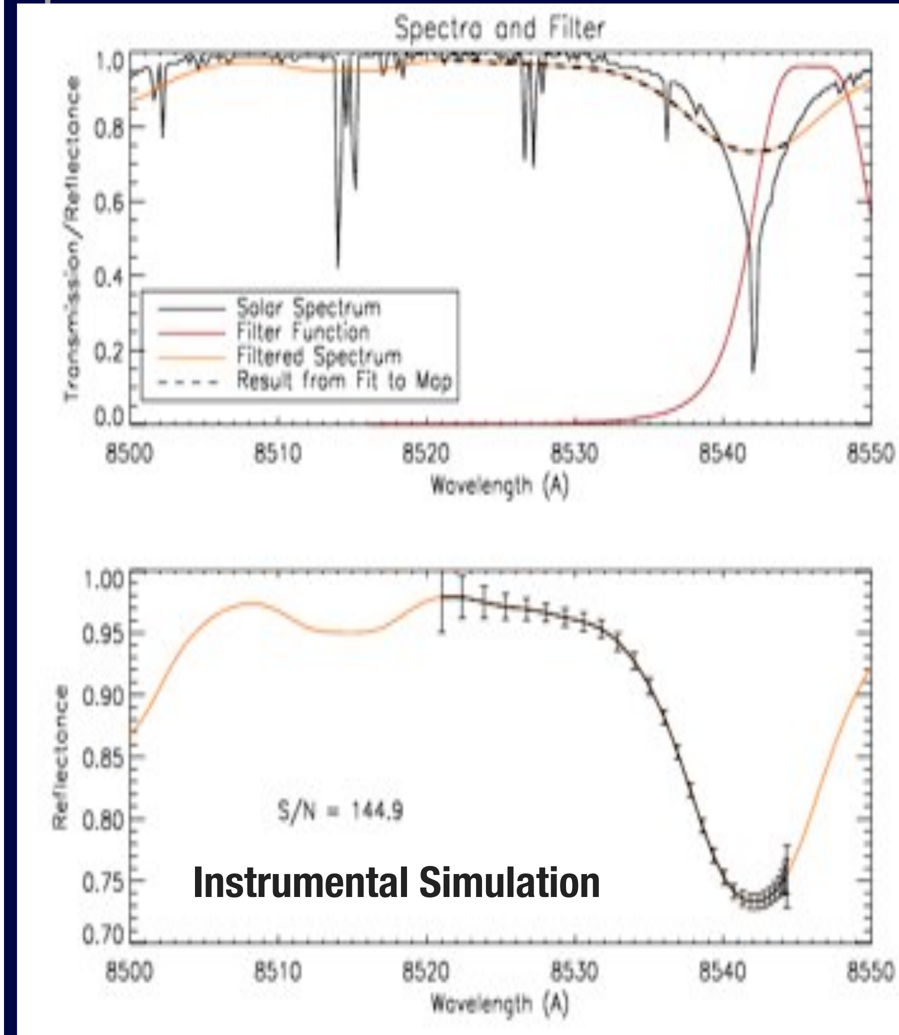
NIST calibration data
I(photo) ~ 30 e-/s

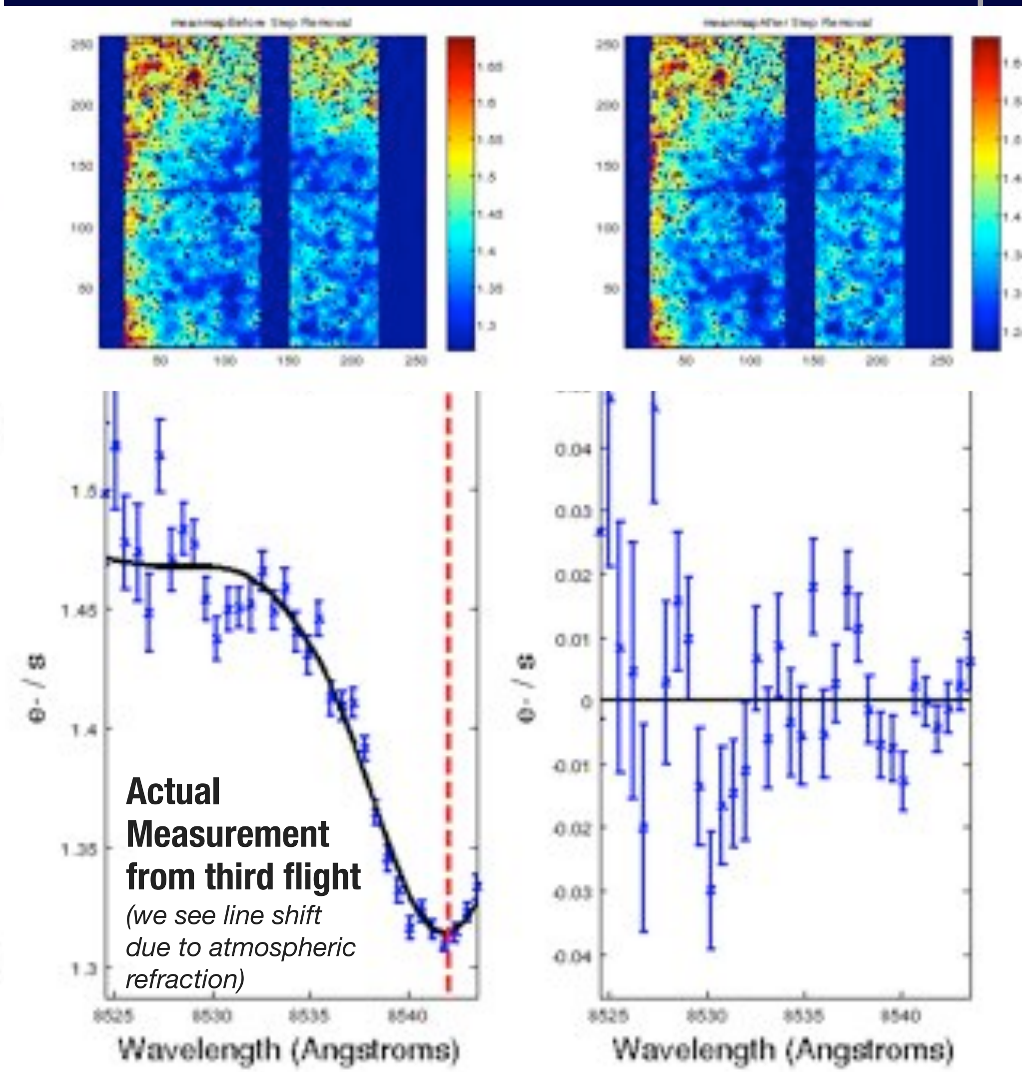
Science Goal:
Measure Fraunhofer Ca II 854.2 nm line EW to 1 % absolute



Asantha Cooray, UC Irvine

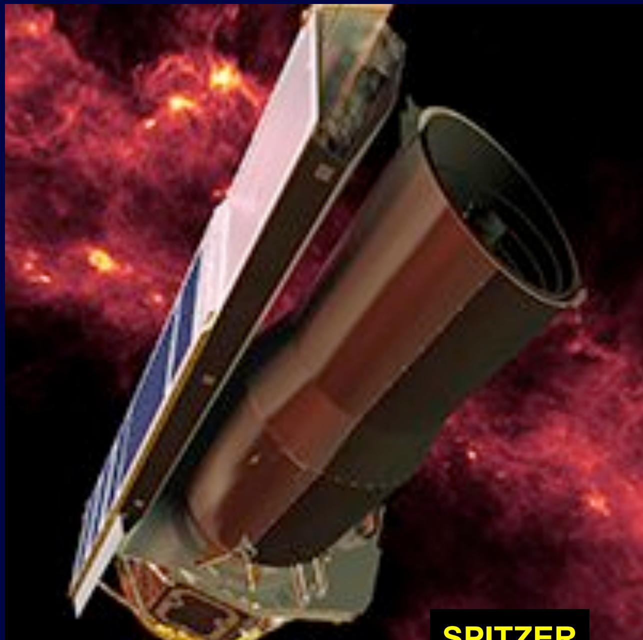
INSTRUMENT RESPONSE TO 8542 Å CA II LINE





CIBER
Cosmic Infrared Background ExpeRiment

How can a rocket experiment compete with these?



SPITZER

IRTS

AKARI

HST

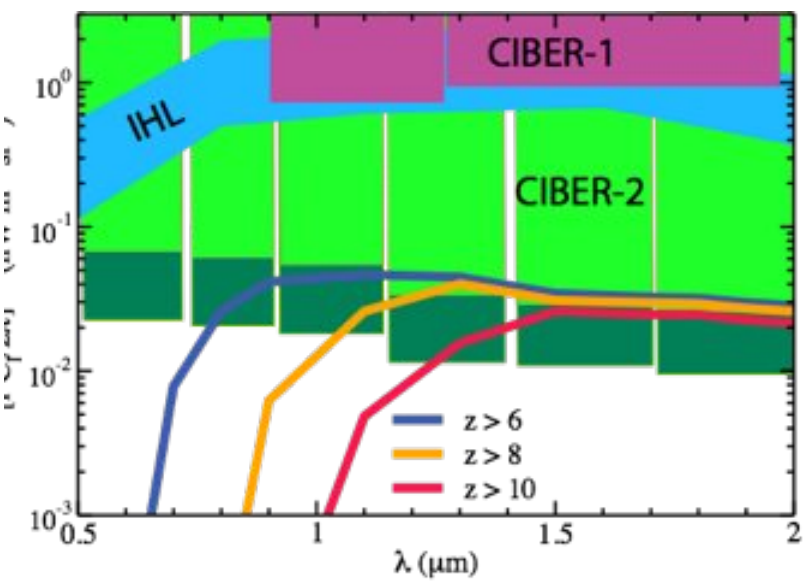
Table 5.2 Comparison with Existing Instruments

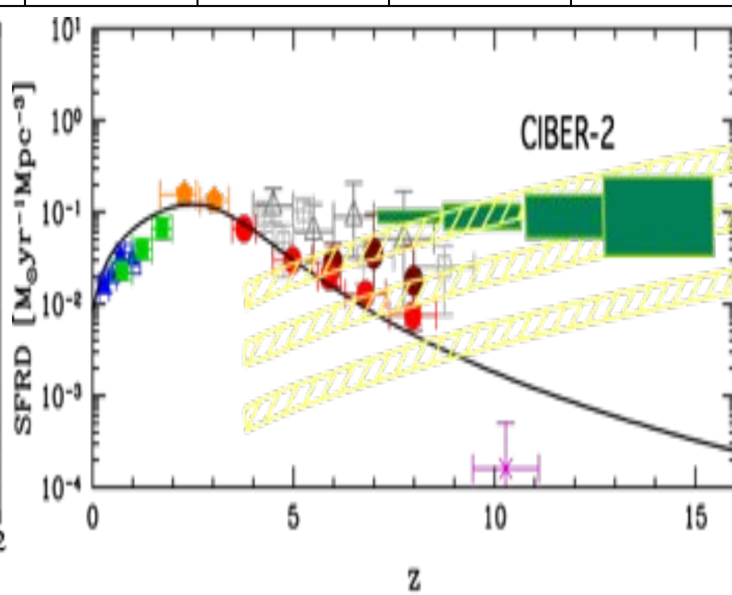
Instrument	Bands [μm]	FOV	Sub-fields	Etendue
CIBER2	0.6, 0.9, 1.4, 2.1	85' x 85'	1	1
CIBER1	0.9, 1.6	120' x 120'	1	0.1
NICMOS	1.1, 1.6, 2.1	1' x 1'	9900	0.002
WFC3	0.6, 1.0, 1.4, 1.6	2' x 2'	1500	0.01
Akari	2.3, 3.2, 4.1	12' x 12'	50	0.02
Spitzer	3.6, 4.5	5' x 5'	270	0.01

Notes: Etendue = Area x Ω x Simultaneous Bands
Sub-fields = number of pointings to cover 2 sq. degrees

Table 1. CIBER2 imager sensitivity in a nominal single 35 s observation

Parameter	**CIBER2**						**Units**
Aperture	28.5						cm
Pixel size	4						arcseconds
Array	HgCdTe						
Format	2048^2						pixels
FOV	1.1 x 2.2 for imager bands, 0.4 for LVF						degrees
Dark current	<0.05						e-/s
RN (CDS)	12						e-
Band	1	2	3	4	5	6	
λ	600	800	1030	1280	1550	1850	nm
Δλ/λ	0.33	0.25	0.24	0.20	0.20	0.16	
Array QE	0.90	0.80	0.83	0.81	0.82	0.82	
Optics QE	0.75	0.73	0.81	0.85	0.87	0.87	
Photo current	9.5	6.8	8.1	7.8	7.7	3.8	e-/s
νIν	525	450	400	380	320	224	nW m^{-2} sr^{-1}
δνIν (1σ/pix)	38.0	44.8	33.9	30.6	25.0	23.0	
δFν (3σ)	21.5	21.1	21.0	21.0	21.0	20.9	AB mag





CIBER-2

4 flights starting late 2015

Expanding the WISH, WISH-spec science case

(a) Multi-band IR background anisotropies in WISH imaging data - especially deep survey - can separate IHL from a high-z reionization component. (CIBER2 -> WISH natural transition)

(b) 2D Galaxy clustering in photometry data + 3D clustering in spectroscopy data

- can WISHspec be used to calibrate photo-z's of faint galaxies below Euclid grism detection threshold (?)

(c) WISHspec IFU allows spectral line intensity mapping, especially Halpha over 1000 sq. degrees; and Ly-alpha during reionization