Non-Redundant Aperture Masking Interferometry (AMI) and Segment Phasing with JWST-NIRISS

~65 mas angular resolution imaging
in F380M F430M & F480M

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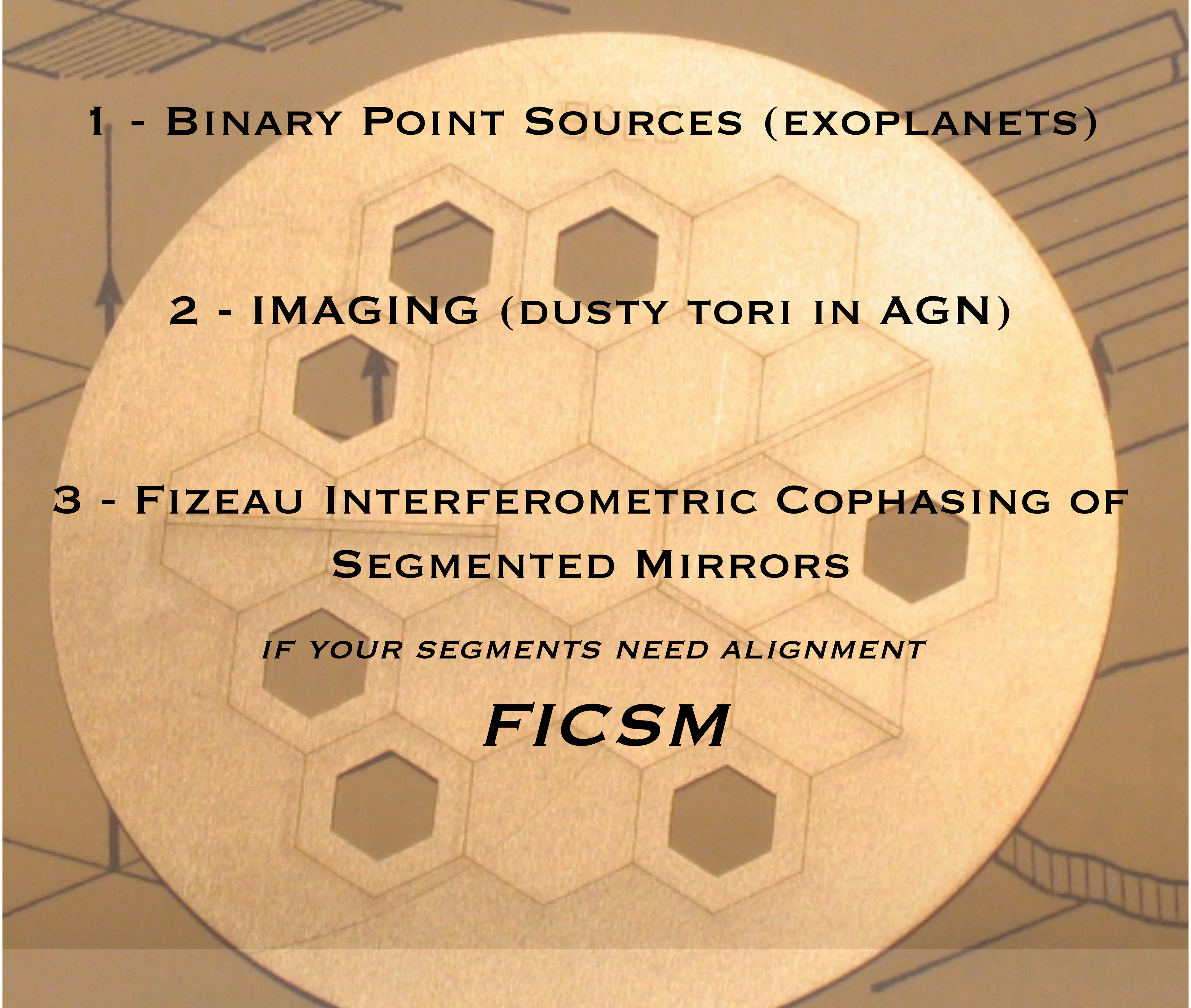
For

The JAM TEAM

(JWST Aperture Masking Team)

David Lafreniere, K. E. Saavik Ford, Barry McKernan, Anthony Cheetham, Alexandra Z. Greenbaum, Peter G. Tuthill, James P. Lloyd, Michael J. Ireland, Rene Doyon, Mathilde Beaulieu, Andre Martel,Anton Koekemoer, Frantz Martinache, Peter Teuben



1 - Binary Point Sources (exoplanets)

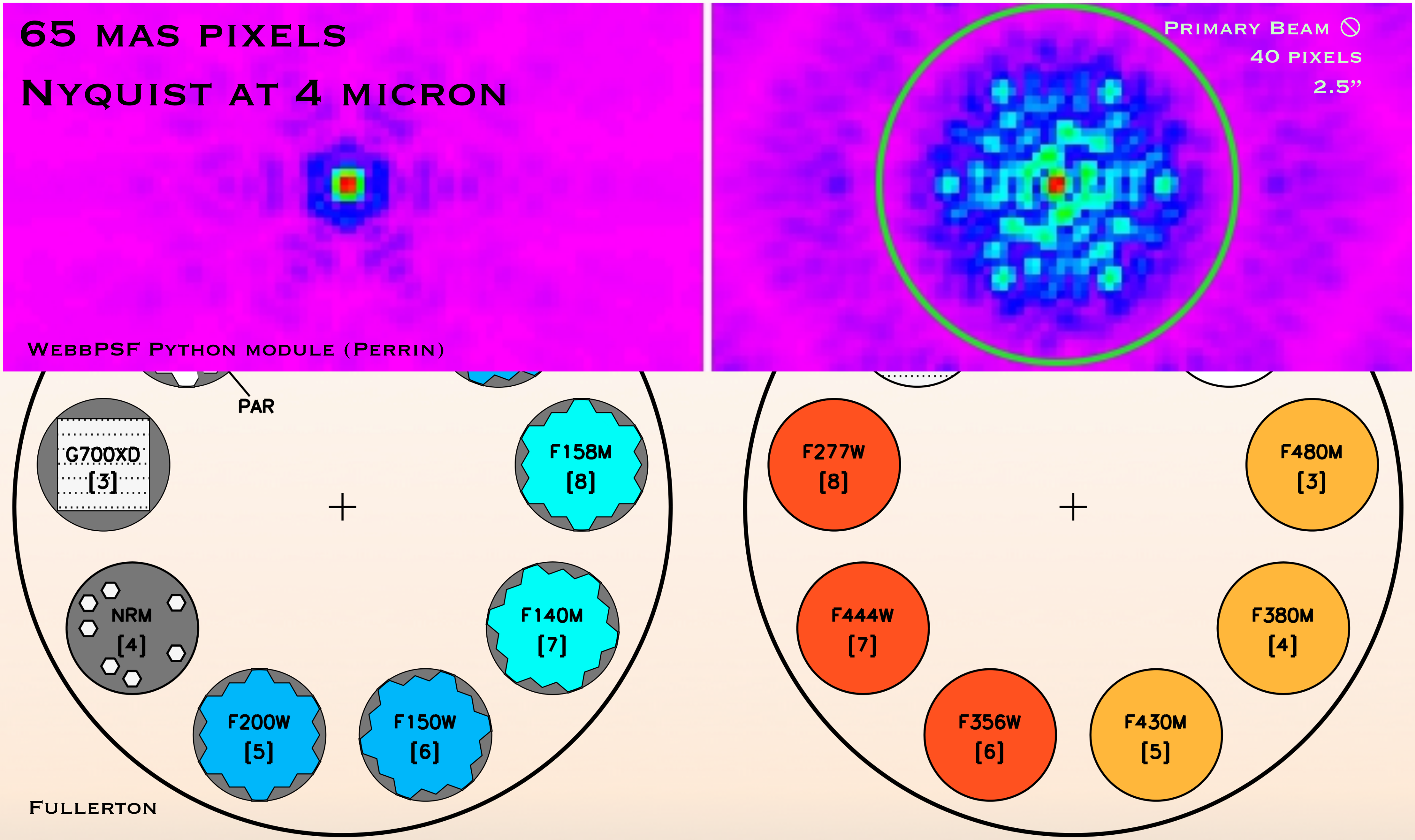
2 - IMAGING (dusty tori in AGN)

3 - Fizeau Interferometric Cophasing of Segmented Mirrors

if your segments need alignment

FICSM

F430M PSF CLEAR   F430M PSF NRM



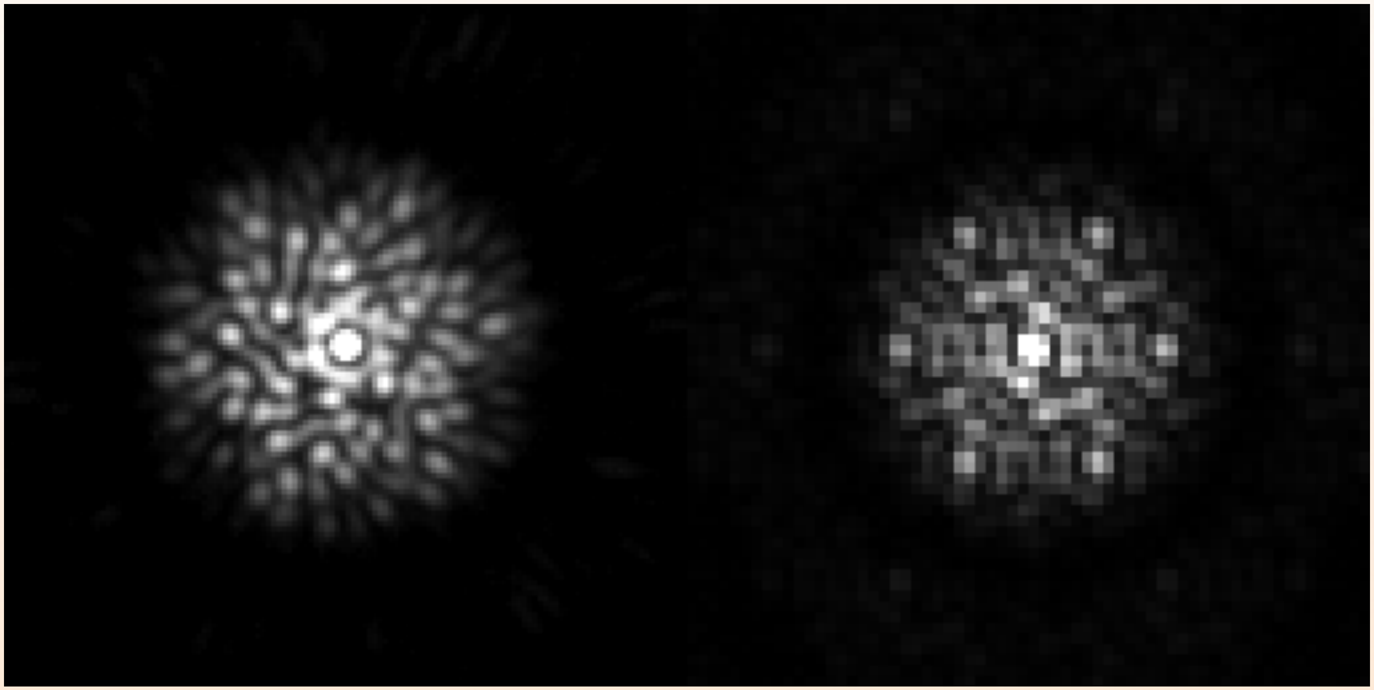
Simulation description

- Master PSF
  - OTE phase maps RevV
  - NRM mask G7S6SC
  - Polychromatic, using F430M filter profile
  - Created with oversampling of 11x11 compared to NIRISS pixels
    - Soummer, Pueyo, Sivaramakrishnan, Vanderbei OpEx 2007
- Pointing
  - Telescope **pointing error for acquisition and dithers**: 15 mas RMS
  - Telescope **pointing jitter while guiding**: 5 mas RMS
  - Simulated at 0.01 pixel precision using oversampled PSFs

Simulation description

- Detector
  - Pixel **flat field** error: 0.1%
  - Non-uniform **intra-pixel sensitivity**
    - 1 at pixel center, decreasing to 0.8 (+/- 0.05) at pixel corners
    - Gaussian profile, Gaussian distribution of corner relative QE
  - 21 e- **read noise** per CDS
  - Mean **dark** current of 0.012 e-/sec
  - Inter-pixel capacitive coupling included
  - Bad pixels included

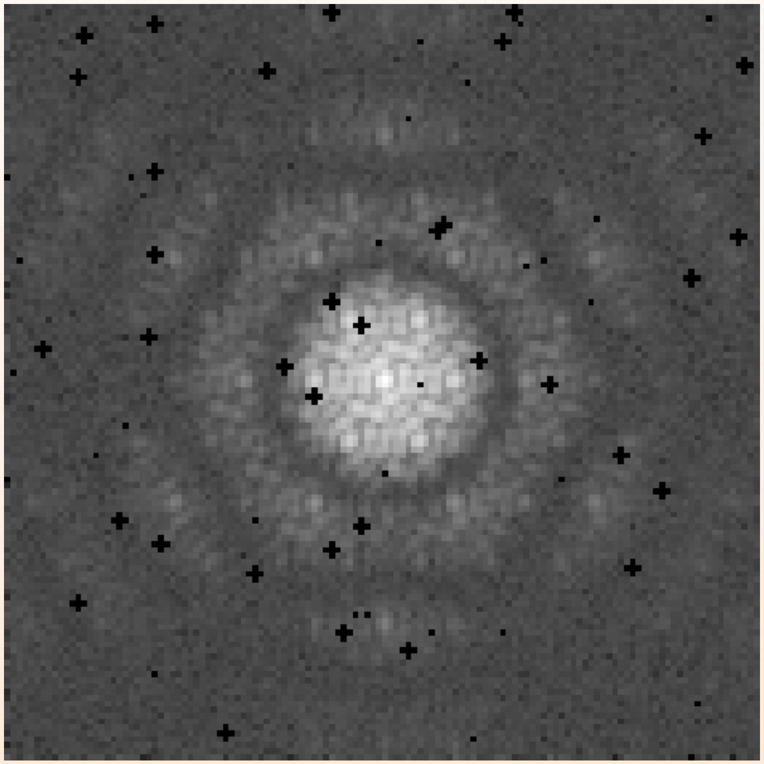
JWST sim cf PHARO data



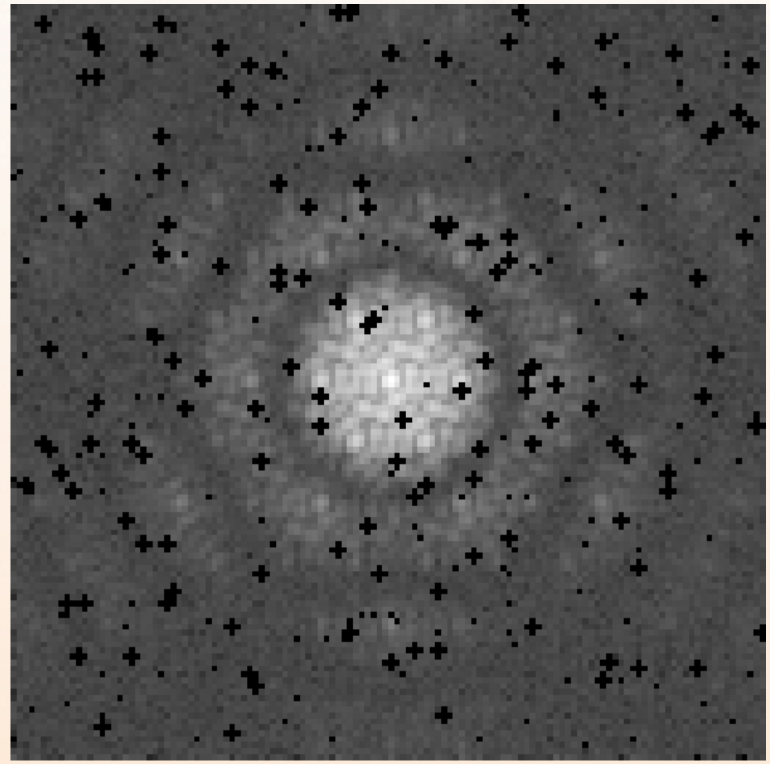
PHARO on Pal 200" : Martinache, Bernat, Lloyd   JWST sim w/jitter

Bad pixels overlaid on PSF

- log display scale



Bad pixel fraction 1%



Bad pixel fraction 5%

- Randomly distributed, 5/6th of bad pixels are grouped in a "cross pattern" while 1/6th are single pixels
- Bad pixels assumed completely unusable

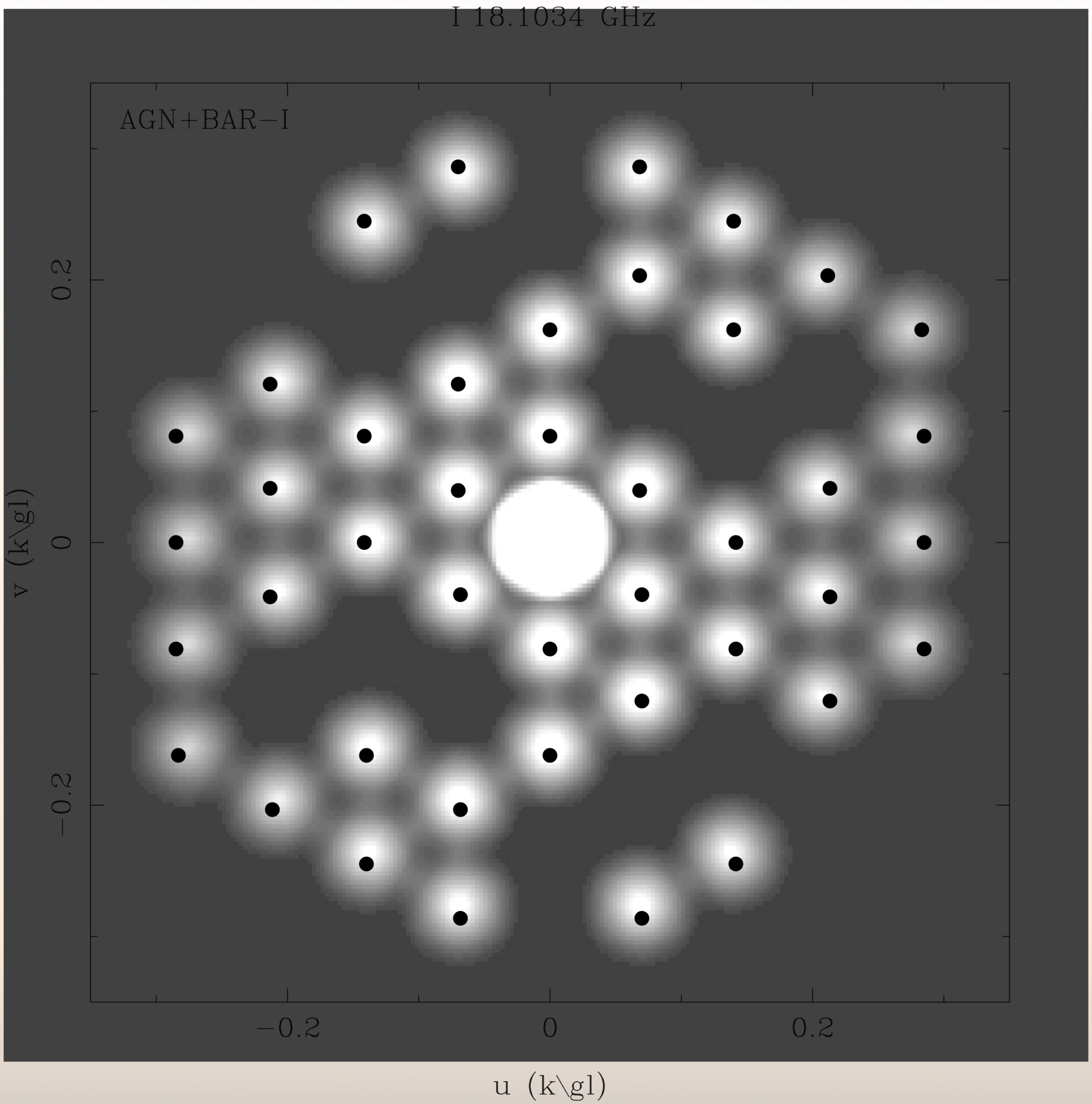
Simulation description

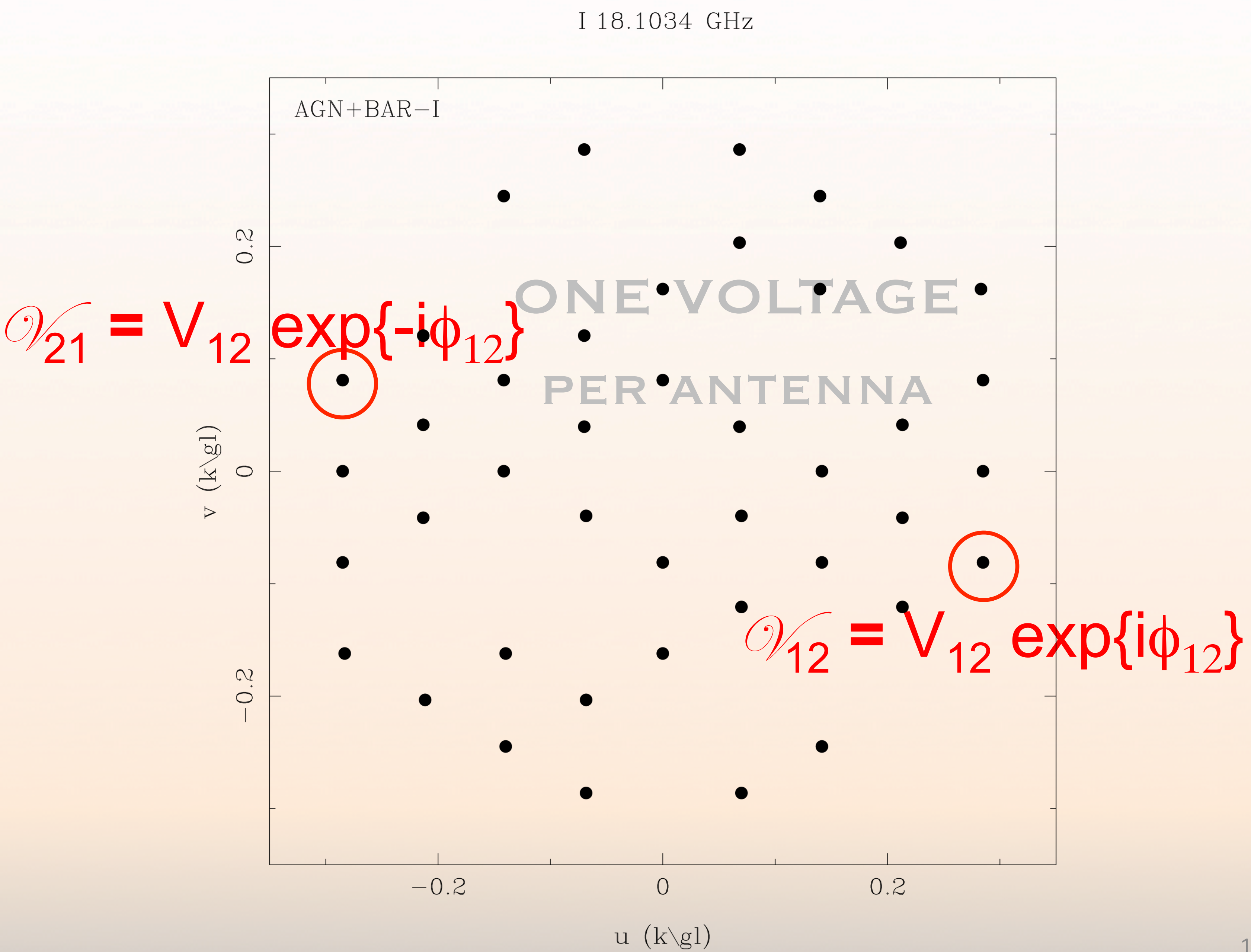
- Observation
  - **L'=7.5** mag star
  - 256x256 subarray (t_{frame}=0.66 s)
  - Read mode, TFIRAPID, N_{frame}=1, N_{group}=14
    - Peak pixel kept at <70000 e- in last read
  - 9 dithers on a 3x3 grid with 4" step
    - **Assumed that the central 7x7 pixel box at each dither position was free of bad pixels**
  - 121 integrations at each dither position
  - 3 hour clock-time total on target
    - plus a similar sequence on a calibrator
    - **12 min exposure on each of target and calibrator**

Results – detection limits

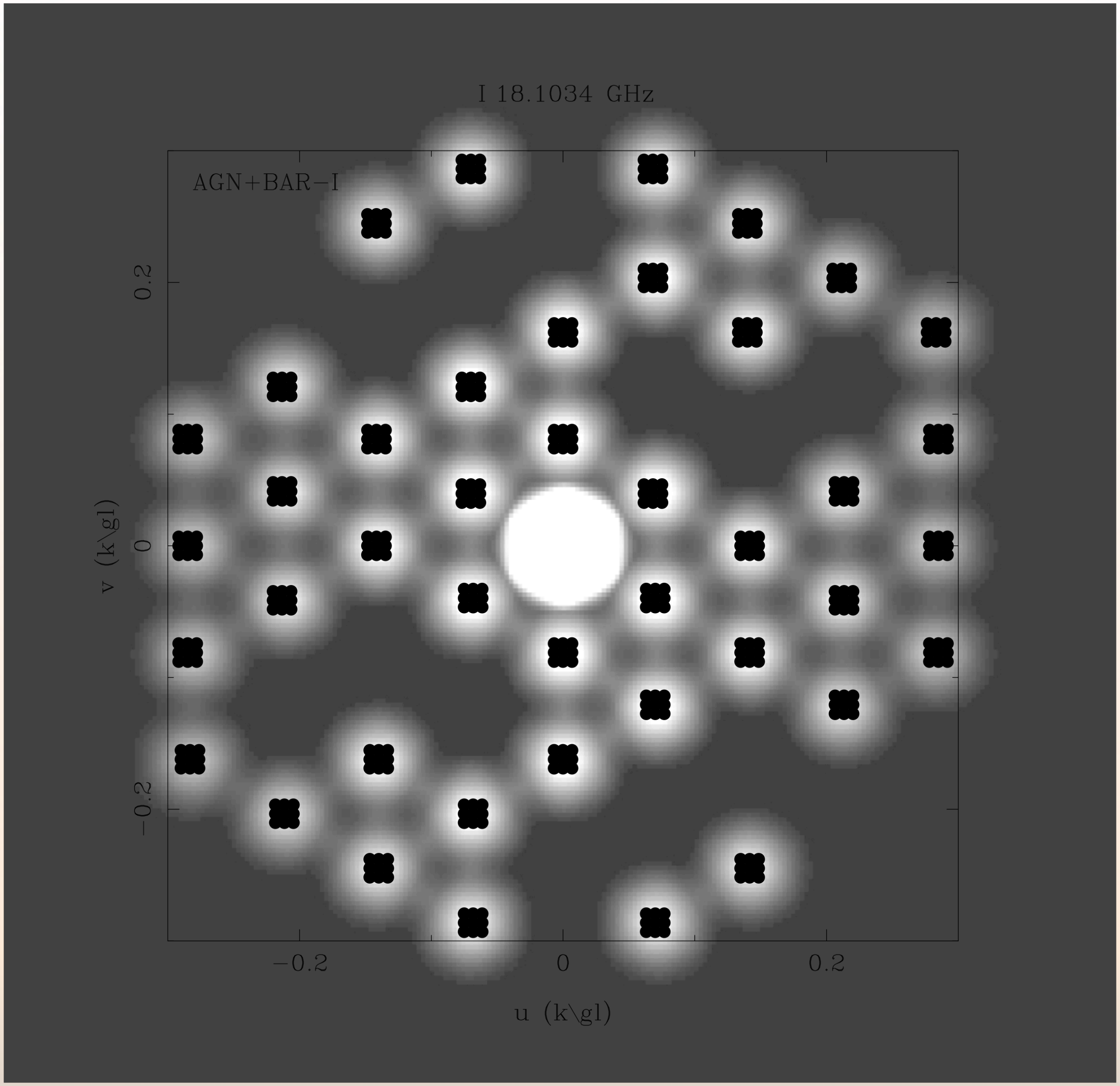
- Magnitude loss in contrast compared with 0% bad pixels

	0.06”	0.08”	0.10”	0.20”	0.30”	0.40”
0%	0.00	0.00	0.00	0.00	0.00	0.00
0.5%	-0.09	-0.09	-0.09	-0.13	-0.20	-0.19
1%	-0.09	-0.10	-0.11	-0.17	-0.26	-0.23
2%	-0.33	-0.34	-0.35	-0.40	-0.51	-0.49
3%	-0.63	-0.63	-0.62	-0.65	-0.75	-0.74
4%	-0.82	-0.81	-0.80	-0.81	-0.91	-0.90
5%	-1.09	-1.06	-1.04	-1.03	-1.12	-1.13

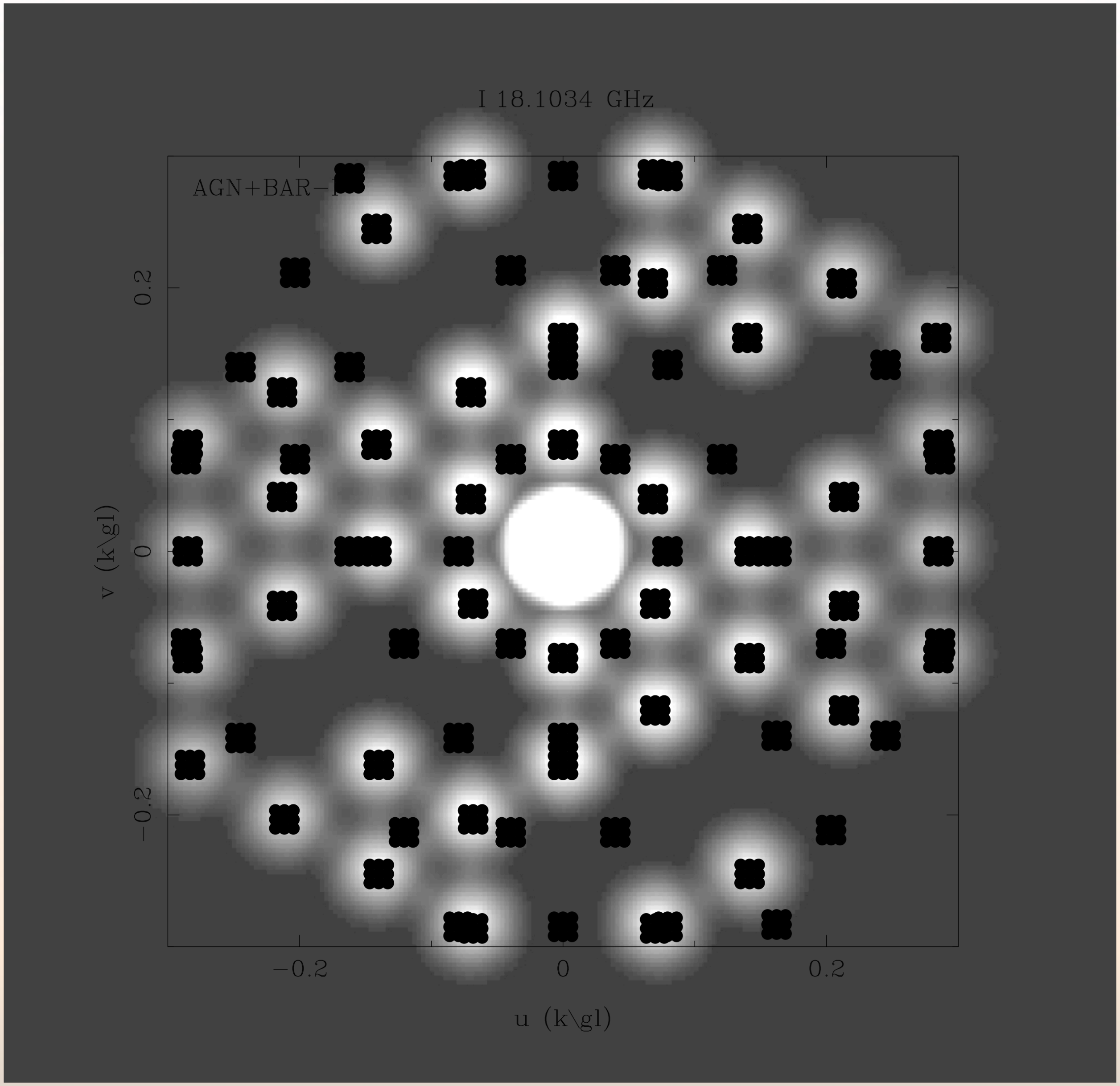

I 18.1034 GHz
AGN+BAR−I
v (k\gl)
u (k\gl)
0.2
0
−0.2
−0.2
0
0.2



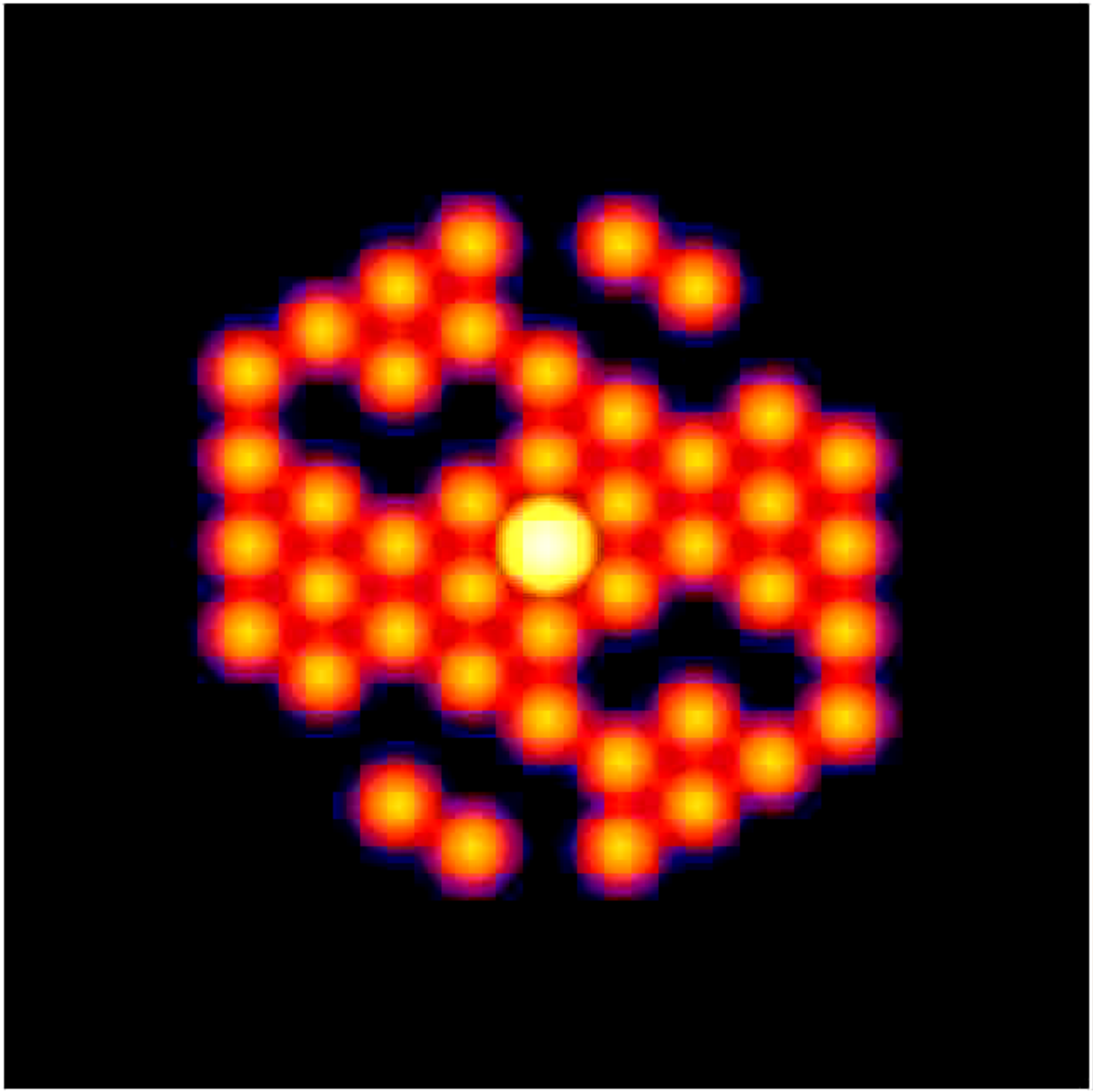
I 18.1034 GHz
AGN+BAR−I
ONE VOLTAGE
PER ANTENNA
$\mathscr{V}_{21} = V_{12}\, \exp\{-i\phi_{12}\}$
$\mathscr{V}_{12} = V_{12}\, \exp\{i\phi_{12}\}$
0.2
0
−0.2
v (k\gl)
−0.2
0
0.2
u (k\gl)

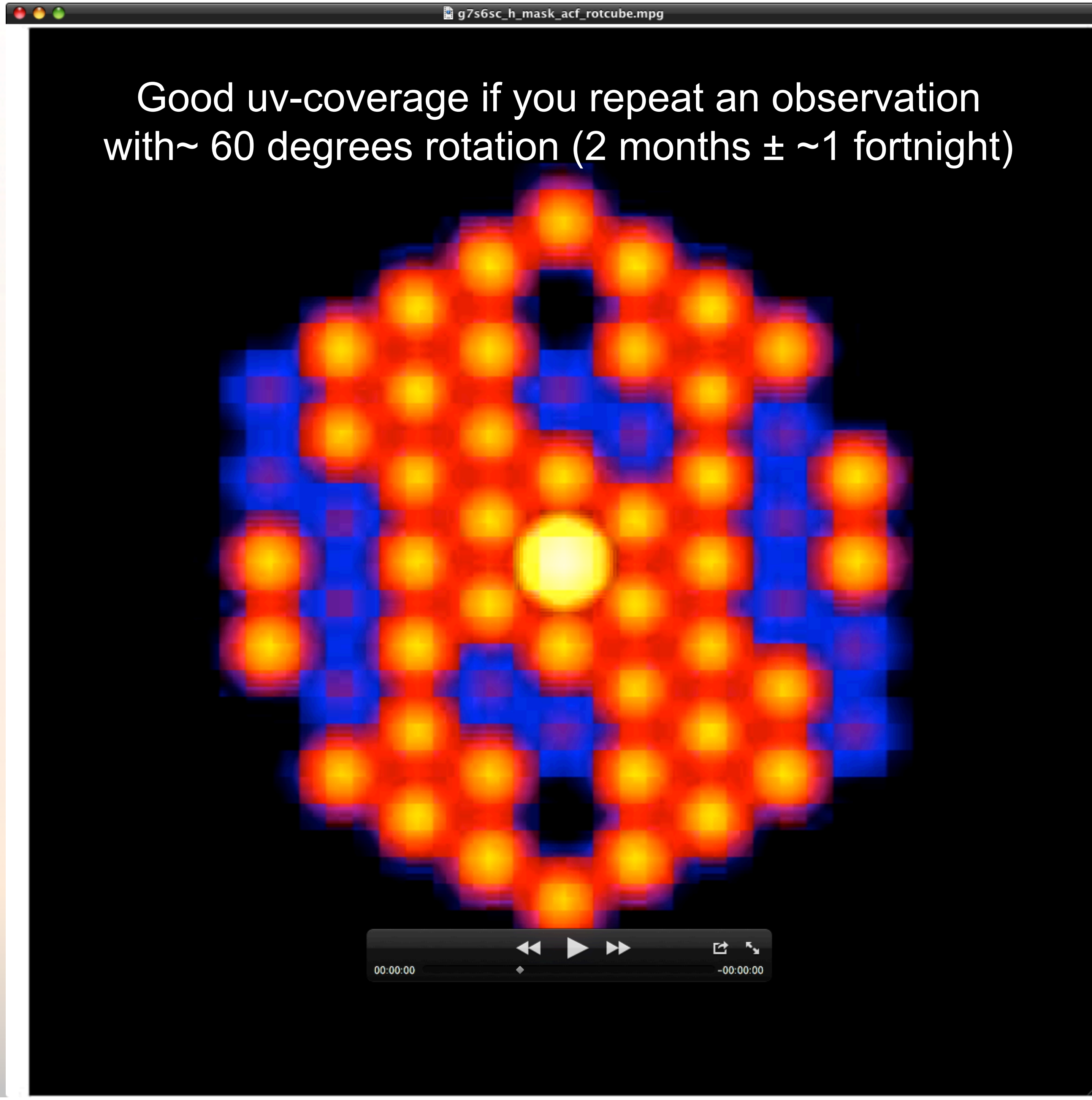


I 18.1034 GHz
AGN+BAR−I
0.2
0
−0.2
v (k\gl)
−0.2
0
0.2
u (k\gl)

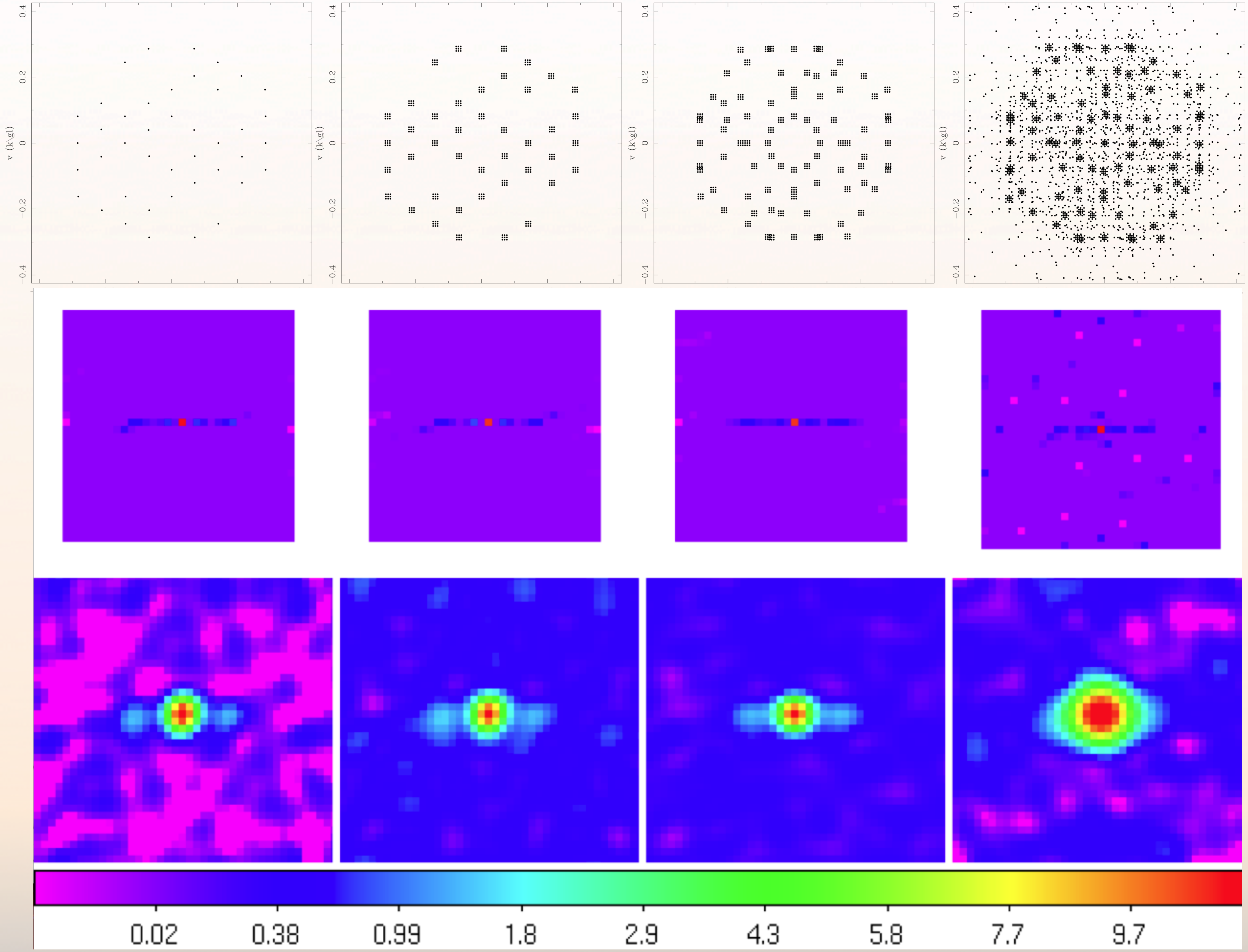


I 18.1034 GHz
AGN+BAR−1
0.2
0
−0.2
v (k\gl)
−0.2
0
0.2
u (k\gl)

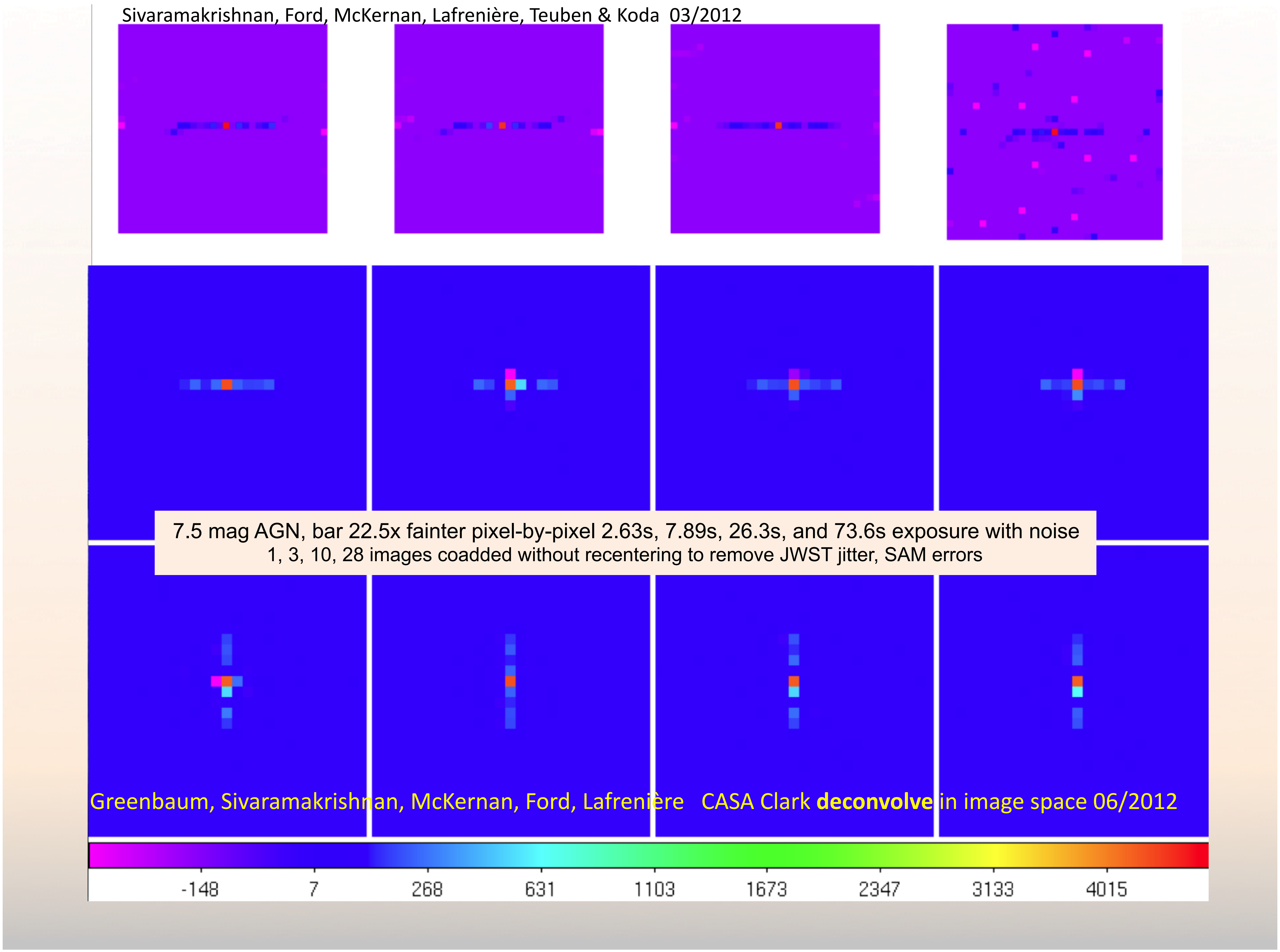



g7s6sc_h_mask_acf_rotcube.mpg
Good uv-coverage if you repeat an observation
with~ 60 degrees rotation (2 months ± ~1 fortnight)
00:00:00
-00:00:00

MIRIAD **invert; clean; restore** – using the normalized point source **dirty map** as **clean**’s beam

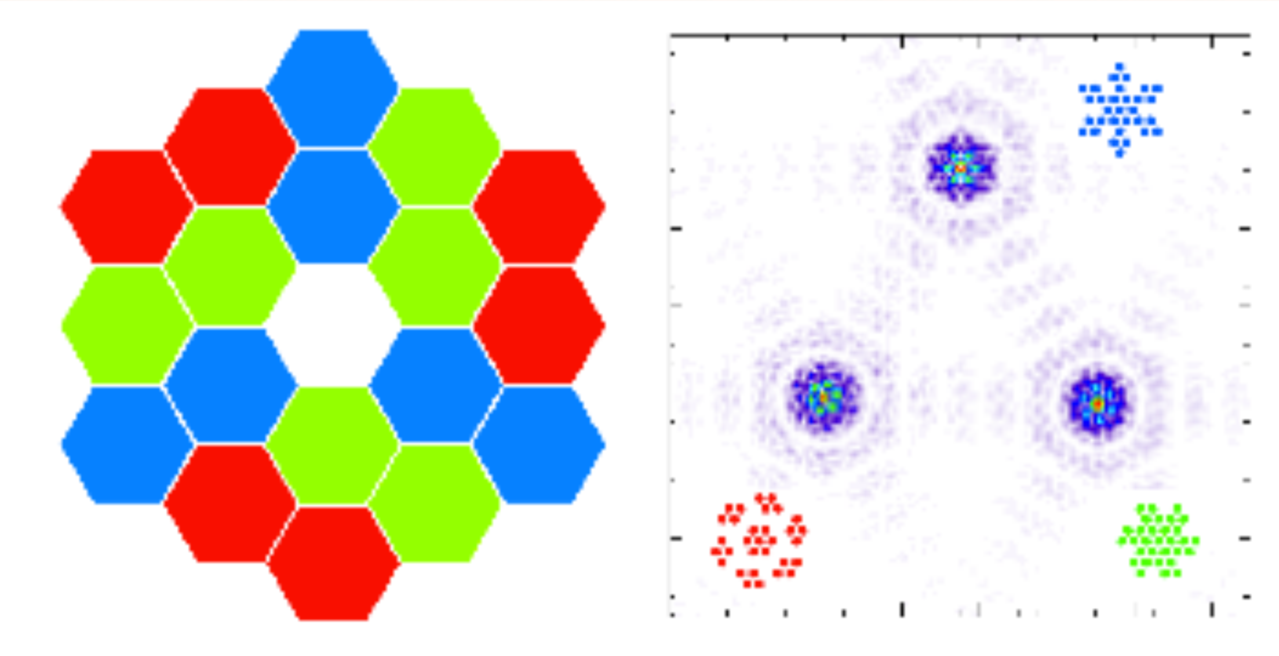


Sivaramakrishnan, Ford, McKernan, Lafrenière, Tuthill, Teuben & Koda 06/2012



Sivaramakrishnan, Ford, McKernan, Lafrenière, Teuben & Koda 03/2012
7.5 mag AGN, bar 22.5x fainter pixel-by-pixel 2.63s, 7.89s, 26.3s, and 73.6s exposure with noise
1, 3, 10, 28 images coadded without recentering to remove JWST jitter, SAM errors
Greenbaum, Sivaramakrishnan, McKernan, Ford, Lafrenière CASA Clark deconvolve in image space 06/2012
-148
7
268
631
1103
1673
2347
3133
4015

3 - FICSM



Segment tilting – choose non-redundant patterns

(eg Monnier et al Keck segment tilting)

Recover segment piston (few nm) & tip-tilt (10mas)

Capture range – 150 micron pistons, 0.5 arcsec tilts (NIRCam)

Should work on NIRISS/NIRCam/MIRI

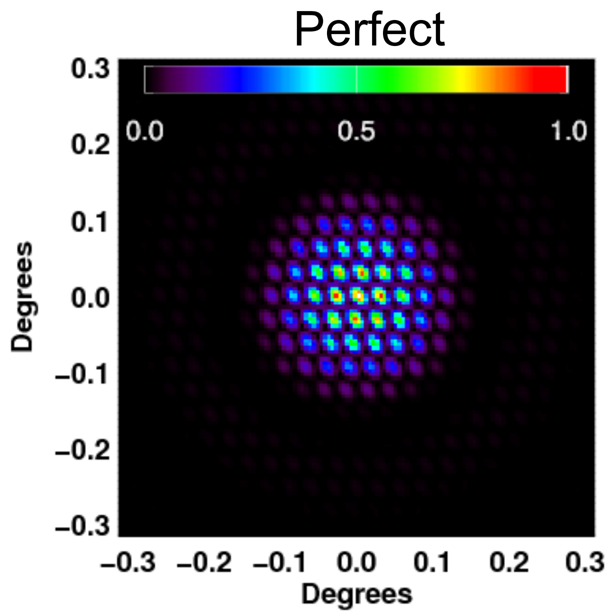
Enables NIRISS WFS (1 NRM + 1 Full Aperture PSF)

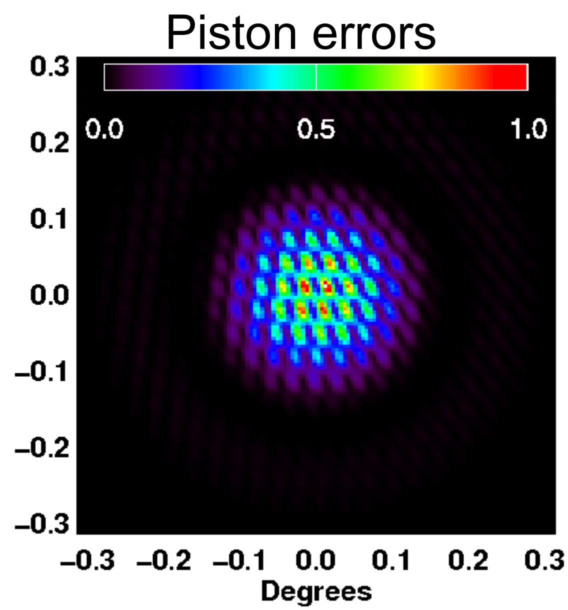
Cheetham et al.

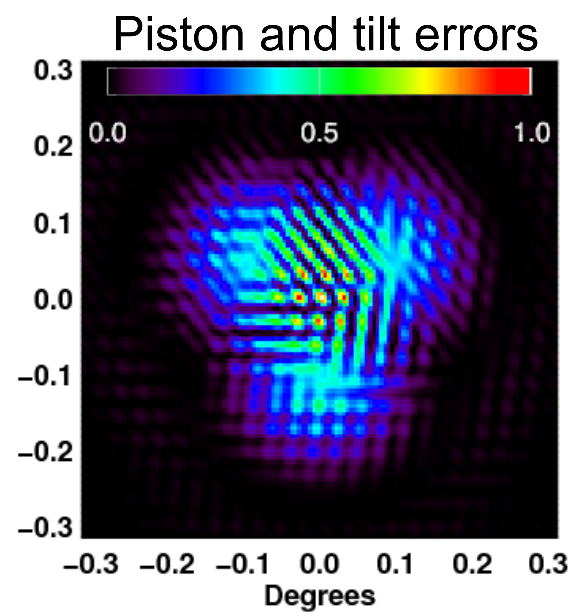
FICSM DATA

PRECOMPUTED LOOK-UP TABLES

Example: Three segments in a group



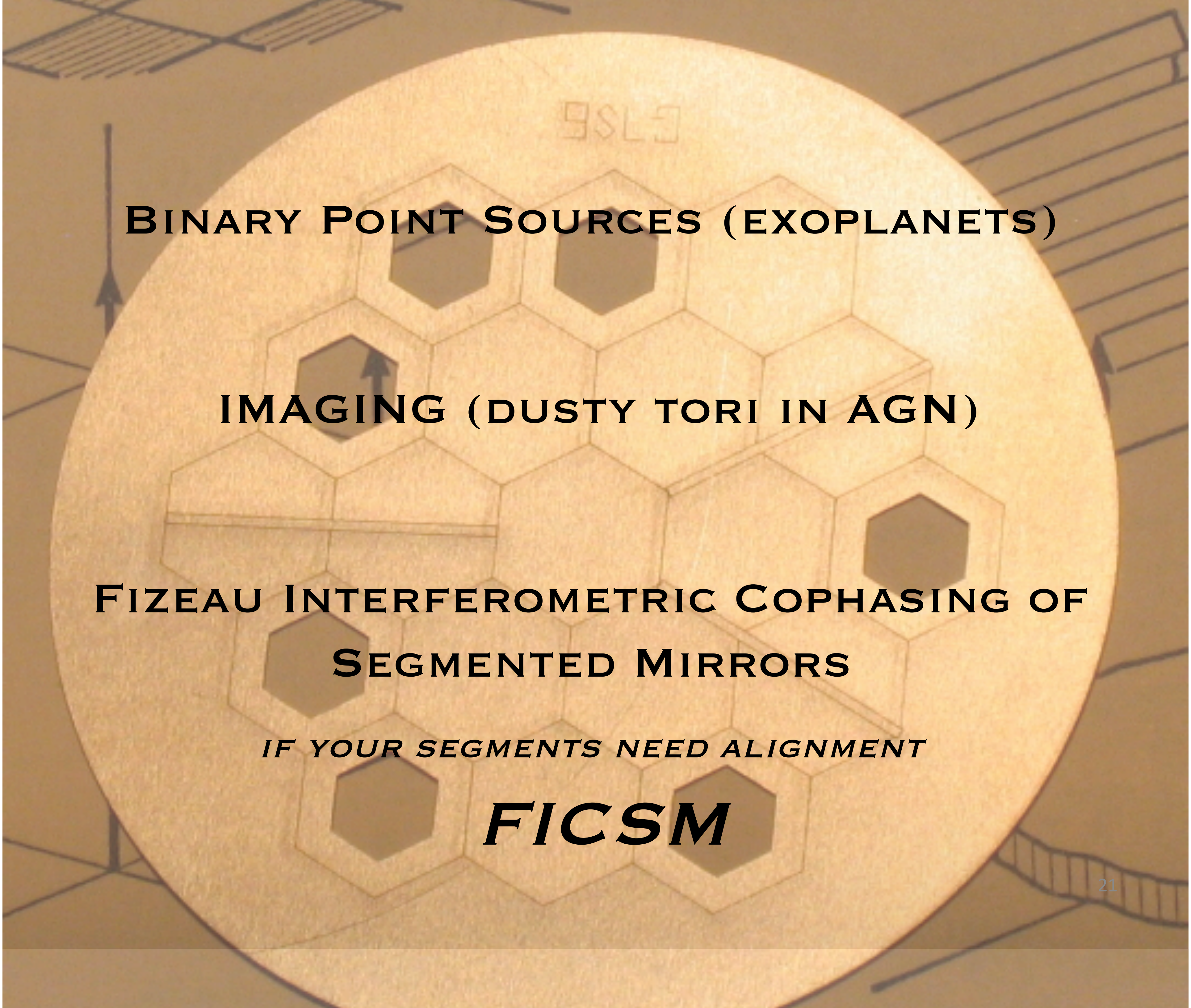




Cheetham Honours Thesis (Sydney), also as JWST-STScI Tech. Report
Cheetham, Tuthill, Sivaramakrishnan & Lloyd, in prep.
Sivaramakrishnan & Acton Operational details for JWST in JWST-STScI Tech. Report

FICSM algorithm

1. An image is taken, with a narrow bandwidth filter
2. The narrowband image is used in a tip/tilt fitting program, to measure tip/tilt
3. The mirrors are adjusted to remove the measured tip/tilt
4. Two images are taken, with broad bandwidth filters at different wavelengths
5. The new images are used in a piston fitting program, where independent measurements are performed on each
6. The piston measurements are compared. If they do not agree, the difference between them and the wavelength difference are used to recover the correct piston
7. The mirrors are adjusted to remove the measured piston
8. The method is repeated once, to remove residual errors.



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Fizeau Interferometric Cophasing of Segmented Mirrors

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