# Wide-Fielding ALMA using Phased Array Feed Receivers

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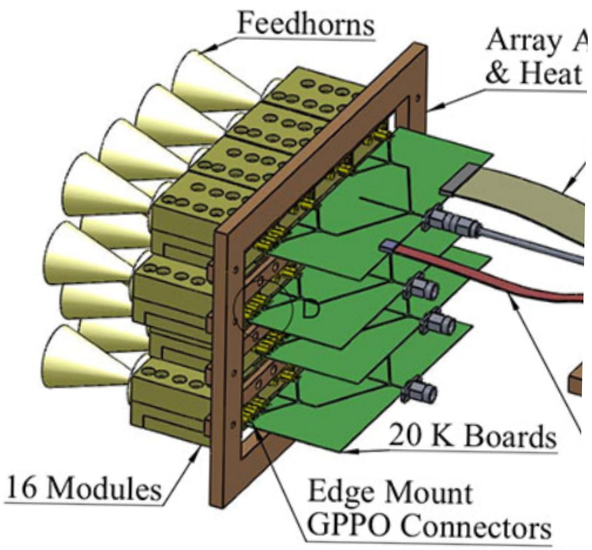
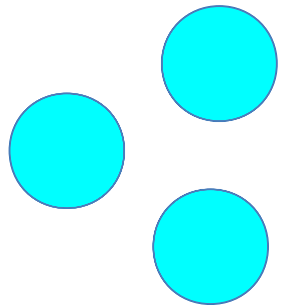
(ALMA Study proposal 2016)

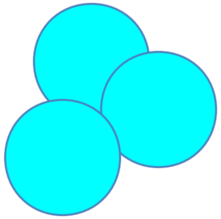
- Current PAF activity at NRAO
- Science case for PAF for ALMA
- Some thoughts on the ALMA PAF instrumentation

# Focal Plane Array vs Phased Array Feed



Beams
of FPA



Beams
of PAF

- FPA : Feed designed to maximize telescope gain and minimize spillover

- PAF : uses electrically small elements; beams are formed by weighted sum of signals from the elements.

- Beams: in FPA do not overlap; in PAF it can overlap (Continuous increase of FOV)

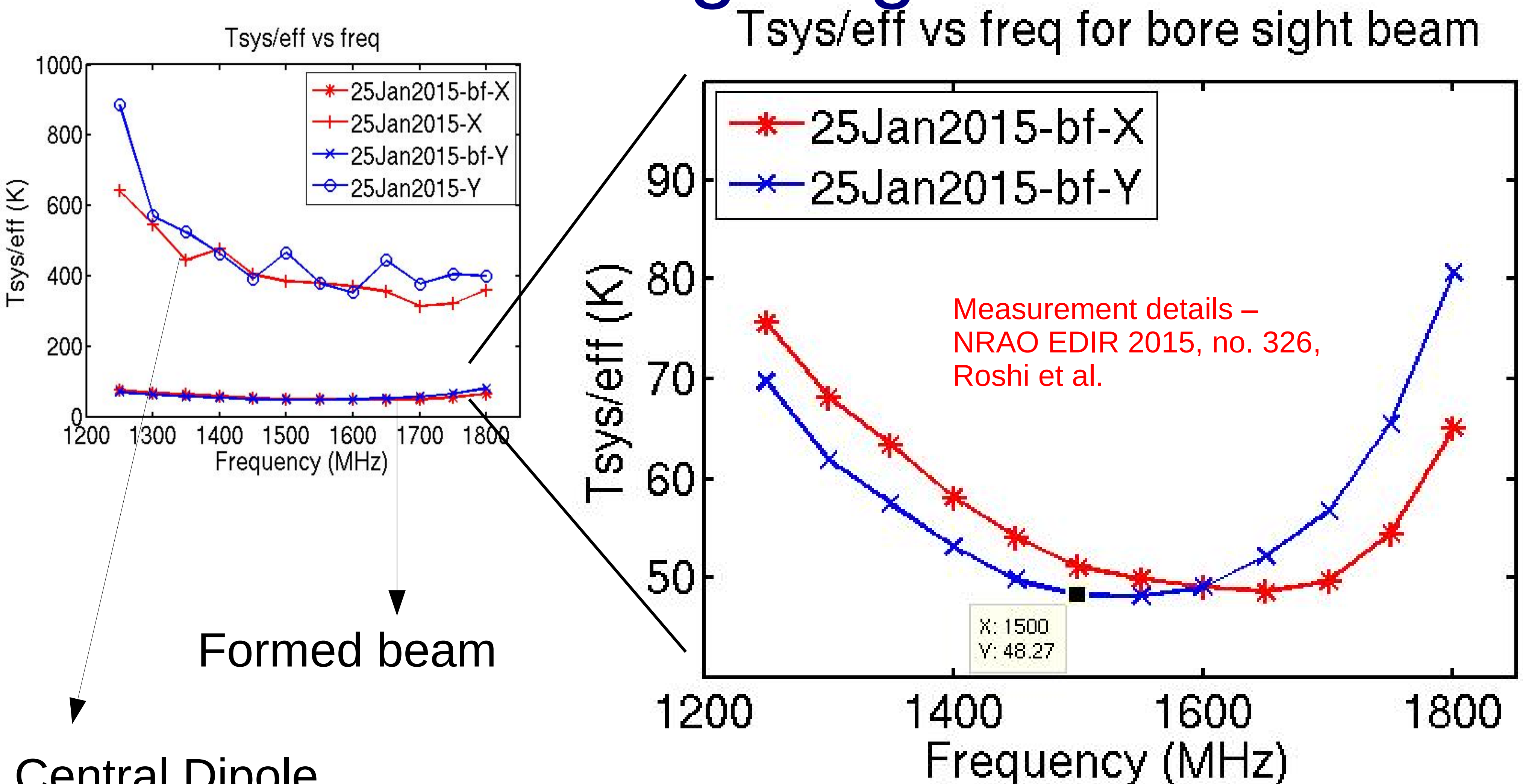
# L-band (1.4 GHz)  Cryo-PAF

19 element dual polarized Kite Array

Kite Dipole

- Cryogenic PAF
- 7 beams are formed by combining the output of 19 elements
- Front end bandwidth ~ 300 MHz centered near 1.5 GHz
- Eventually be used on the GBT

# Boresight beam: $T_{sys}/\eta$ on GBT using Virgo A

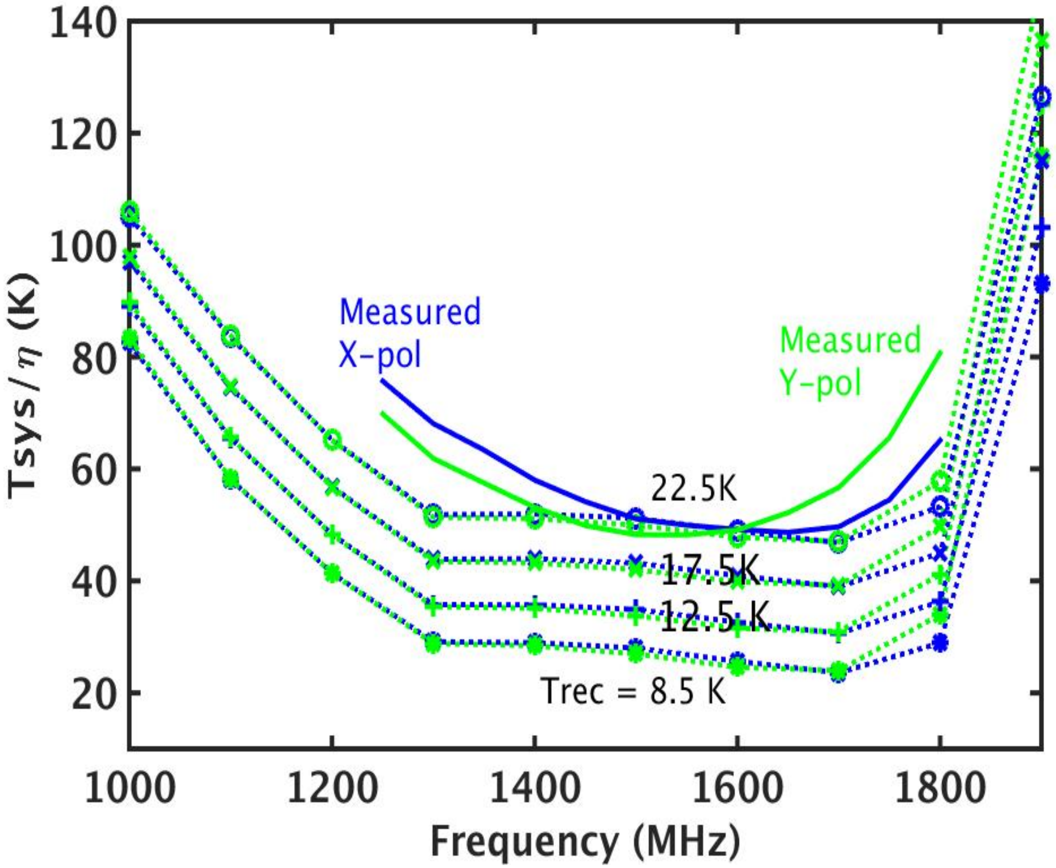



$T_{sys}/\eta$ (inverse SNR) = 48.2 K @ 1550 MHz

# NRAO PAF model vs 2015 obs

## Boresight beam

Model details – NRAO EDIR 2016, no. 330, Roshi & Fisher




| | |
|---|---|
| Thermal transition | 4 K |
| Replacement transistor | 5 K |
| Excess unexplained | 5 K |

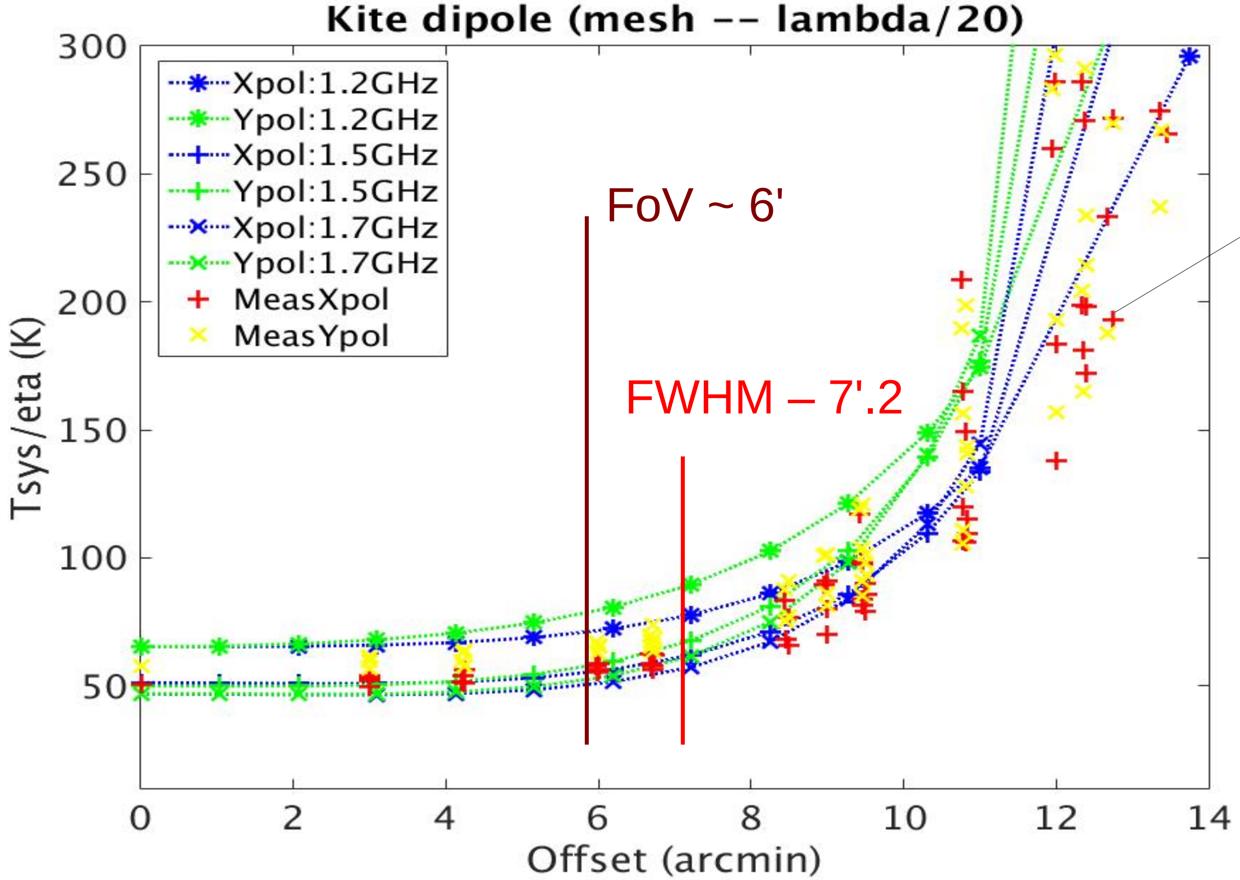
| | |
|---|---|
| Antenna Loss | ? |
| Excess noise in Down converter | 4 K |

Trec ~ 22 K for model to match measurement

Trec is 5 K above what can be accounted for

# NRAO PAF model vs 2015 obs

## Off-boresight beam




GBT Measurement @ 1.7 GHz on Virgo A

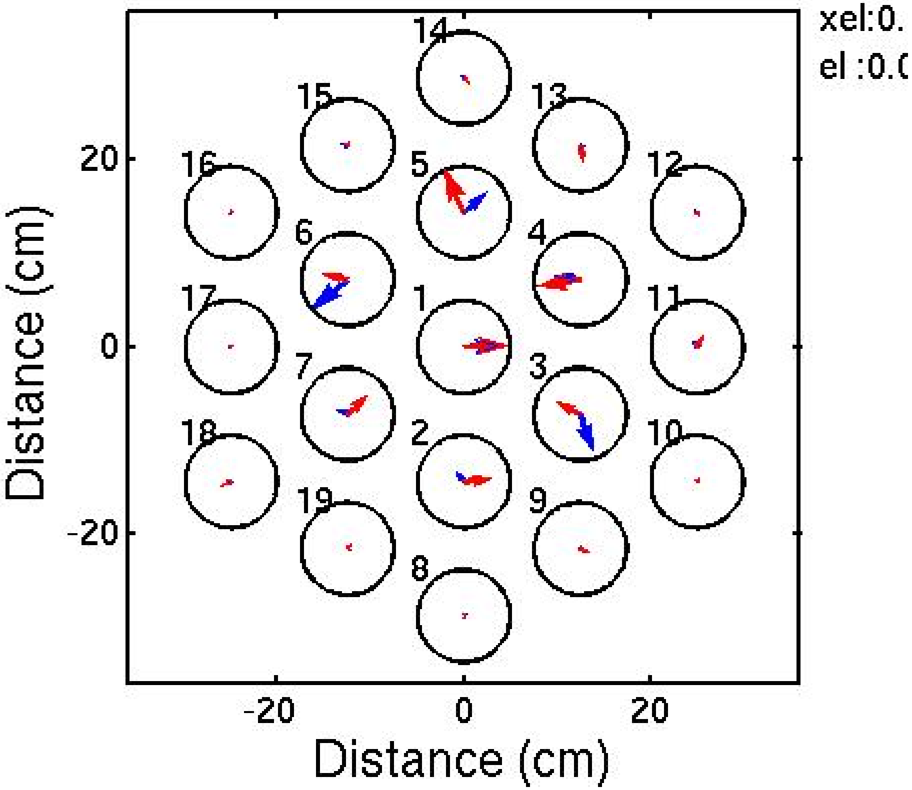
- $T_{sys}/\eta$ = 63 K @ 7'.2 (FWHM) @ 1.7 GHz

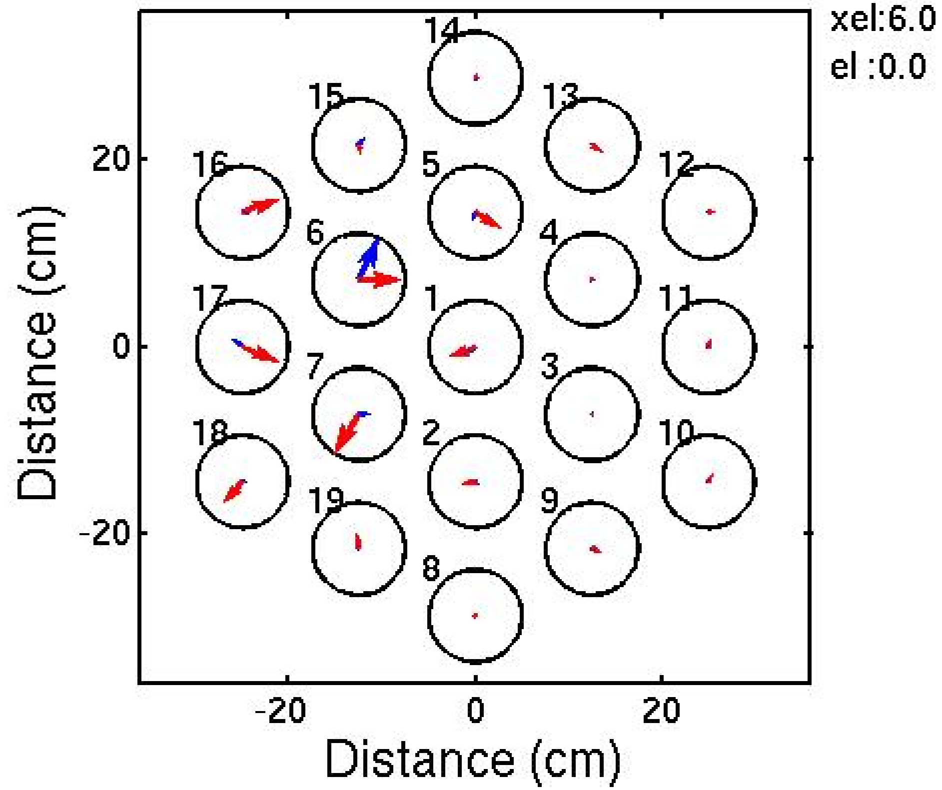
- Survey speed compared to GBT L-band feed : PAF is 20% better (Current GBT L-band $T_{sys}/\eta$ ~ 26 K)

Model results match well with measurements for Trec ~ 22 K

Spillover efficiency – 97 % for Trec ~ 22 K
Aperture efficiency – 65 % for Trec ~ 22 K

# Weights vs offset from boresight

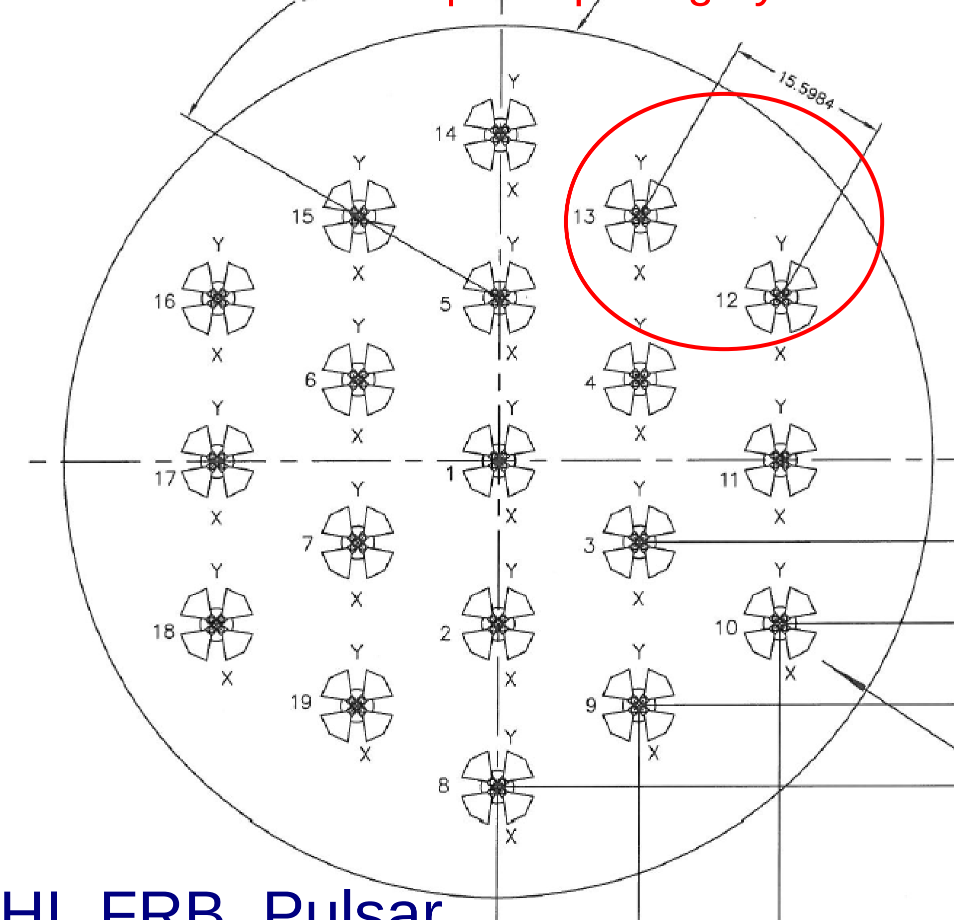



FOV is limited by the array size to ~ 6'

# New PAF Instrumentation in 2016
# Increased FOV

Increase the dipole spacing by ~ 30 %




- Scientific instrument on the GBT – HI, FRB, Pulsar
- Bandwidth – 150 MHz; Digital downconverter & beamformer.
- On going work.

# PAF for ALMA (Band 3)

Study proposal submitted in 2016:

- Initial study at Band 3 (no SIS mixer; LNA or MMIC exist)
- Physical size of elements reasonable
- Interesting science cases; wide usage; available in all antennas.

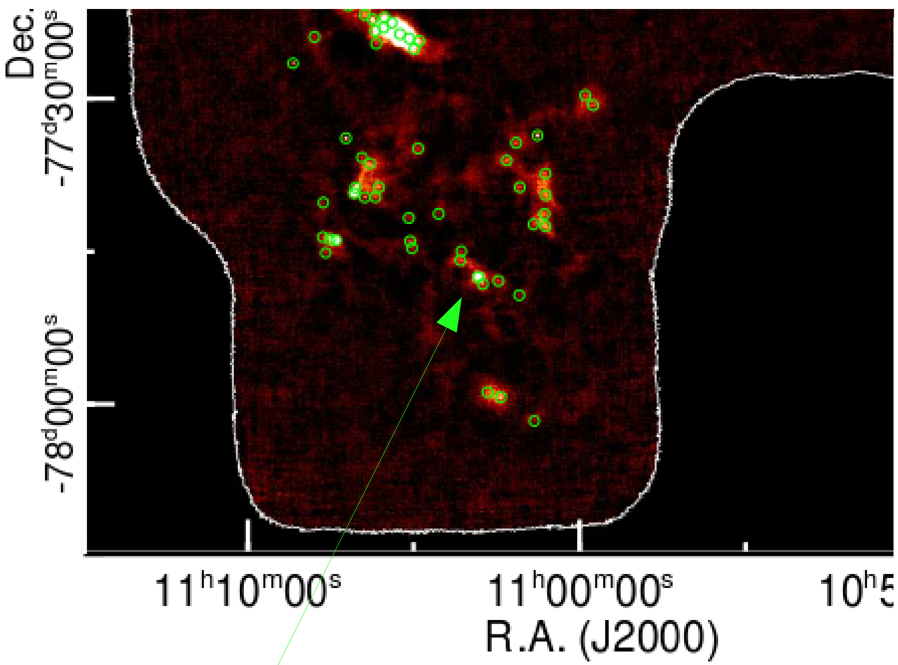
- Need to build prototype (Development proposal + Study)

# PAF vs FPA for ALMA

- PAF : continuous FoV → uniform uv sampling
- PAF: compensate off-axis optical aberration
- PAF: use as multi-object spectrometer
- Long term goal – short spacing over the PAF FoV
- PAF system is compact and can fit into the limited physical size of the current cryostat

- Price to pay – signal processing at the antenna base; signal transport; correlator hardware + software

# Science case for PAF development




Band 3 primary beam on Chamaeleon I
870 micron image (Dunham et al 2016)

Band 3 resolution → $10^{-4}$ pc

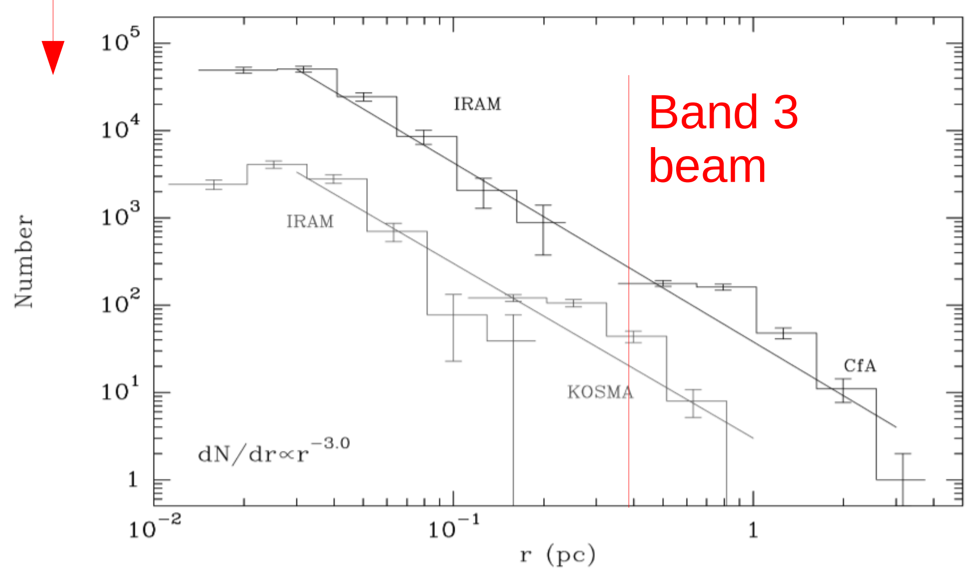
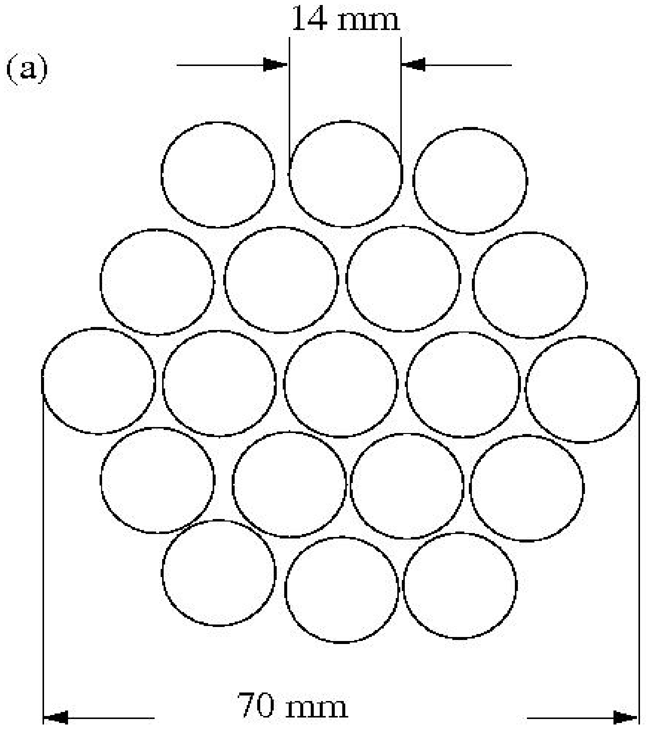


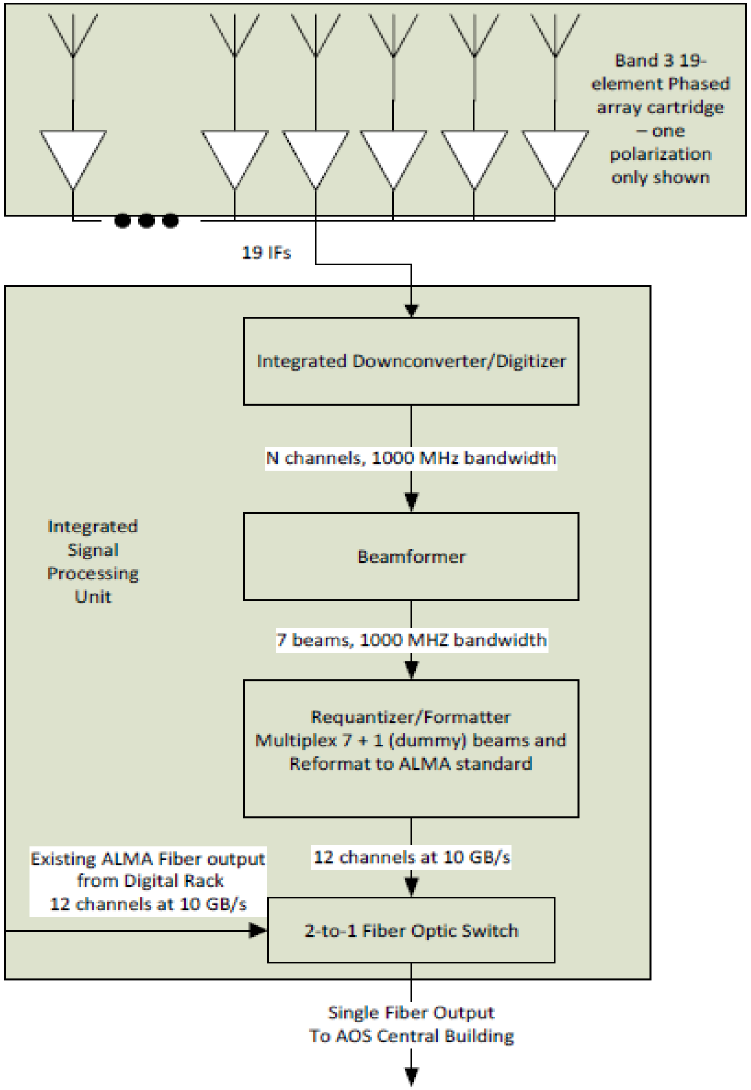

**Fig. 2.** Combined size spectrum for the Polaris Flare in the $^{12}$CO (1⟶0) and (2⟶1) lines. The solid lines represent fits to the data.

(Heithausen et al 1998)

- To obtain the full physical picture of molecular clouds large range in physical scale (100 pc to 10 AU) needs to be observed in different spectral line. Needs mosacing with high angular resolution. Increasing FoV reduces observing time.
- Extragalactic observations : Blind survey; multi-object spectroscopy
- CO intensity mapping (single dish)

# Initial thoughts on ALMA PAF




- 7 beams on the sky
- Bandwidth ~ 1 GHz (~2000 km/sec)
- Simultaneous $^{13}CO$ and $C^{18}O$
- Deploy in four 12 m antennas; use part of the correlator in sub-band mode

# Thank You

Ack: T. Beasley, A. Wootten, R. Fisher