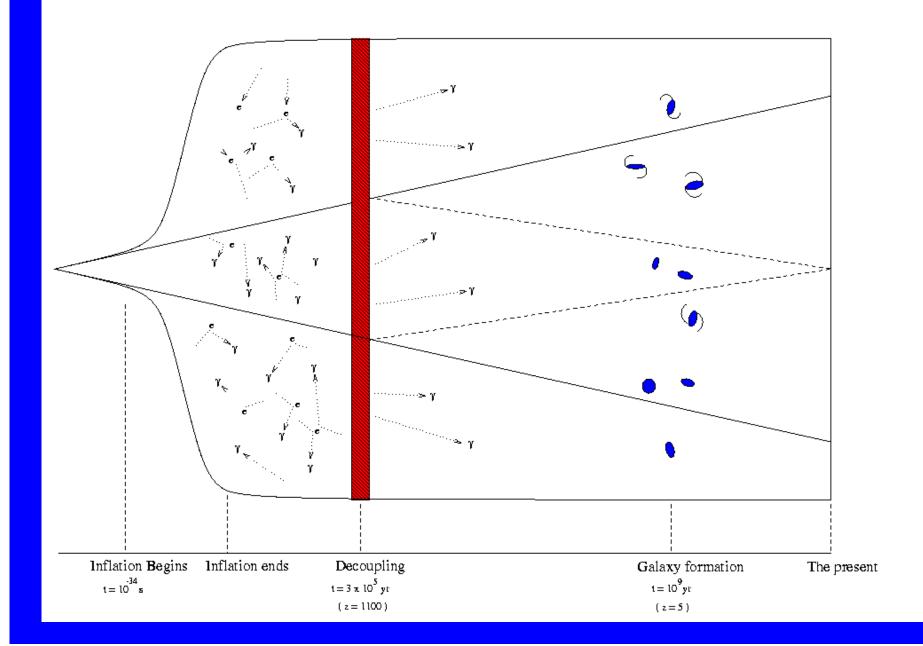
Interferometric Observations of the CMB from the South Pole with DASI Clem Pryke Madison Astrophysics Seminar October 26 2000

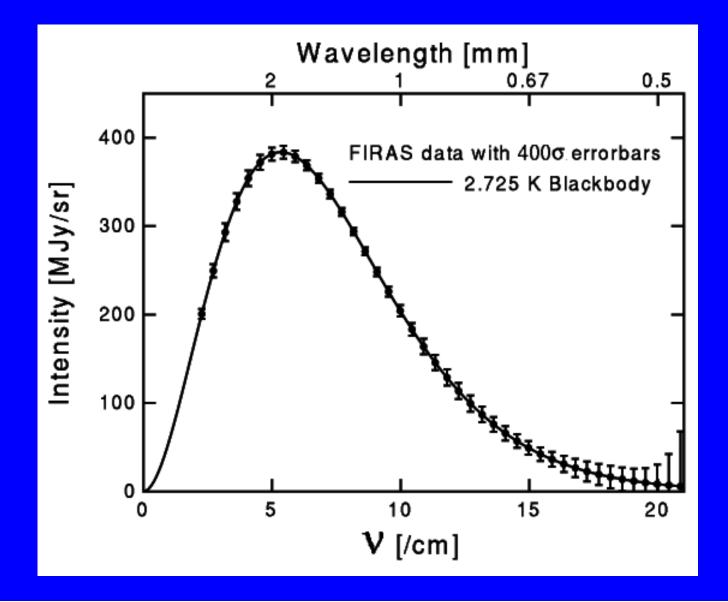
## Outline

- CMB, multipoles, and current anisotropy data
- How DASI works in principle
- Design and implementation
- Deployment
- Analysis overview
- Conclusions

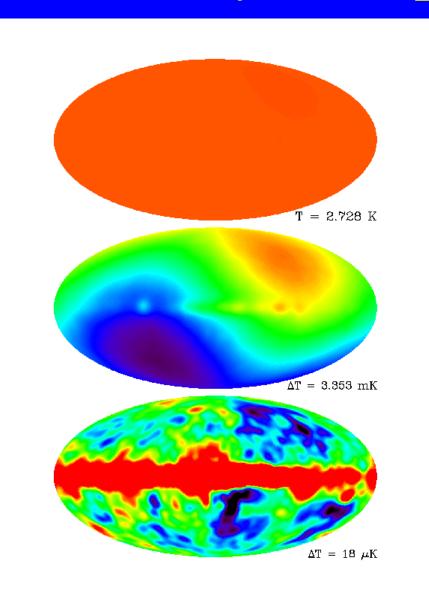
#### A Cartoon History of the Universe



#### **CMB** is Blackbody Radiation



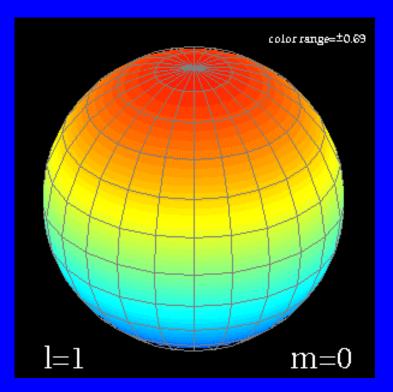
## CMB is nearly Isotropic

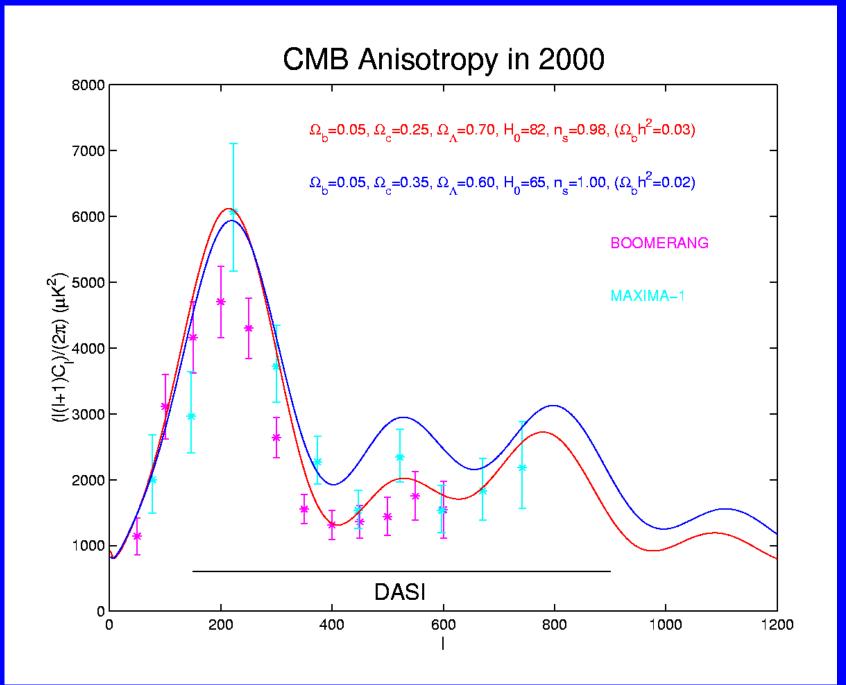


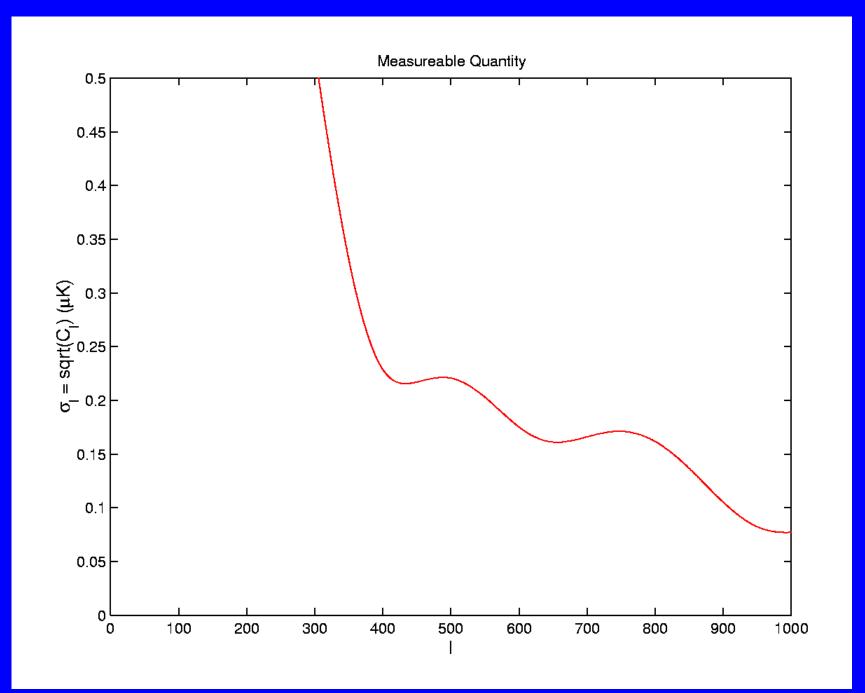
$$T(\theta,\phi) = \sum_{l=0}^{\infty} \sum_{m=-l}^{+l} t_{l,m} Y_{l,m}(\theta,\phi)$$

$$t_{l,-m} = t^*_{l,+m}$$

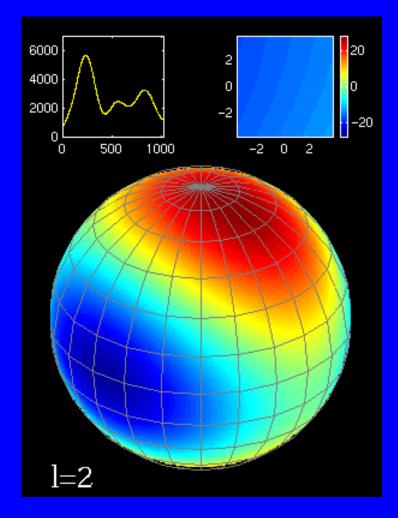
# Multipole Components



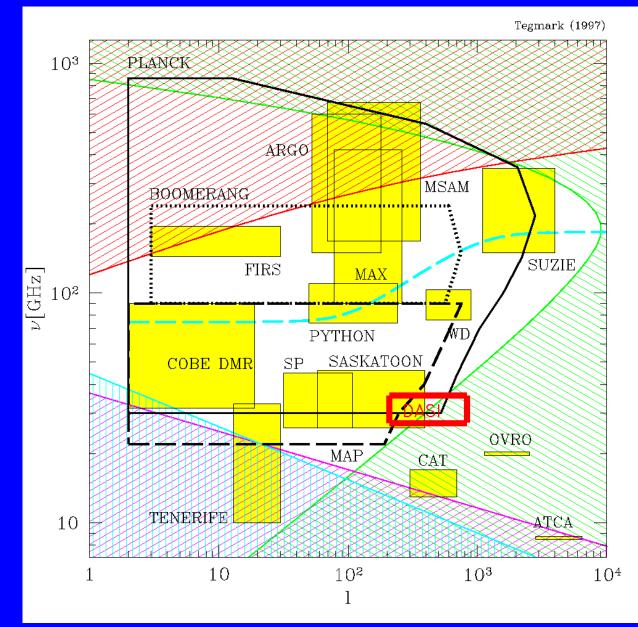




## **CMB Sky Simulation**



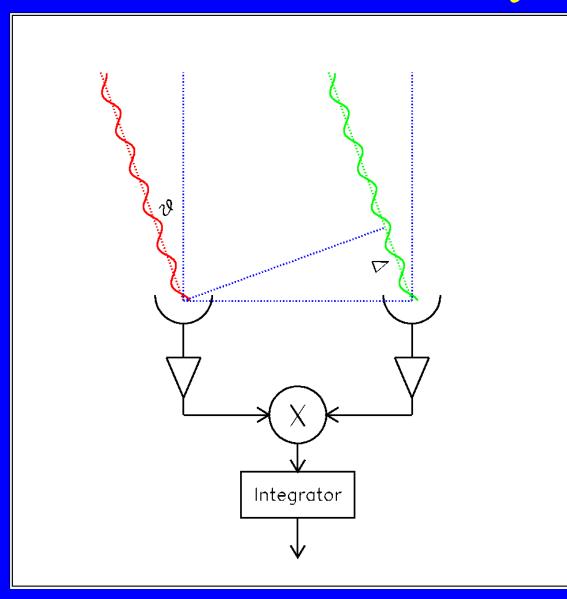


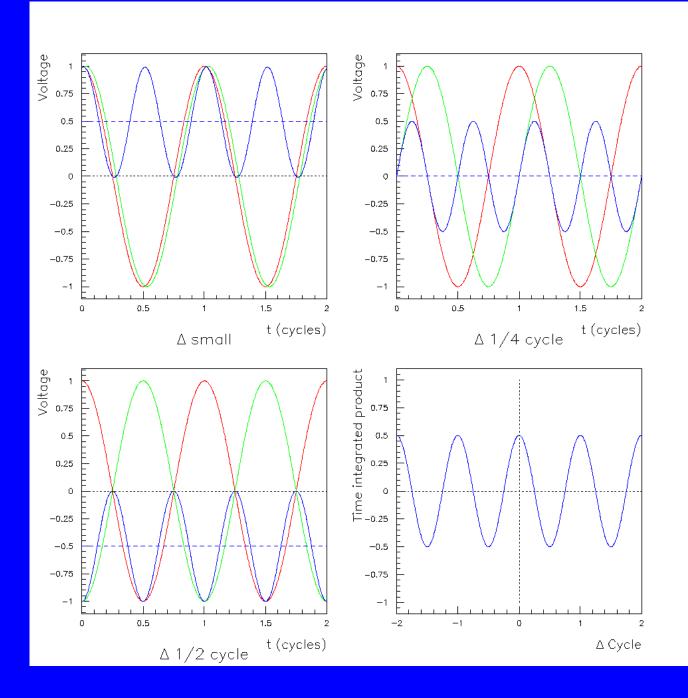


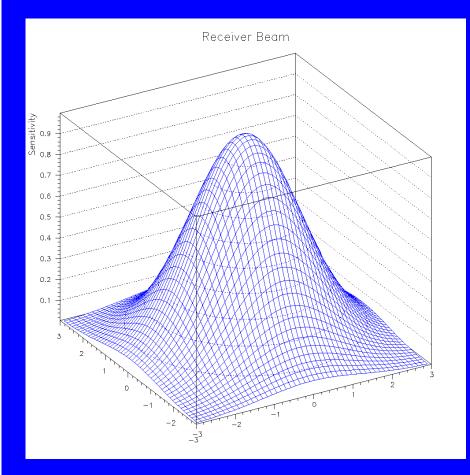
#### Why an Interferometer?

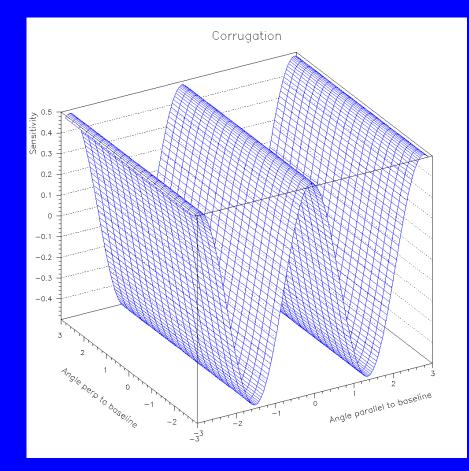
- Directly measures power spectrum of the sky.
- Intrinsically stable only correlated signals are detected.
- Designer can control angular range covered.

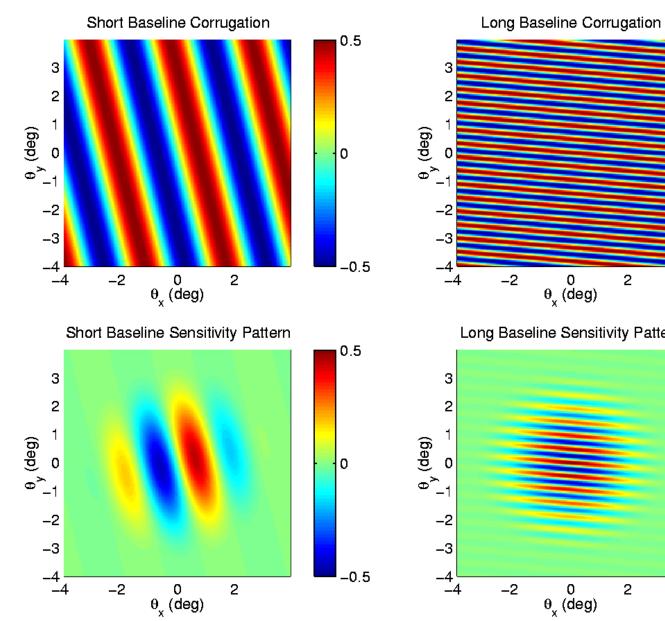
## **Radio Interferometry**





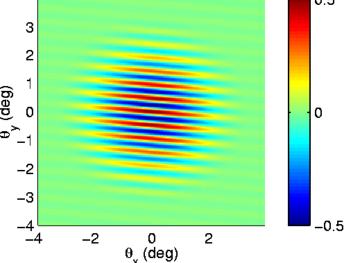


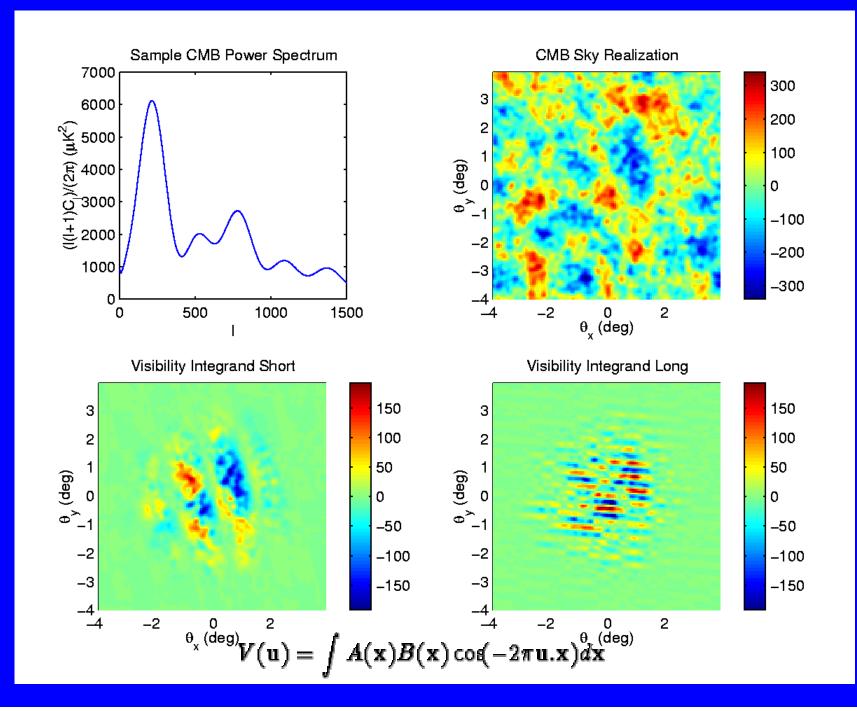


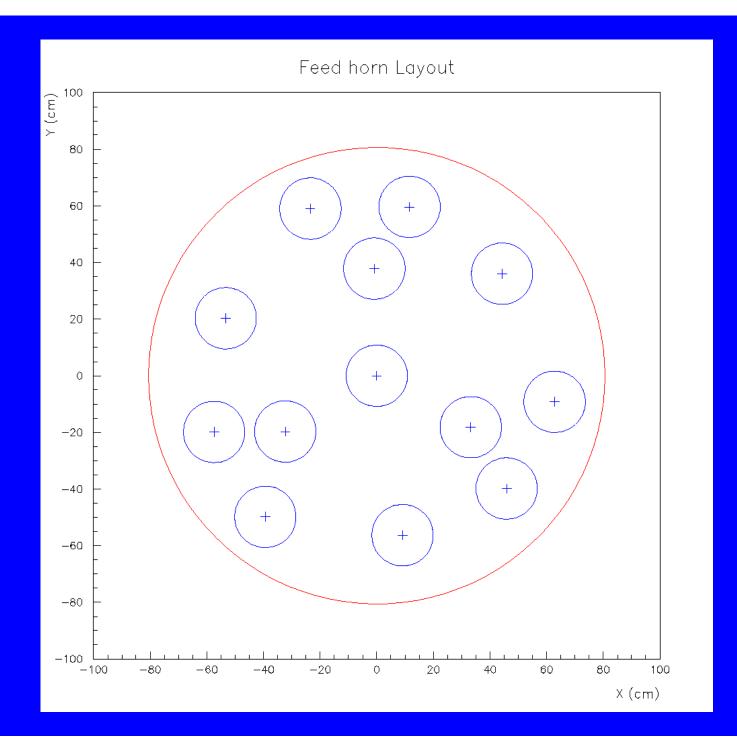


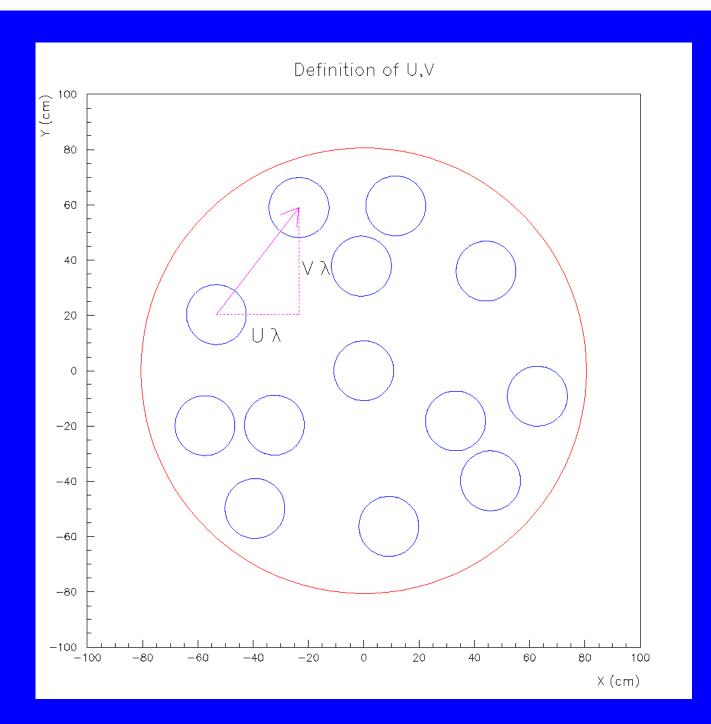
0 -0.5 Long Baseline Sensitivity Pattern 0.5

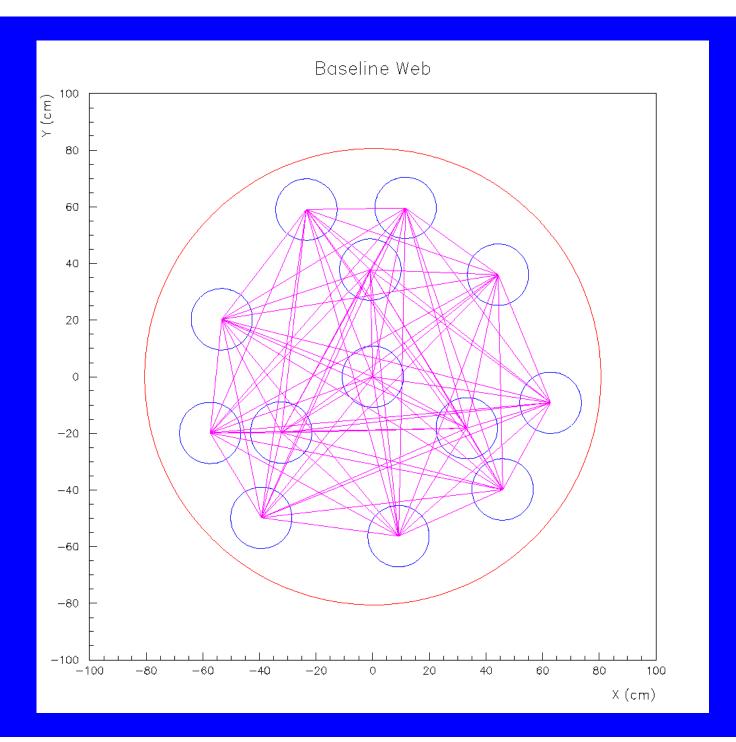
0.5

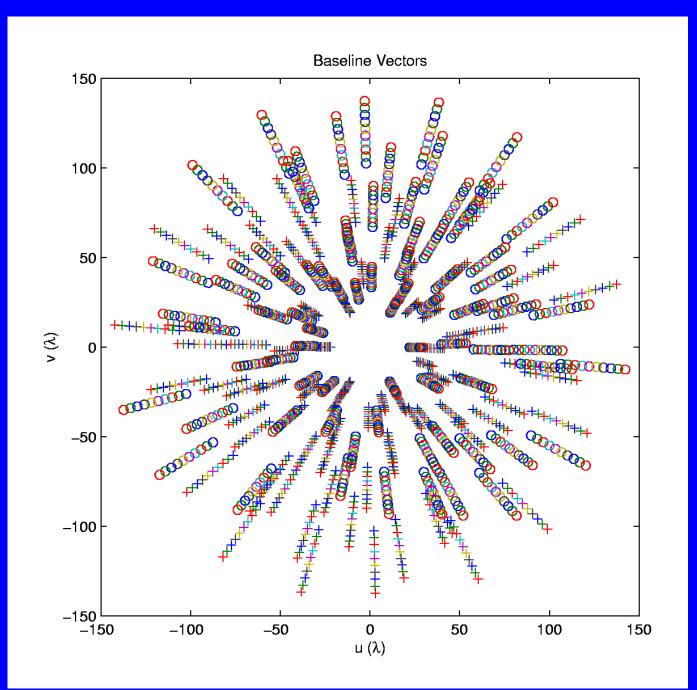


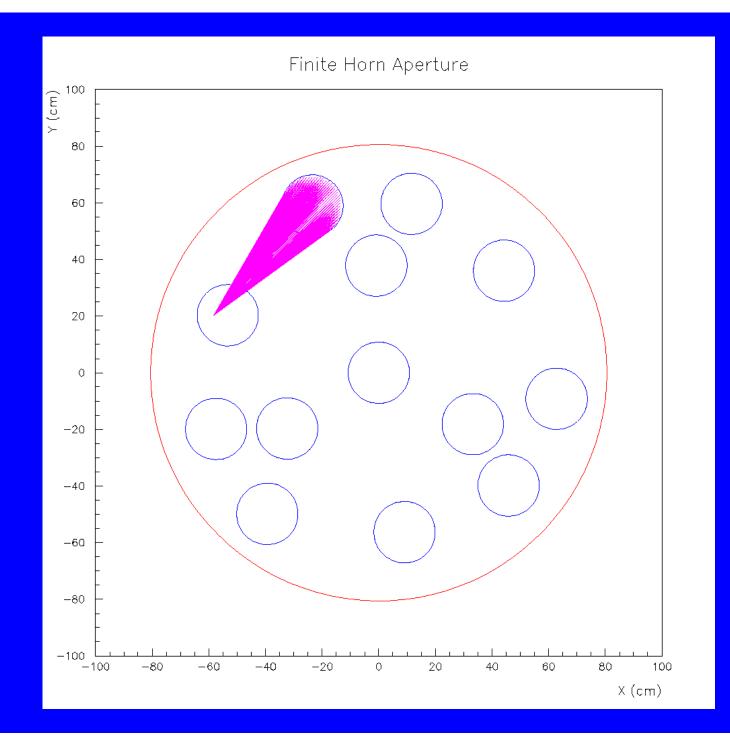




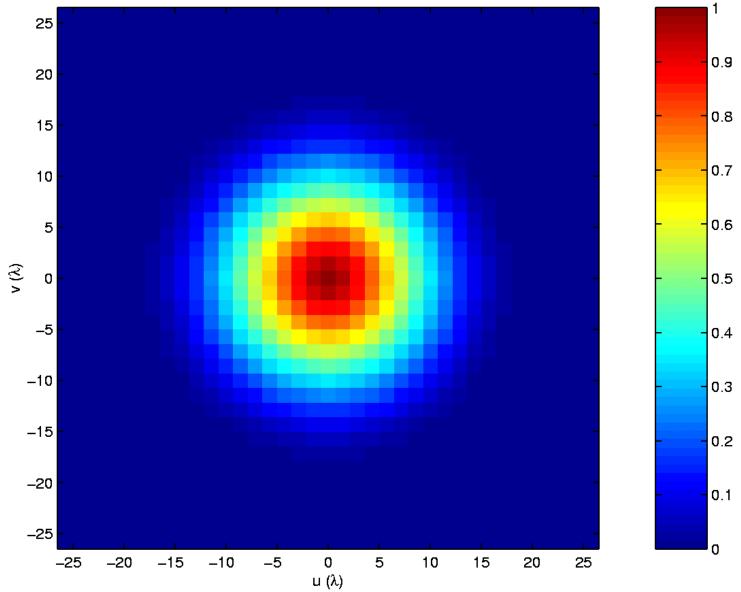




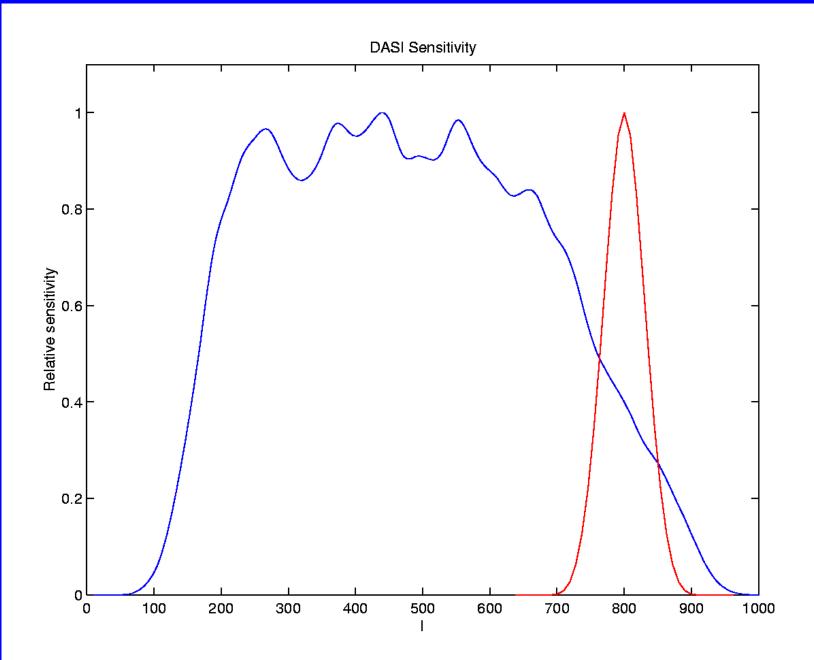




Baseline Sampling Pattern

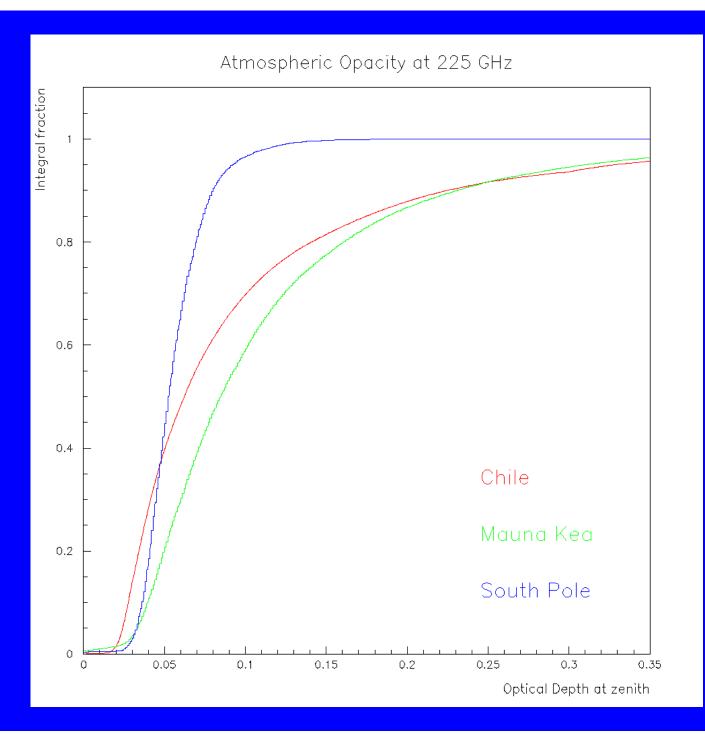


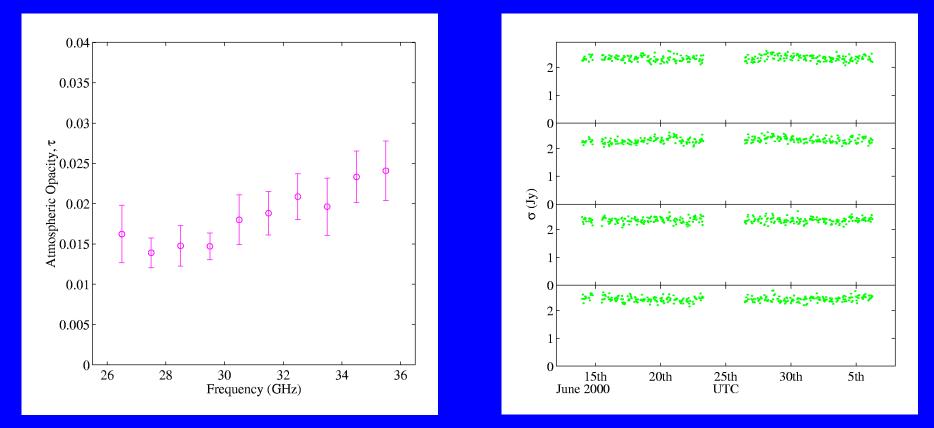
UV Plane Coverage 1 150 0.9 0.8 100 0.7 50 0.6 ע (צ) א 0 0.5 0.4 -50 0.3 -100 0.2 0.1 -150 0 0 u (λ) 150 -150 -100 -50 50 100

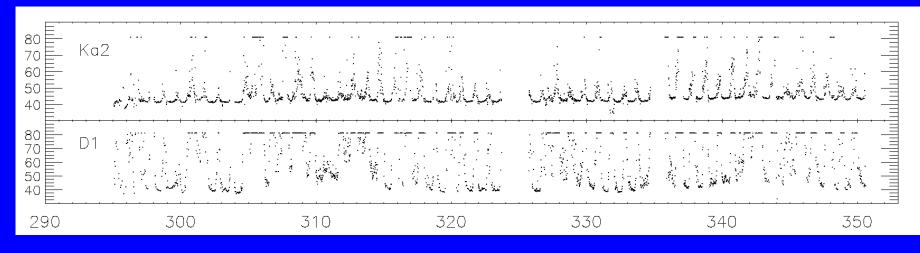


#### Why at the South Pole?

- Low atmospheric moisture
- Atmosphere highly stable
- No Sun for 6 months of the year
- Fields remain at constant elevation angle
- Existing infrastructure and logistics







#### **DASI/CBI** Collaboration

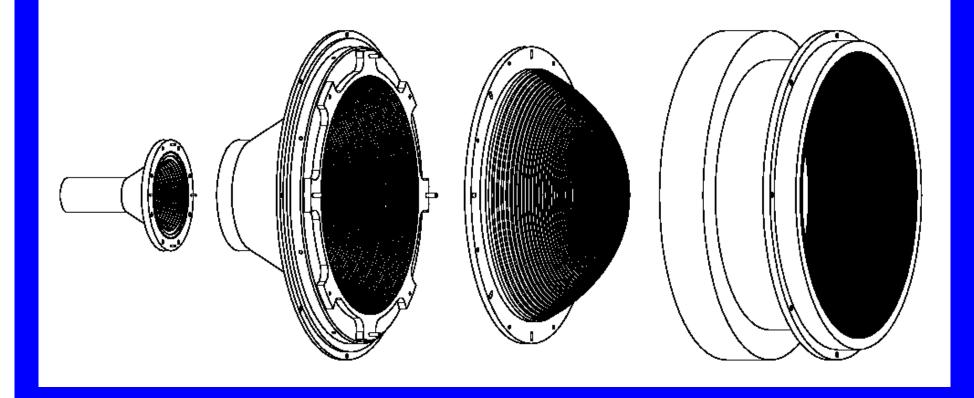
- CBI at CalTech / Chile
- Steve Padin / Tony Readhead
- Tim Pearson, Martin Shepherd
- John Cartwright

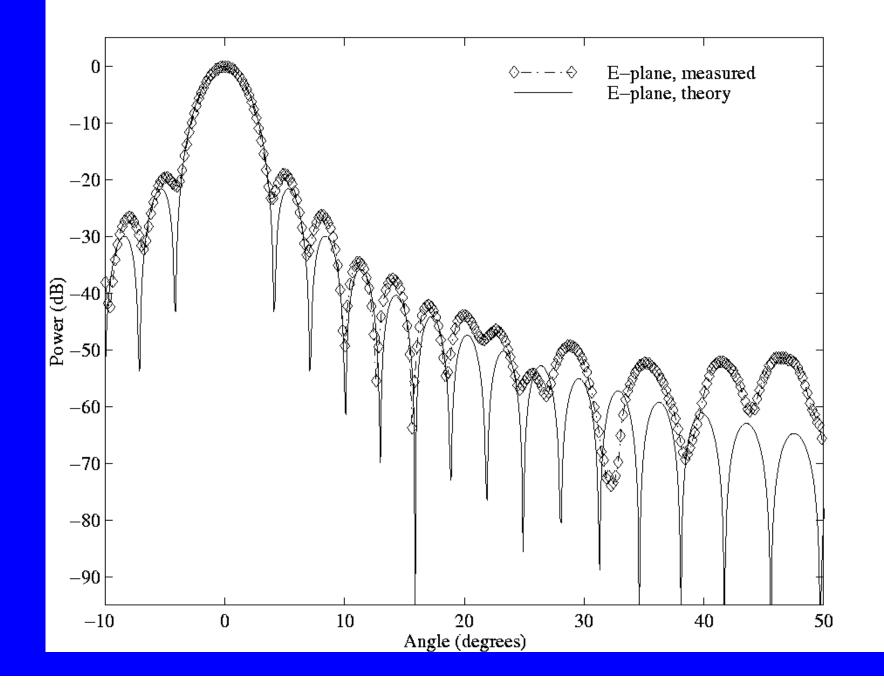
- DASI UofC / South Pole (CARA)
- John Carlstrom / Mark Dragovan
- Bill Holzapfel, Erik Leitch, Clem Pryke
- Nils Halverson, John Kovac
- Ethan Schartman
- John Yamasaki / Gene Davidson

### **DASI** Design

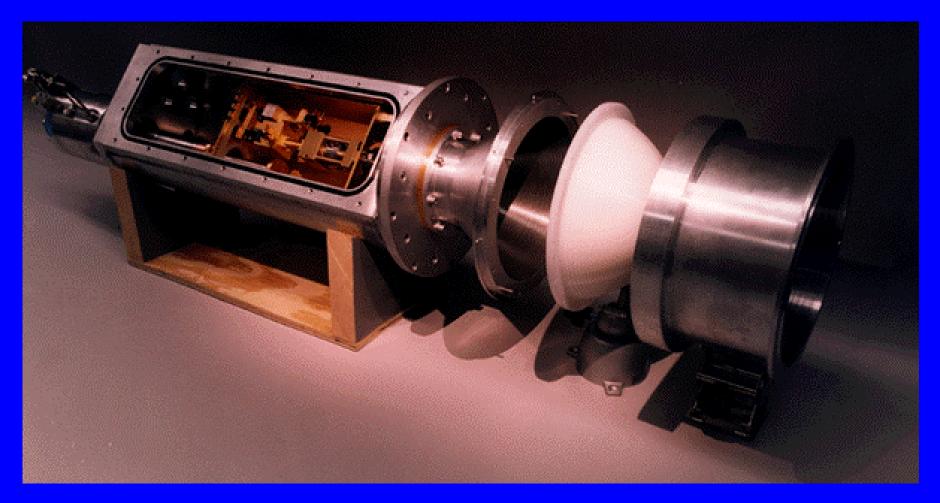
- Corrugated microwave feedhorns
- 26-36 GHz HEMT amplifiers cooled to 20K, downconvert to 2-12 GHz
- Passive filter splits into 10 x 1GHz bands
- Each band correlated to form 156 visibilities

## Feedhorns

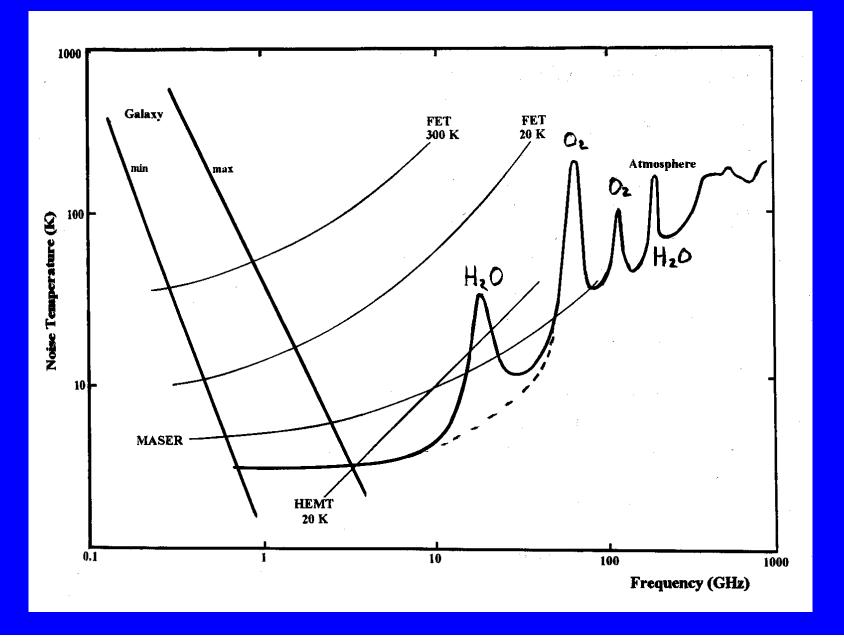




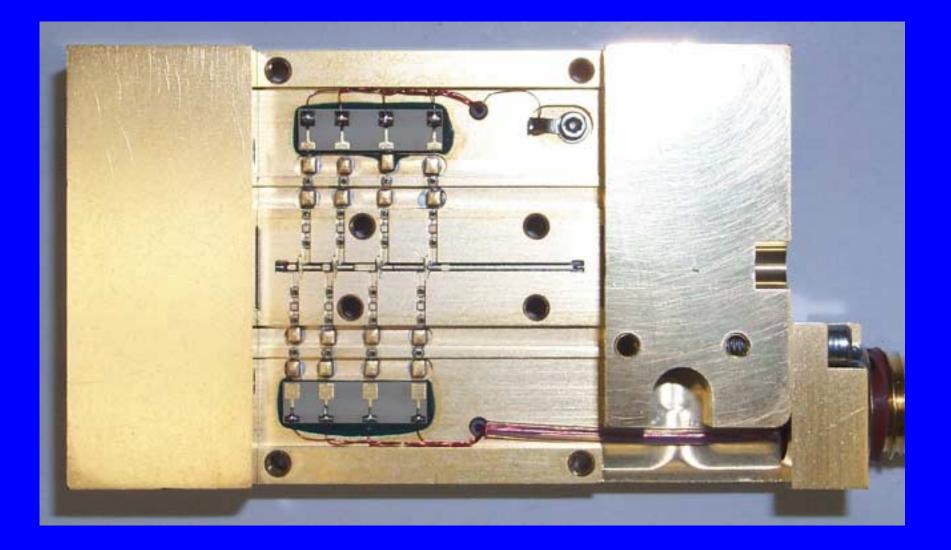
## Receivers



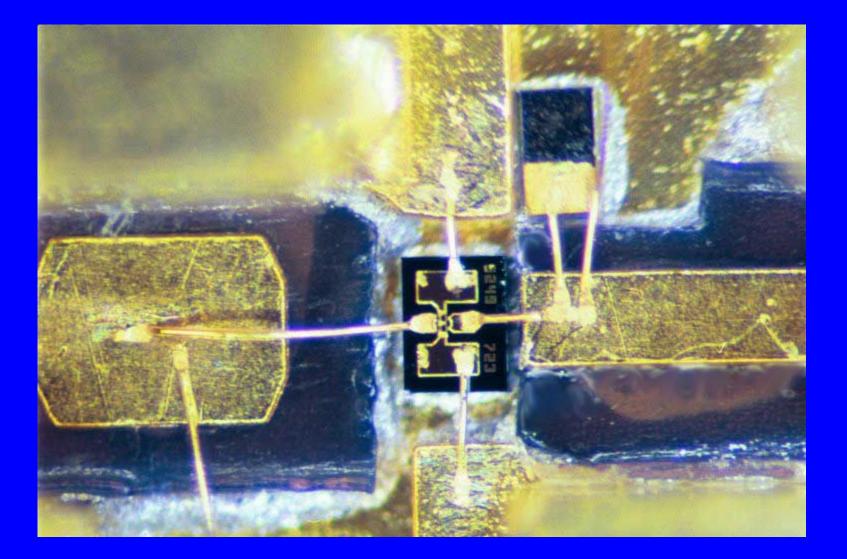
## **Atmospheric Emission**



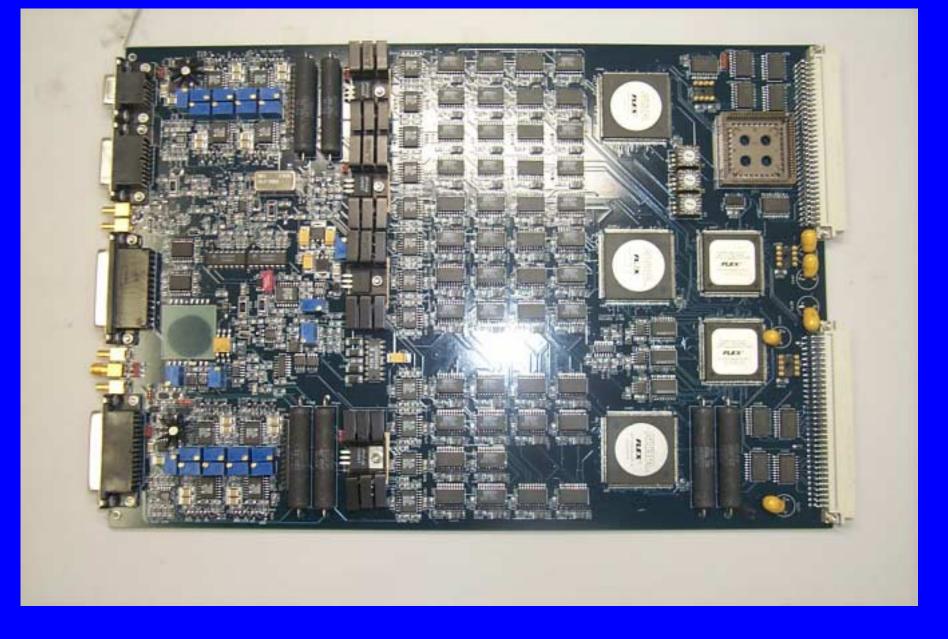
# **HEMT Amplifiers**



# First stage FET



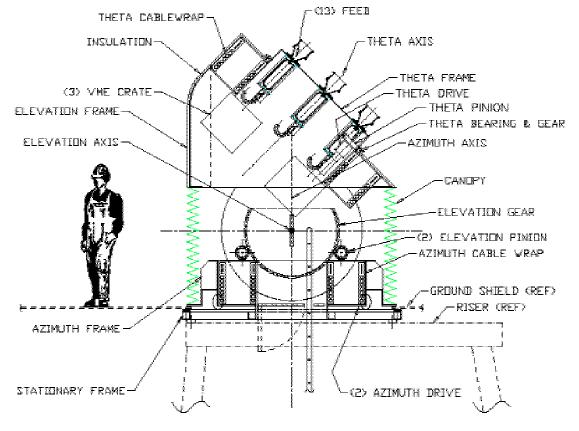
## **Receiver Control Card**



## **Correlator Card**



## **DASI** Mount



SIDE VIEW - EL =  $45^{\circ}$ 

## DASI Deployment

- Mount completed April 99 by Vertex Inc.
- Initial assembly and integration in EFI high bay.
- Moved out to parking lot July 99
- Disassembled for shipping August 99
- Arrived in Antarctica October 99
- Arrived at South Pole November 99
- Fully operational by station closing February 00
- Data taken from sunset to sunrise

## DASI at Vertex



# DASI Leaves High Bay



# Summer Testing



## Arrival in Antarctica



## Arrival at South Pole



# Re-assembly



# Lifting to Tower



## Cover for Working



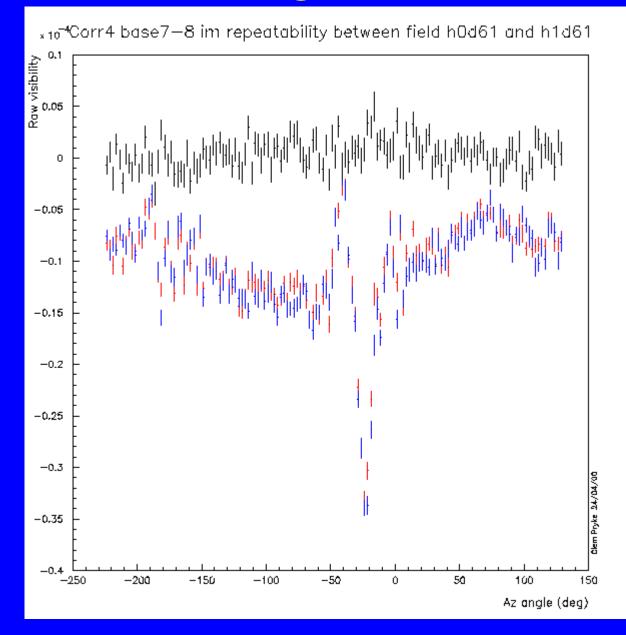
## DASI at Sunset

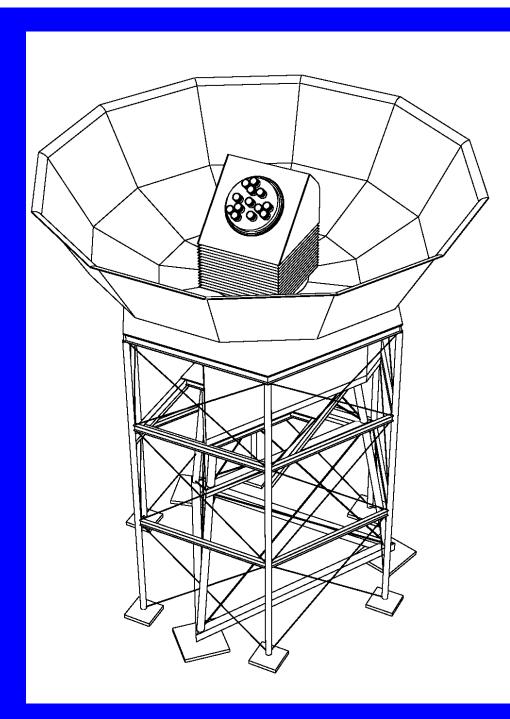


## First Impressions

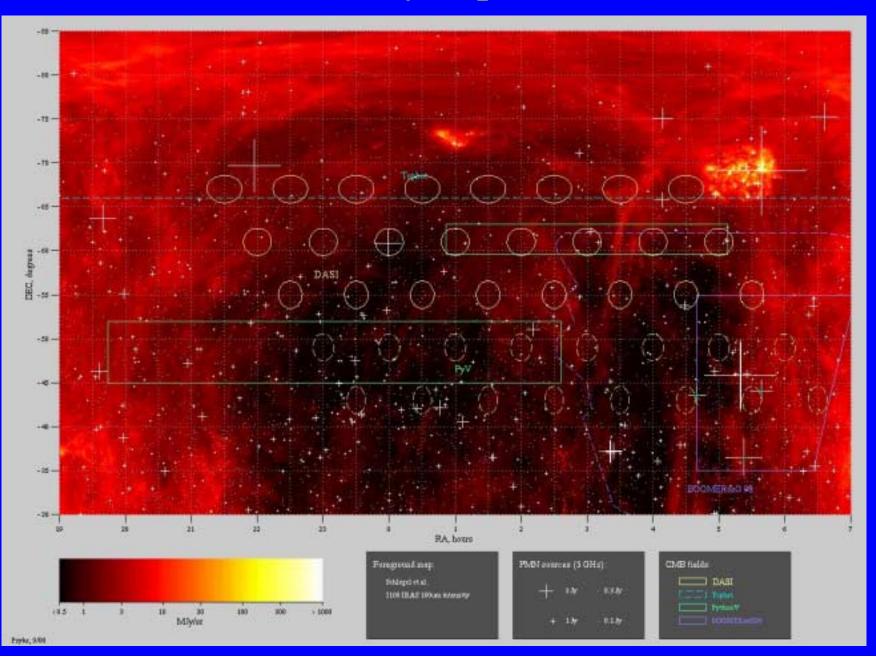
- System works well and is very stable
- Imaged astronomical object quickly
- Initially ground pickup seemed to be a problem...

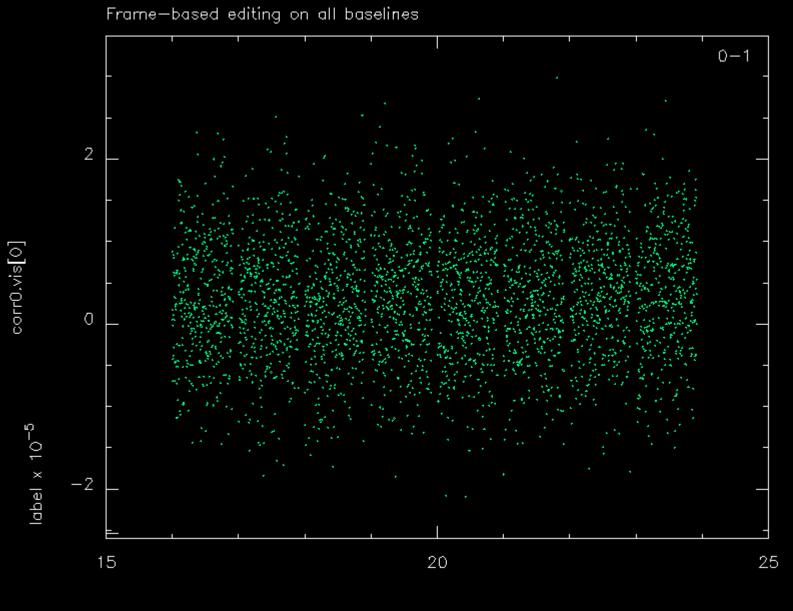
## Ground signal is stable





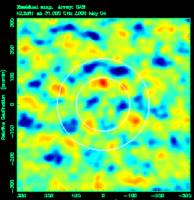
### Southern Dust Skymap and DASI Fields







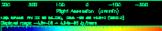
### Raw Images

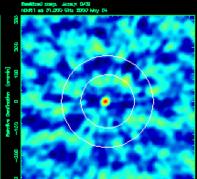


Transfer tra

2000 3200 100 0 −100 −320 −32 Right Assembles (arcmis) sequence ret an an account, set +2 or (arcmis) Diphyse range −484+25 + 0.14+04 (arcmi

-MET-WET-WET & WE MET SUF WET WET



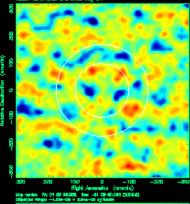


Were returned with the second of the second

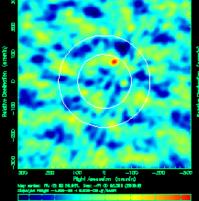
Arrest Dist

way watan na sa ta anani, awa -ta ta sakar (anan) Dagana maya - 1.276-10 - 2.385-10 (ataun - 1.677 - 2.077 - 4.677 - 1177 - 1177 - 1177 - 1177

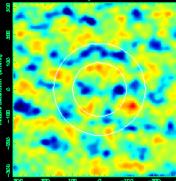
Desidual stage Arreys DAS House at 31,000 SHz 3500 May 0



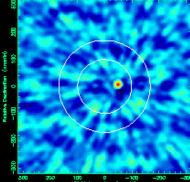
Residual stag, Jarrey (W3) Salet et 34.000 alle 3000 Mey a



#### Beelfand 1003), Jerseyn (MSI Mediti ac 31,000 dek 2000 May Di



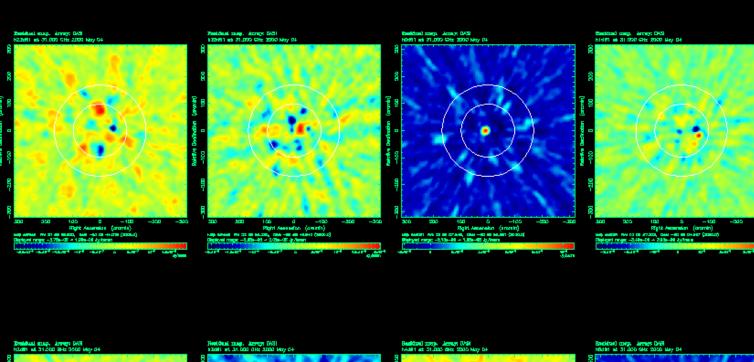
350 2050 10日 0 -1030 -日月は人はeventein (cronch) はpresent Partie (1980-0) はpresent Partie - 13-4-0 + 4-4-0-2 (Salam 1 日月の日日 - 13-4-0 + 4-4-0-2 (Salam 1 - 13-1 - 13-5 - 13-4-1 + 13-5 - 13Bredetard corp. Jarrays DAR Histolin at 31 JOO Sets 2000 May D4

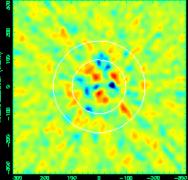


200 250 100 0 -100 -200 Hight Assamation (promin) May series: RV: H 68 67/99. Den: -11 (01 15/46 (2000.0) objecte mayer -scatt-on + 1.754-56.42/home

-0.01<sup>-1</sup> - 0.01<sup>-1</sup> - 0.01<sup>-1</sup>

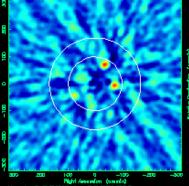
#### **Ground Subtracted**





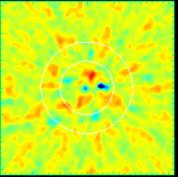
Right Assembles (cromin) Represente: Nr. D1 d9 H4201, Nex -H (3)+60.041 (20040) Represented -1.120-08 + 1.00-08 (20040)

อสริ⊢นองเรื⊣เริ⊣องเรื่ง สสริ เริ่มสร้



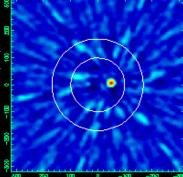
Pight America (onunis) Neptania: No de la Maiti, Sac -49 do Idalis (debin) départe majo -3.11-11 - 1 -1.09-00 (g/main

-201 -10 1 1 2 212 8.18 401 201 201 202



Hight Assession (arrents) high webs: No 63 bi 67/40, Dec -41 bi 16.00 (2010.0) chapter mage -2.0-00 + 1.00-00 (2010.0)

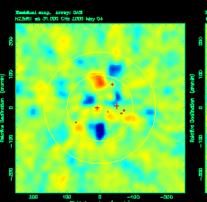
-3898 -375 -3878 -38 -59 -598 0 577 3 107



Hight Accumulan (arcmin) Kight Accumulan (arcmin) Kight pentar: No M DI 47275, Dec -41 (4 16:54 (2003)) diapter mays -cumu-cu + taxa-ca (ginari

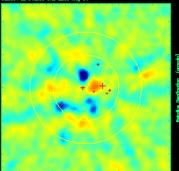
-202 0 200 000 000 000 10 1200 1400 10

#### Ground and Point Sources Subtracted

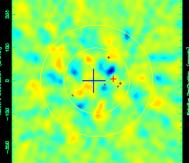


300 100 0 −100 −200 Right Assends (corris) way away mist at match, wai +3 or (+2m (corst)) Diphyter range -0.05 + 3.11 + 0.04 (corst) Diphyter range -0.05 + 0.11 + 0.04 (corst)

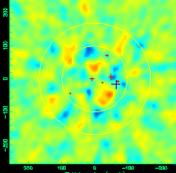




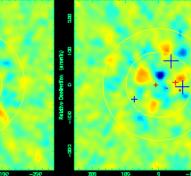




203 100 0 -100 -200 Right Americkin (month) e water ne or an orang, na -et a suar (mont) high anyo- 071 - 0.114 (Artina)

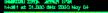


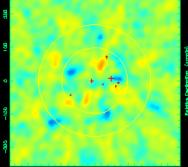
Red Gald Table, Arven (143)



2073 1075 0 — 1070 — 2070 Plight American (constrict) Naphartine: The OE BD Matheff, Gener – 97 00 Matheff (construct) Salangan rengen – 5. mar + 0.1 mar - 0.7 Mathef

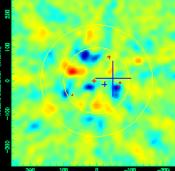
-10 -64 -61 -68 1 67 61 67 63





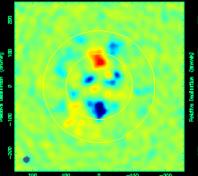
200 100 0 - 100 - 20 High Ausensien (arcela) Lapanian R-6 8 M 07:40, Dec. -41 80 (4.07) (2000) Chappen may - 0.031 + 0.14 (2000) Company - 0.14 (2000)





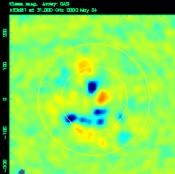
### ...Plus Cleaning





Might Ascendos (arcmis) No 01 de Stalle, Leo -44 de Stalle (20042)

(A) 64 dafteren Biz 52 a 22.4 (anerik) al - Malf

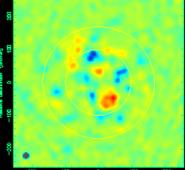


200 103 0 -130 Fight Assession (anoth) Namerian Rozz IV Nation, per -14 of Alexa (anoth) Nam Phile 22 -2344 (anoth) of -1544 Deep Phile 22 -2344 (anoth) of -1544

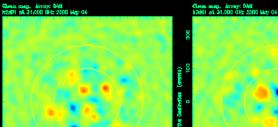
Charas samp. Jacony: DASI Naditi na 31.000 ofte 2000 May Di

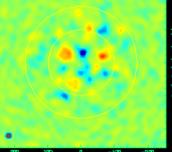
200 100 0 -100 High Assentian (Arrenta) Hay pairs - 2014 (Arrenta) Hay pairs - 2014 (Arrenta Perry PAHA 23. - 2014 Grantal Arrenta Perry PAHA 23. - 2014 Grantal Arrenta

#### Secondary, Java, NG 1951 et 31.000 GHz 2000 May 04

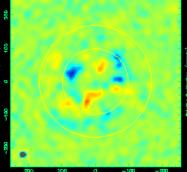


High According (around) High According (around) May parts 124 978 47272. Dev -182 16 54447 (2000) May parts 1279 Aylant Benu Mith 22 5 204 (around) 41 -420<sup>4</sup>



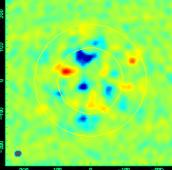


#### Clinical scalage. Jaconge: DAGI M-681 at: 21,000 OHz: 2000 Nay D4



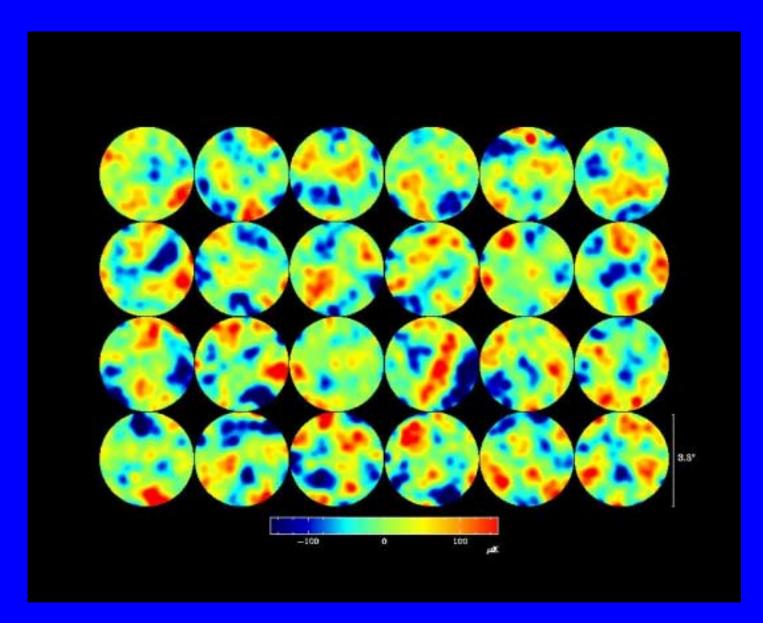
2000 IDU Pigit Association (promiti) Right Association (promiti) Map seekin: RA: BI 30 837-460, Dax -411 80 18.208 (2010) Mar seekin: RA: BI 30 (promiti) at -450.9

#### Checo comp. Jacoby D451 N5491 at 31,000 94tr 2000 May D4

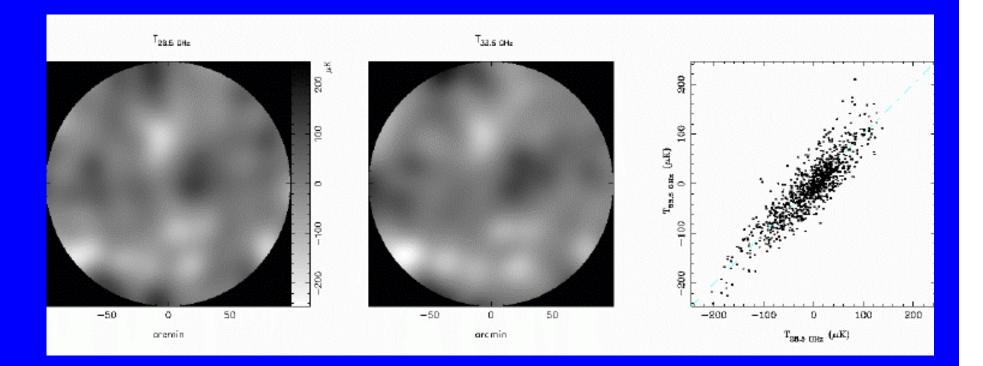


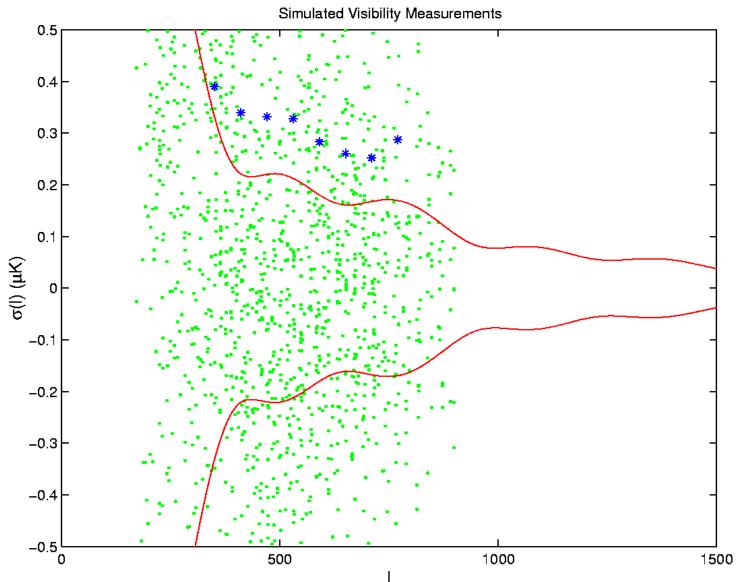
Mig No. Aucumation (percent) New webs WHM As Yes, Date —11 (51 (51-55 (2000.0) New WHM As Yes (2001.0) (2001.0) Date (Fibble 55 (2014 (2001.0) ) (1-65.0)

### Primary Beam Adjusted

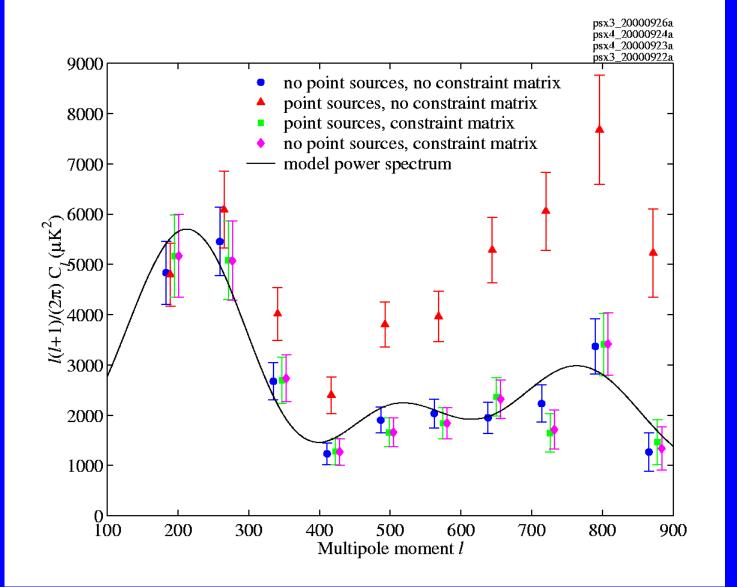


### Images have expected spectrum





## Simulations!



## Conclusions

- DASI has run excellently in it's first season.
- 1000 (good) hours of CMB field integration have been collected.
- Ground subtraction is necessary, but seems to work fine.
- Point source subtraction is also required.
- Construction of analysis "machinery" is almost complete.
- Look forward to a power spectrum soon.