Z-SPEC

A Broadband Millimeter-wave Grating Spectrometer

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SCIENCE

Case for broadband millimeter-wave spectroscopy

Redshift measurements of dusty submillimeter galaxies using mid-J CO rotational lines

- For z > 0.9, at least 2 CO transitions available in Z-Spec's bandpass
- Does not rely on detection at other frequencies, reducing selection effects

Systematic line surveys of LIRGs, ULIRGs, and nearby starbursts

- High-density tracers, CO cooling, optically thin isotopes are simultaneously accessible : ^{12}CO, ^{13}CO, HCN, CN….
- Complementary data to lower-J transitions previously obtained at radio frequencies

DESIGN

Requirements

Broadband to cover entire 1mm atmospheric transmission window (190 – 310 GHz)

Diffraction grating spectrometer with moderate resolution (R 250 ~ 400)

Sensitivity limited by sky & telescope background

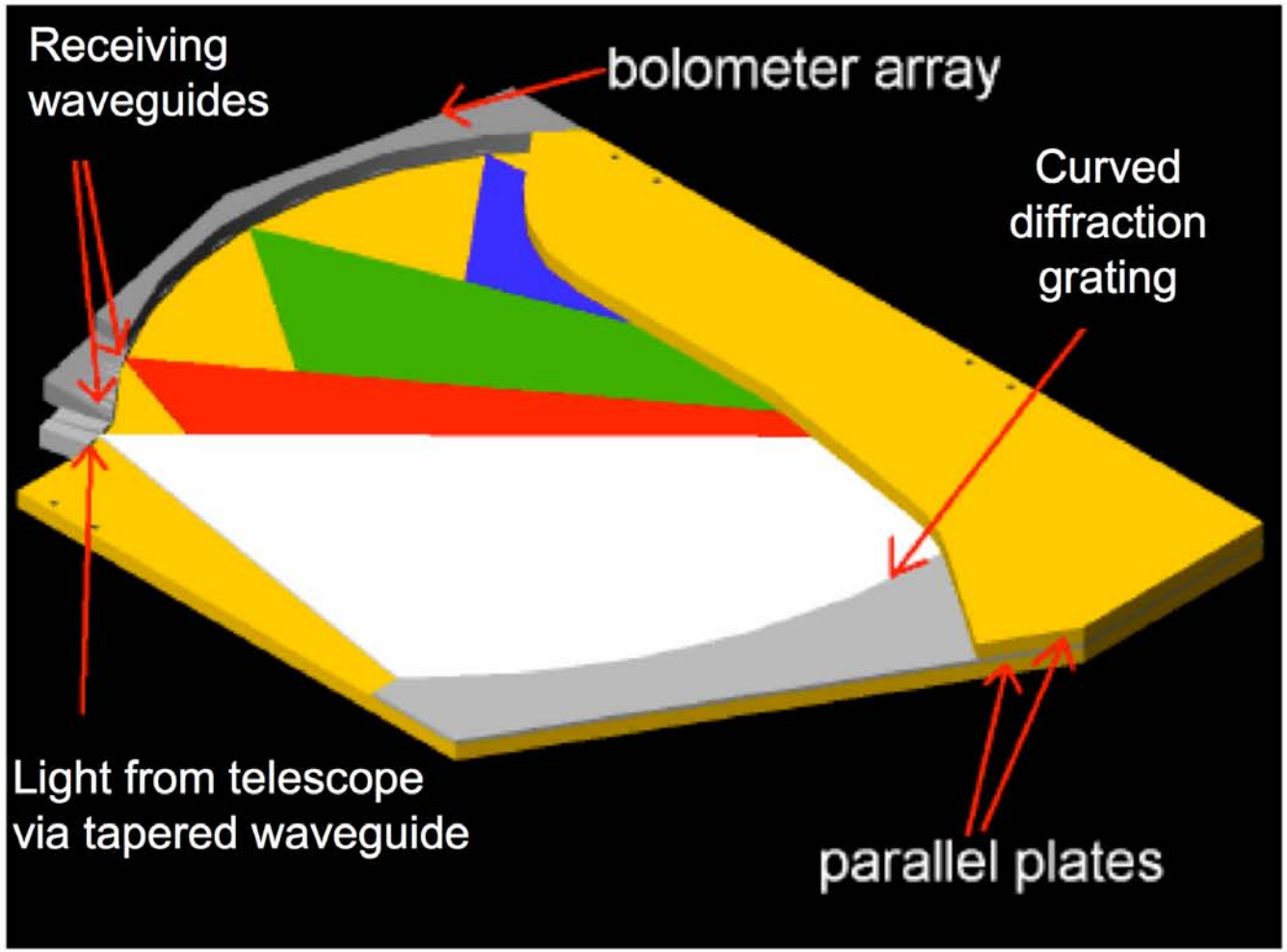
Cold → bolometers and entire grating cooled to 70 mK

Space-efficient → minimum mechanical envelope

Concept demonstration scalable to higher frequencies

DESIGN

Curved grating in a 2-D envelope (WaFIRS)

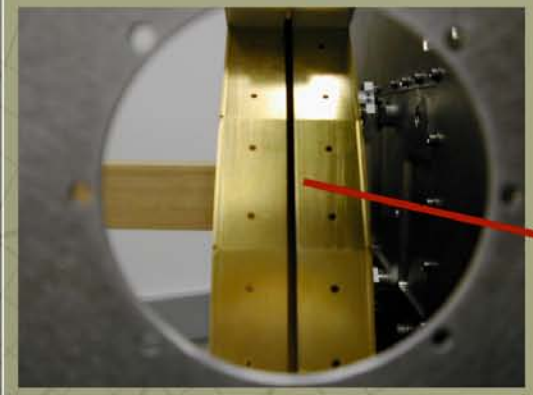


WaFIRS module in Z-Spec

DESIGN

Stackable

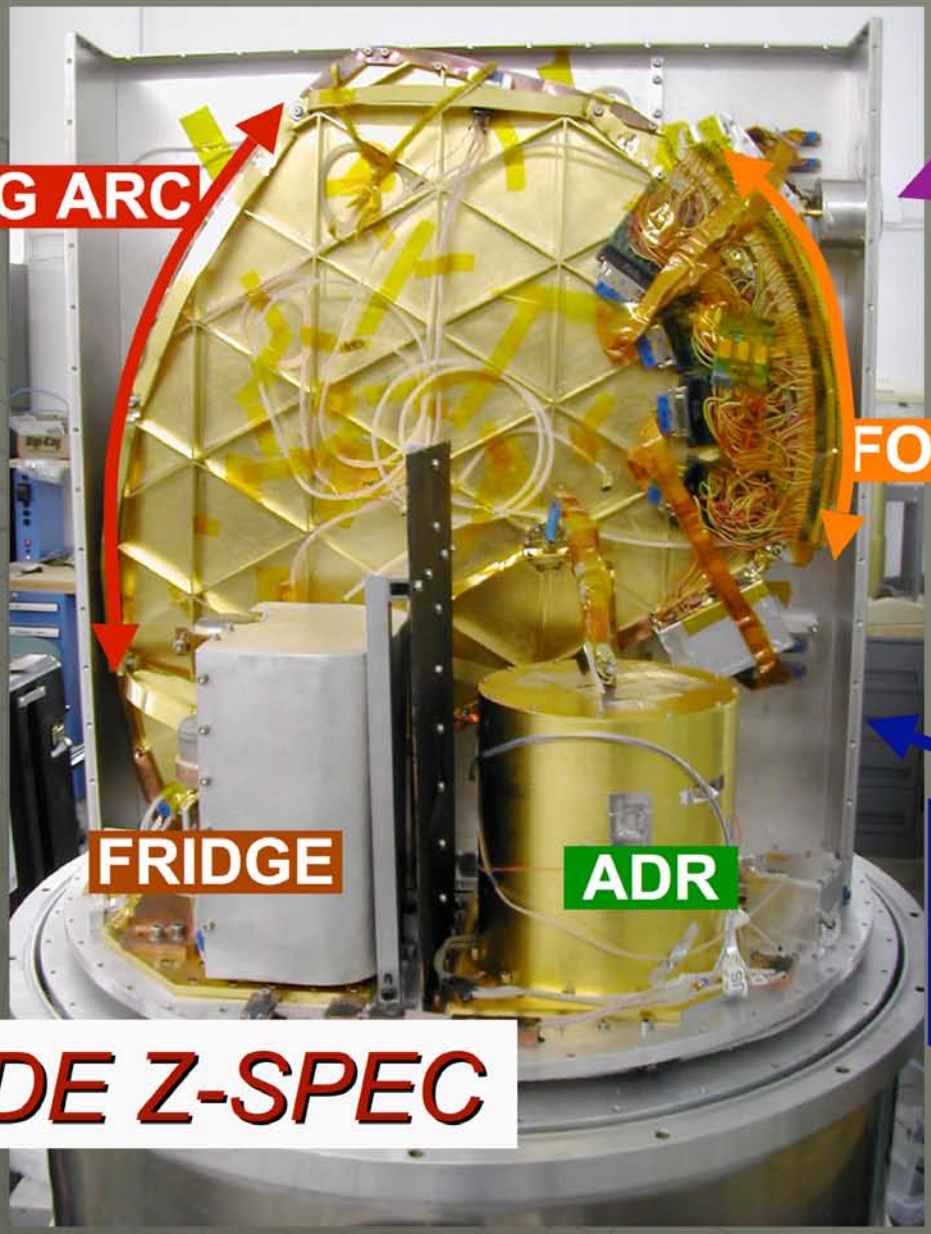
can multiplex spatially or in different frequency bands



2.5 mm plate separation

Compact
(62 cm x 48 cm x 3.3 cm)

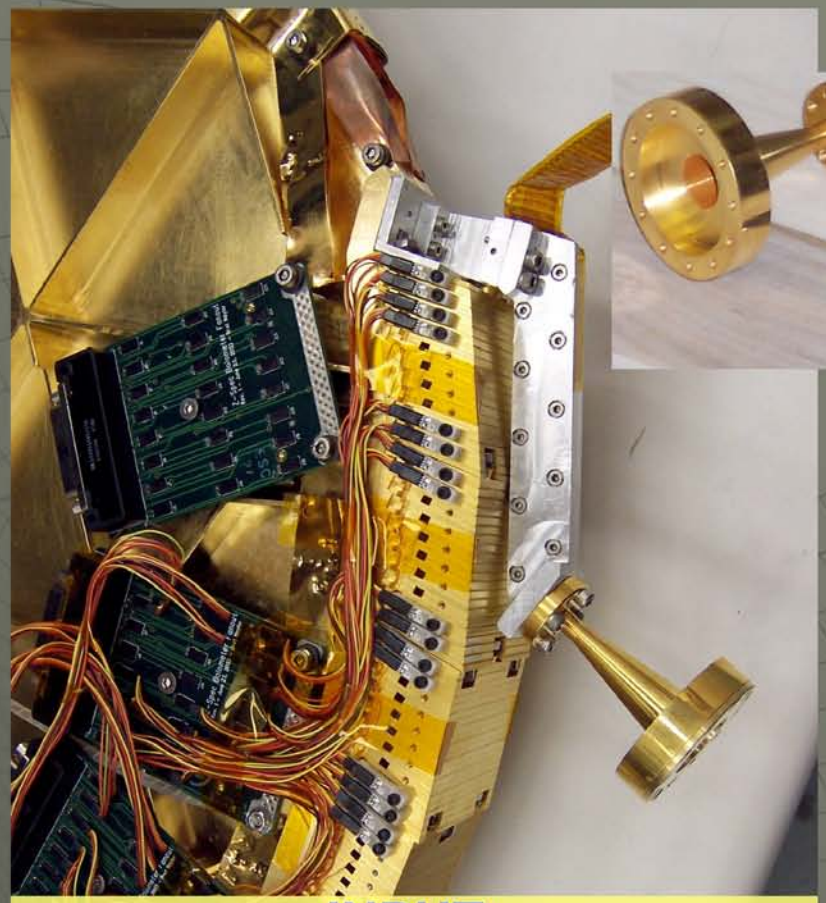
DESIGN

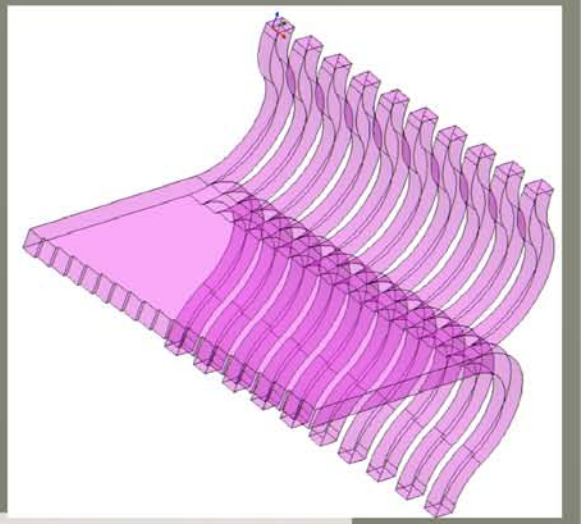


INSIDE Z-SPEC

Coupling Structures

D E S I G N





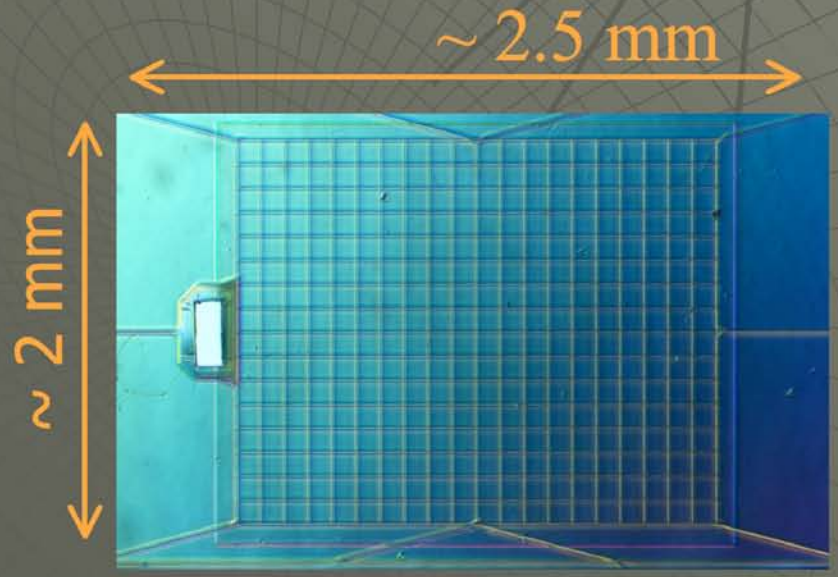
INPUT:
Corrugated Feedhorn + Rectangular Waveguide

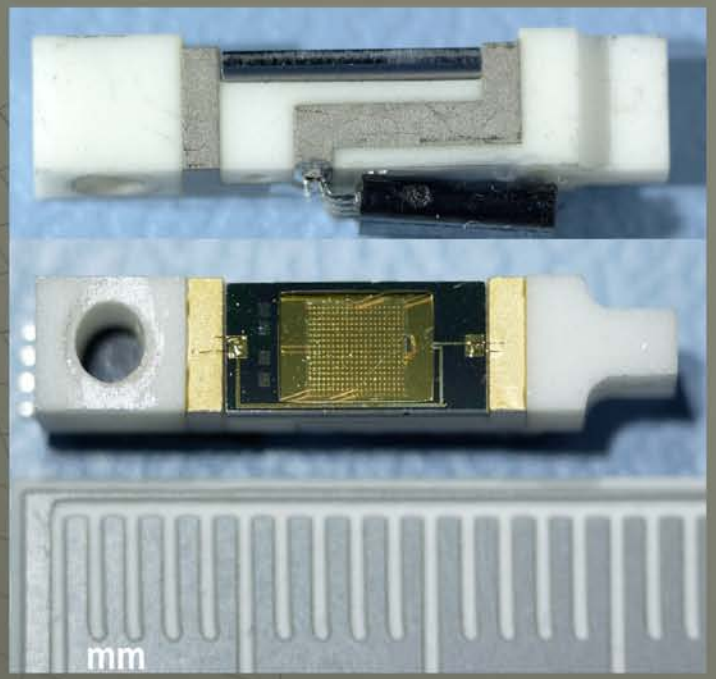
OUTPUT:
Waveguide Bendblocks

DESIGN

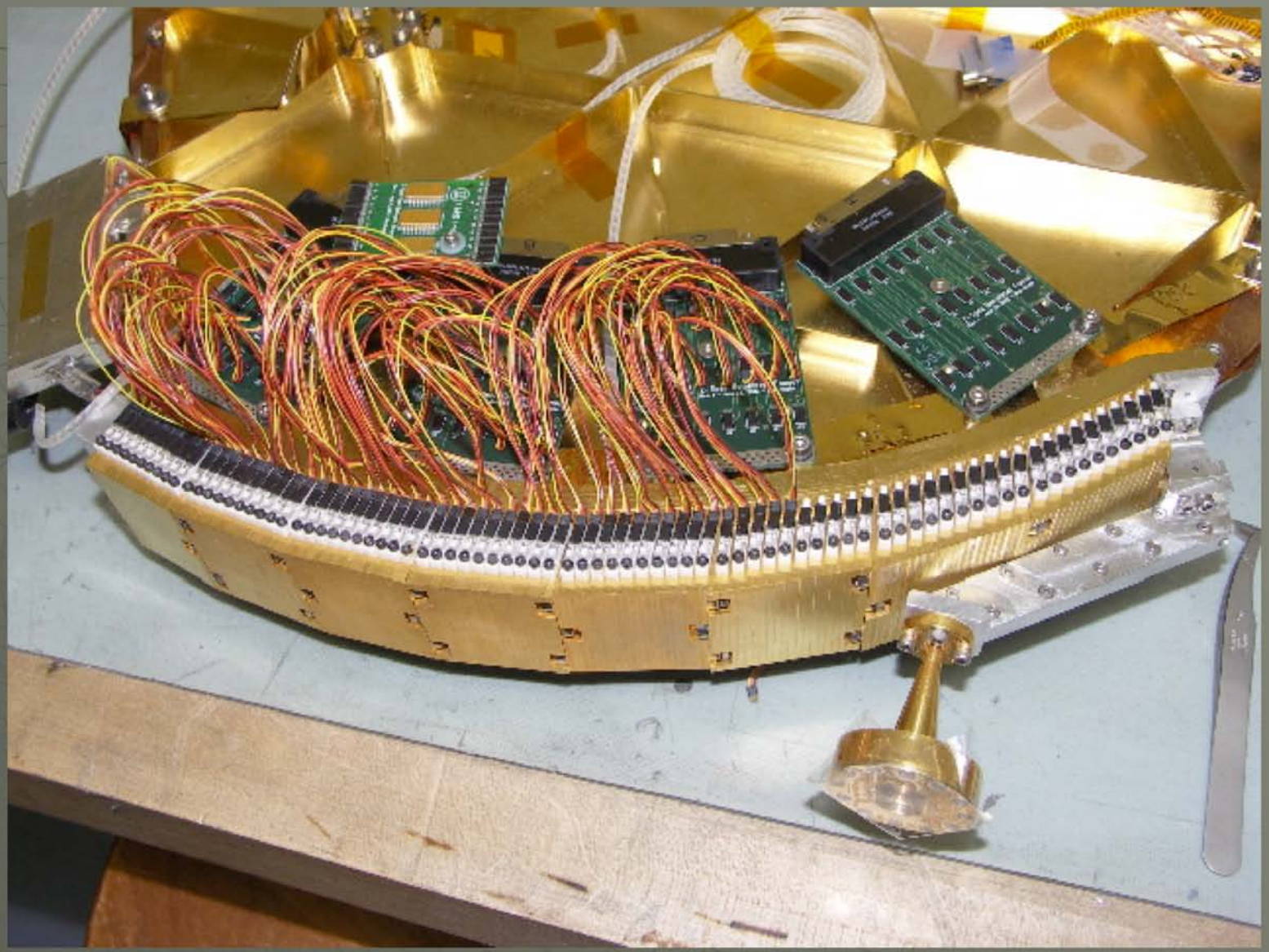
Detectors

- 160 Si_3N_4 micromesh bolometers with NTD germanium thermistors at < 100 mK
- Bolometers individually mounted
- Design NEP ~ $4x10^{-18}$ $WHz^{-1/2}$





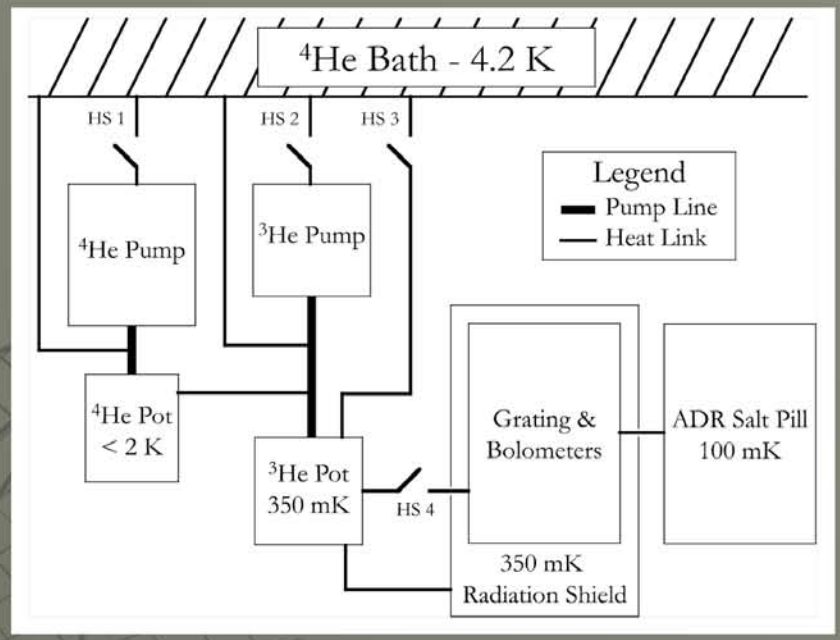
DESIGN



Cryogenics

D E S I G N

3He/4He Fridge

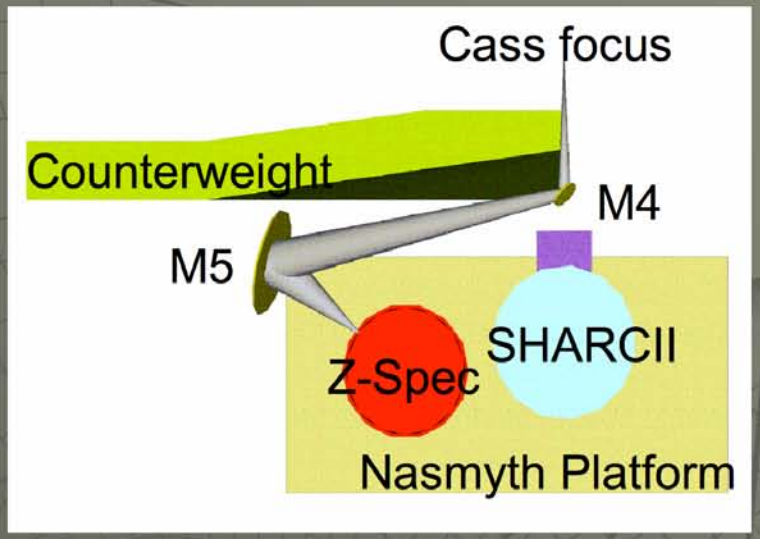


- Entire grating + detectors to 60 – 90 mK
- 2-stage cooling is fully automated
- No pumping on ^{4}He bath
- ADR Hold time 16 ~ 20 hours
- ^{4}He fill every 48 hours

ADR

DESIGN

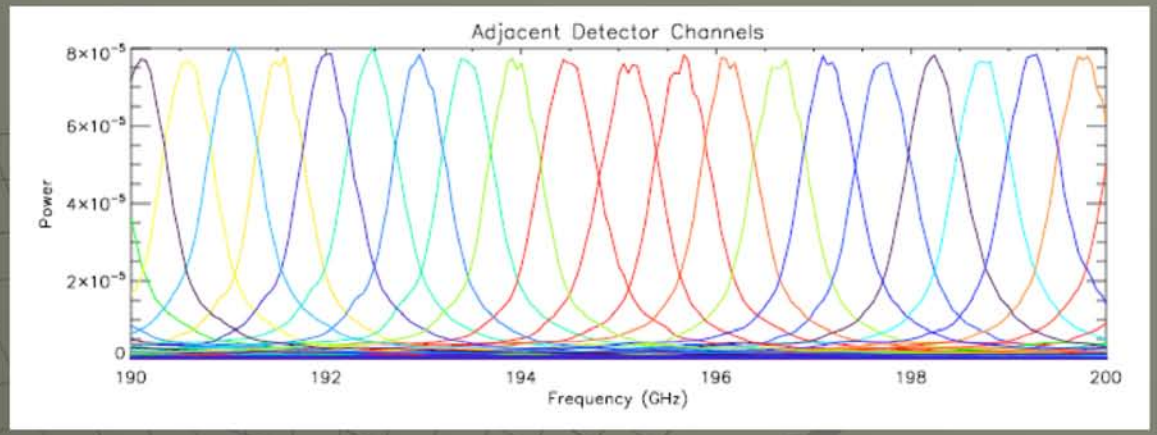
At the CSO – Right Nasmyth port

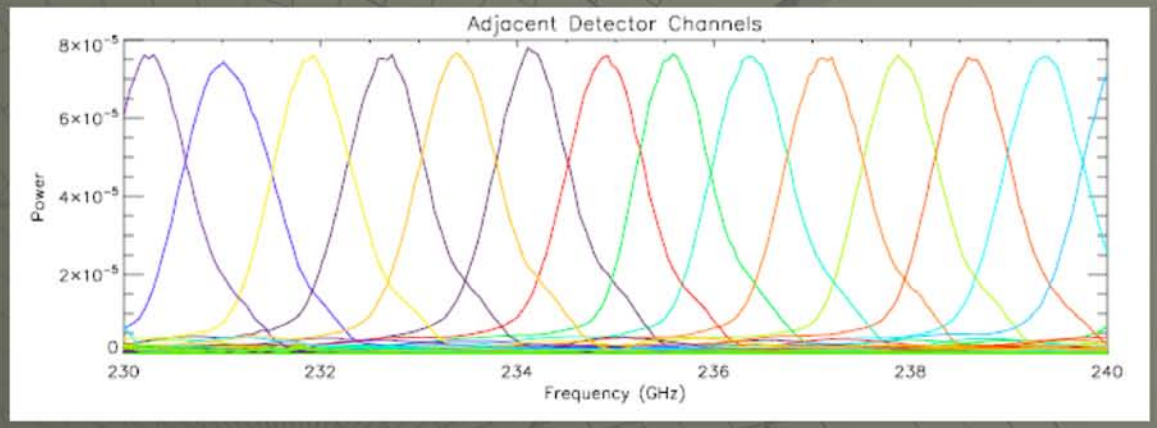


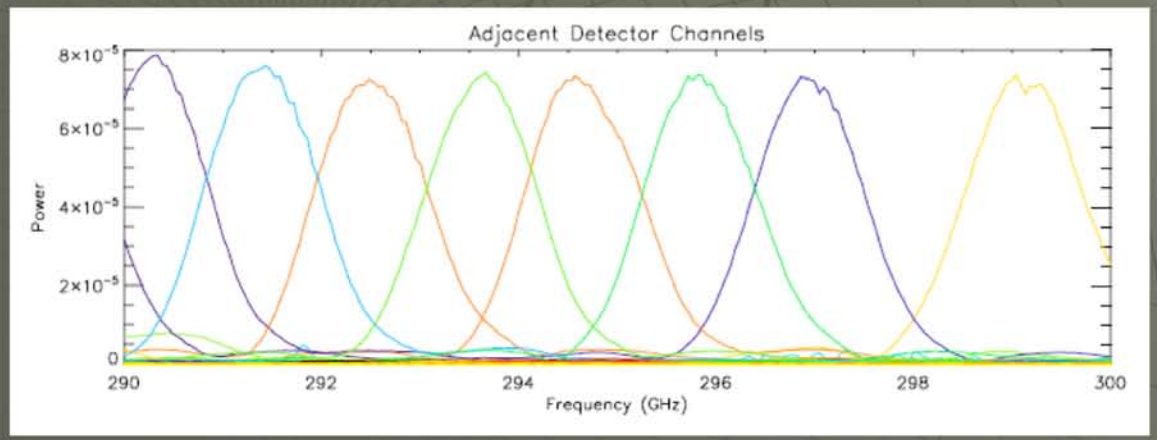
ellipsoidal M5 converts f/12 from telescope to f/3

spillover efficiency limited by secondary taper (89 ~ 91% theoretical)

PERFORMANCE







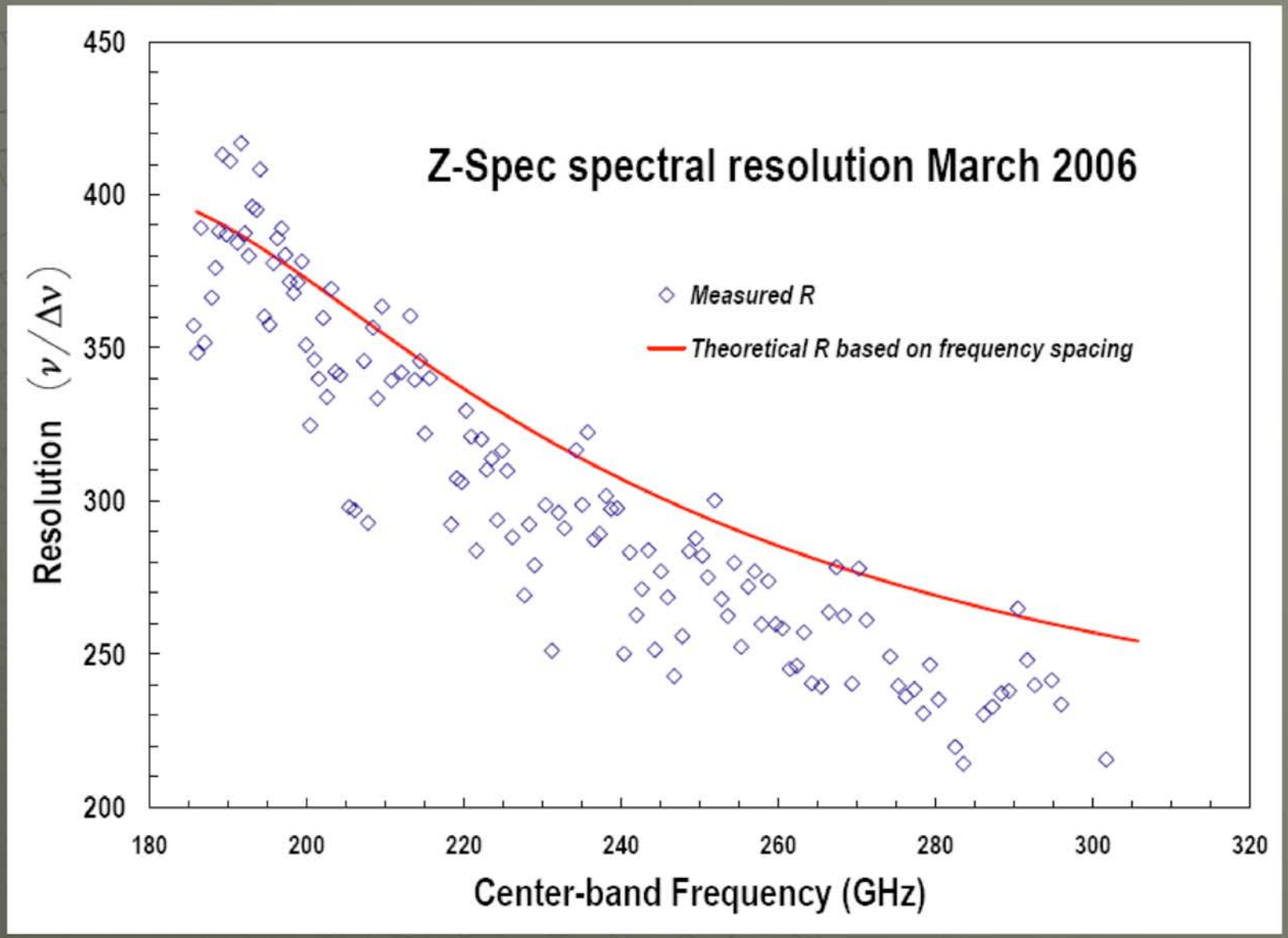
Spectral Response measured with FTS

Thorough coverage, not oversampled

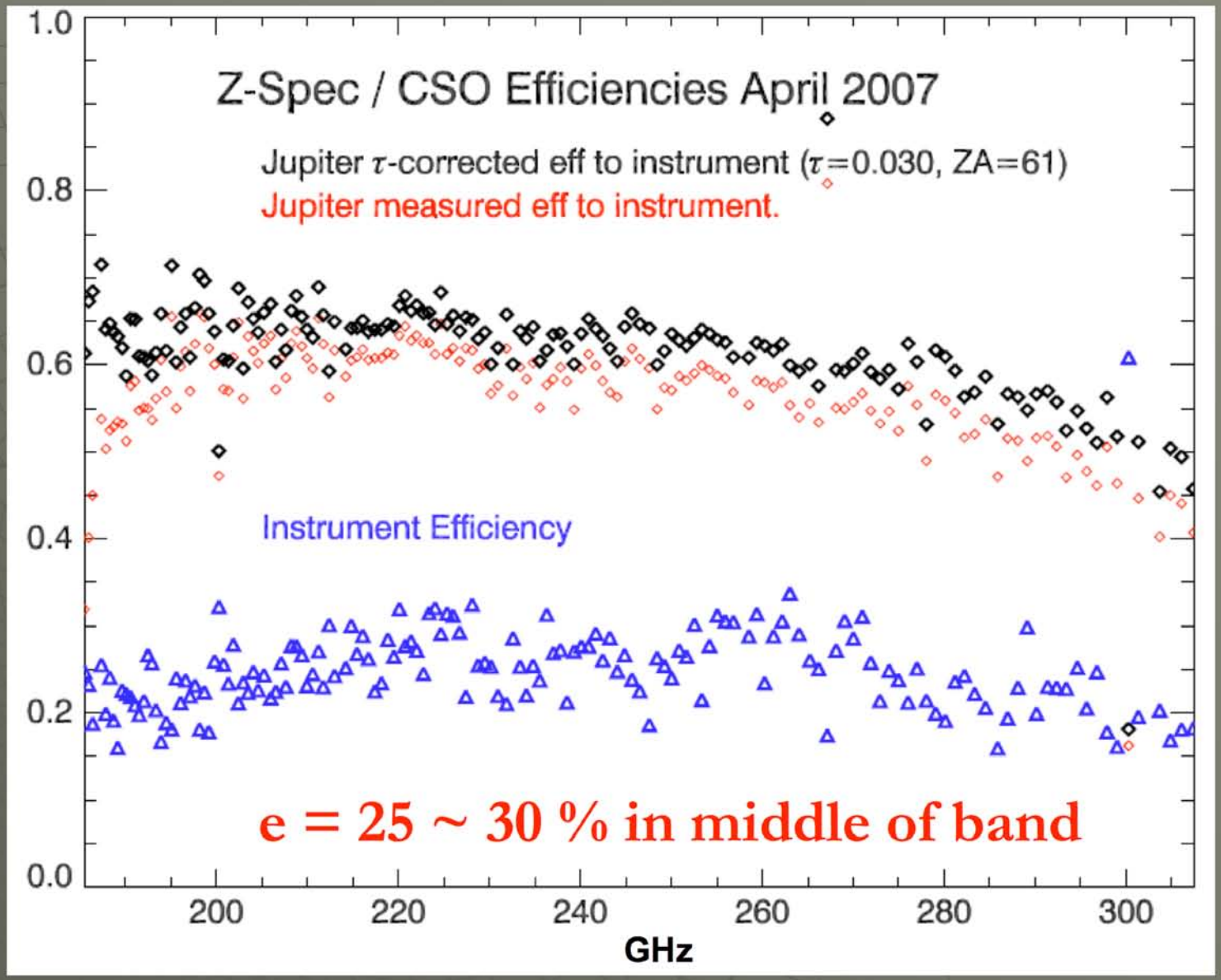
185 – 305 GHz (FTS resolution ~ 100 MHz)

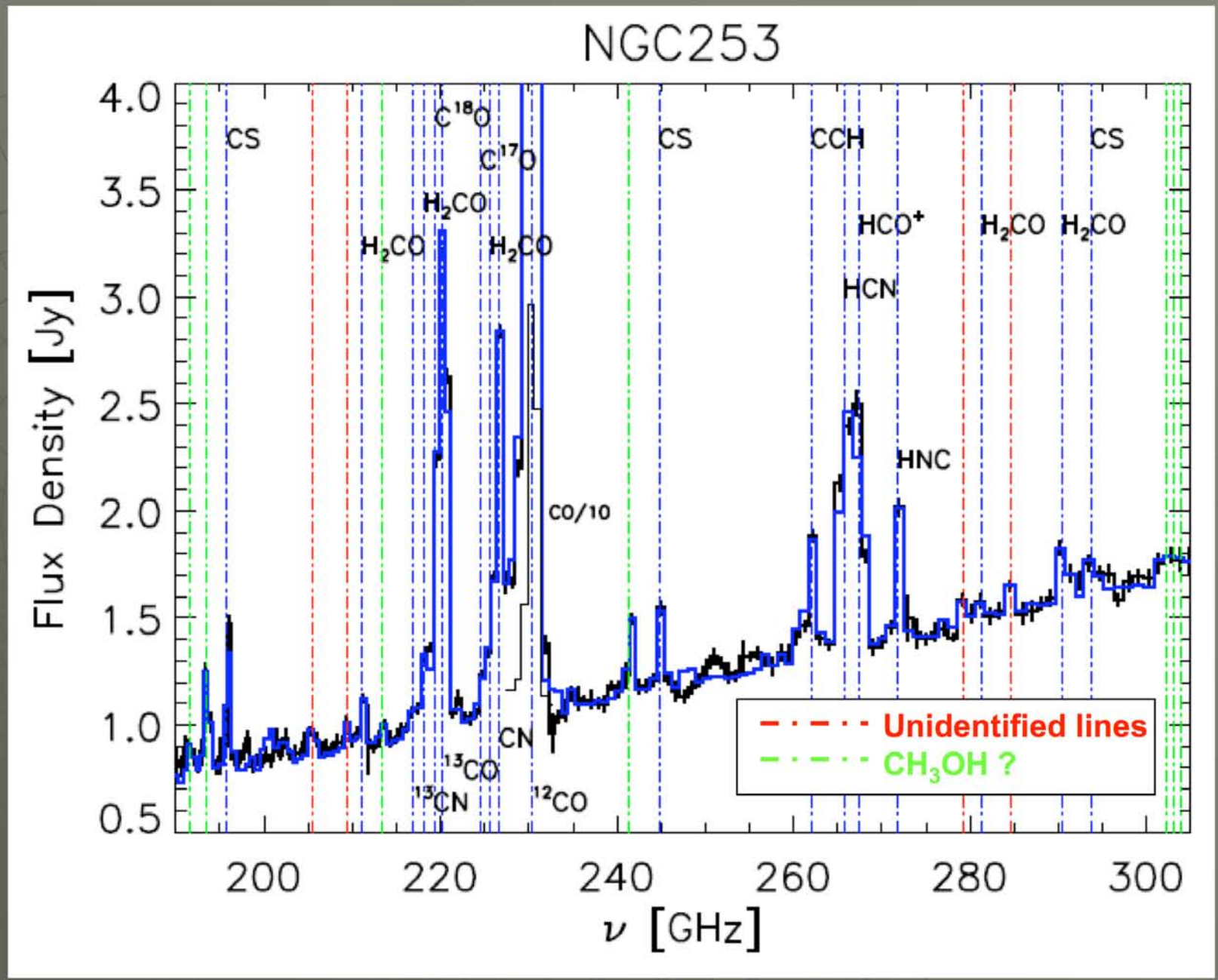
Peak height normalized to one

PERFORMANCE



PERFORMANCE




NGC253
Flux Density [Jy]
ν [GHz]
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
200
220
240
260
280
300
CS
C18O
C17O
H2CO
H2CO
H2CO
CS
CCH
HCO+
HCN
H2CO
H2CO
CS
HNC
CO/10
CN
13CO
13CN
12CO
Unidentified lines
CH3OH ?

PERFORMANCE

Spectral Lines in NGC253					
Species	Transition	Freq [GHz]	Flux [Jy km s^{-1}]	[K km s^{-1}]	SNR
CO	J=2→1	230.35	41645.4	1281.4	158.9
^{13}CO	J=2→1	220.22	4080.3	125.5	68.8
C^{18}O	J=2→1	219.38	1055.0	32.5	22.0
C^{17}O	J=2→1	224.53	58.2	1.8	1.9
CN	J=2→1	226.66	2418.8	74.4	60.2
^{13}CN	J=2→1	216.87	191.3	5.9	3.8
CCH	J=3→2	262.01	857.6	26.4	19.8
HCN	J=3→2	265.67	1992.1	61.3	28.2
HCO$^+$	J=3→2	267.34	1987.9	61.2	22.8
HNC	J=3→2	271.76	875.2	26.9	15.6
CS	J=4→3	195.80	785.8	24.2	17.3
CS	J=5→4	244.74	548.1	16.9	11.5
CS	J=6→5	293.68	380.7	11.7	5.1
H_2CO	$J_{K_a,K_c}=3_{1,3}\rightarrow 2_{1,2}$	211.04	349.0	10.7	10.6
H_2CO	$J_{K_a,K_c}=3_{0,3}\rightarrow 2_{0,2}$	218.05	434.7	13.4	10.0
H_2CO	$J_{K_a,K_c}=3_{1,2}\rightarrow 2_{1,1}$	225.52	325.2	10.0	8.0
H_2CO	$J_{K_a,K_c}=4_{1,4}\rightarrow 3_{1,3}$	281.30	189.3	5.8	2.9
H_2CO	$J_{K_a,K_c}=4_{0,4}\rightarrow 3_{0,3}$	290.39	599.3	18.4	7.9

3.5 hrs at the CSO in November 07

Chopping at 1.4 – 1.6 Hz with 90" throw

$\tau_{225\ GHz}$ range .1 ~ .2

PERFORMANCE