

# PROBING THE PRIMORDIAL POWER SPECTRUM USING THE VSA

(PLUS WMAP, CBI AND ACBAR)

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IAC, TENERIFE

REBOLO, BATTYE et al, astro-ph/0402466

DICKINSON et al, astro-ph/0402498

# PLAN

- ▶ COMMENTS ON CMB v OTHER COSMOLOGICAL PROBES
- ▶ MAIN RESULTS ON RUNNING SPECTRAL INDEX
  - WMAP+VSA (Rebolo et al)
  - WMAP+VSA+CBI+ACBAR
- ▶ DISCUSSION - INFLATION, DEGENERACIES
- ▶ BROKEN POWER LAW MODEL
- ▶ SYSTEMATICS
- ▶ FUTURE OBSERVATIONS WITH VSA

# METHODOLOGY

- USE COSMOMC (LEWIS & BRIDLE)

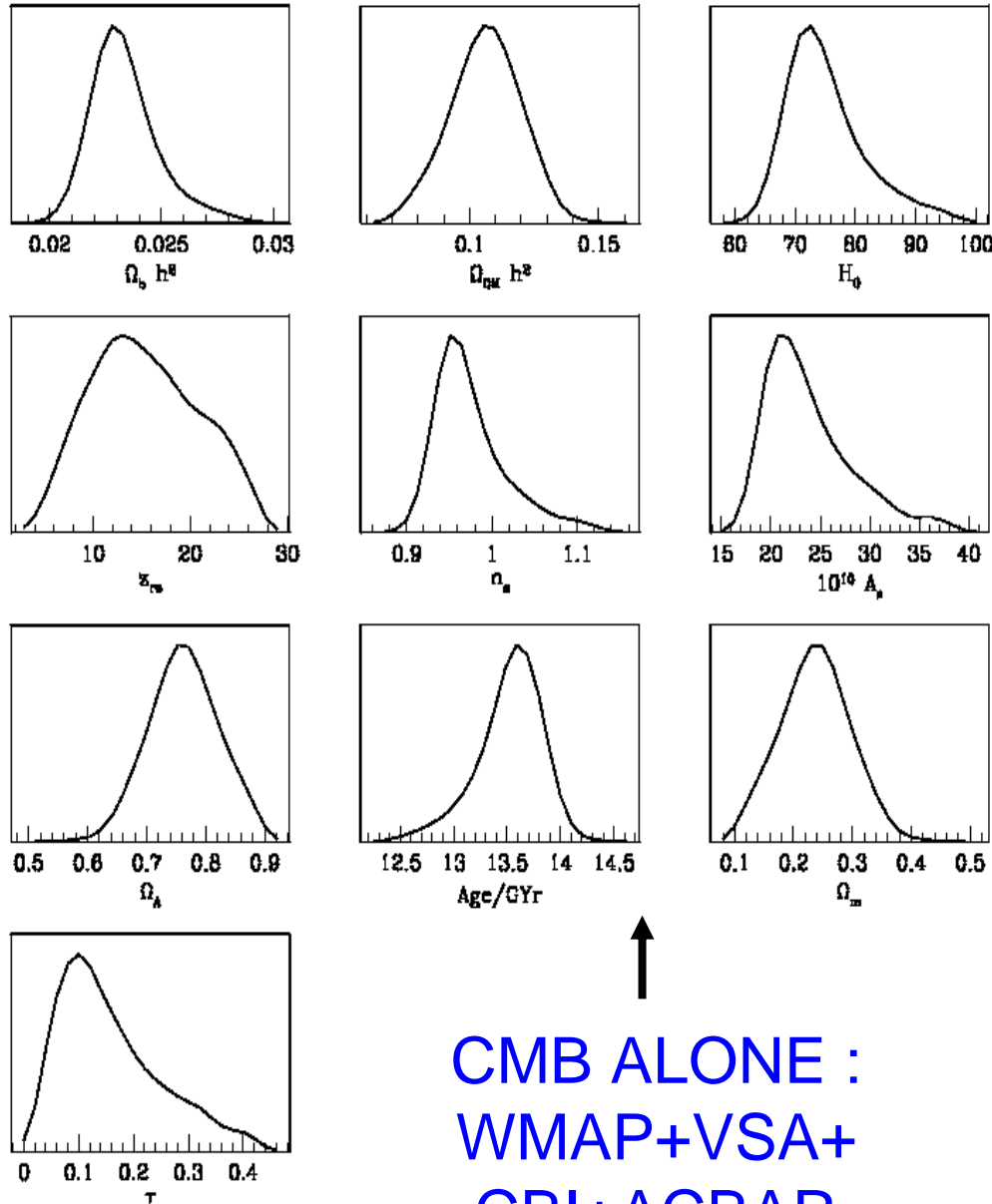
- MARKOV CHAIN MONTE CARLO CODE
- USES COVARIANCE INFORMATION
- AT LEAST 5 SEPARATE CHAINS

- FLAT UNIVERSE

- FLAT PRIORS :

PARAMETER	FLAT PRIOR
$\Omega_b h^2$	(0.005, 0.1)
$\Omega_m h^2$	(0.01, 0.99)
$h$	(0.4, 1.0)
$z_{re}$	(4, 50)
$10^{10} A_s$	(10, 100)
$n_s$	(0.5, 1.5)
$n_{run}$	(-0.2, 0.2)

# CMB AS A COSMOLOGICAL PROBE



CMB ALONE :  
WMAP+VSA+  
CBI+ACBAR

## CMB v 2dF/HST/BBN

	CMB	OTHER
$\Omega_b h^2$	$0.023 \pm 0.001$	$0.022 \pm 0.002$
$\Omega_m h^2$	$0.106 \pm 0.013$	$0.093 \pm 0.045$
$h$	$0.75 \pm 0.05$	$0.69 \pm 0.06$
$\tau$	$0.15 \pm 0.07$	—
$A_S$	$24 \pm 4$	—
$n_S$	$0.975 \pm 0.042$	—

CMB IS THE MOST  
POWERFUL PROBE  
OF COSMOLOGY

# RUNNING SPECTRAL INDEX

POWER SERIES  
IN  $\log(k)$



$$\log P(k) = \log A_S + (n_S - 1) \log(k/k_c) + \frac{1}{2} n_{\text{run}} (\log(k/k_c))^2 + ..$$

DROP HIGHER  
ORDER TERMS



$$P(k) = A_S \left( \frac{k}{k_c} \right)^{n_S - 1 + \frac{1}{2} n_{\text{run}} \log(k/k_c)}$$

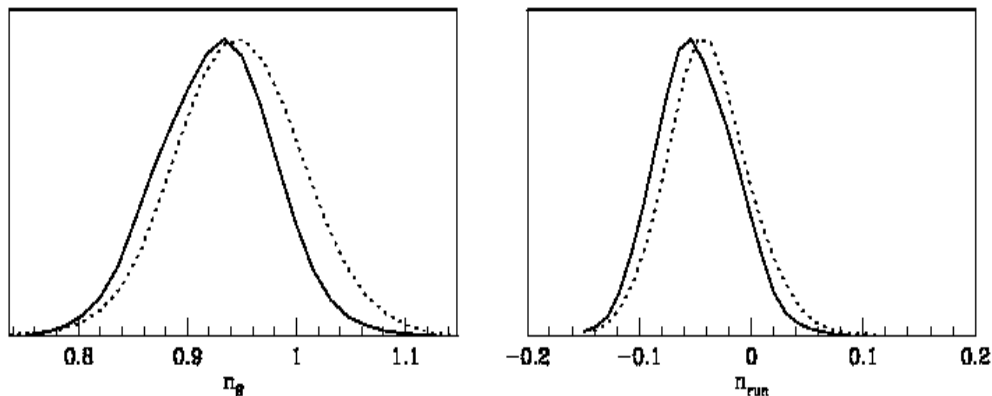
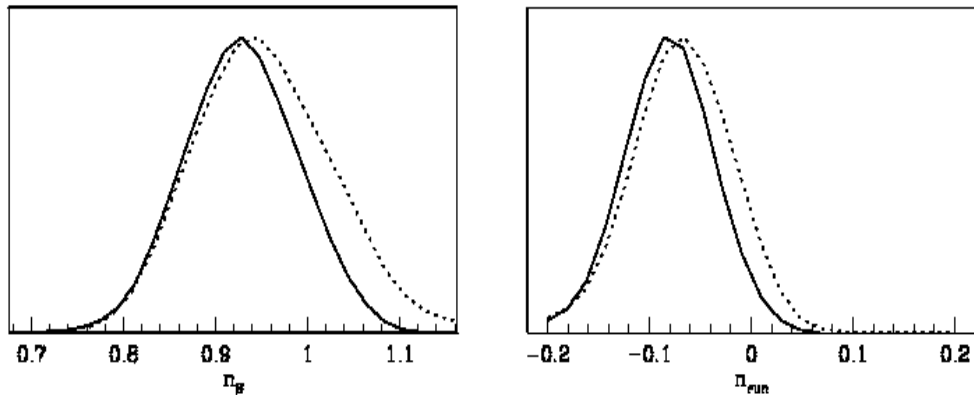
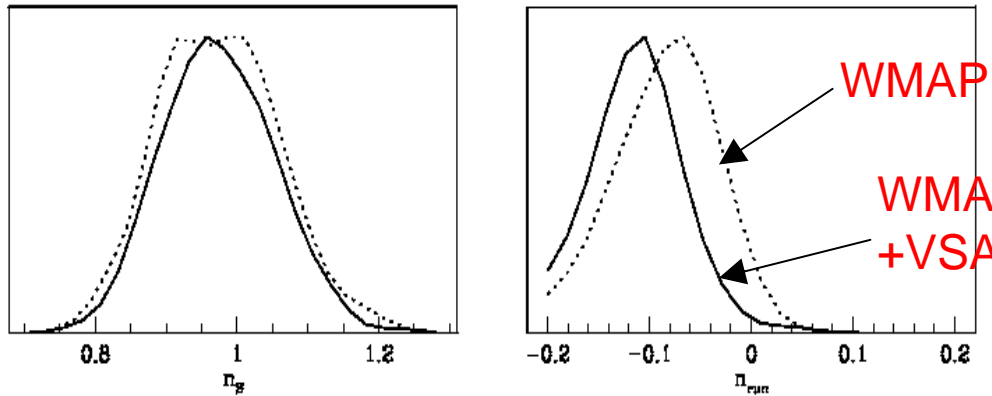
SPECTRAL INDEX :

$$n(k) = \frac{d(\log P)}{d(\log k)} = n_S - 1 + n_{\text{run}} \log(k/k_c)$$

FIRST > SECOND →  $|n_S - 1| \gg \frac{1}{2} n_{\text{run}} \log(k/k_c) \approx 2 n_{\text{run}}$

SPERGEL ET AL : -0.031 +/- 0.016 (WMAPext+2dF+Ly $\alpha$ )

# WMAP+VSA



WMAP+VSA :

$$n_S = 0.974 \pm 0.076$$
$$n_{run} = -0.110 \pm 0.040$$

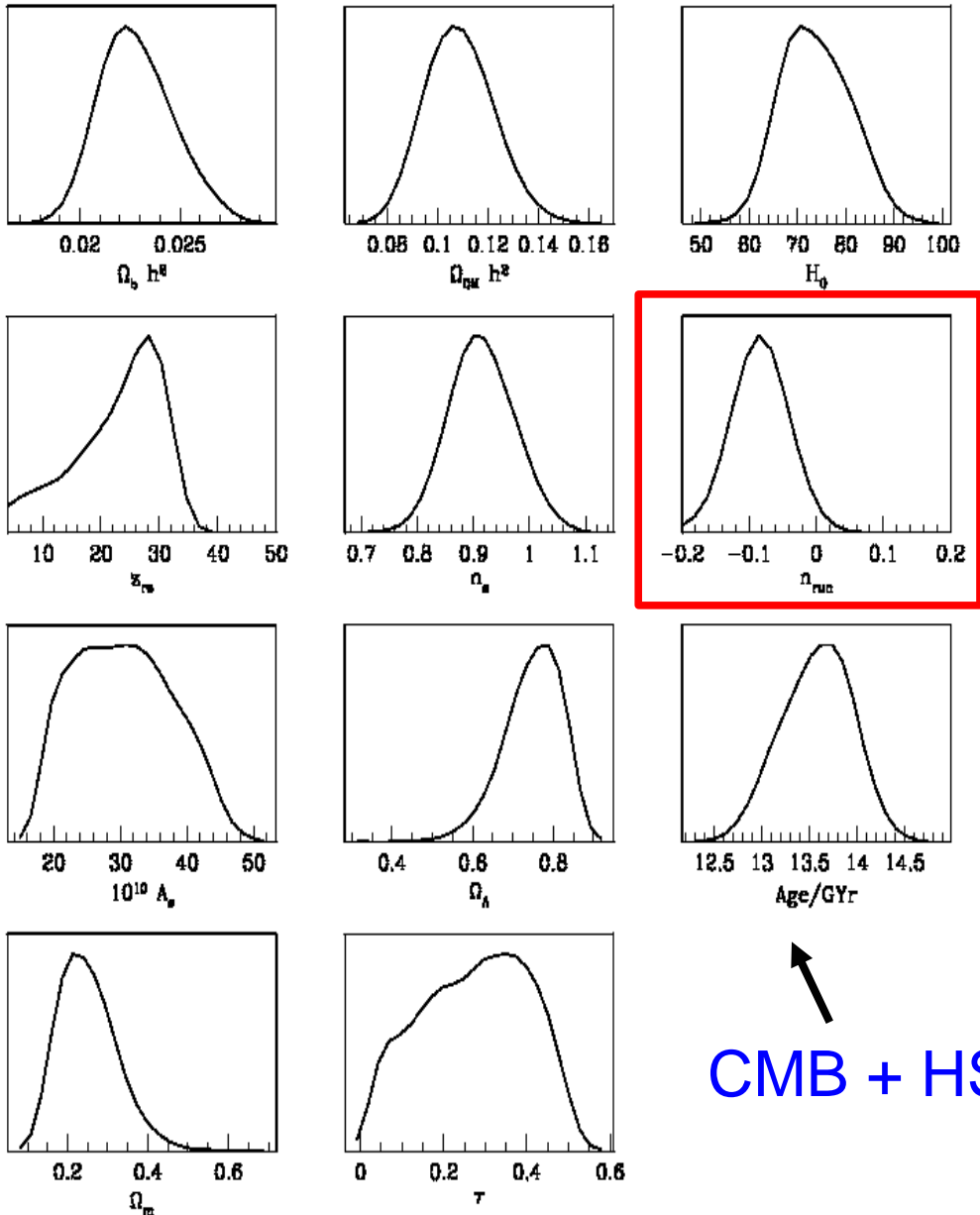
WMAP+VSA+HST :

$$n_S = 0.928 \pm 0.059$$
$$n_{run} = -0.080 \pm 0.039$$

WMAP+VSA+2dF :

$$n_S = 0.926 \pm 0.049$$
$$n_{run} = -0.049 \pm 0.033$$

# 1<sup>st</sup> YEAR WMAP+VSA+CBI+ACBAR



CMB ALONE

$$n_s = 0.955 \pm 0.084$$

$$n_{run} = -0.097 \pm 0.044$$

CMB+HST

$$n_s = 0.915 \pm 0.058$$

$$n_{run} = -0.083 \pm 0.038$$

$$n_{run} < -0.002(2\sigma)$$

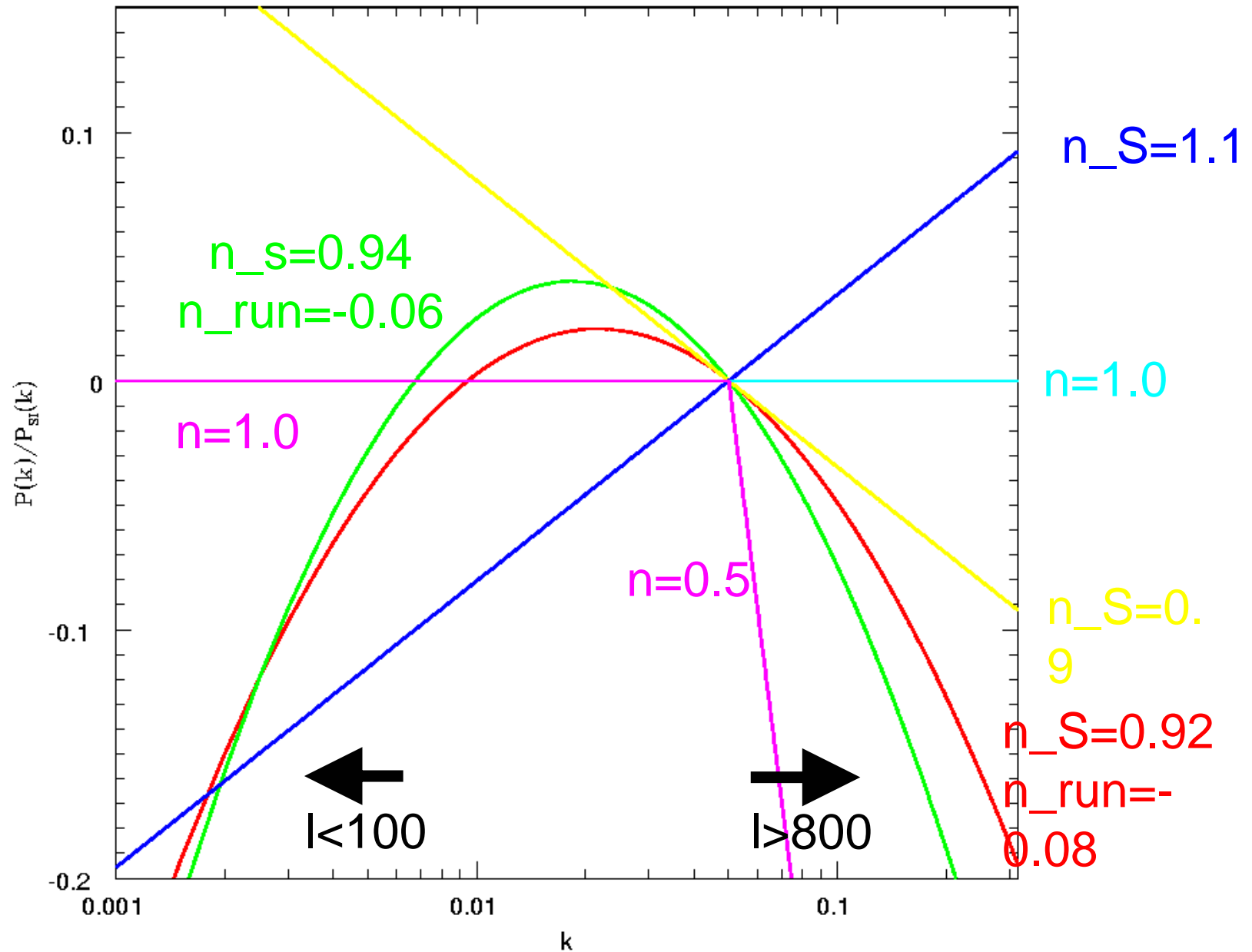
CMB+2dF

$$n_s = 0.904 \pm 0.050$$

$$n_{run} = -0.057 \pm 0.033$$

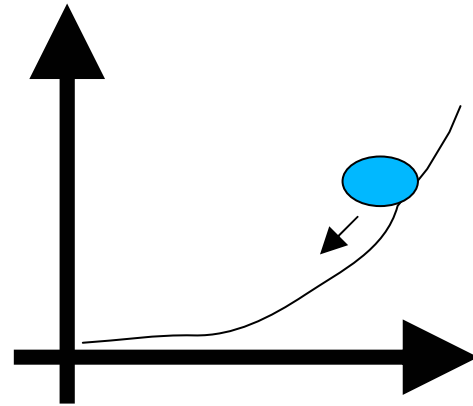
CMB + HST

# UNDERSTANDING RUNNING





# IMPLICATIONS FOR INFLATION



CHAOTIC INFLATION:

$$V(\phi) \propto \phi^p$$

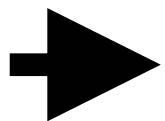
SPECTRAL INDEX :  
(N = NUMBER OF E-FOLDS)

$$n_S(N) \approx 1 - \frac{p+2}{2N} < 1$$

RUNNING :

$$n_{\text{run}} = -\frac{dn_S}{dN} \approx -\frac{p+2}{N^2} \approx -\frac{2}{p+2}(n-1)^2$$

NB NO TENSORS

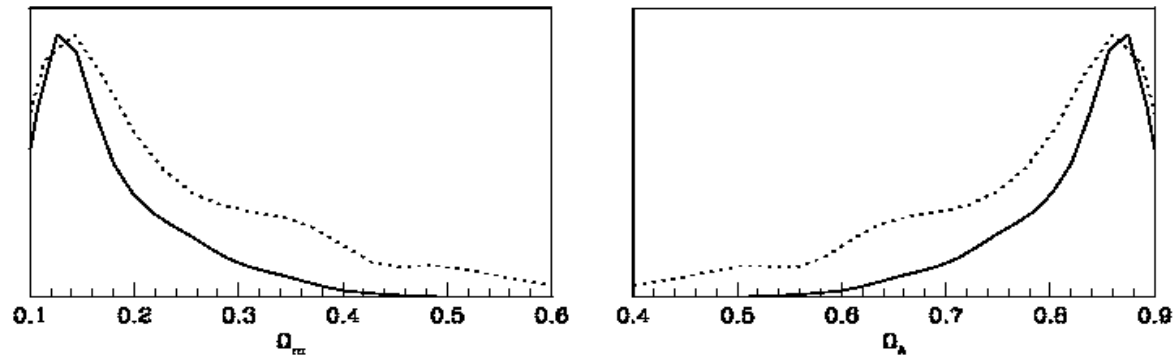


SEE TALK BY WILL KINNEY (THURSDAY AFTERNOON)

# EFFECTS OF INCLUDING 2dF

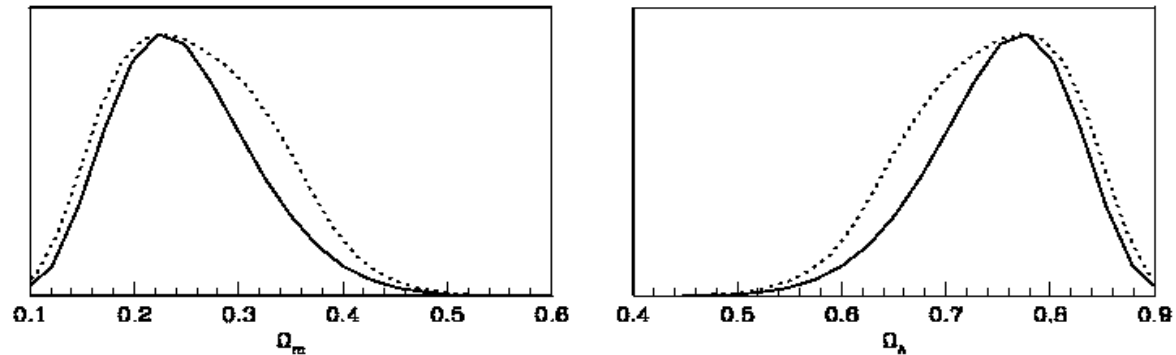
SETS THE VALUE OF  $\Gamma = \Omega h$

CMB ALONE :



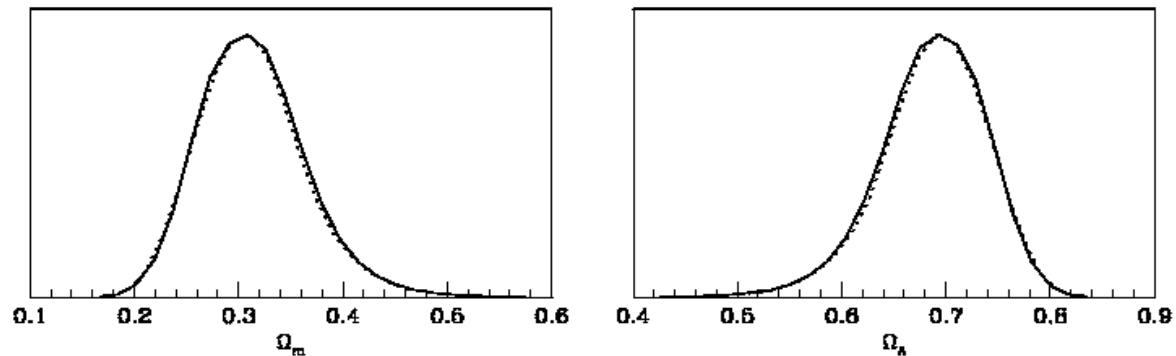
$\Gamma = \Omega h \sim 0.1$

HST PRIOR :



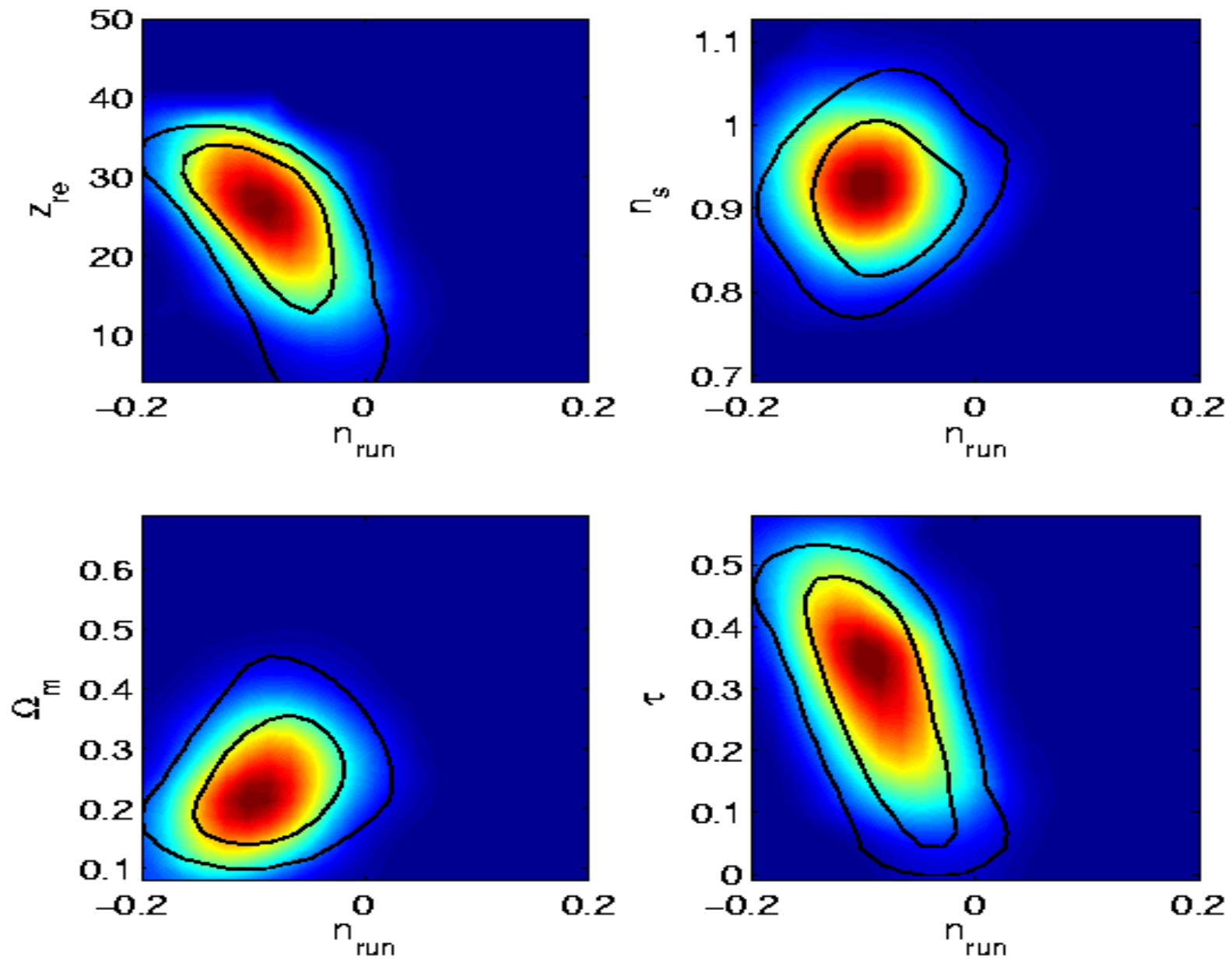
$\Gamma = \Omega h \sim 0.15$

2dF PRIOR :



$\Gamma = \Omega h \sim 0.2$

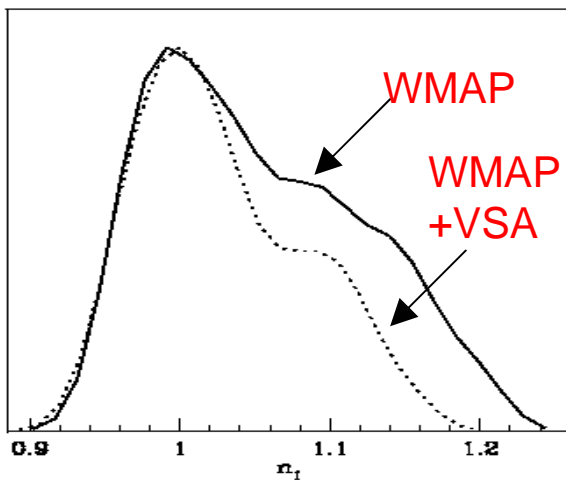
# DEGENERACIES



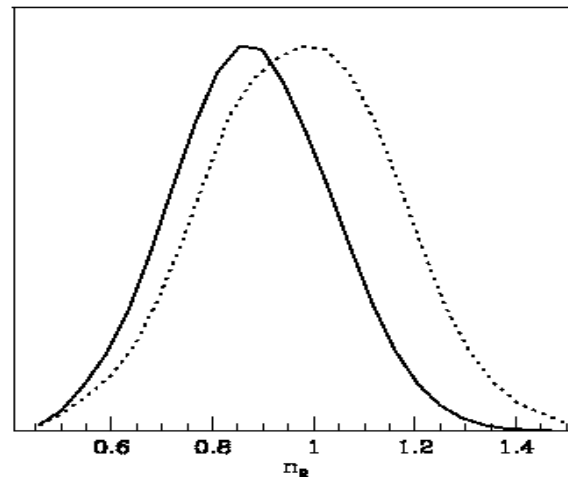
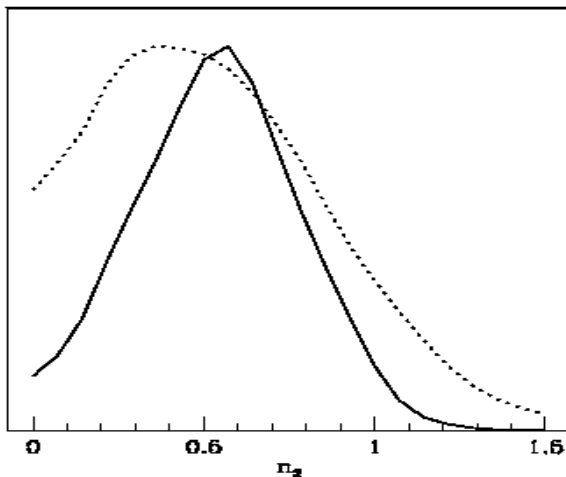
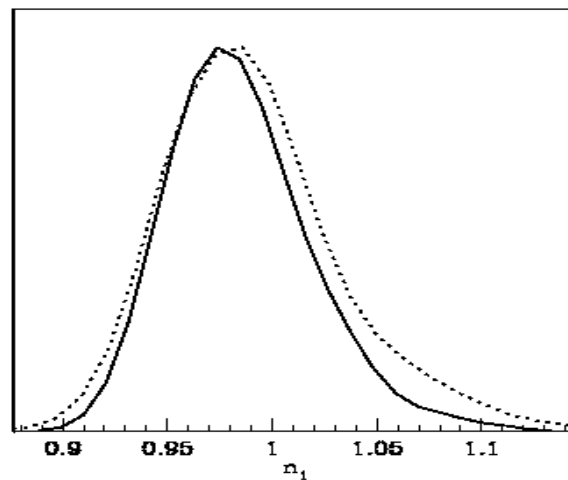
# BROKEN POWER LAW MODEL

$$n(k) = \begin{cases} n_1 & k < k_c \\ n_2 & k > k_c \end{cases}$$

HST PRIOR



2dF PRIOR



## WMAP+HST

$$n_1 = 1.03 \pm 0.05$$

$$n_2 = 0.55 \pm 0.32$$

## WMAP+HST+2dF

$$n_1 = 1.05 \pm 0.05$$

$$n_2 = 0.54 \pm 0.22$$

## WMAP+2dF

$$n_1 = 0.99 \pm 0.04$$

$$n_2 = 0.97 \pm 0.18$$

## WMAP+VSA+2dF

$$n_1 = 0.98 \pm 0.05$$

$$n_2 = 0.87 \pm 0.15$$

# SYSTEMATICS

## ➤ CALIBRATION

3% UNCERTAINTY IN POWER

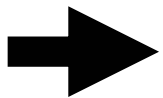
## ➤ POINT SOURCE SUBTRACTION

RESIDUAL CORRECTION

## ➤ $l < 10$ (SEE ANZE SLOSAR'S TALK SATURDAY)

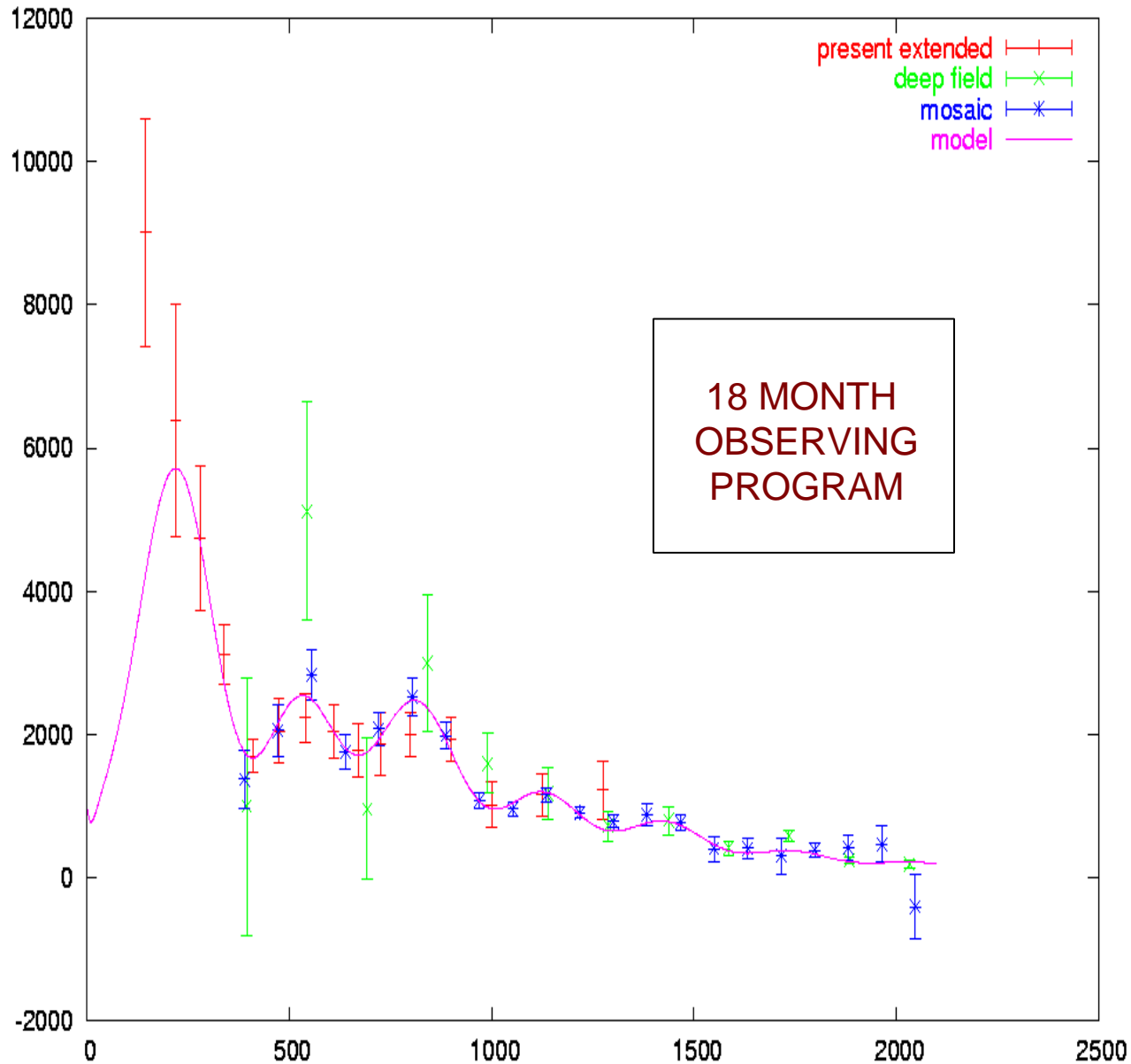
MAYBE A PROBLEM WITH WMAP  $l < 10$ ?

RELAXING THE STRENGTH OF ASSUMPTIONS



REDUCES THE SIGNIFICANCE OF THE RESULT

# FUTURE OBSERVATIONS WITH VSA



ENHANCED VSA :

10 IN SPEED  
3 IN SENSITIVITY  
 $I < 2500$

ERRORBAR ON  $n_{\text{run}}$

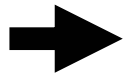
$\pm 0.038$



$\pm 0.027$

# SUMMARY

- CMB MEASUREMENTS ARE THE GOLD STANDARD TEST
- THEY PREFER RUNNING SPECTRAL INDEX
- AT THE EXPENSE OF HIGH-REDSHIFT IONIZATION
- 2dF WEAKENS THE RESULT
- SYSTEMATICS?
- WE CAN DO BETTER WITH A CHEAP UPGRADE



**IF THIS IS TRUE THIS IS A  
CHALLENGE TO THE  
STANDARD VIEW OF INFLATION**