Designing the POLAR Array

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wish list

- r, r-n_s
- r-n_T relation
- total neutrino mass, neutrino mass hierarchy
- curvature
- w, w_a-w_0
- various dark energy models
- and more…

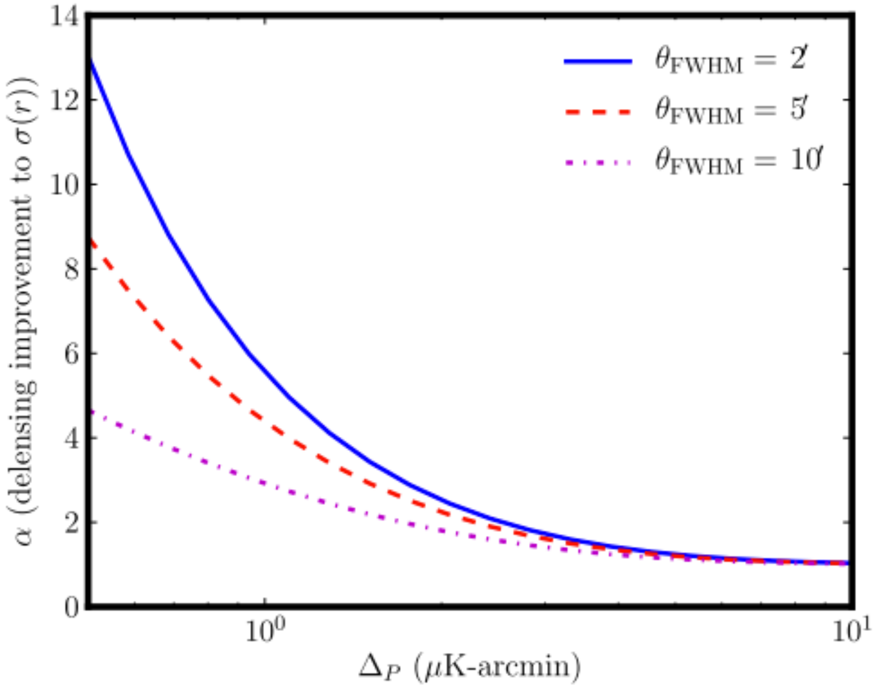
limited budget!

but you're clever…

- know how well the cosmological parameters of concern can be constrained given model depends on:
  - mapping speed of the instrument, i.e. sensitivity
  - beam size
  - sky coverage, when the sensitivity is so good that the map is cosmic variance limited
- know how to parameterize telescope costs for various beam sizes, number of detectors, etc.

How to get the most out of a limited budget?

you observe…



Smith et. al. (2010)

how much improvement in parameter constraints do you get by having a 2’ over a 5’ beam size?

bigger beam is cheaper to build and easier to scale…

the plan

- assume cost of telescope = $D^{2.5}$ + fixed cost for each receiver

Aperture Dia. (m)	Beam (arcmin)	Approx. unit cost ($m)	# of tel. w/ fixed budget
2	5	2	10
3	3.3	3.8	5
4	2.5	6.7	3
5	2	10.9	2

- crossed-Dragone systems (~2000 TES pairs per receiver) at 150GHz

translated into sensitivity

Aperture Dia. (m)	Beam (arcmin)	# of tel. w/ fixed budget	sensitivity (μK-arcmin)
2	5	10	**7.8**
3	3.3	5	**9.3**
4	2.5	3	**10.6**
5	2	2	**11.4**

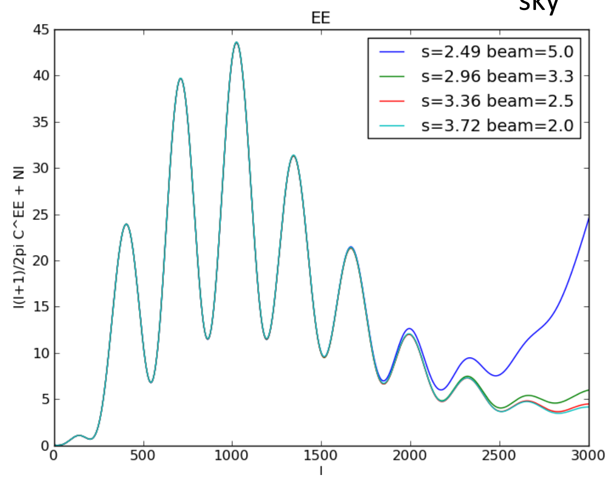
statistical noise varies…

- for different:
  - beam sizes
  - sensitivities
  - sky coverage $s_{eff} = \sqrt{s^2 \times f_{sky}}$

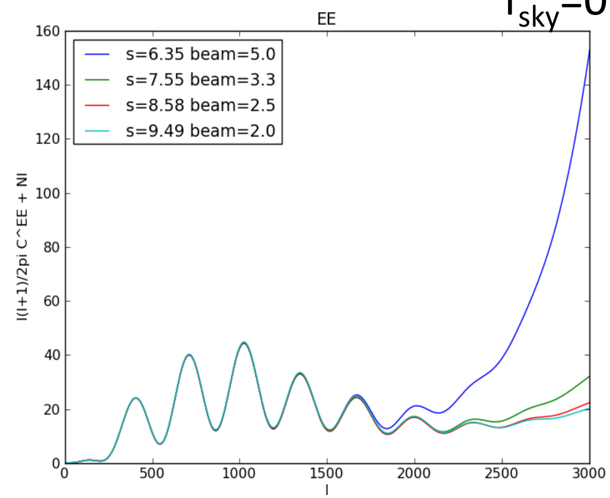
- Temperature and polarization

$$N_l = s^2 \exp\left(\frac{l(l+1)\Theta_{FWHM}^2}{8\log 2}\right)$$

f_{sky}=0.1

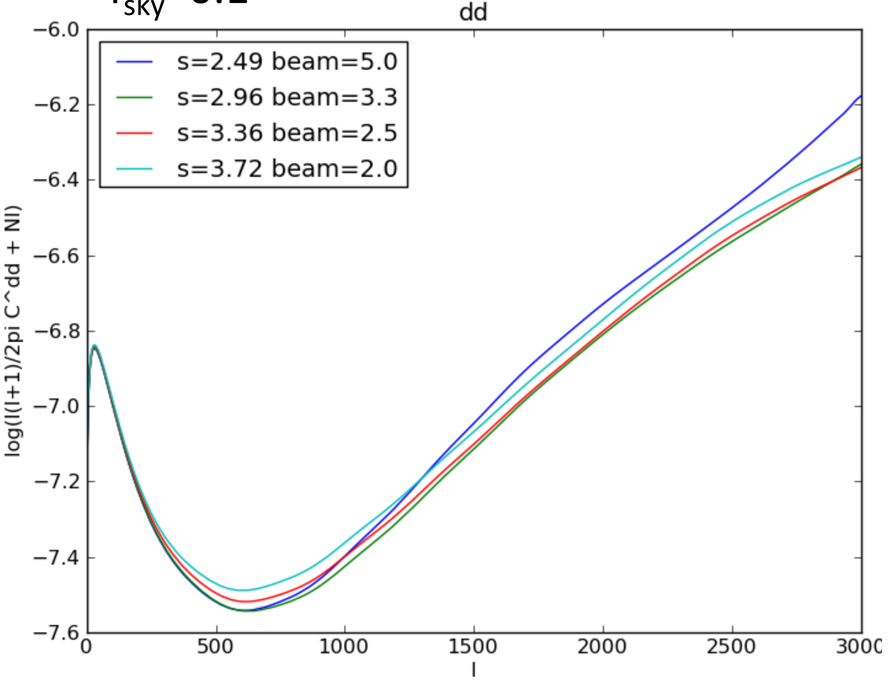


f_{sky}=0.65

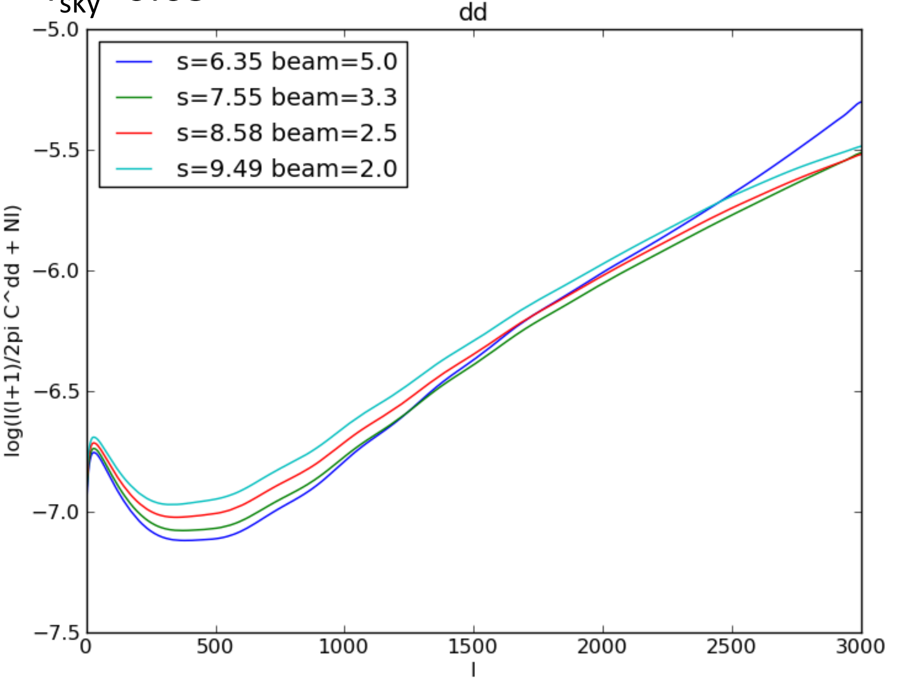


lensing noise

f_{sky}=0.1



f_{sky}=0.65



QE noise: Okamoto & Hu (2003)

Fisher matrix formalism

$$F_{ij} = \sum_l \frac{2l+1}{2} f_{sky} \times Tr\left[\mathbf{C}_l^{-1} \frac{\partial \overline{\mathbf{C}}_l}{\partial \theta_i} \mathbf{C}_l^{-1} \frac{\partial \overline{\mathbf{C}}_l}{\partial \theta_j} \right] \qquad \sigma(\theta_i) = \sqrt{(F^{-1})_{ii}}$$

where
$$\mathbf{C}_l = \begin{bmatrix} C_l^{TT} + N_l^{TT} & C_l^{TE} & C_l^{Td} \\ C_l^{TE} & C_l^{EE} + N_l^{EE} & C_l^{Ed} \\ C_l^{Td} & C_l^{Ed} & C_l^{dd} + N_l^{dd} \end{bmatrix}$$

for TT, EE $N_l = s^2 \exp\left(\frac{l(l+1)\Theta_{FWHM}^2}{8 \log 2} \right)$

N^{dd} -> Okamoto &Hu (2003)

Fisher matrix formalism

- Combining different surveys' contributions
  - Use Planck's temperature and polarization spectra (TT, TE, EE)
  - combine the Fisher matrix by

$$F_{ij}^{total} = f_{sky}^{POLAR} F_{ij}^{POLAR} + \left(f_{sky}^{Planck} - f_{sky}^{POLAR} \right) F_{ij}^{Planck}$$

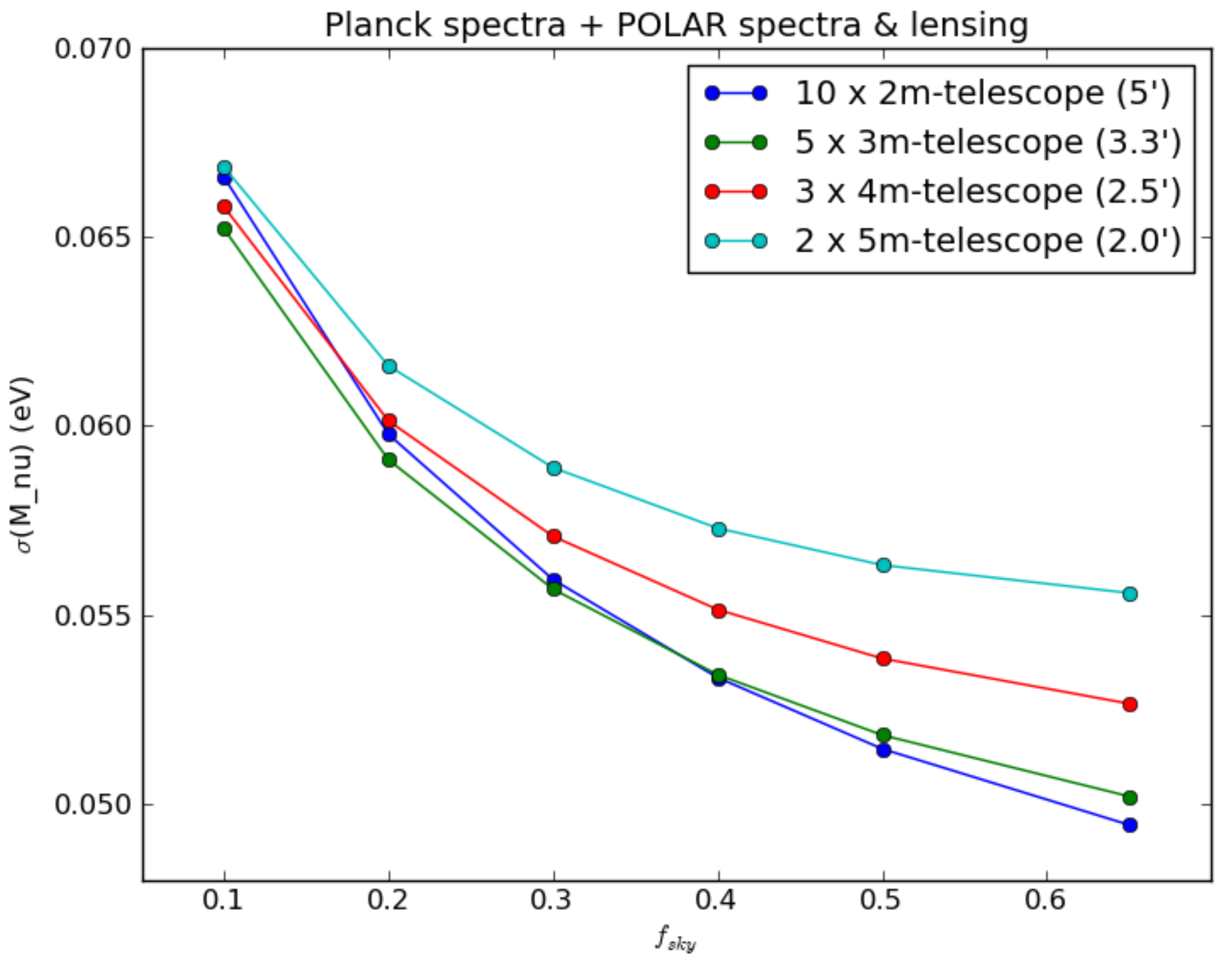
- Adding priors

$$F_{ii}^{prior} = F_{ii}^{noprior} + \frac{1}{\sigma_{ii}^2}$$

where σ_{ii} is 1-sigma of a normal distribution prior

  - use H_0 prior, from HST $\sigma(H_0)$ = 3.6 km/s/Mpc

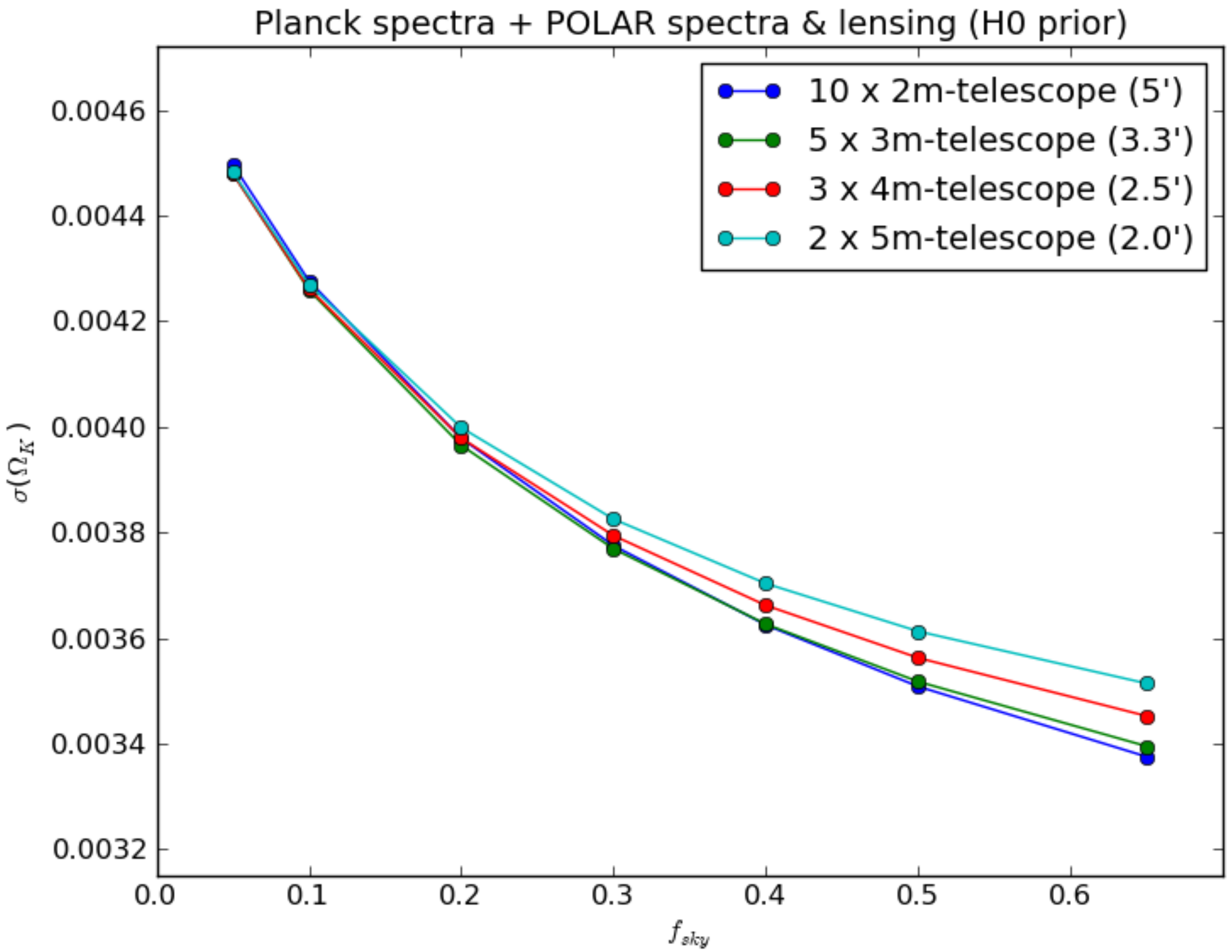
Neutrino mass constraint



Planck constraints:
0.46eV (no lensing)

Parameter space: $\Omega_b h^2, \Omega_{cdm} h^2, \Omega_\nu h^2, H, A_s, n_s, \tau, Y_{He}$

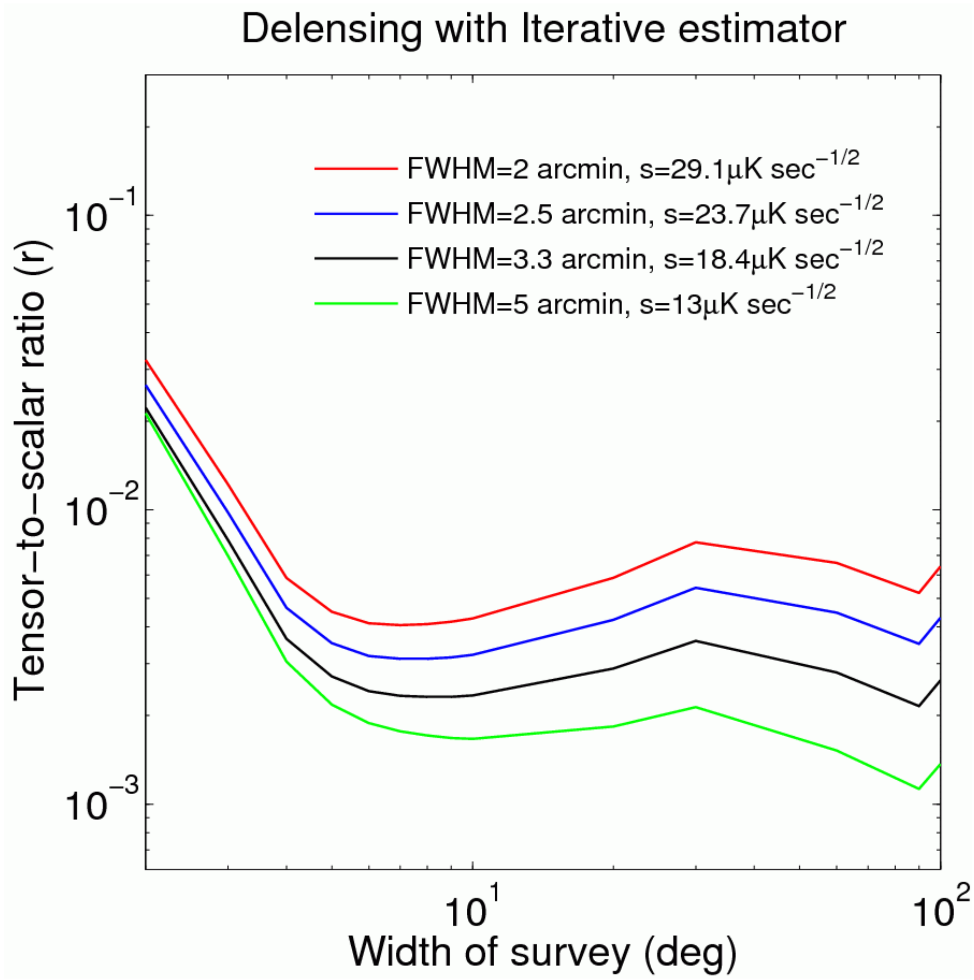
Curvature constraint



Planck w/ H0: 0.0115

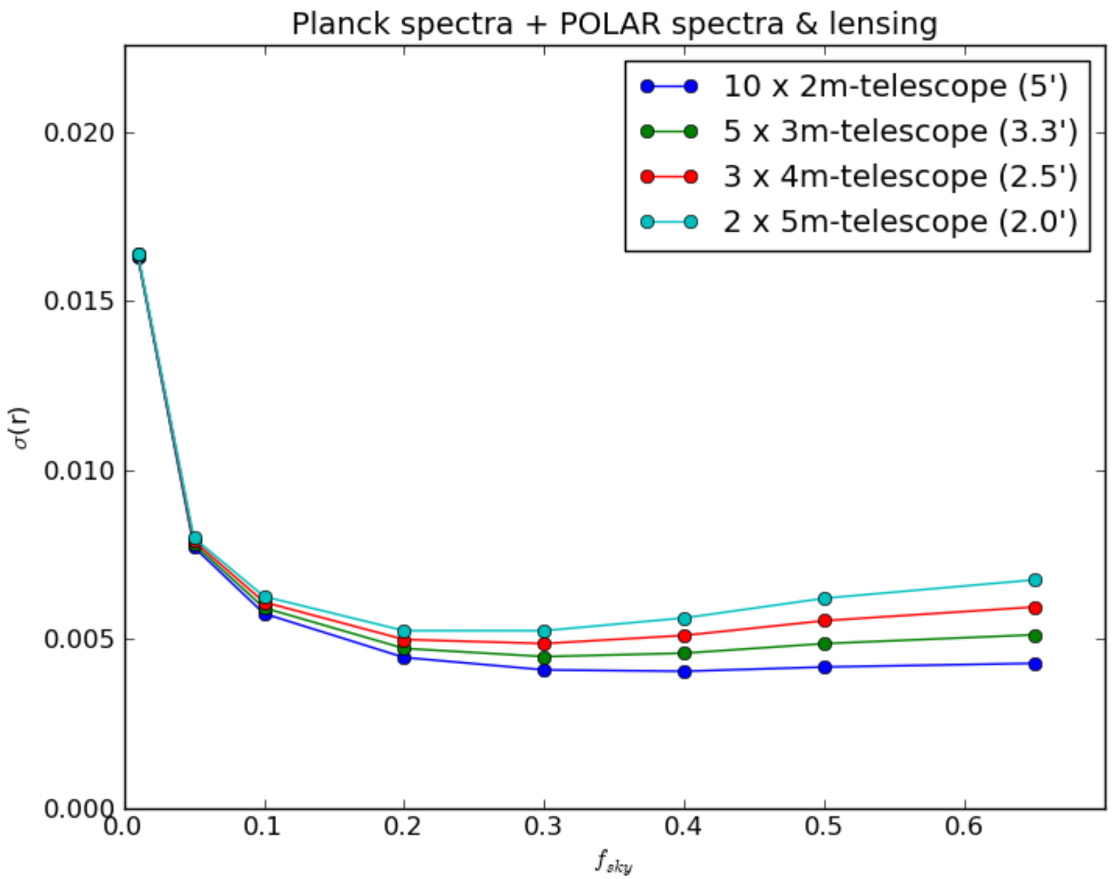
Parameter space: $\Omega_b h^2, \Omega_{cdm} h^2, \Omega_K, \Omega_\upsilon h^2, H, A_s, n_s, \tau, Y_{He}$

r constraint



WH Teng

r constraint



at $r_{fid} = 0.1$

lensing as noise
consistency relation imposed
$n_T = -r/8$

Parameter space: $\Omega_b h^2, \Omega_{cdm} h^2, r, A_s, n_s, \frac{\partial n_s}{\partial \ln k}, \tau, H_0$

1 sigma constraints with f_{sky}=0.2, 5' beam 10 element array

	no CR		CR	
	Planck*	Planck* + POLAR	Planck*	Planck* + POLAR
(r_{fid}=0.1) r	0.0955	0.0207 (4.6)	0.0596	0.0045 (13.2)
n_s	0.0076	0.0047 (1.6)	0.0076	0.0046 (1.6)
n_T	0.476	0.246 (1.9)	---	---

*Planck's C^{TT} C^{TE} C^{EE}

1 sigma constraints with f_{sky}=0.2, 5' beam 10 element array

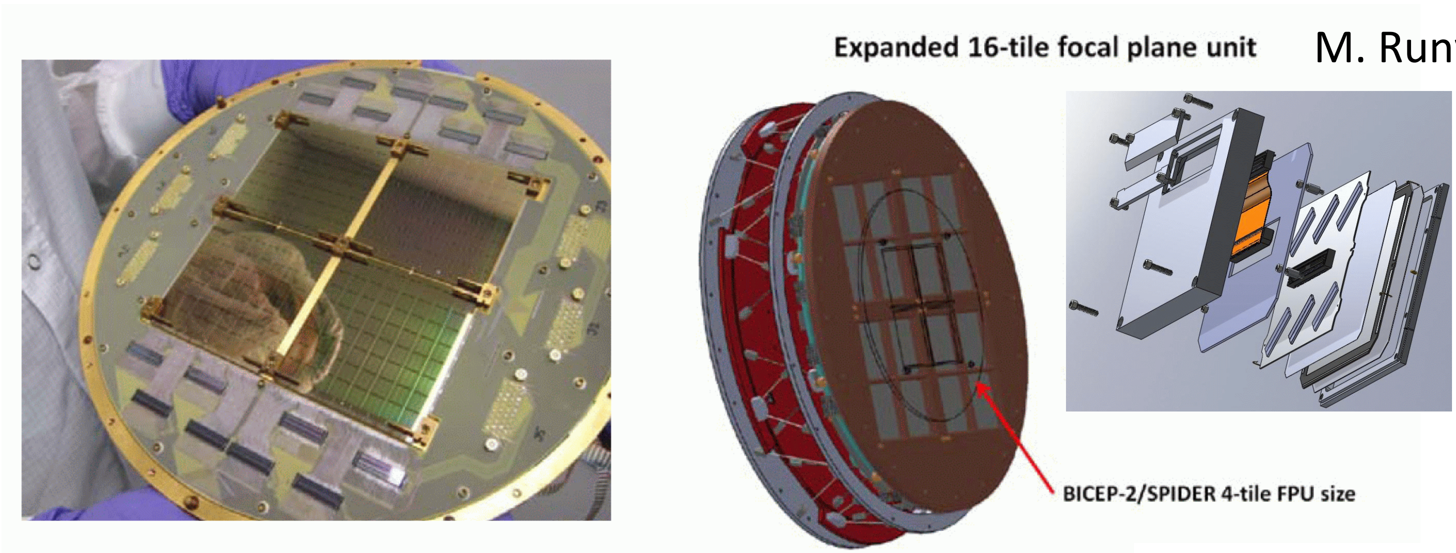
	Planck	Planck + POLAR		Planck	Planck + POLAR
$\Omega_b h^2$	2.30e-04	9.45e-05	τ	4.7e-03	3.26e-03
$\Omega_{cdm} h^2$	1.39e-03	8.65e-04	n_s	7.47e-03	3.95e-03
$\log(A_s)$	2.32e-02	1.39e-02	Y_{he}	1.039e-02	4.34e-03

	Planck	Planck + POLAR	Planck	Planck + POLAR
M_ν	0.46	0.06	0.48	0.091
$\Omega\kappa$ (w/ H_0)	--	--	0.011	0.004

future work

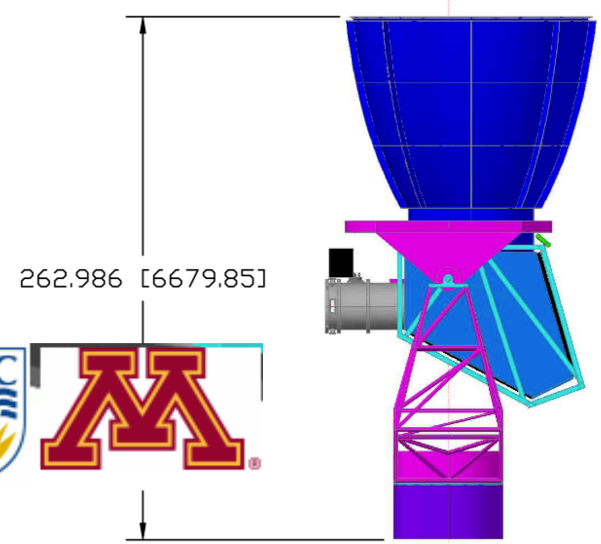
- systematics
  - foregrounds
  - lensing reconstruction
  - beam systematics
- Cross-correlation with optical surveys

POLAR-1



M. Runyan

K. Thompson



- 1.6m (6’), 2000 detector pairs @150 GHz
- 300-400 deg^2 survey
- Deployment in late 2012

POLAR Array

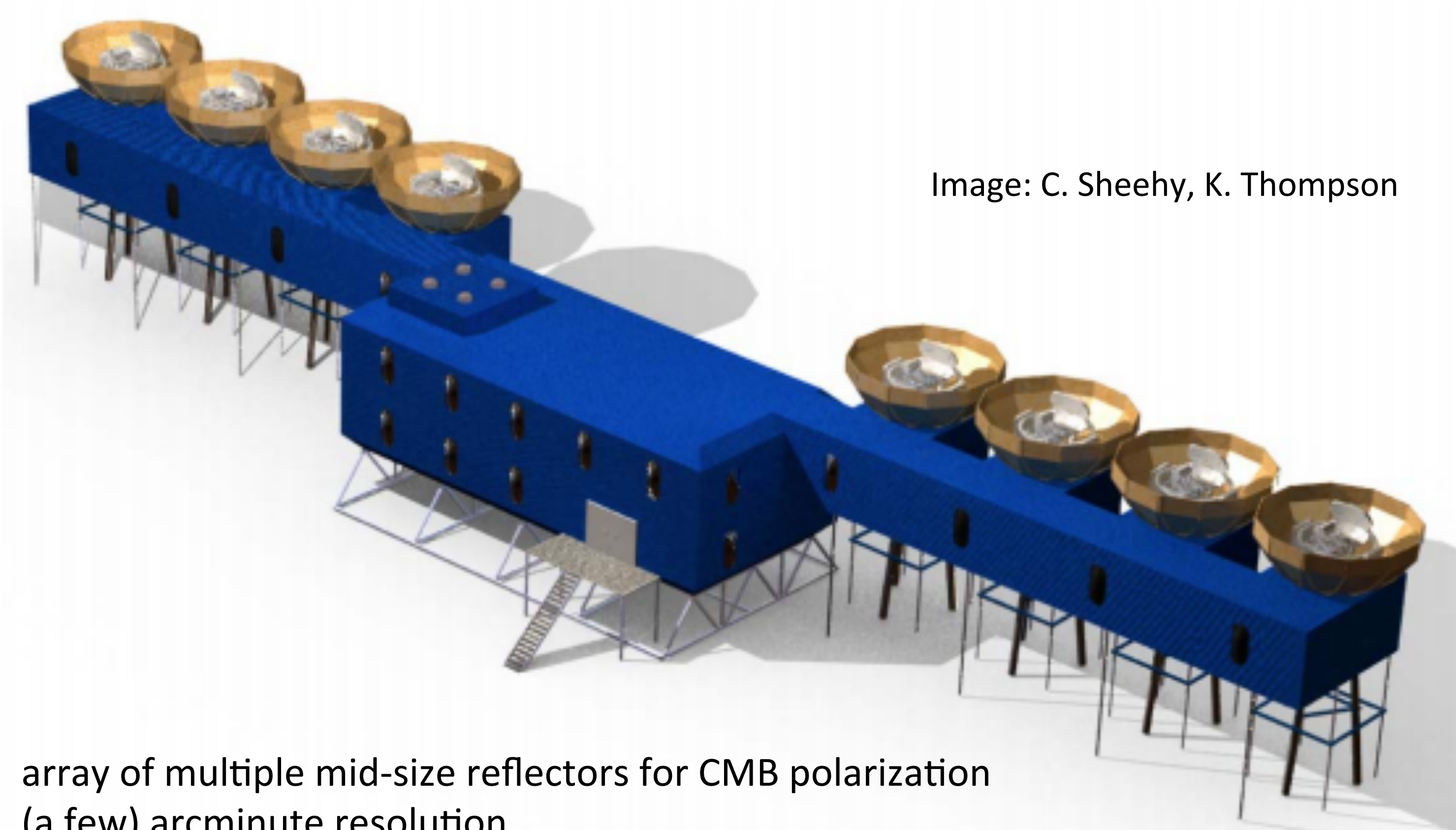


Image: C. Sheehy, K. Thompson

- array of multiple mid-size reflectors for CMB polarization
- (a few) arcminute resolution
- multi-frequency (distribution TBD)
- 10% the survey speed of CMBPOL

Thank you