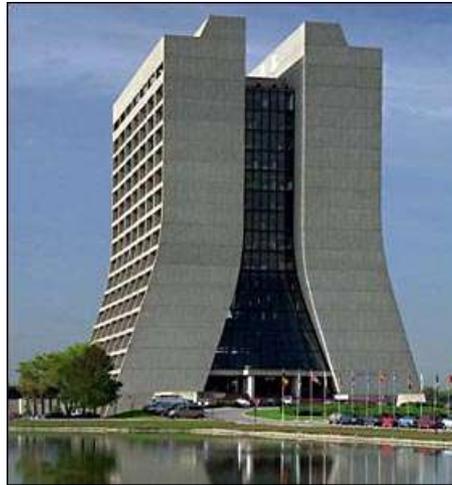


# 21<sup>cm</sup> Experiment for the 21<sup>st</sup> Century



# Three Pillars of DE Science



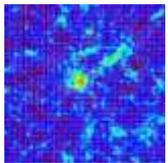
## **SN: supernovae**

- Best at low  $z$  ( $z < 0.8$ )
- Purely geometric probe



## **BAO: baryon acoustic oscillations**

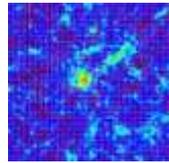
- Best at high  $z$  ( $z > 0.8$ )
- Purely geometric probe



## **WL: weak lensing**

- Probes both geometry and gravity
- Most prone to systematic errors

# DE Can't Stand On 2 Legs

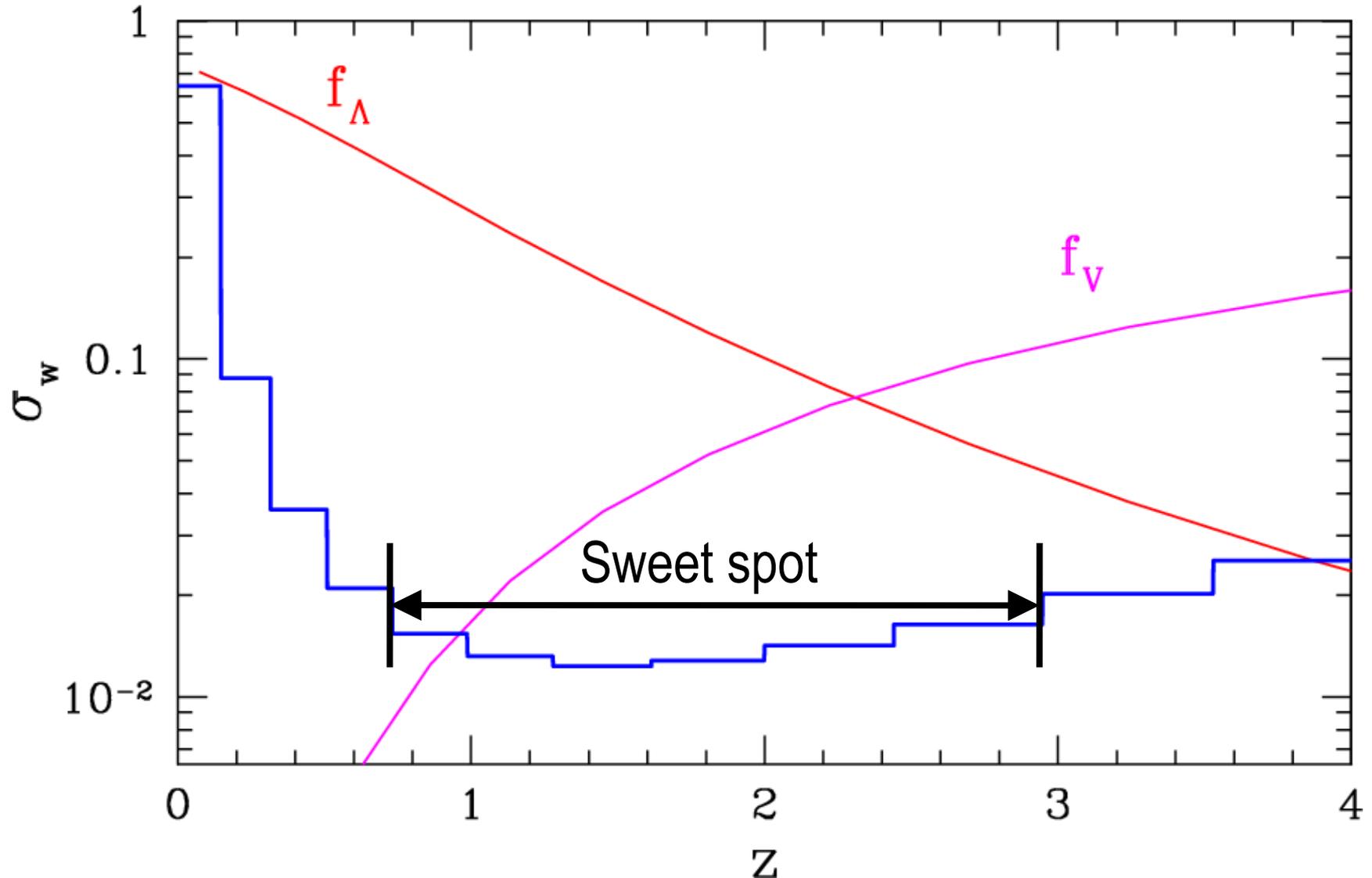


SN	SN	BAO	BAO	WL	WL	DETF	$1\sigma$ err	$1\sigma$ err	$1\sigma$ err
$z_{\max}$	mag err	$z_{\max}$	$f_{\text{sky}}$	$N/10^9$	err/stat	FoM	$w_p$	$\ln H_0$	$\Omega_K$
0.8	0.005	3.0	0.250	1.0	2.0	975.7	0.011	0.0050	0.00036
XX	XX	3.0	0.250	1.0	2.0	295.0	0.017	0.0153	0.00040
0.8	0.005	XX	XX	1.0	2.0	418.8	0.014	0.0089	0.00201
0.8	0.005	3.0	0.250	XX	XX	667.5	0.014	0.0052	0.00048

It is also crucial to have a cross-check.

(Numbers courtesy D. Eisenstein)

# Baryon Acoustic Oscillations



# Whom Are We Against?

*Photometric BAO is fundamentally limited* ●

- **BigBOSS** (\$100M, done by 2020 )
  - FoM = 175 (285 with BigBoss-South)
  - 14,000 (24,000) deg<sup>2</sup>
  - Based on [OII] emission line
- **JDEM** (~\$B, done by 2021)
  - FoM = 250
  - Full sky, cosmic variance limited
  - Based on H $\alpha$  emission line

# Why Do 21cm?

- Radio 21cm window offers a completely independent check on DE measurements, with entirely different systematics.
- In the radio we detect mostly dwarf, HI rich, slow star-forming galaxies.
- Optical-IR surveys all rely on emission line (i.e. actively star-forming) galaxies.
- Two approaches will sample two very different galaxy populations, with different biasing properties.

# Why Fermilab?

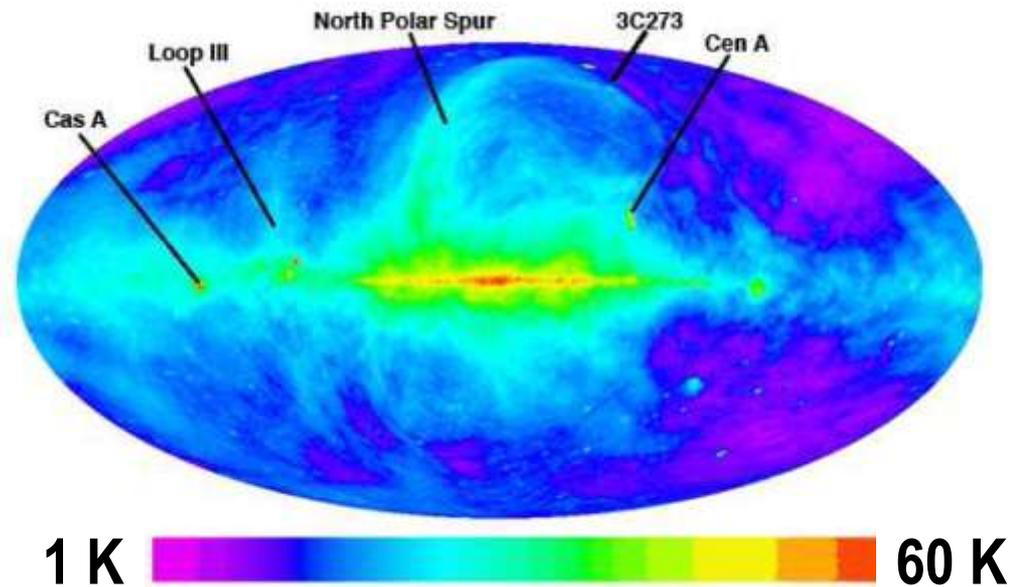
- A window of opportunity exists if we move fast - competing, larger efforts will ***not*** produce results before ~2020 (if they are funded at all).
- No serious competing efforts in the radio BAO currently exist, but other groups are starting to organize.
- 3+ EOR 21cm experiments (similar technology, non-overlapping science goal).

# Who Is Riding This Wagon For Free?

- Other science goals:
  - Search for pulsars (should be a factor 5-10 more efficient than current surveys) – GR, gravity waves, etc.
  - Evolution of neutral hydrogen in  $1 < z < 4$  interval (synergy with NSF-funded ALMA, SDSS).
  - Direct observations of proximity zones around bright quasars (synergy with SDSS).
  - Tons of galactic science.

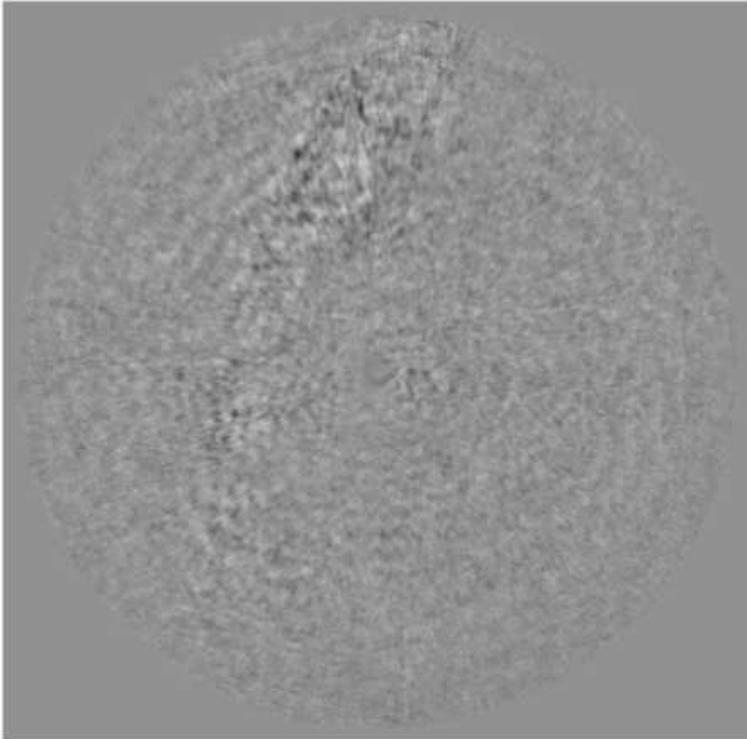
# Will It Be Done?

- The crucial difficulty of this project is in the weakness of the signal relative to foregrounds:
  - Galactic synchrotron
  - External radio galaxies
  - Galactic free-free

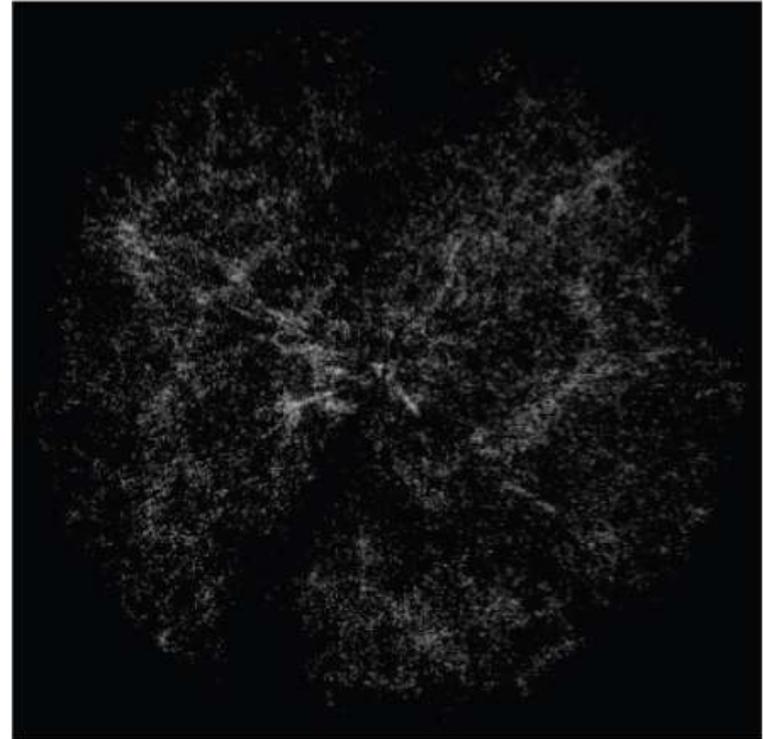


# Already have...

HIPASS HI Survey



6dF Optical Galaxy Survey



Pen et al. 2008: x-correlation of HIPASS & 6dF ( $z \sim 0.04$ )  
Chang et al 2010: x-correlation of GBT & DEEP2 ( $z \sim 1.0$ )

# The End

