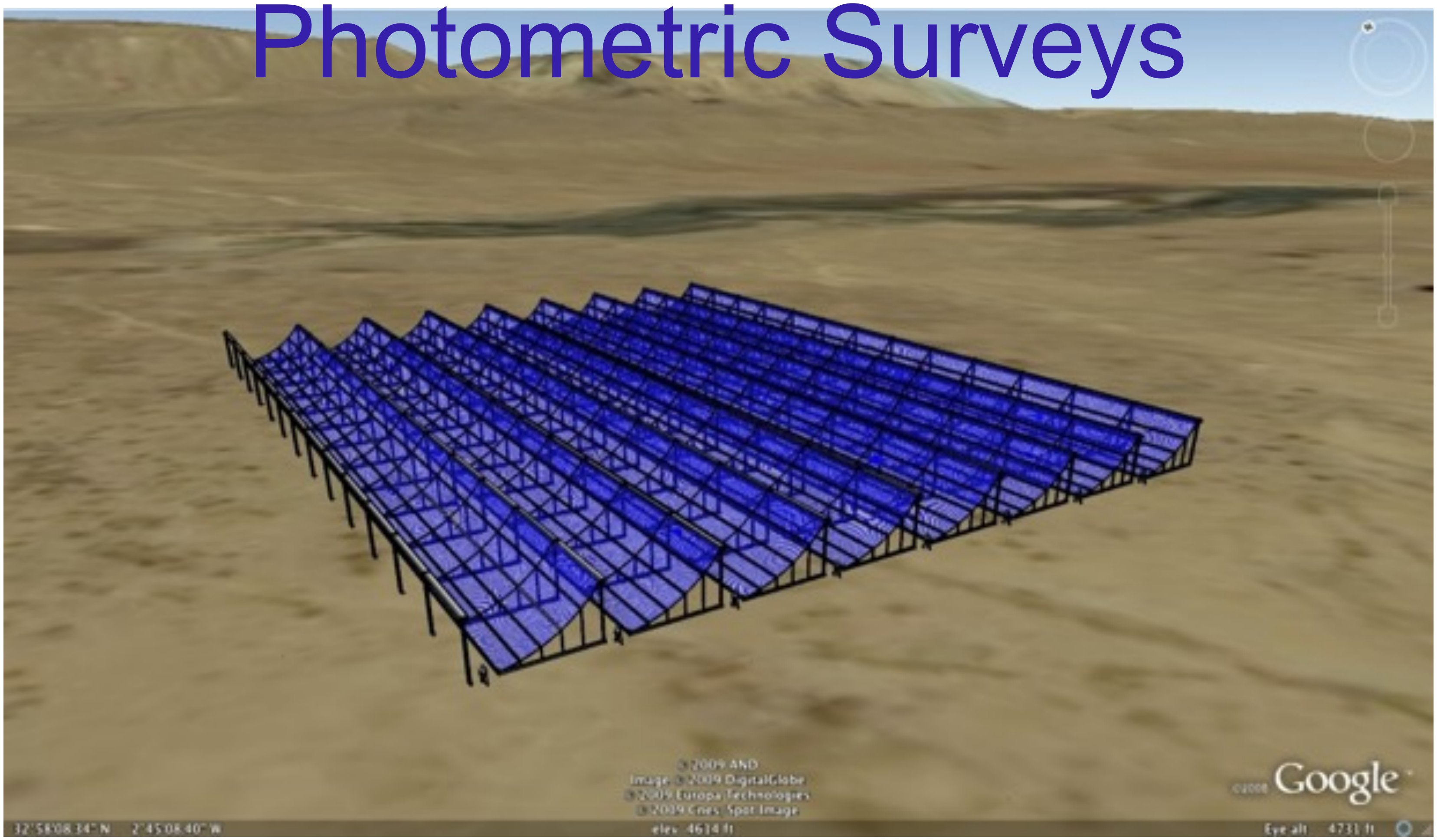
Correlating Non-linear Structure in 21cm Intensity Maps with Photometric Surveys



NRAO-HQ
7 May 2013
Charlottesville

Albert Stebbins
Fermilab

Redshift Resolution

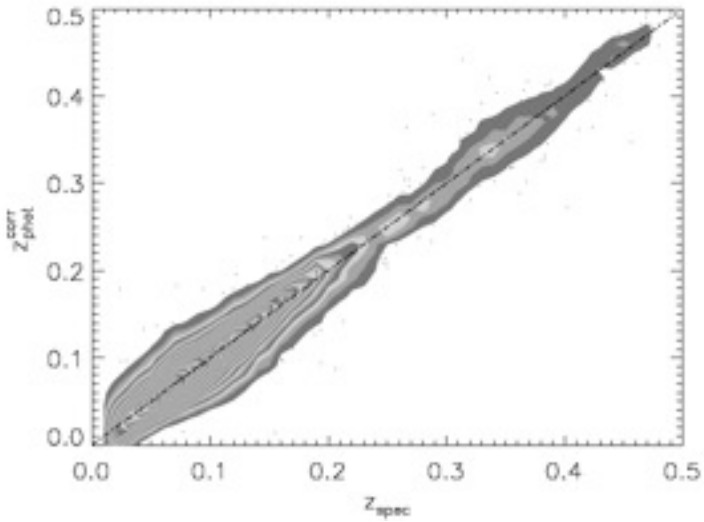
Unlike Optical / IR for 21cm

Redshift Determination is Easy and Cheap

FFT RF spectral analyzer of incoming signal (1GHz).

Imaging and spectroscopy in same observation.

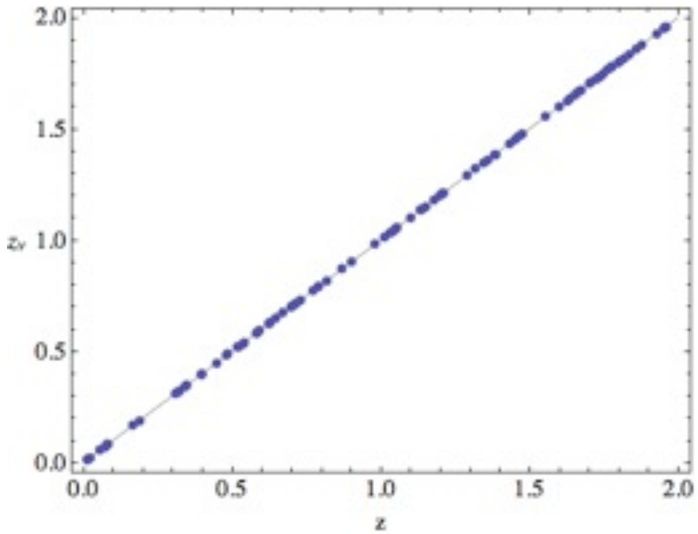
cheap photometric z



D'Abrusco 2007

versus

cheap radio z



good radial resolution

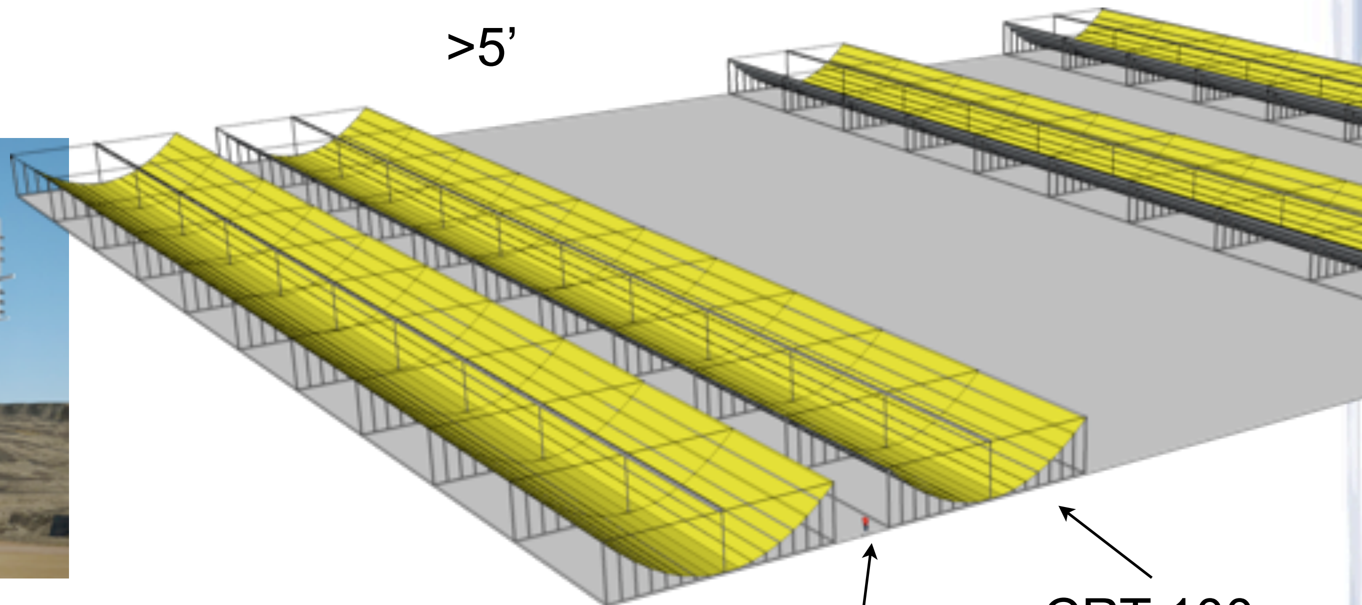
$\theta \sim \lambda / D$

Angular Resolution is more challenging for 21cm than for optical / IR because of diffraction limit.

Need 100m telescope for only 10’ resolution!

Fortunately cost per unit area is small.

>5’



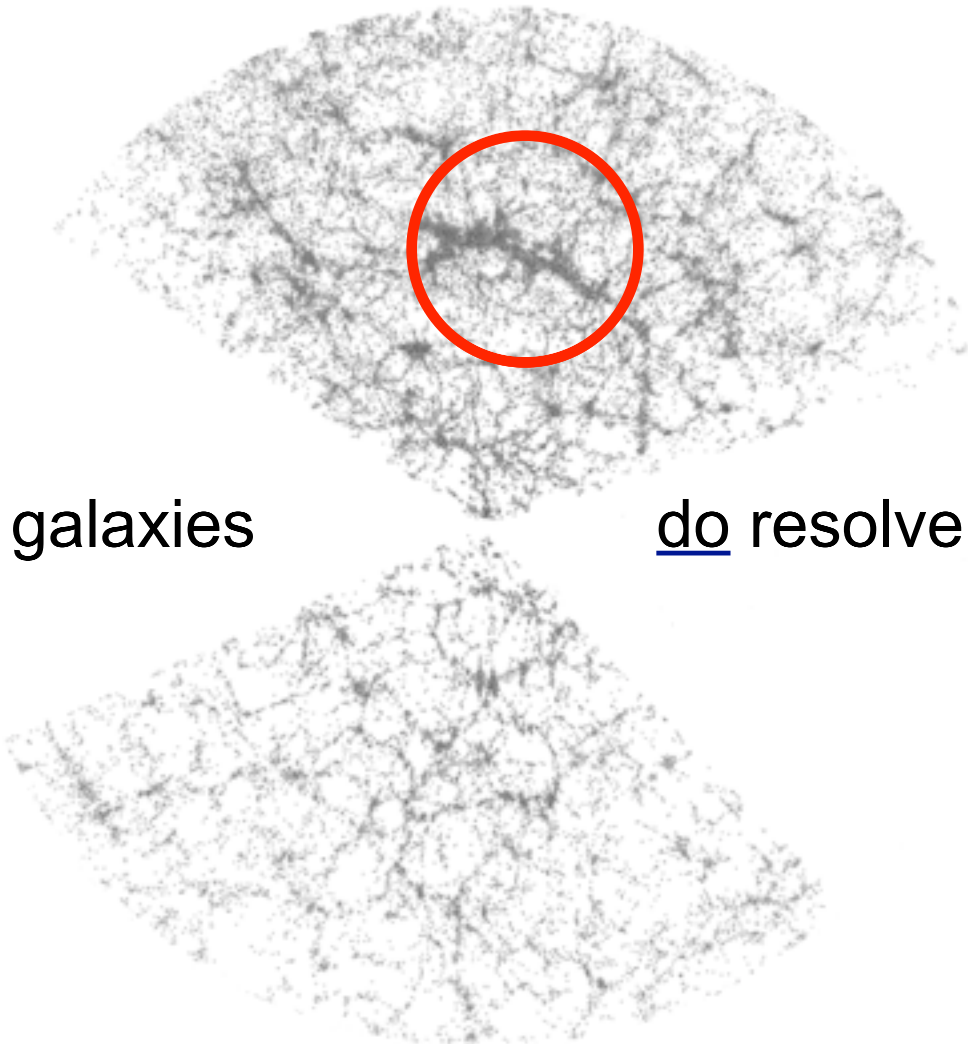
LSST

<1’’

human

CRT 100 m

INTENSITY MAPPING



<u>do not</u> resolve galaxies

<u>do</u> resolve LSS / BAO

Peterson *et al* 2006

Wang *et al* 2006

Seo et al. 2010.

Expensive to resolve individual galaxies (e.g. SKA)

instead only resolve what is needed for BAO features!

Foreground Subtraction

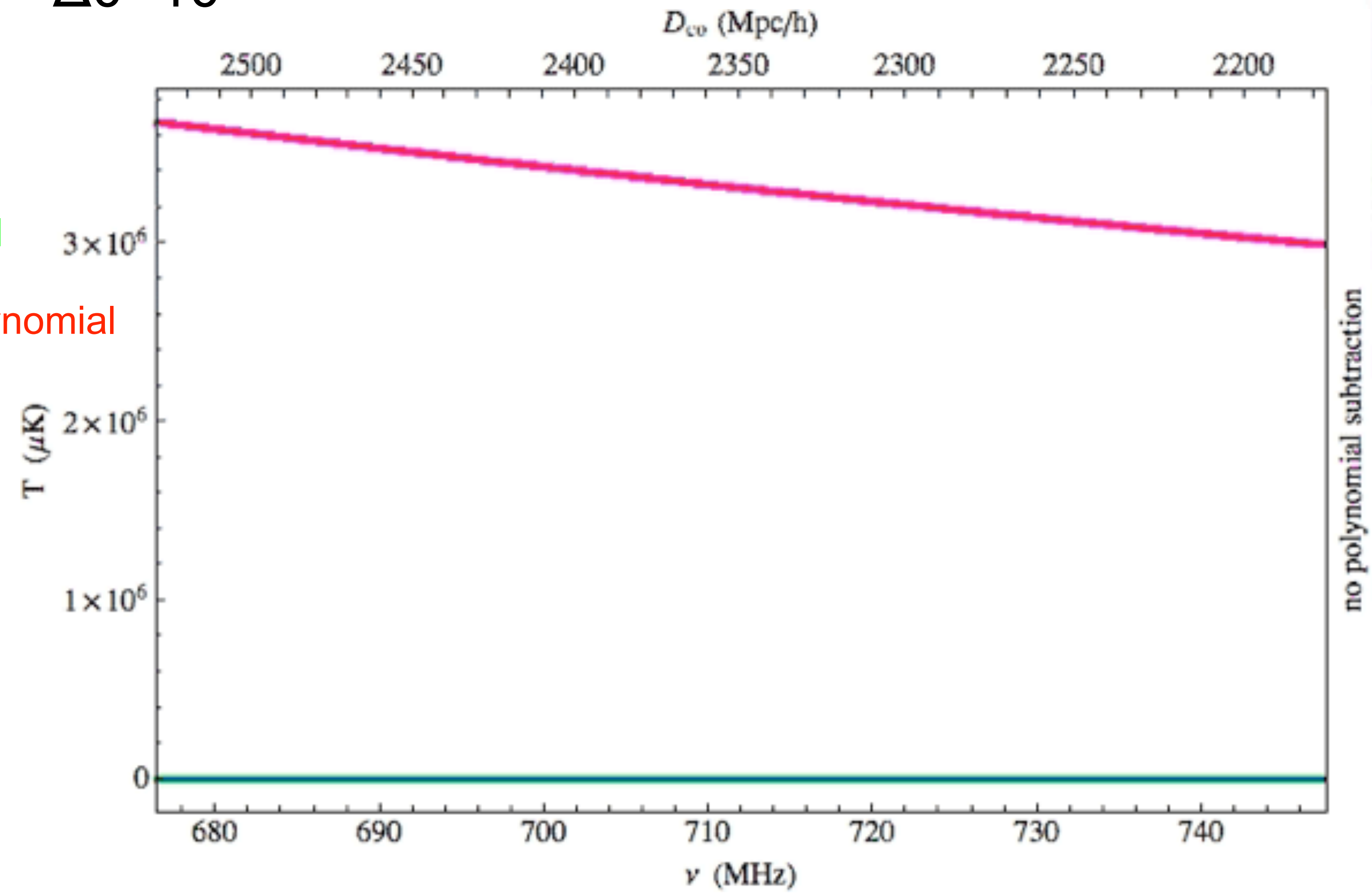
Δθ=10'

21 cm signal

21cm-polynomial

21 cm+synch-polynomial

residual



Foreground Subtraction

More detailed simulation of residual foreground contamination for a cylinder telescope

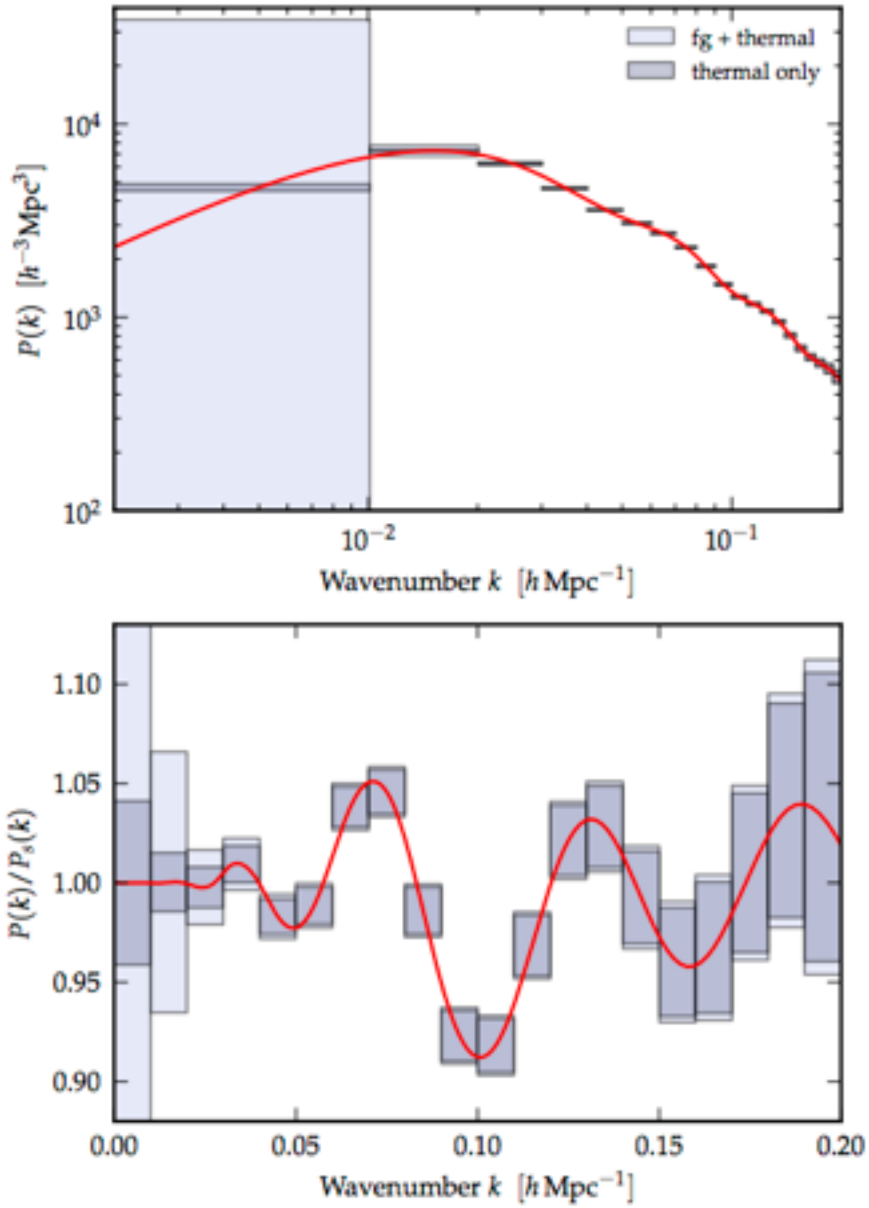
Shaw *et al*. 2013

2 x 15m x 100m cylinders

2 x 60 dual polarization feeds

T_{sys} = 50K

2 full years observation time



Better Together

spectral resolution of HI intensity mapping survey
angular resolution photometric optical / IR survey

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Naive Combination:

inverse variance weighted estimates in k-space

$\delta\rho/\rho(\mathbf{k}) = (\sigma_{opt}(\mathbf{k})^2\, \delta\rho/\rho_{HI}(\mathbf{k}) + \sigma_{HI}(\mathbf{k})^2\, \delta\rho/\rho_{opt}(\mathbf{k}))/(\sigma_{opt}(\mathbf{k})^2 + \sigma_{HI}(\mathbf{k})^2)$

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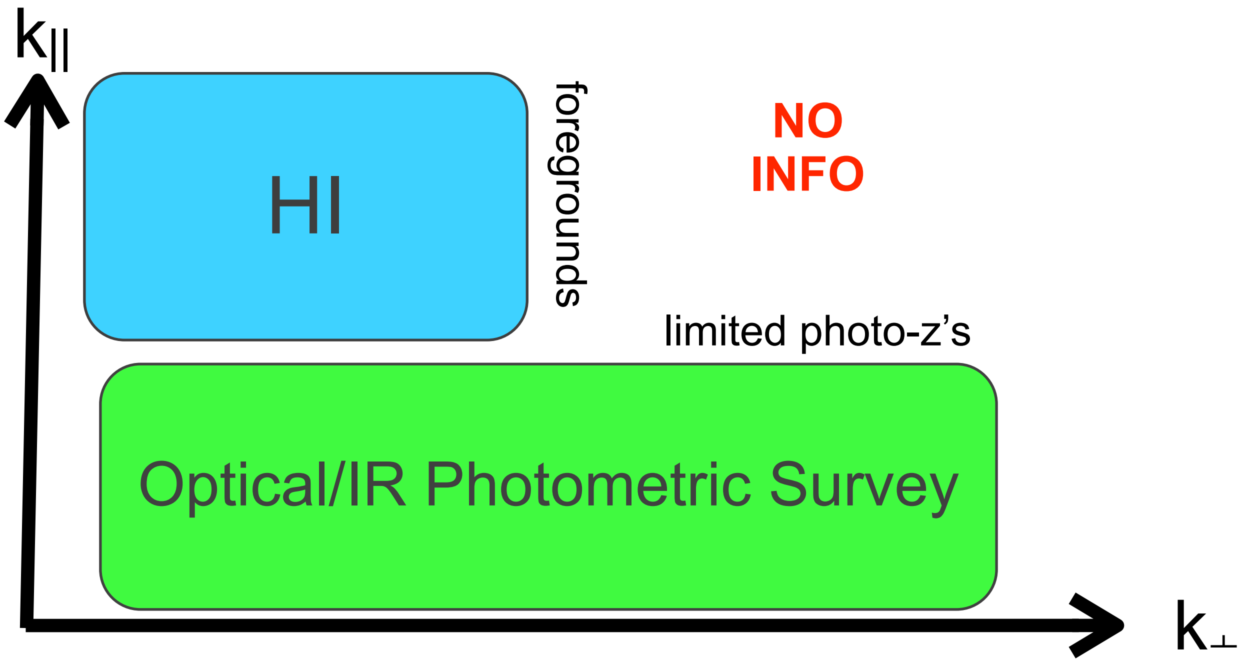

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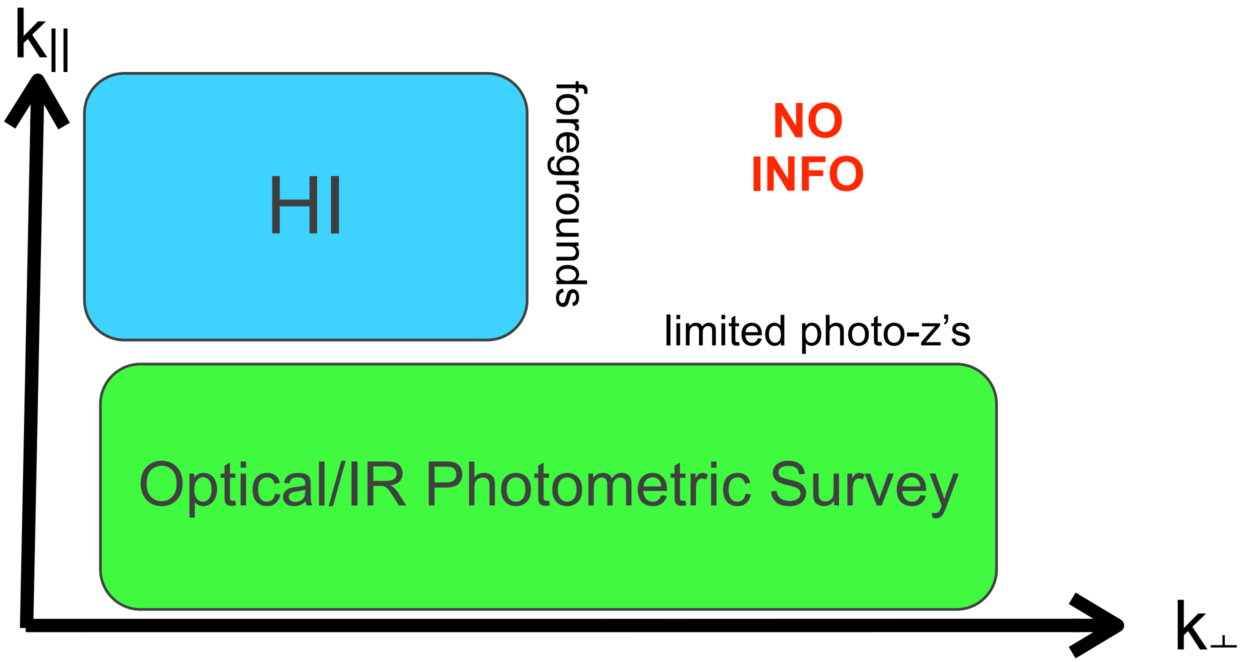
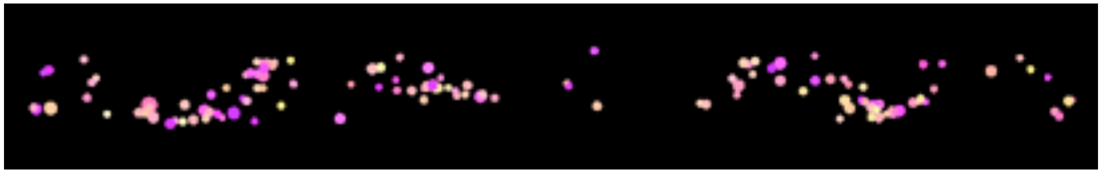


In linear (homogeneous Gaussian) theory this is optimal.

NON-GAUSSIAN INTENSITY MAPS



DEEP2

Davis ++ 2004++

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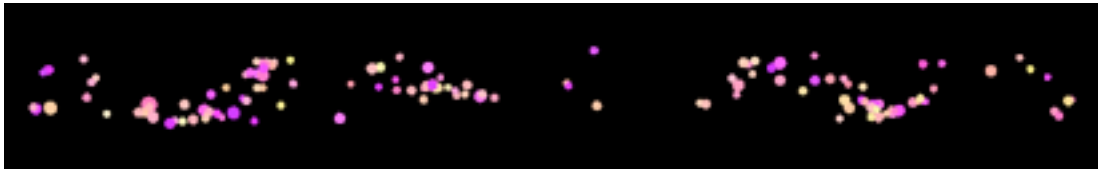

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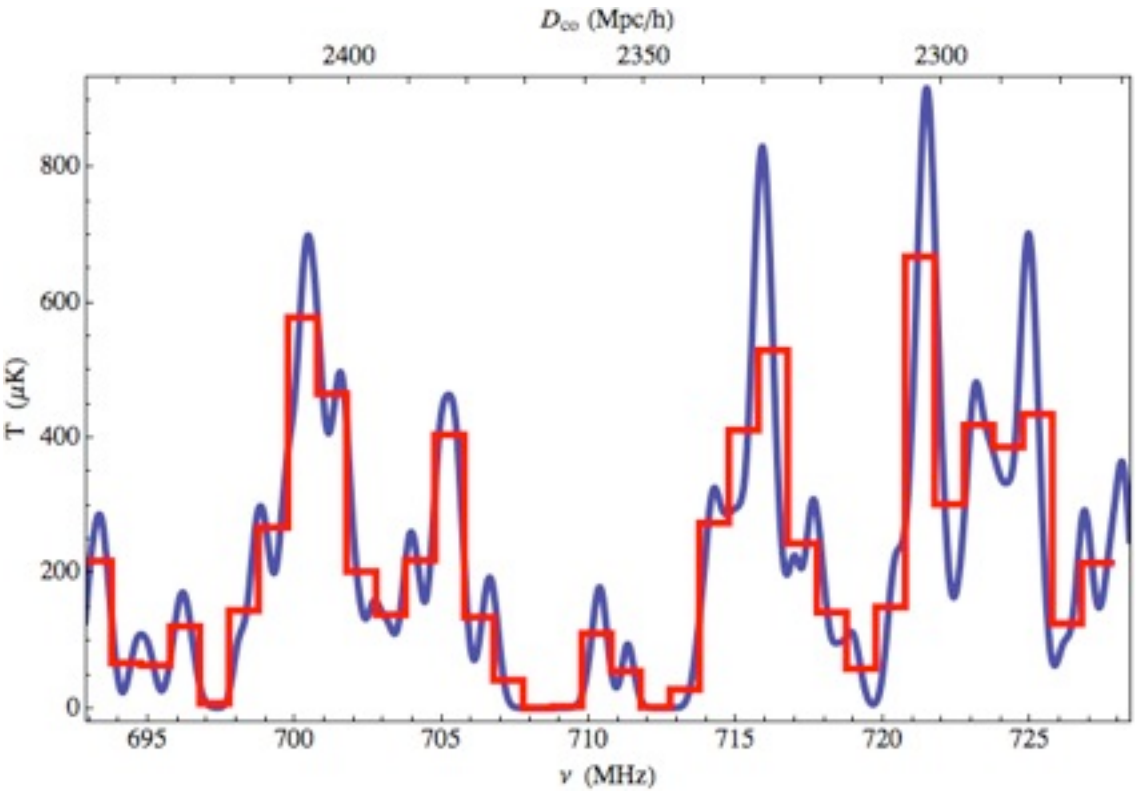

HI

$\Delta\nu$=1 MHz

$\Delta\theta$=10’

Tully-Fisher

$M_{HI} \propto L_B$

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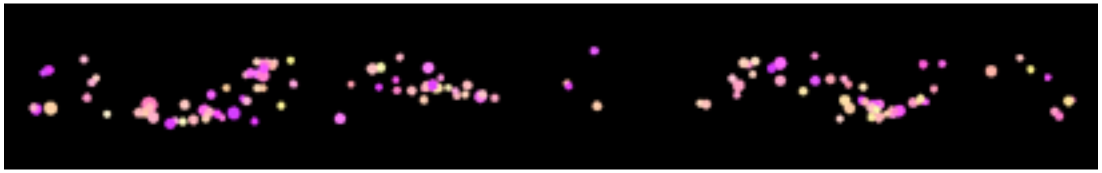

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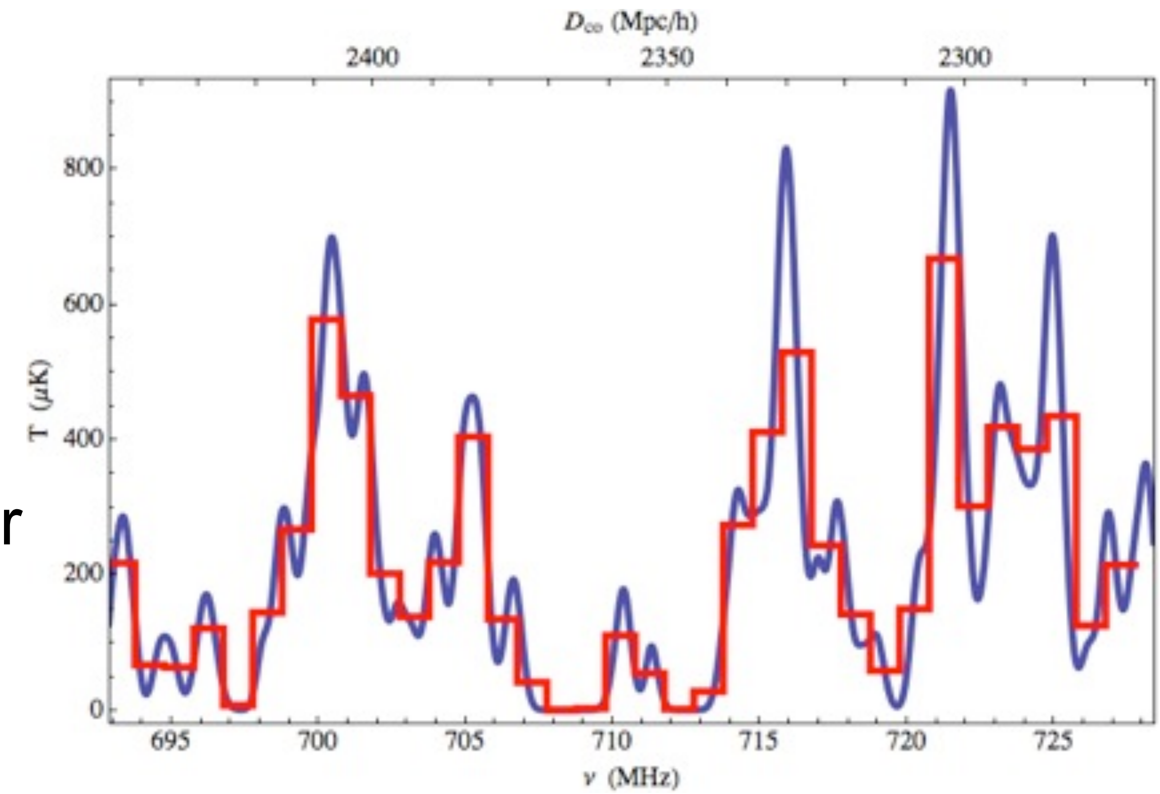

HI

We can <u>nearly</u> resolve galaxy structures in redshift space.

Alfalfa Survey

Giovanelli, Haynes, ++   2005++

400/h Mpc

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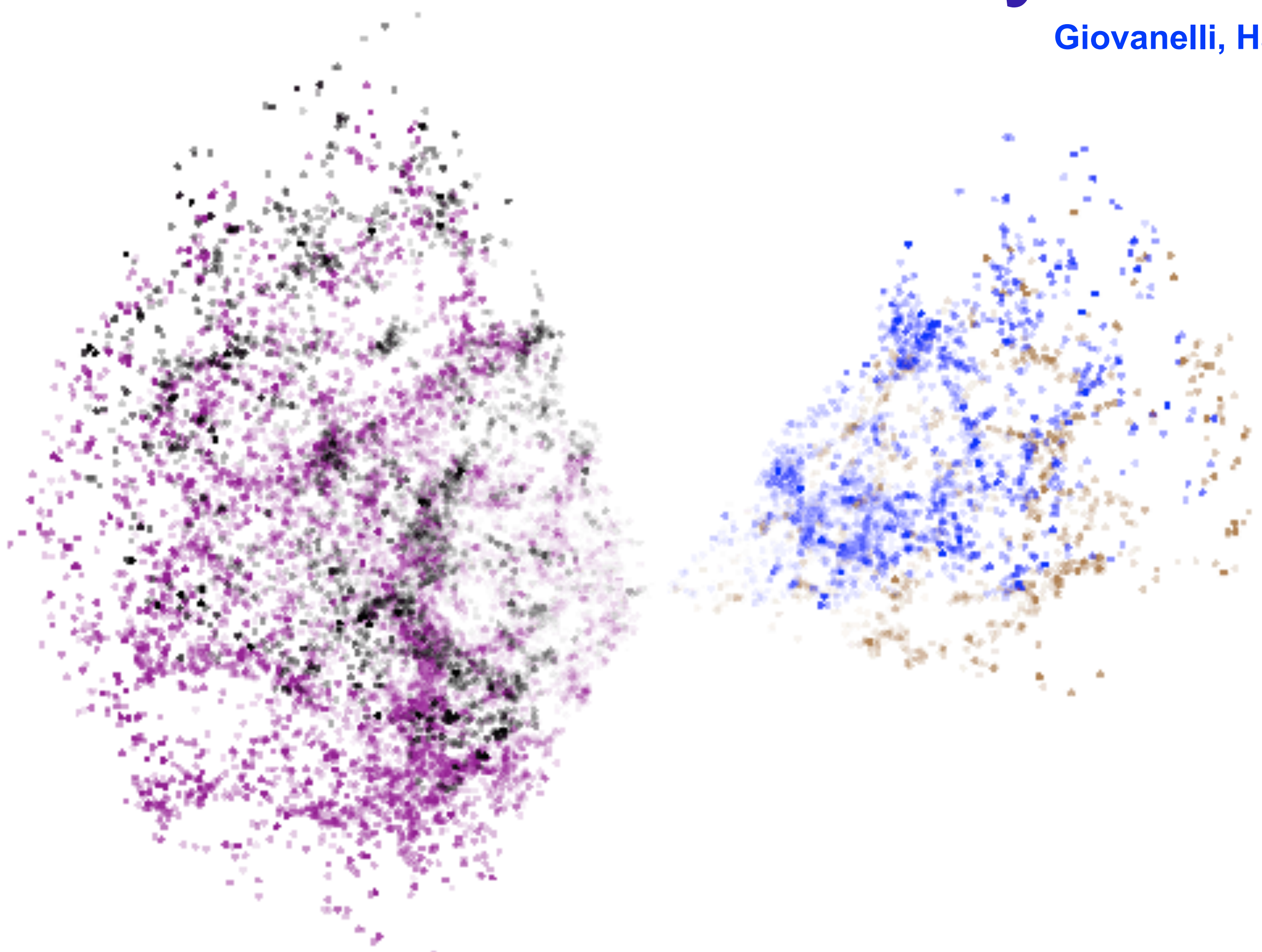

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How To Use Non-Gaussianity I

LSST

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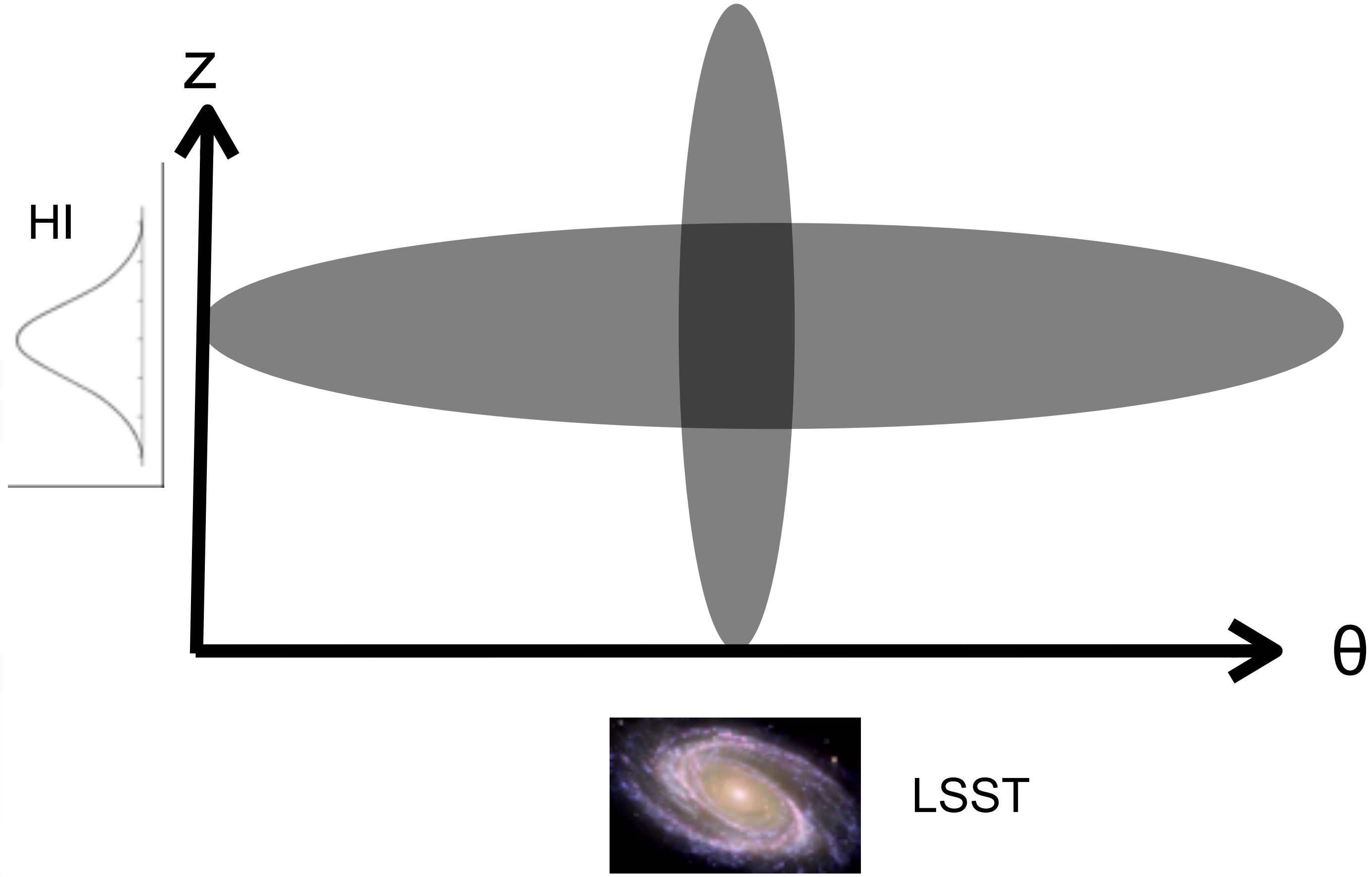

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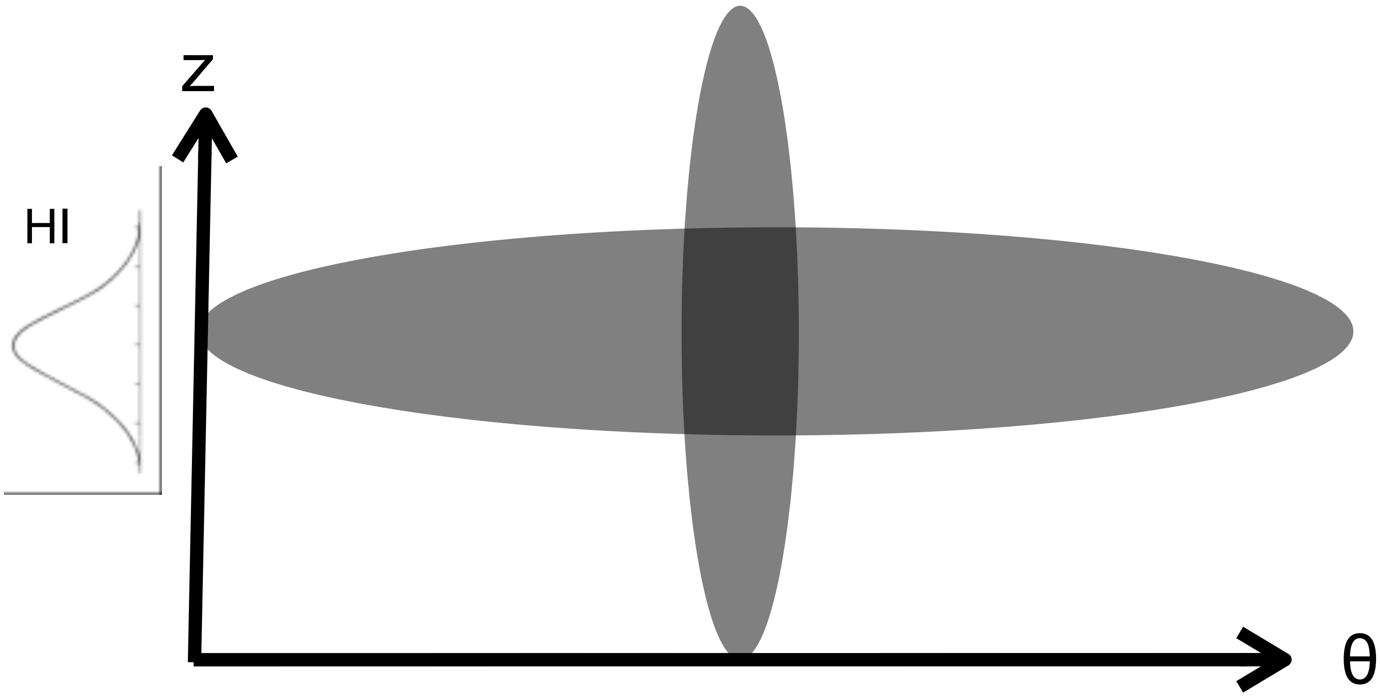

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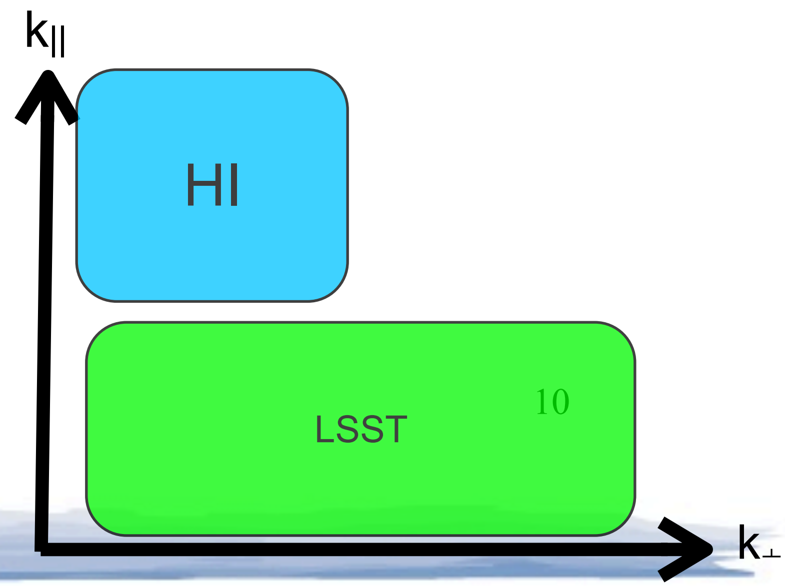

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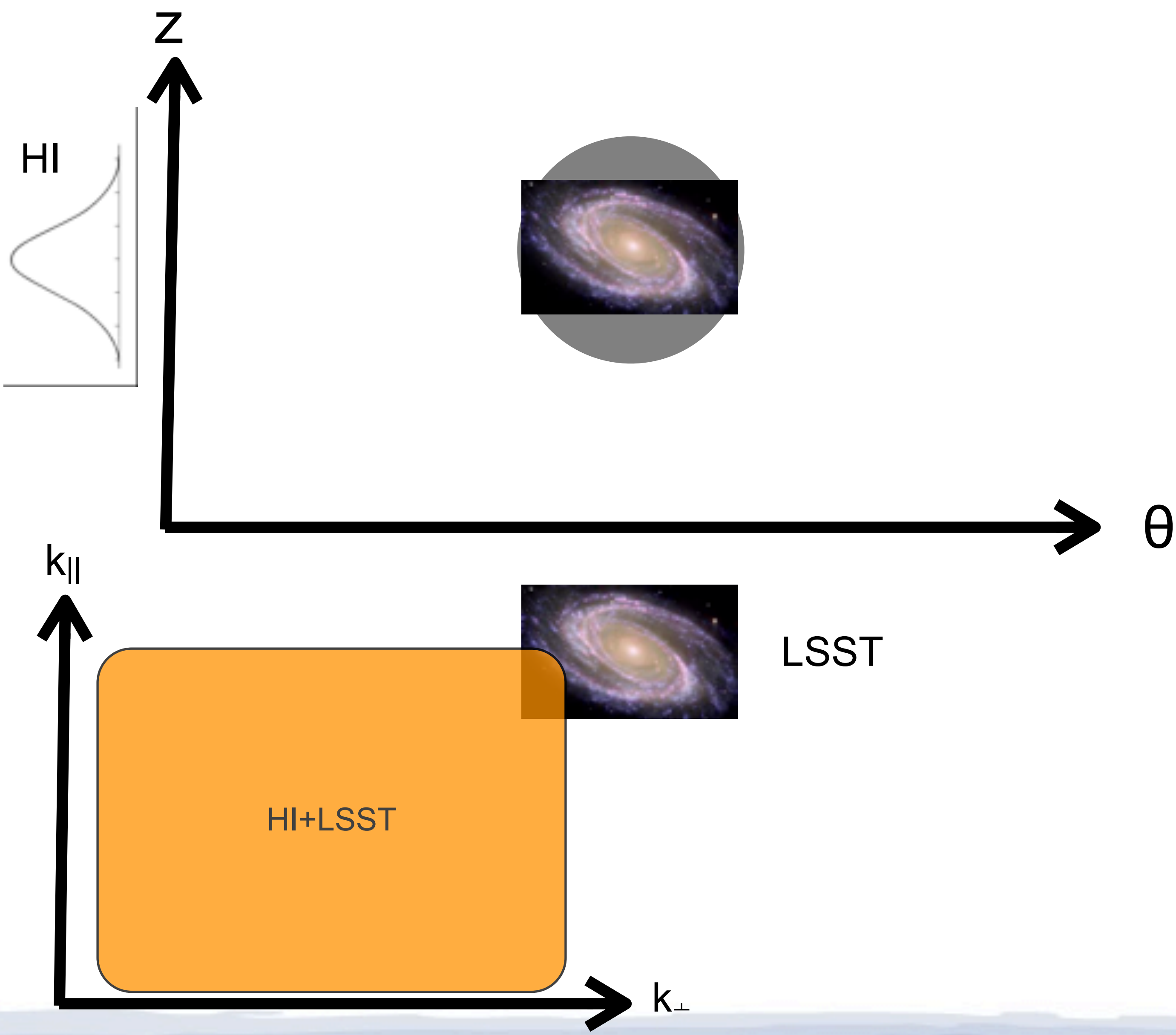

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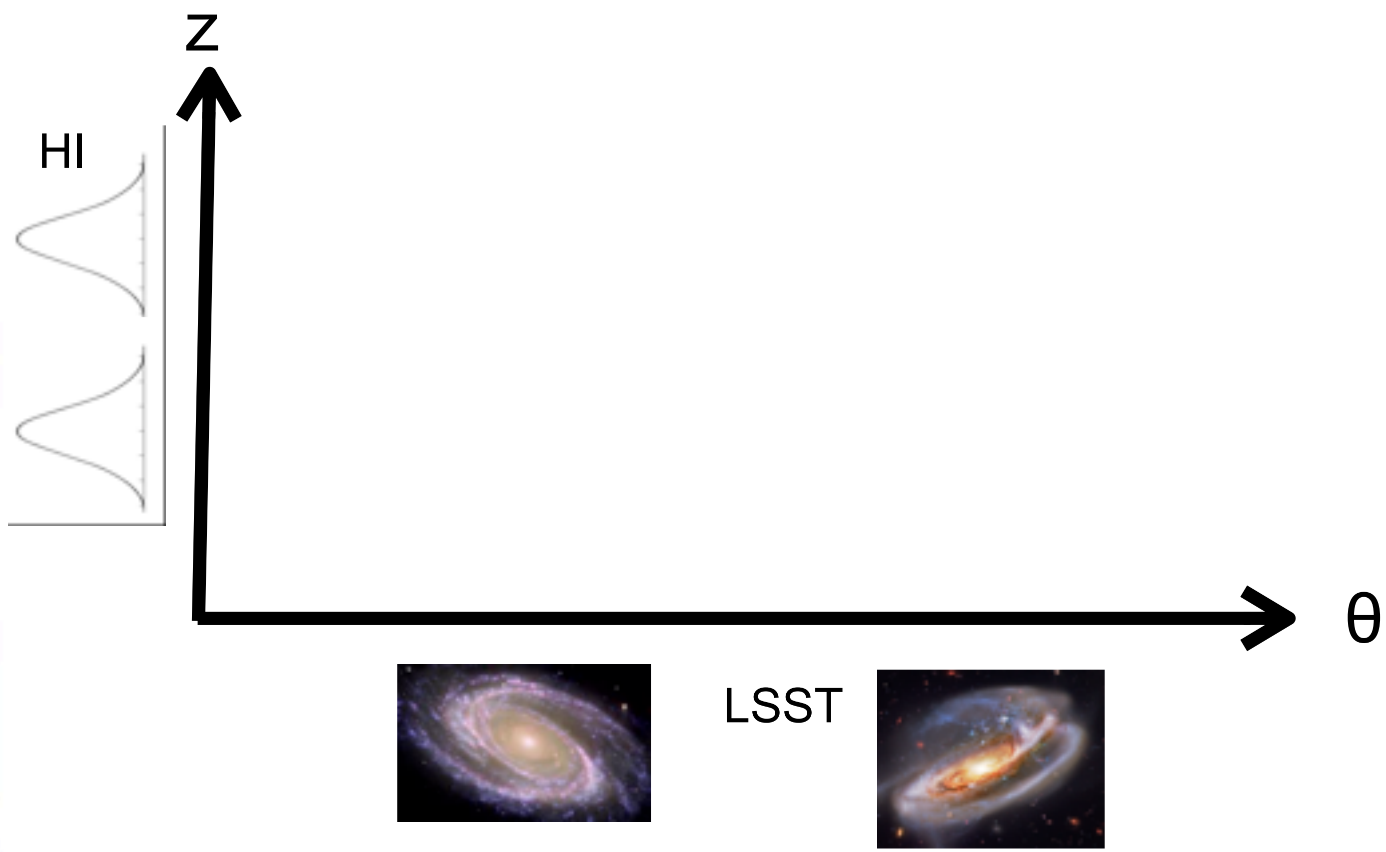

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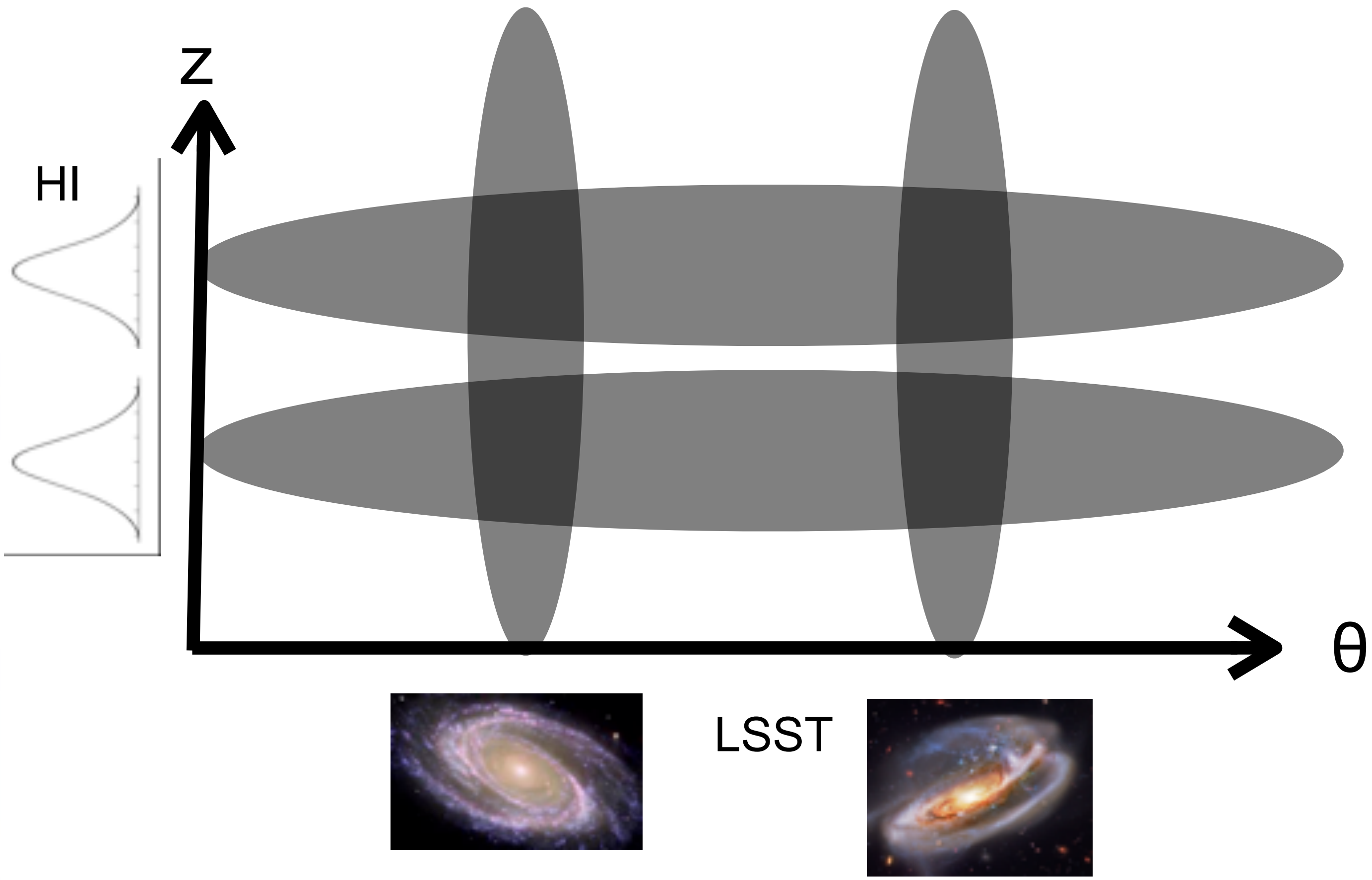

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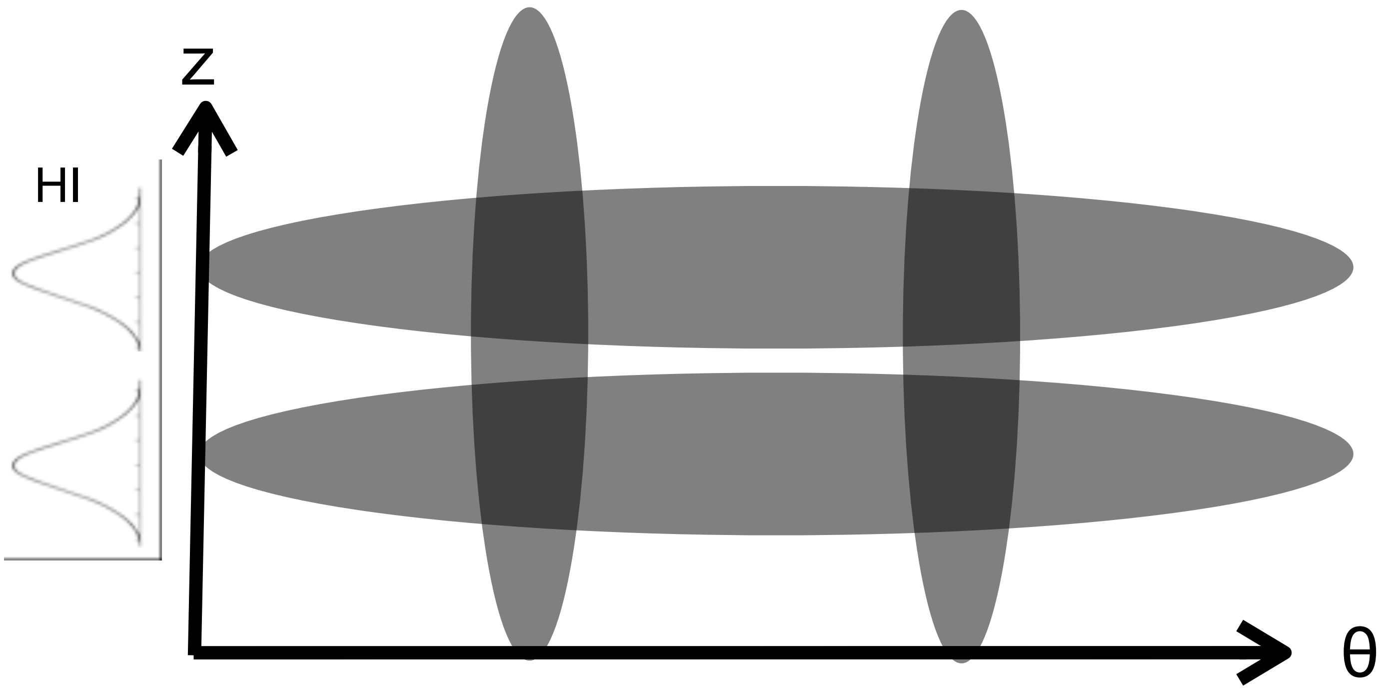

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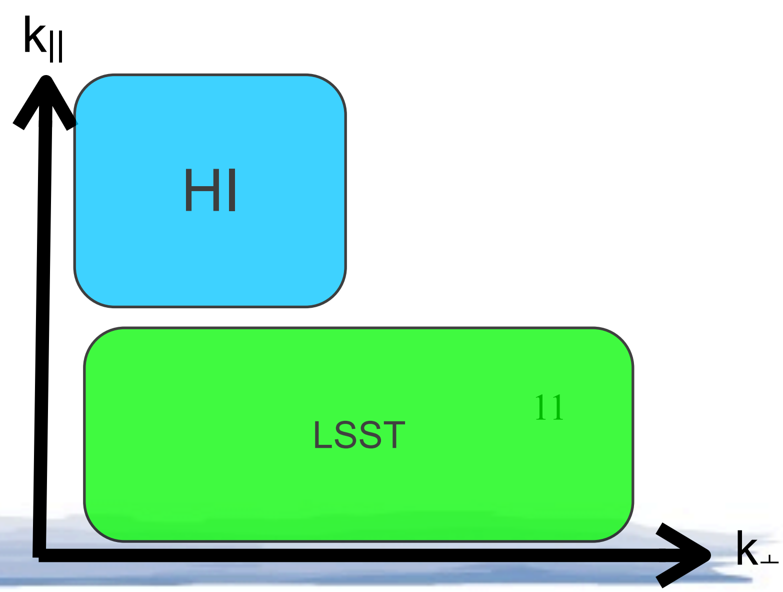

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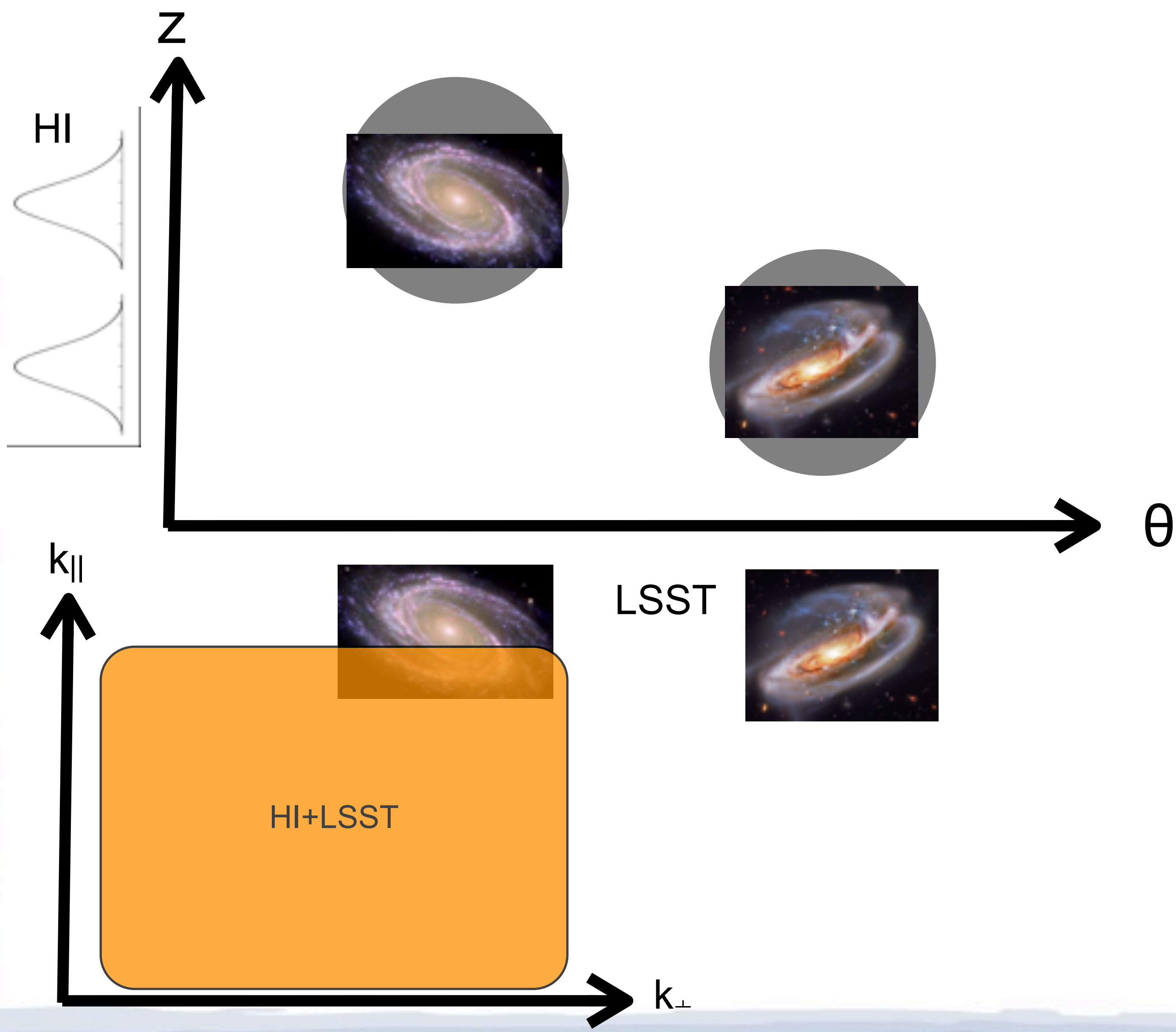

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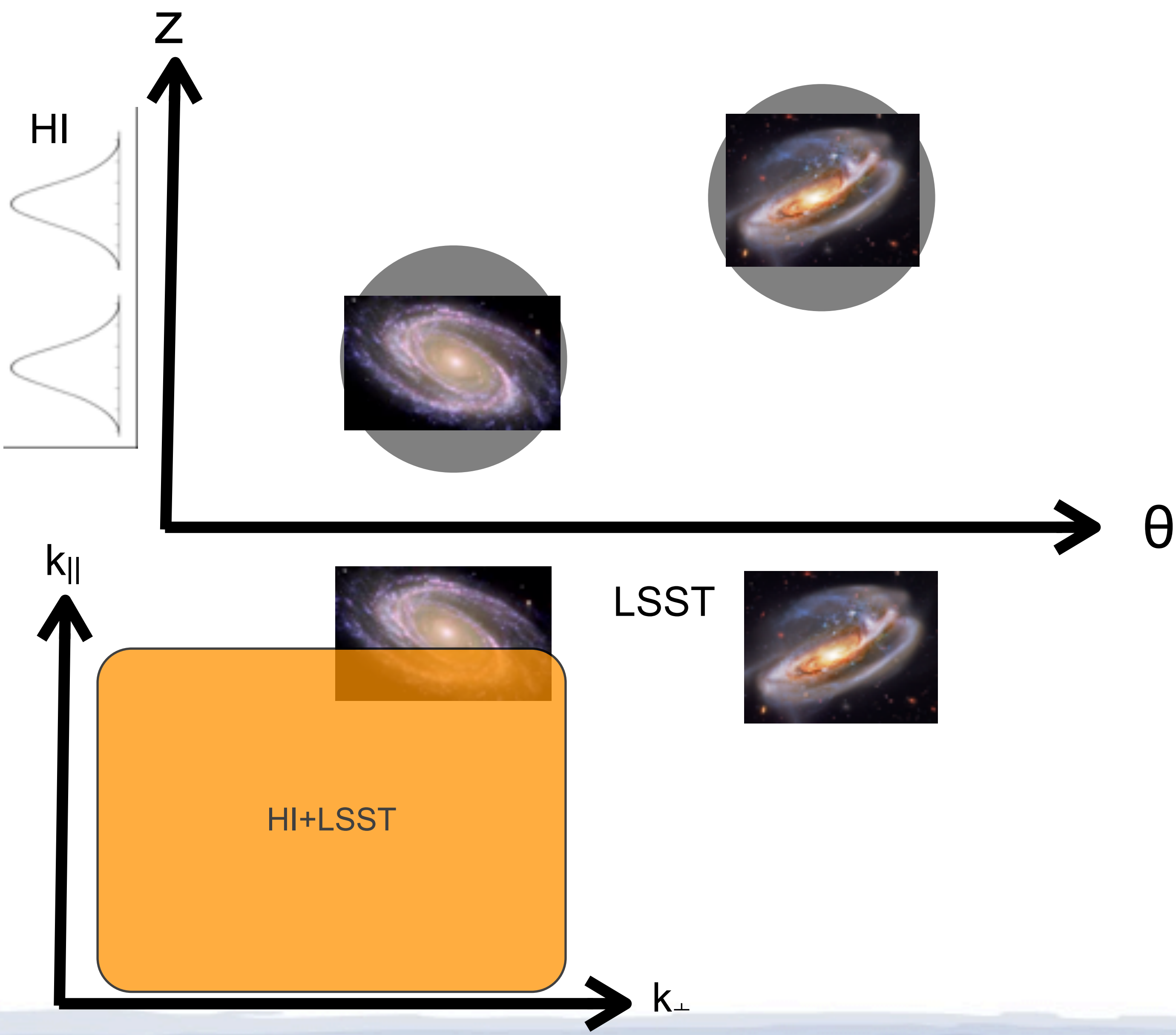

Ambiguity
in
galaxy
locations

Rules of Thumb

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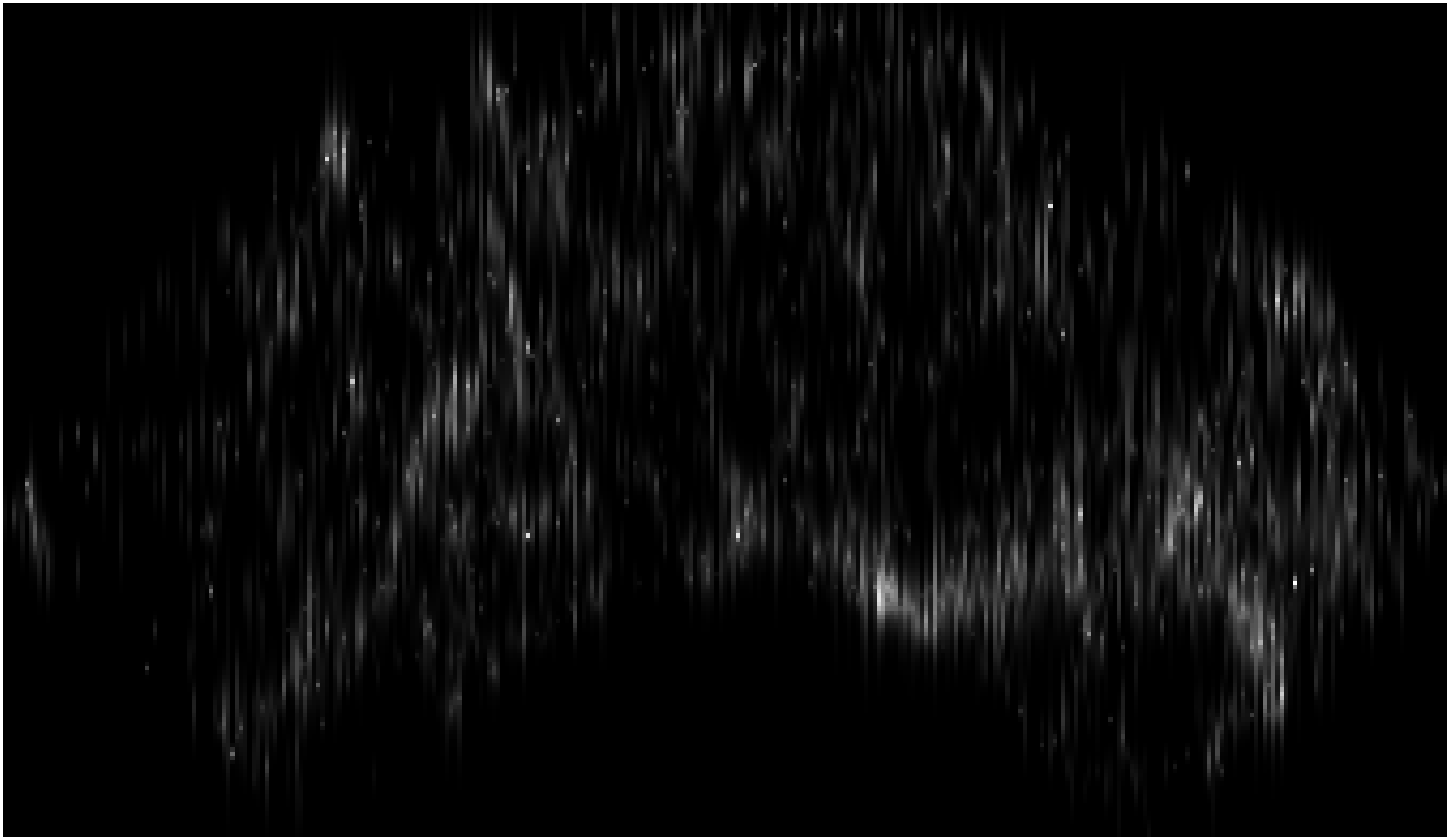
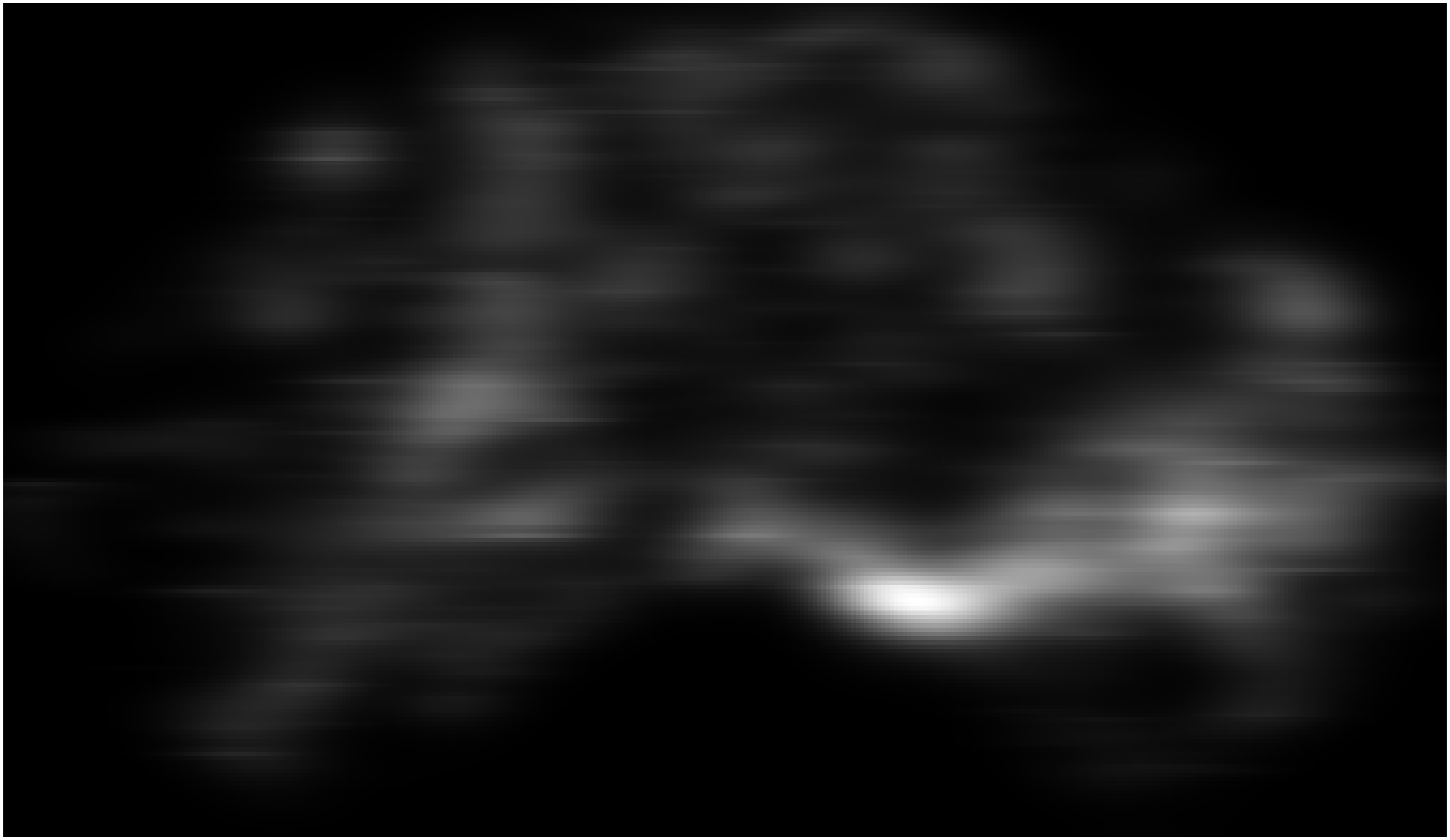
- ALFALFA has improved our knowledge of HI

Slice Through ALFALFA Catalog

Slice through ALFALFA w/ Linewidth

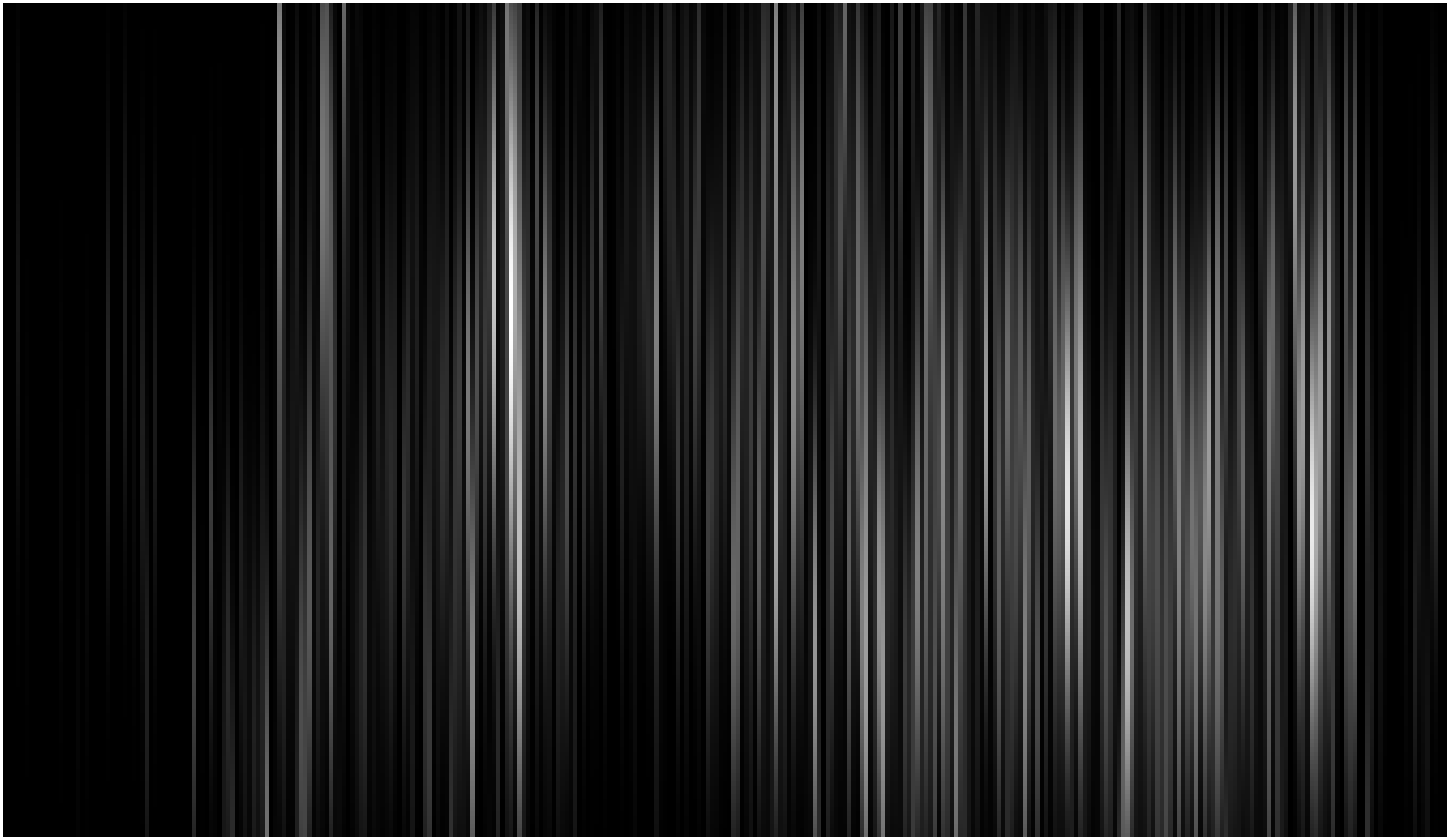


ALFALFA @ z=1 w/ 10' beam

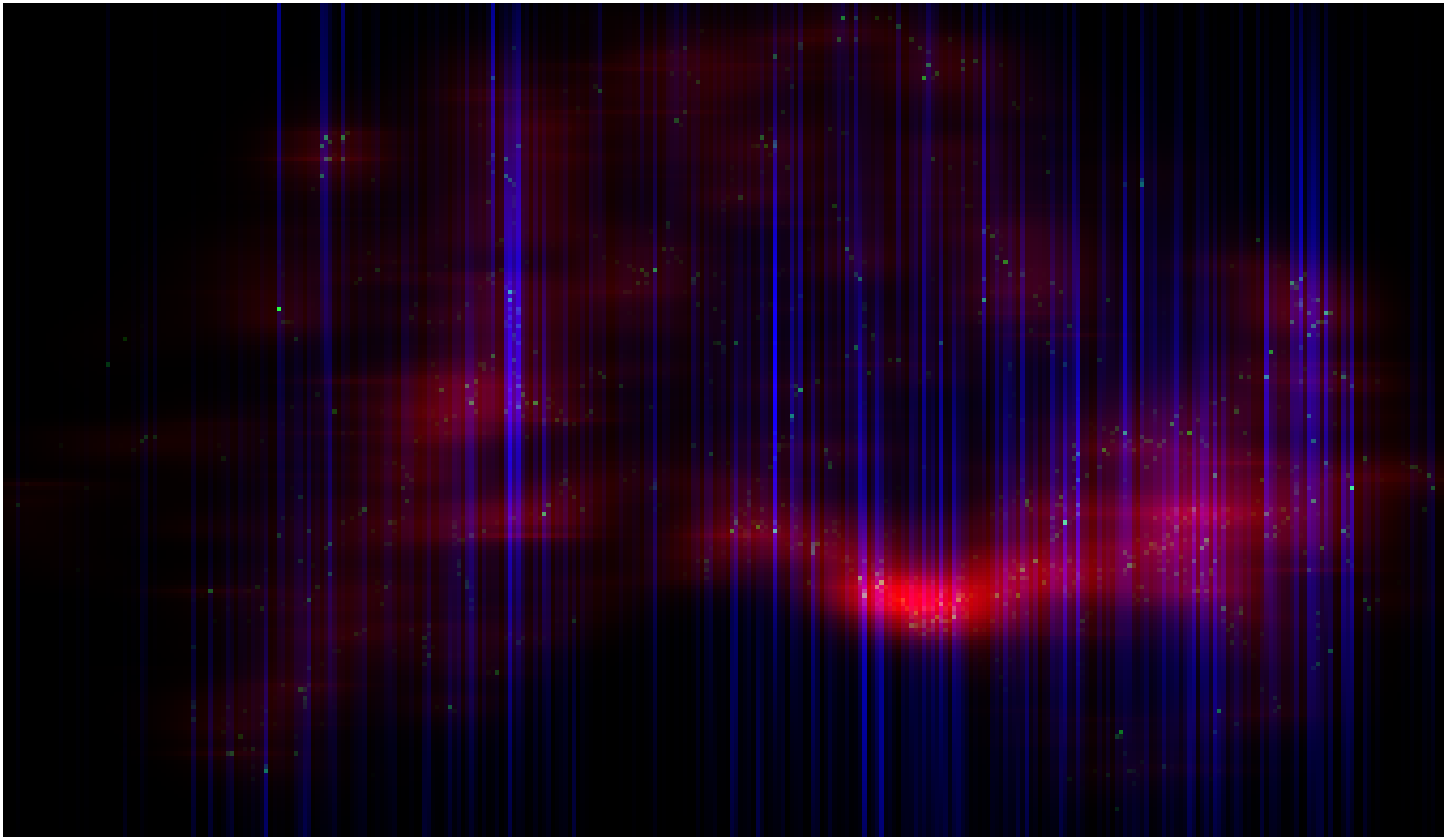


ALFALFA slice @ z=1 w/ σ_z = 0.01

z=1, σ_z = 0.1 ALFALFA distribution



Composite: HI + Optical w/ Answers



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- More precise inferences can be obtained using, *e.g*. a Monte Carlo Markov Chain.
- A photo-z enhancers (MKIDS?) could help!

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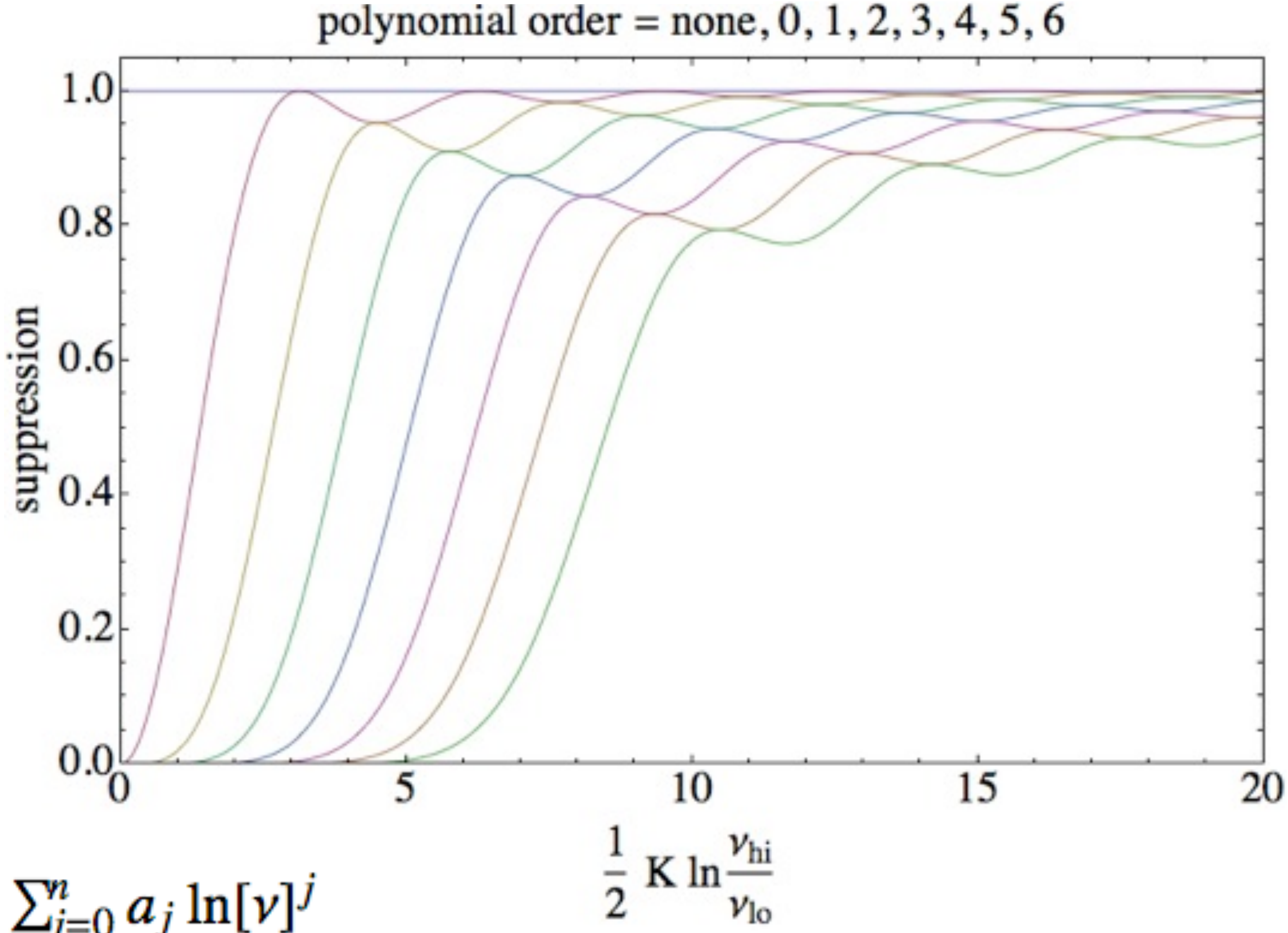
Additional Slides

Loss From Polynomial Subtraction

$$I_\nu^{\rm sync}[\hat{\boldsymbol{n}}] = \frac{I_0}{2\pi}\left(\frac{\nu}{\nu_0}\right)^p \int_{-\infty}^{\infty} dK\, e^{i K \ln\left[\frac{\nu}{\nu_0}\right]}\, \tilde{I}^{\rm obs}_{(p)}[K]$$



$$I_\nu^{\rm fit} = (\nu/\nu_0)^p \sum_{j=0}^{n} a_j \ln[\nu]^j$$

Optical Analog