

# Probing galaxy evolution, dark energy, and cosmic magnetism with a deep 1000 hour Jansky VLA survey



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Atacama Large Millimeter/submillimeter Array  
Karl G. Jansky Very Large Array  
Robert C. Byrd Green Bank Telescope  
Very Long Baseline Array



# Collaborators



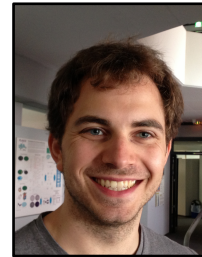
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(NRAO Socorro, USA)



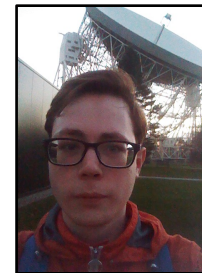
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# The survey: 1 khr single pointing in COSMOS

- Joint observing with CHILES
- 4 dedicated continuum subbands
  - 4x128 MHz between 1-1.9 GHz
  - 2 MHz channels
  - Include cross-hand data (full polarization)
  - Expected rms 0.7  $\mu$ Jy at 4'' resolution
- First 160 hours obtained
- Tentative survey name:  
CHILES CONtinuum POLarization



**CHILES**  
**CON POL**

# Key science

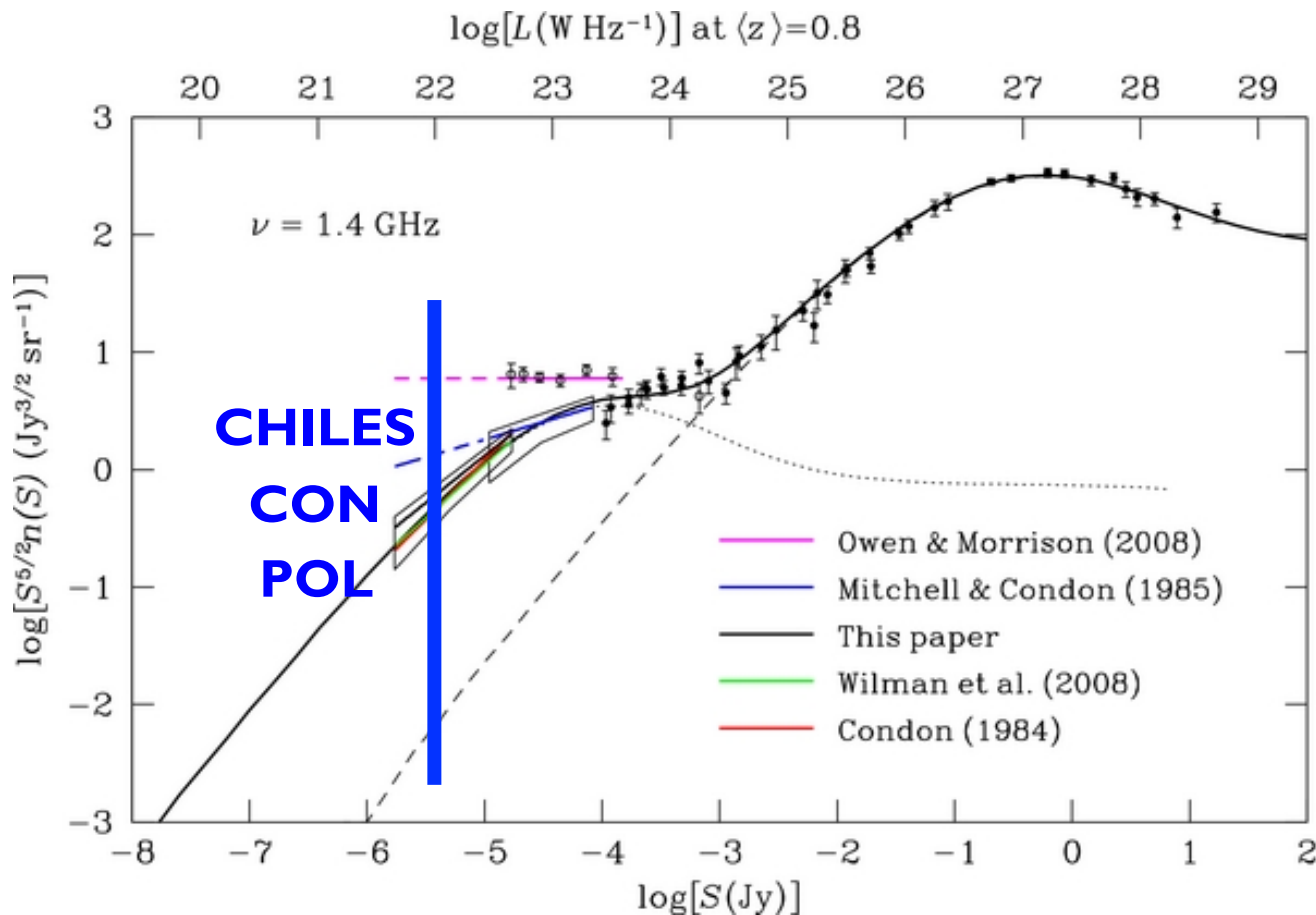
- Public multiwavelength source catalog and images
- Galaxy evolution
- Weak lensing techniques and dark energy
- Origin of cosmic magnetism

# Legacy catalog

- Expect ~4000 sources, of which ~50 will be linearly polarized
- Circular polarization catalog for studies of high latitude pulsars, stellar sources, AGN
- CHILES CON POL is deep enough to probe significant numbers of star forming galaxies and radio-quiet AGN, i.e. bulk of extragalactic sources detected in infrared, optical, and X-ray (SKA-era science!)
- Gold standard cross-matched catalog (extensive multiwavelength data in COSMOS) → will be suitable to inform machine learning algorithms for shallower surveys, e.g. SKA1-survey

# Experiment I: galaxy evolution

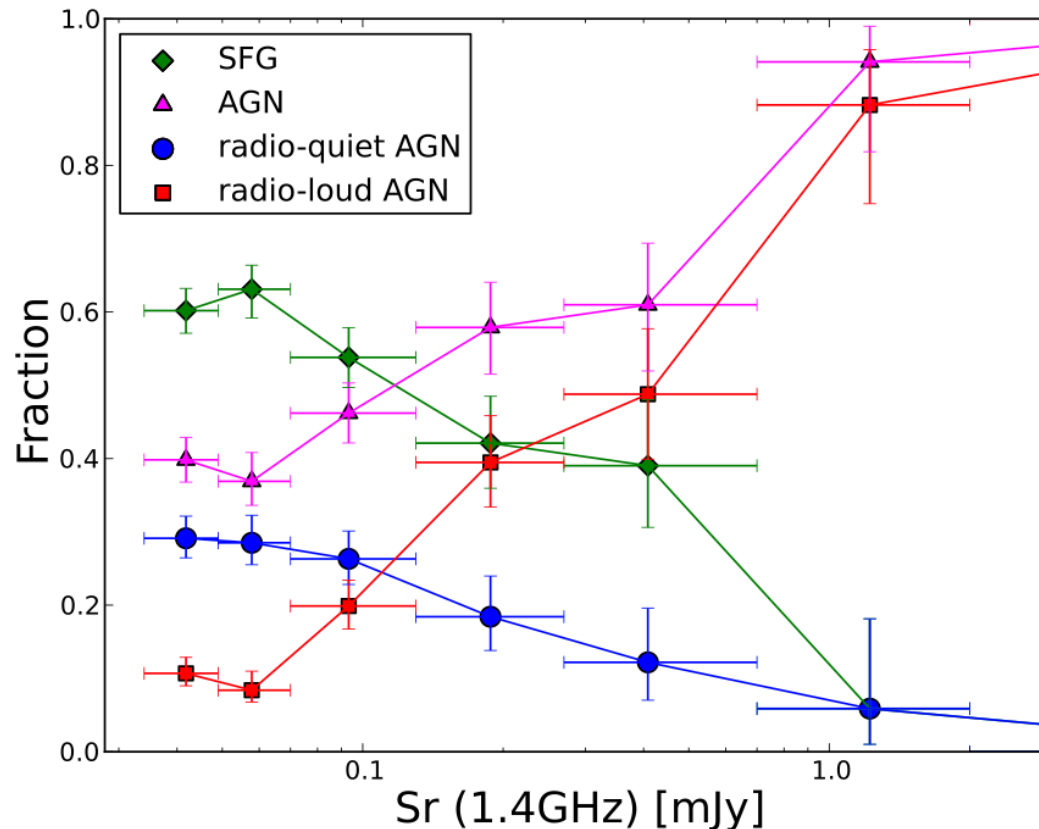
Radio source counts  $\rightarrow$  fundamental constraints on galaxy evolution



Condon+2012



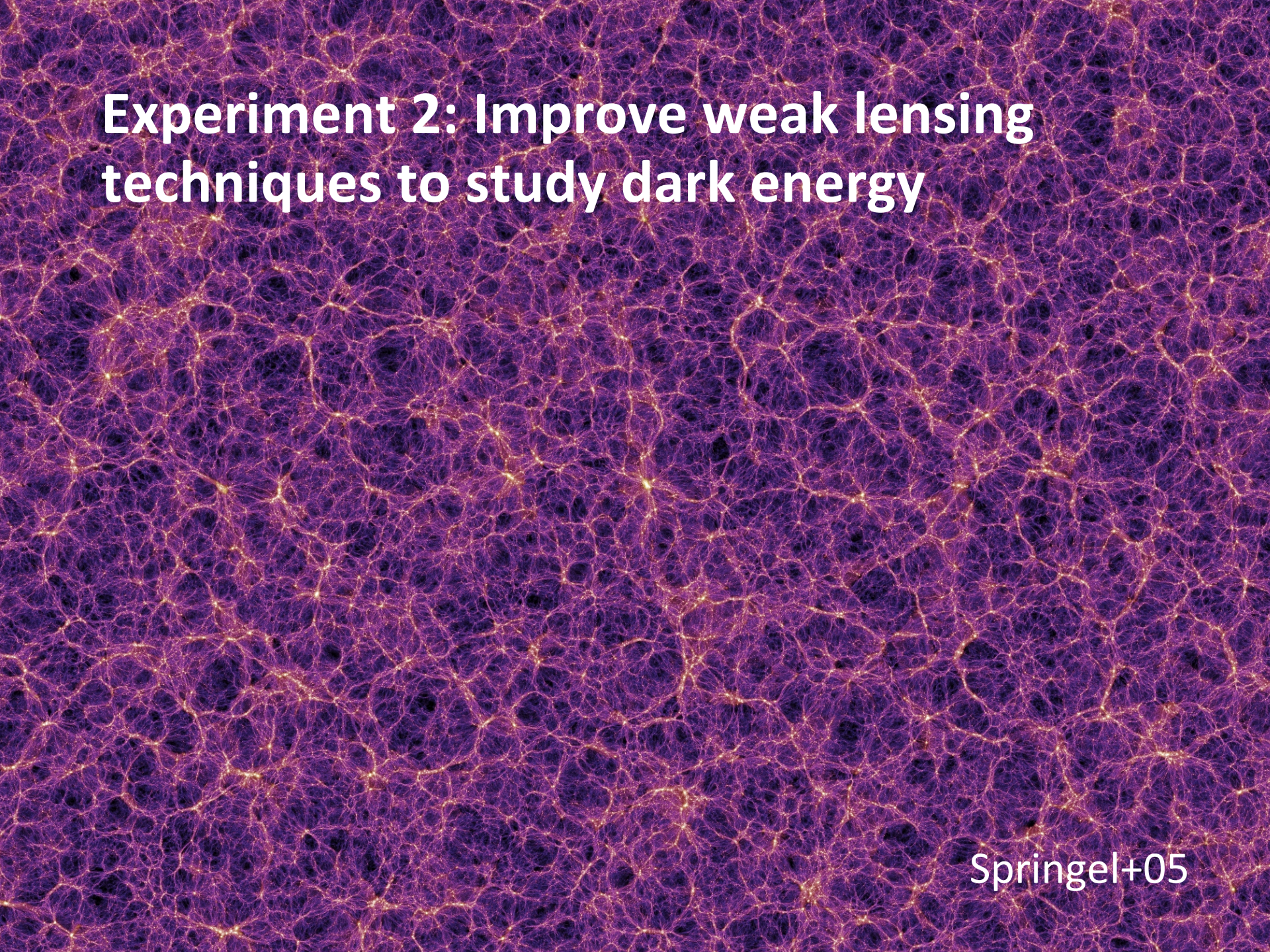
# Luminosity functions: star formation regime



Bonzini+2013

We will extend CDFS work an order of magnitude fainter in flux density to probe the black hole accretion and star formation histories of the Universe



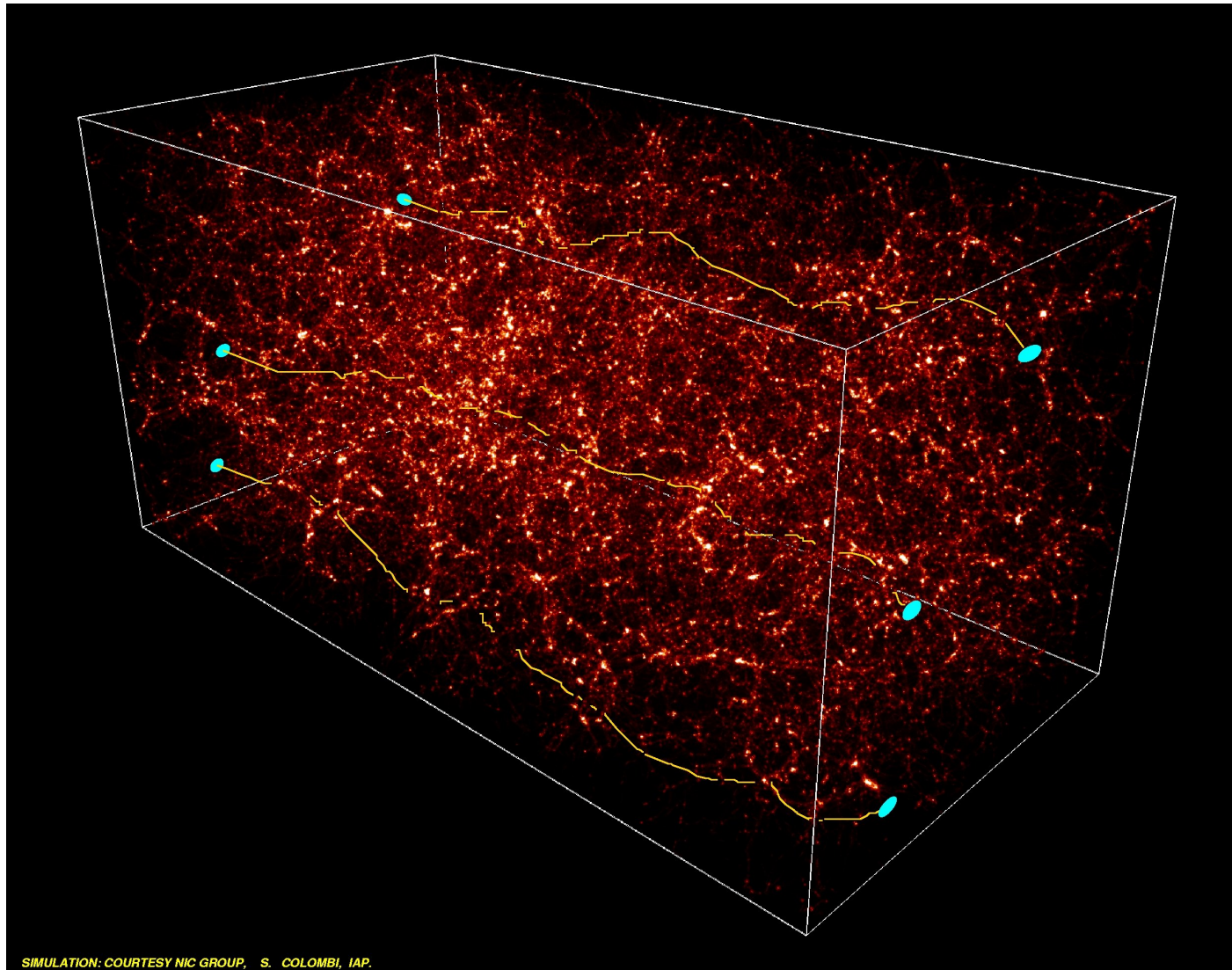
A visualization of the cosmic web, showing a dense network of dark matter filaments and clusters. The filaments are represented by thin, interconnected lines of purple and blue, while the clusters are shown as brighter, more concentrated regions of yellow and orange. The overall structure is a complex, interconnected mesh that fills the entire frame.

# Experiment 2: Improve weak lensing techniques to study dark energy

Springel+05



# Weak gravitational lensing by the cosmic web



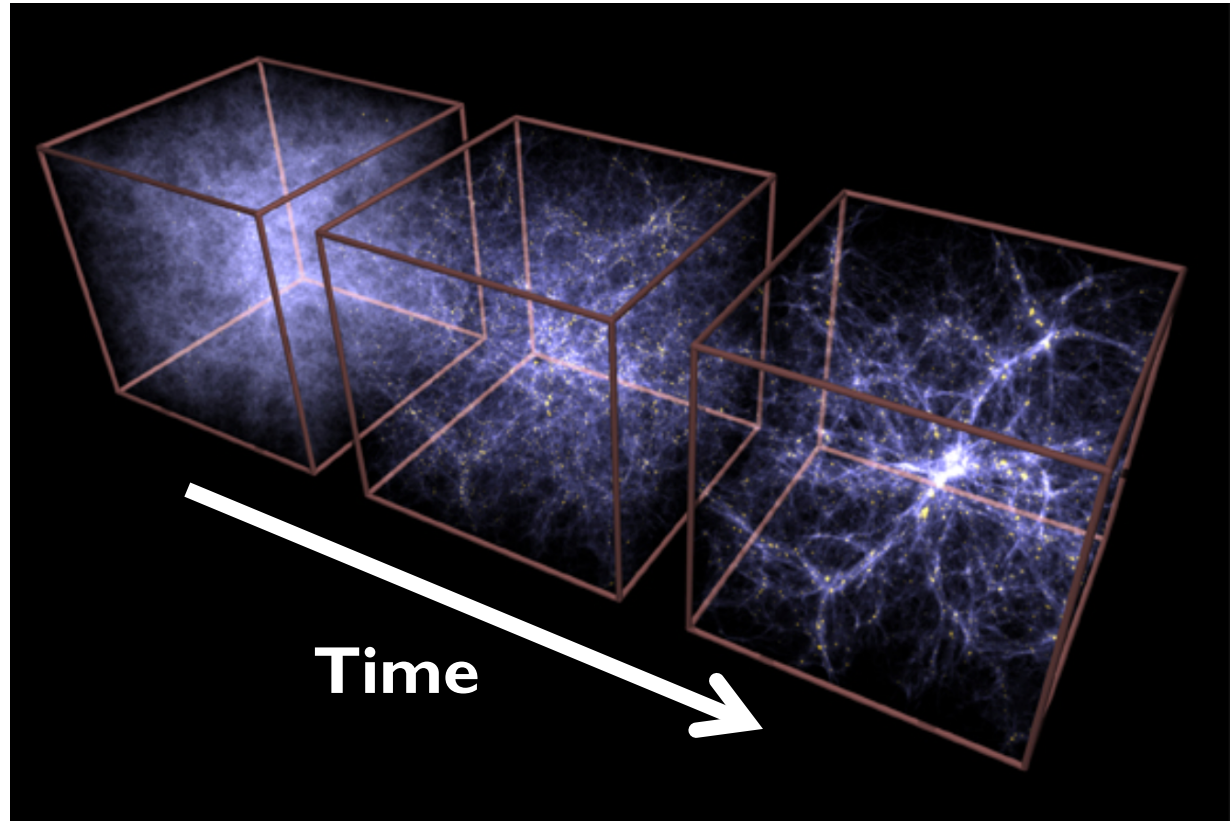
S. Colombi; <http://www.cfht.hawaii.edu/News/Lensing/>

# Dark energy modulates growth of structure

more dark energy



suppression of structure



MPE / V. Springel



# Weak lensing: A key cosmological probe

- *Directly* sensitive to total matter content of Universe (galaxy-matter bias avoided, cf. baryonic acoustic oscillations)
- Optical weak lensing surveys already competitive for  $\Omega_m$  and  $\sigma_8$
- Bin in redshift to directly probe growth of structure (weak lensing tomography)
- Combine with Type Ia supernovae and CMB to better constrain:
  - Equation of state of dark energy ( $w$ ) and possible evolution
  - Sum of neutrino masses ( $\Sigma m_\nu$ )
- Strong community support, e.g. *WFIRST* (NASA), *Euclid* (ESA)

# The catch: Systematic errors

- High source densities needed to reduce shear statistical error
  - Systematic errors beginning to dominate statistical errors:
    - Instrumental (e.g. optical PSF anisotropies)
    - Unknown intrinsic alignment of galaxies
- Radio observations can mitigate both systematics
- needed for precision cosmology

# Solution: combine with radio observations

- Mitigate intrinsic alignment biases by combining optical and radio
- Radio PSF stable and well characterized
- Measure intrinsic (unlensed) galaxy alignments using:
  - Position angle of linear polarization (Brown & Battye 2011)  
→ unaffected by weak lensing
- Radio sources typically higher redshift than optical  
→ provides unique high- $z$  lever arm to probe growth of structure
- Develop and test these techniques using observational data

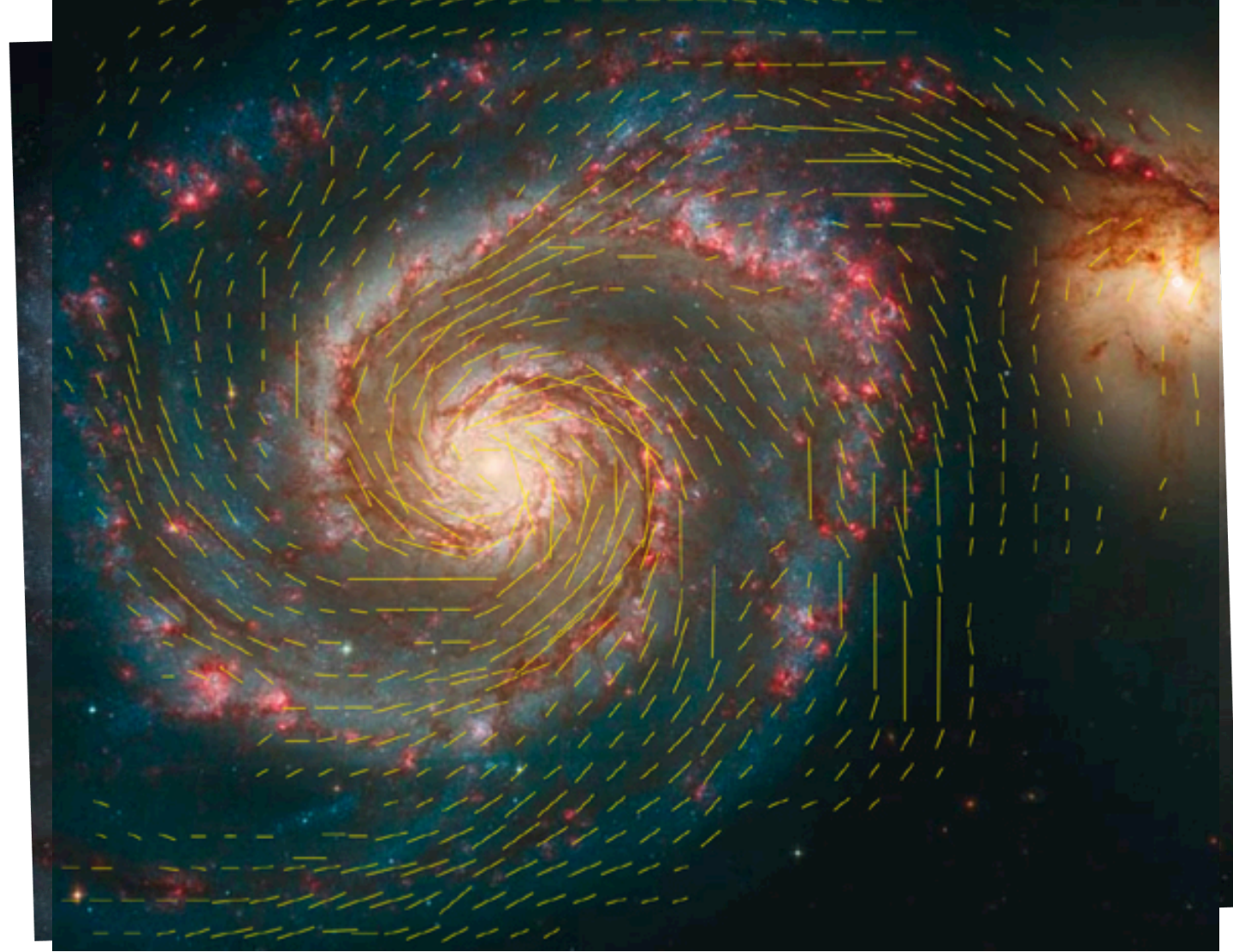
# Experiment 3: Probe origin of cosmic magnetism

The background of the slide is a deep space image filled with numerous small, distant galaxies. Overlaid on this are several bright, glowing orange-yellow elliptical shapes, likely representing active galactic nuclei or star-forming regions. Thin, white, curved lines sweep across the image, representing the paths of cosmic magnetic field lines. These lines are more densely packed around the bright orange regions, suggesting a stronger magnetic field in those areas.

Mihos / Huey / Durrer / Science 06

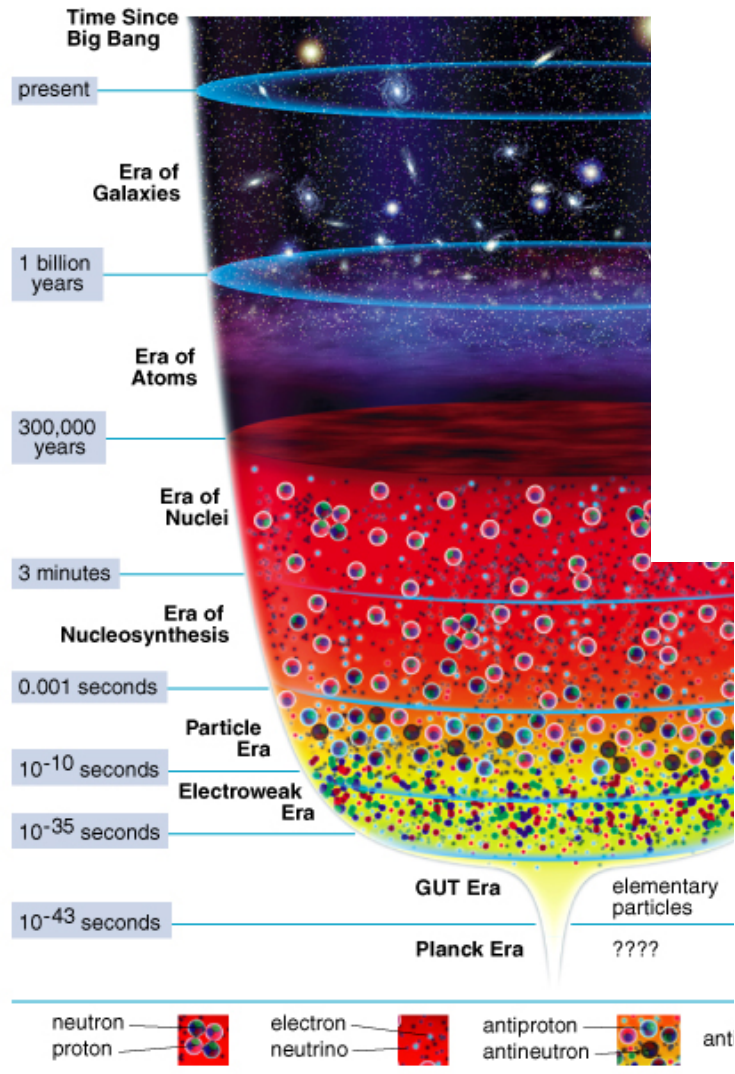


# Magnetic fields in galaxies



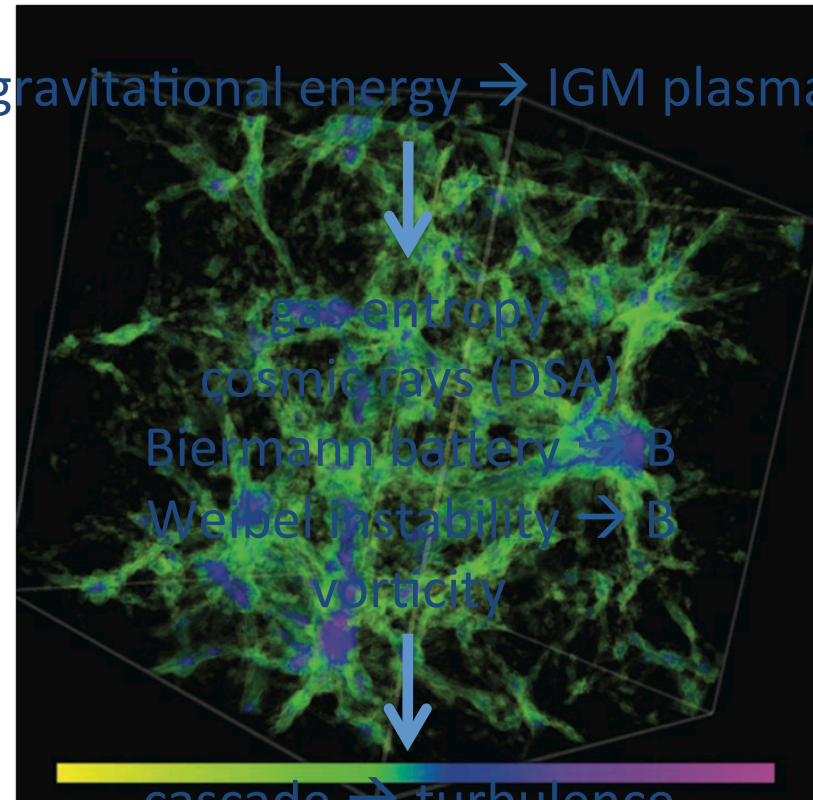
M51: Stenlund & Watzgaurum / Beck et al. / Hubble Heritage

# Magnetogenesis

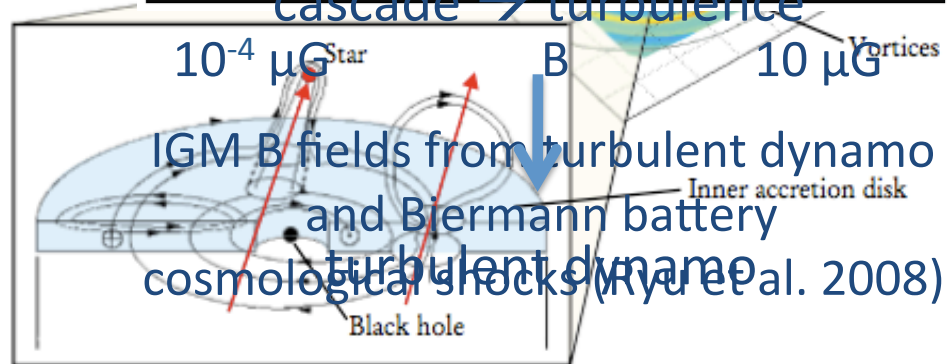


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gravitational energy  $\rightarrow$  IGM plasma



cascade  $\rightarrow$  turbulence



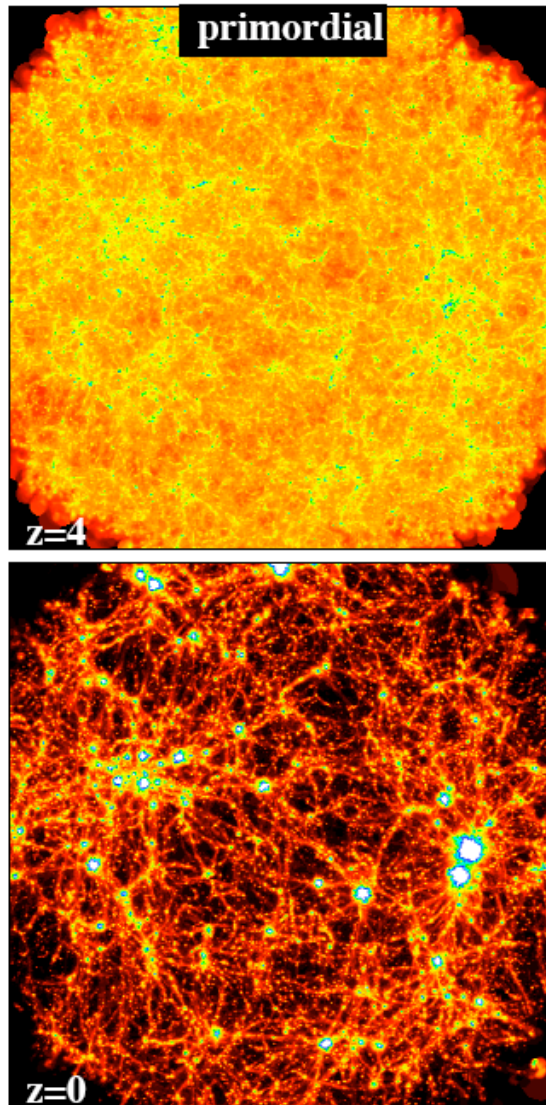
Colgate et al. 2001, Phys. Of Plasmas

# Magnetism matters!

- High- $z$  star formation (Tan & Blackman 2004; Schleicher+2009)
- Thermal and ionization history of post-recombination era (Sethi et al. 2008; Sethi & Subramanian 2009)
- Supression of low-mass haloes through modification of Jeans mass (Subramanian & Barrow 1998; Rodrigues+2010)
- Constraints on the neutrino mass (Yamazaki+2010)
- Generation of gravitational waves (Caprini 2006)
- Phase diagram of electroweak theory (Giovannini & Shaposhnikov 1998)
- Baryon asymmetry of the Universe (Semikoz 2009)
- Dark energy (Contopoulos & Basilakos 2007)
- Important to be able to differentiate between different models of magnetogenesis!



# Different seeding conditions



Donnert et al. 2008

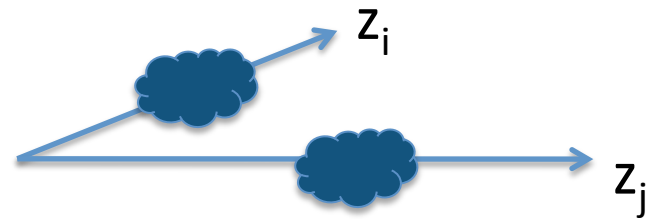


# Measure magnetic power spectrum in intergalactic filaments of cosmic web

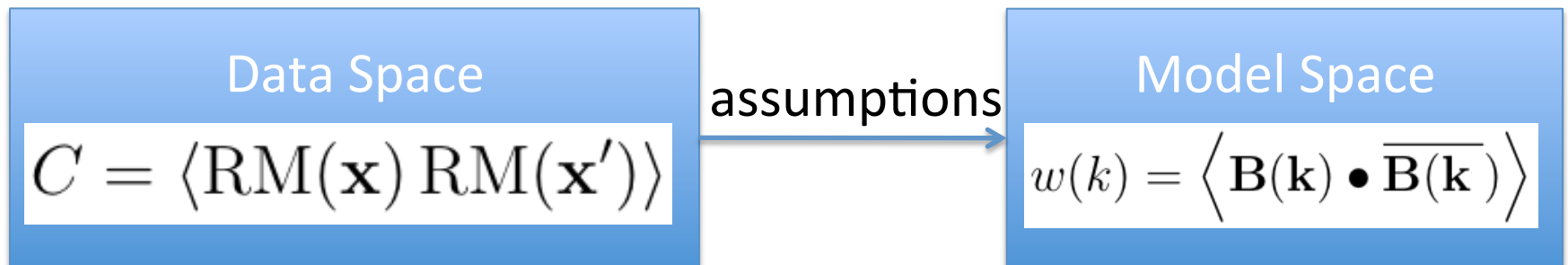
- Each proposed origin predicts power spectrum (strength vs. coherence length scale)
- Make first measurement to support/constrain/refute models
- Method: measure 2-pt correlation of RM's (Kolatt 1998; Kuchar & Enßlin 2011; Hales+prep)

$$\Theta = \Theta_0 + \text{RM} \lambda^2$$

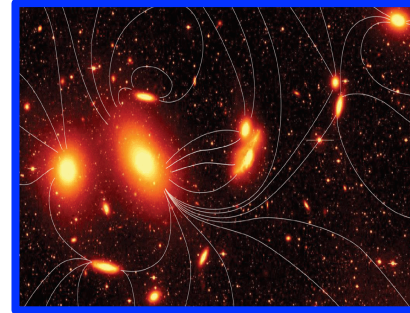
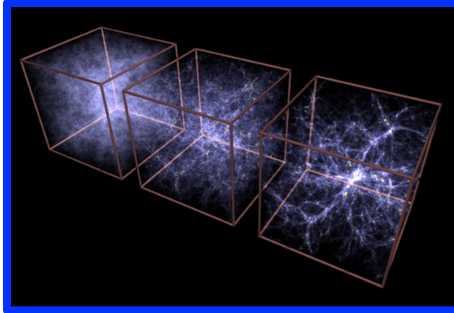
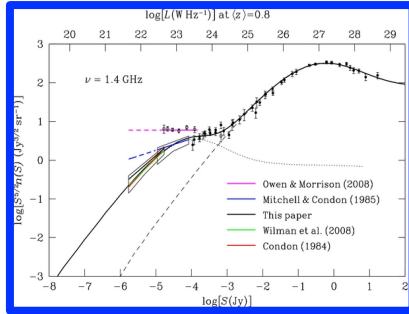
$$\text{RM} = K \int n_e \vec{B} \cdot d\vec{l}$$



Bayesian Inference:



# Summary



- CHILES CON POL will probe galaxy evolution, weak lensing techniques, and the origin of cosmic magnetism
- Multiwavelength catalog will have legacy value into the SKA era
- Start thinking about science you can do with CHILES CON POL!  
Talk to me about advance access to the catalog (from mid 2014)