Durham Lightcones:

Synthetic galaxy survey catalogues from GALFORM

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ICC

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European Research Council

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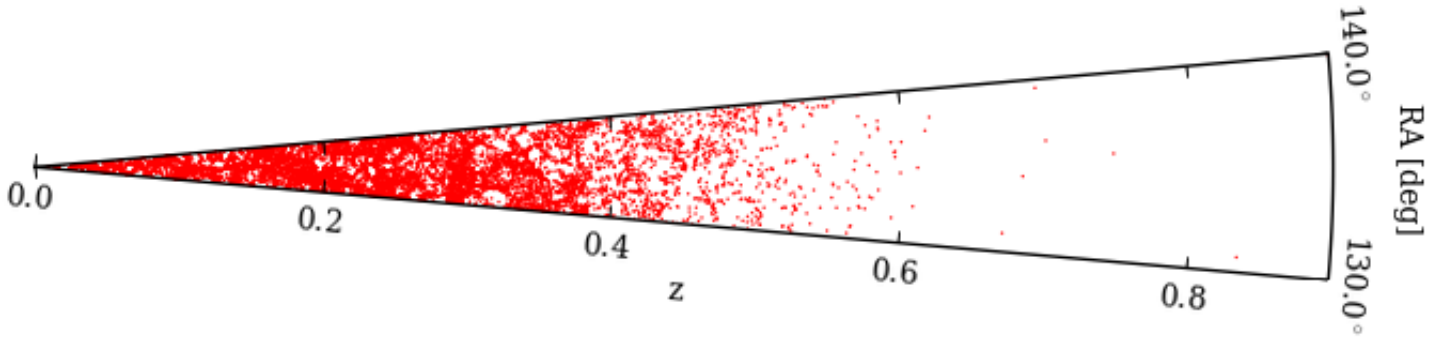
Outline

1. How are the lightcone mocks constructed?
2. What mocks are available currently?
3. Ongoing and near-future developments.



Wedge of a GAMA-09h lightcone in redshift and RA, 0.2 deg wide in declination, of the predicted distribution of all galaxies with r band magnitude selection (>20.2).

Why are lightcone mocks useful?

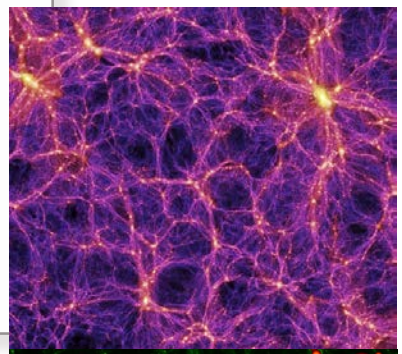
Prediction

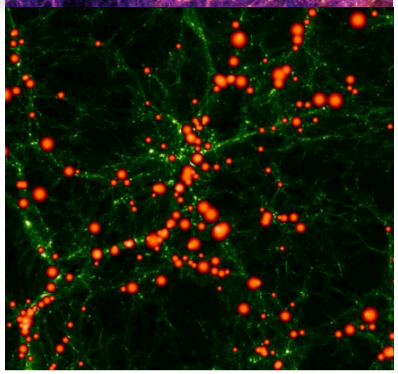
- Lightcone mocks can be made for different:
  - dark energy cosmologies
  - galaxy formation models
  - scales/wavebands already/not yet probed by observations

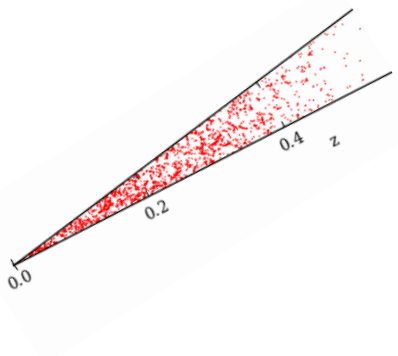
Calibration

- Test existing estimators: e.g. group-finders
- Define new estimators/statistics
- Uncover systematic effects
- Estimate errors

1 Building lightcones







- Dark Matter N-body simulation
  - Cosmological model
- Populate simulation with galaxies
  - Galaxy Formation models
- Apply survey specific limits

Building lightcones: Millenium Simulations

Dark Matter N-body simulations available:

Millennium Simulation	Cosmology	Box Length (Mpc/h)	Equivalent maximum z	Min Halo Mass (M_0/h)	Useful for studies like …
I	WMAP1	500	0.17	1.7×10^{10}	e.g. groups, ..
WMAP7	WMAP7	500	0.17	1.9×10^{10}	e.g. groups, ..
MXXL	WMAP1	3000	0.72	1.4×10^{11}	e.g. clustering
II	WMAP1	100	0.03	1.1×10^{8}	Converg. Testing
WMAP7 for 977 snapshots	WMAP7	125	0.04	1.9×10^{10}	Converg. Testing
Milli	WMAP1	62.5	0.02	1.7×10^{10}	Code testing
GPICC	Sanchez et al (2009)	1000	0.3	1.4×10^{11}	Testing

WMAP1 : $\Omega_m = 0.250$, $\Omega_\Lambda = 0.750$, $\Omega_b = 0.0450$, $h = 0.730$, $\sigma_8 = 0.90$

WMAP7 : $\Omega_m = 0.272$, $\Omega_\Lambda = 0.728$, $\Omega_b = 0.0455$, $h = 0.704$, $\sigma_8 = 0.81$

Sanchez et al (2009) : $\Omega_m = 0.261$, $\Omega_\Lambda = 0.739$, $\Omega_b = 0.0440$, $h = 0.716$, $\sigma_8 = 0.80$

Building lightcones: GALFORM

Define hierarchical galaxy formation model using:

- Gas cooling & disk formation
- SF & feedback
- Galaxy mergers
- Chemical evolution & enrichment
- Dust extinction

Compare with observations for

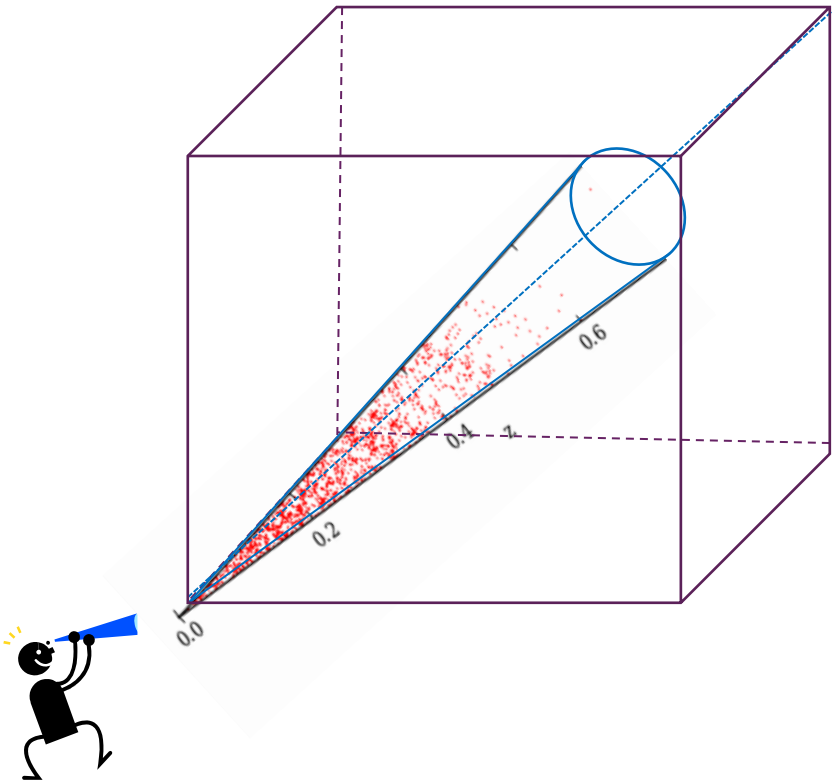
- LF
- HI MF
- gas metallicity
- disk radii
- morphological fraction
- …

Building lightcones: GALFORM

Model	Cosmol-ogy	Updates	Tuned to?	Subsequently provides good match to
Cole+, 2000	WMAP 1	Original	• Local B- and K-band luminosity functions • metalicities & disk radii • morphological fraction	• Mass to light ratio • Average colours
Baugh+, 2005	WMAP 1	dust	• As for Cole et al. 2000 • + LBG luminosity function	• Galaxy number counts at 850 μm
Bower+, 2006	WMAP 1	AGN feedback	• As for Cole et al. 2000 • + local black hole–bulge mass relation	• Evolution of K band luminosity & stellar mass function
Font+, 2008	WMAP 1	ram-pressure stripping	• As for Bower 06	• colours of satellite galaxies + environmental dependence
Lagos+, 2012	WMAP 1	new sf law(s)	• As for Bower 06	• HI mass function • 12CO(1–0) lum function
Gonzalez+, 2013	WMAP 7	Lagos for WMAP 7	• As for Lagos 12	…
Lacey+, 2013	WMAP 7	Match sub-mm	• As for Lagos 12 + sub mm counts	…

Building lightcones: Survey Specific limits

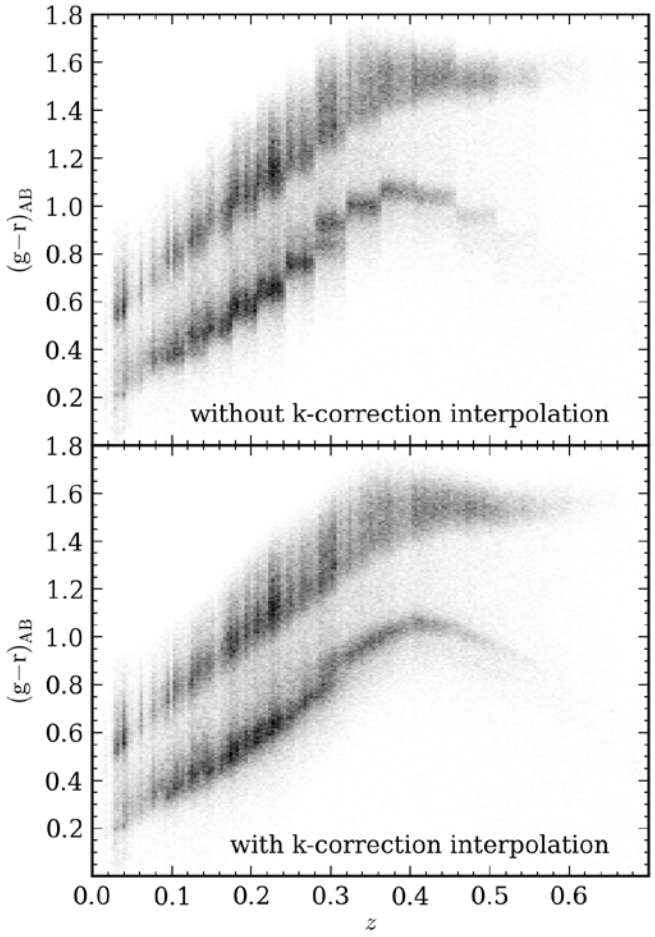
Merson et al (2012)

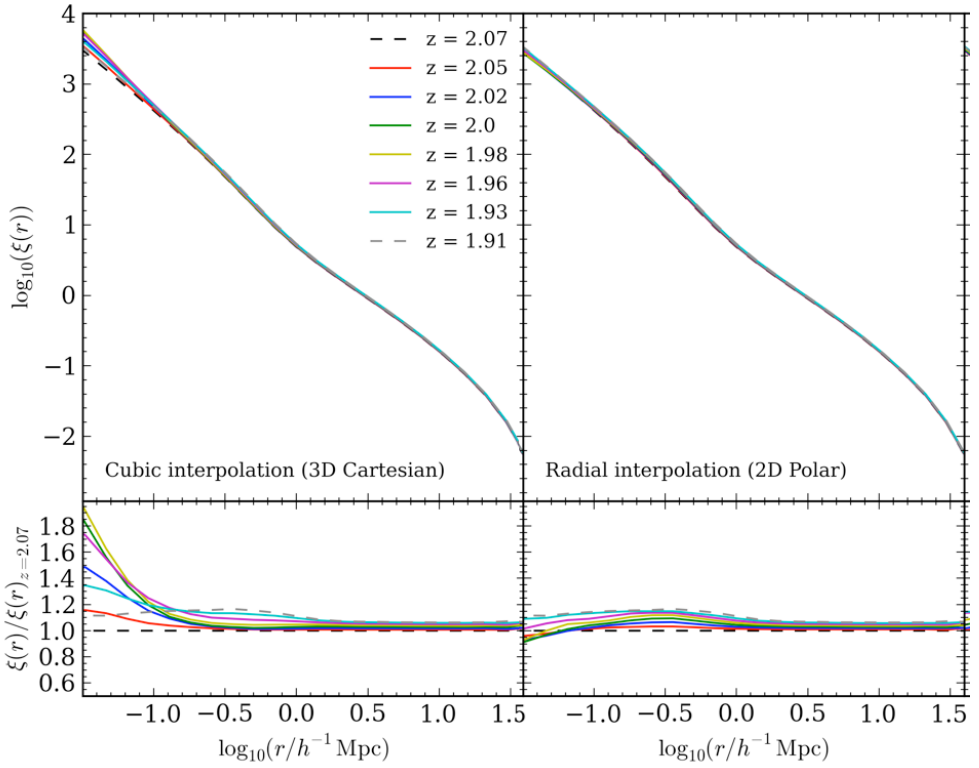


- Given cube of galaxies
- Tile to get required volume
- Position observer
- Apply solid angle mask
- Calculate halo redshift that enters the observers lightcone
- Interpolate positions of galaxies
- Interpolate magnitudes
- All other properties take values from previous snapshot
- Apply survey specific flux limits

Building lightcones: Survey Specific limits

Merson et al (2012)





2 Availability of lightcones

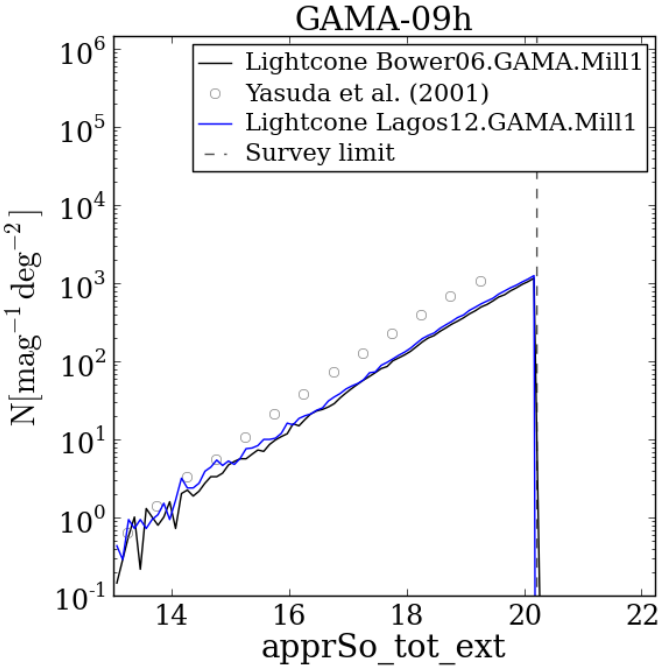
Lightcones have already been produced for surveys including:

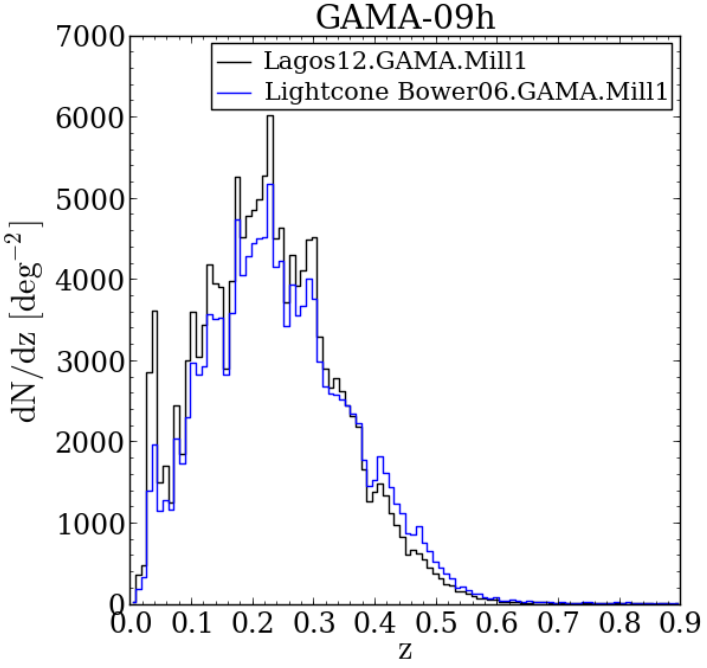
- GAMA
- PanSTARRS
- Taipan
- SDSS
- Euclid
- …..

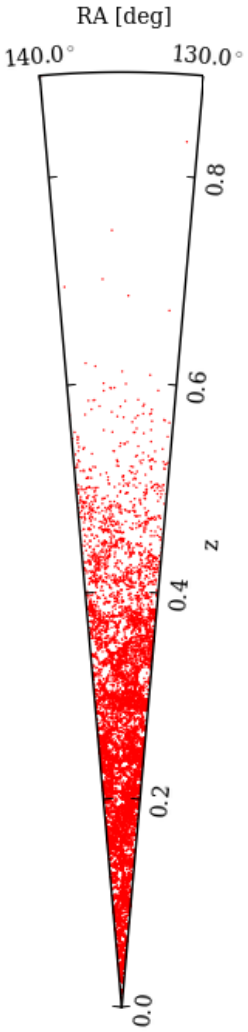
Lightcone deliverable

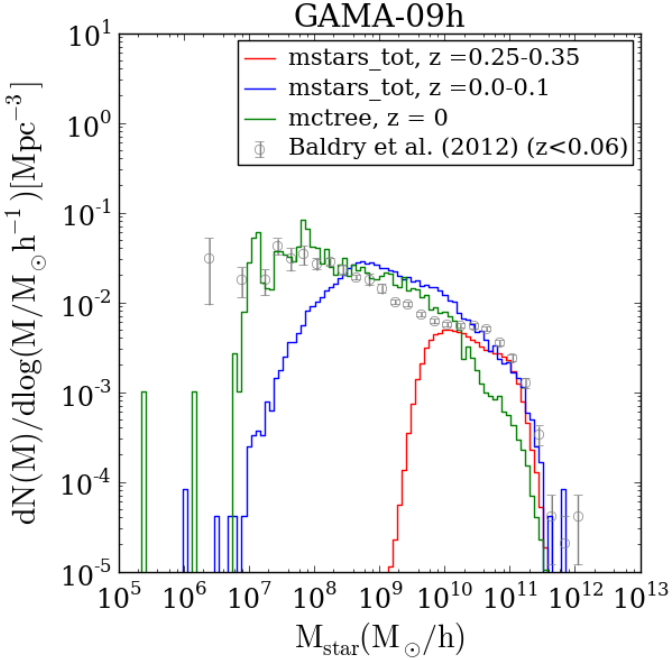
- Lightcone
  - 512 hdf5 files
  - contains galaxy & halo
    - positions
    - velocities
    - masses
    - apparent magnitudes
    - redshifts
    - etc ….
- Accompanying pdf readme file
  - Description of how lightcone was made for different:
    - cosmologies
    - galaxy formation models
    - survey limits etc
  - Validation plots
    - Number counts, luminosity functions, HOD and mass functions
    - Plots compared with observational results.

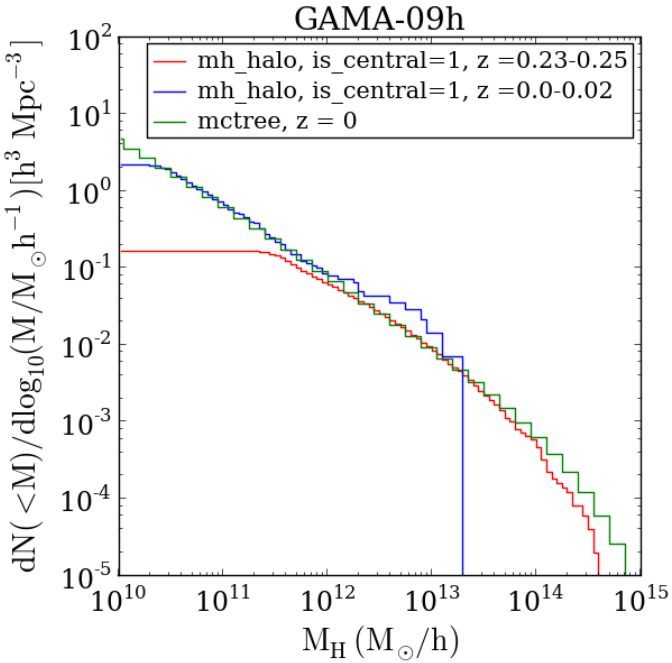
Lightcone deliverable





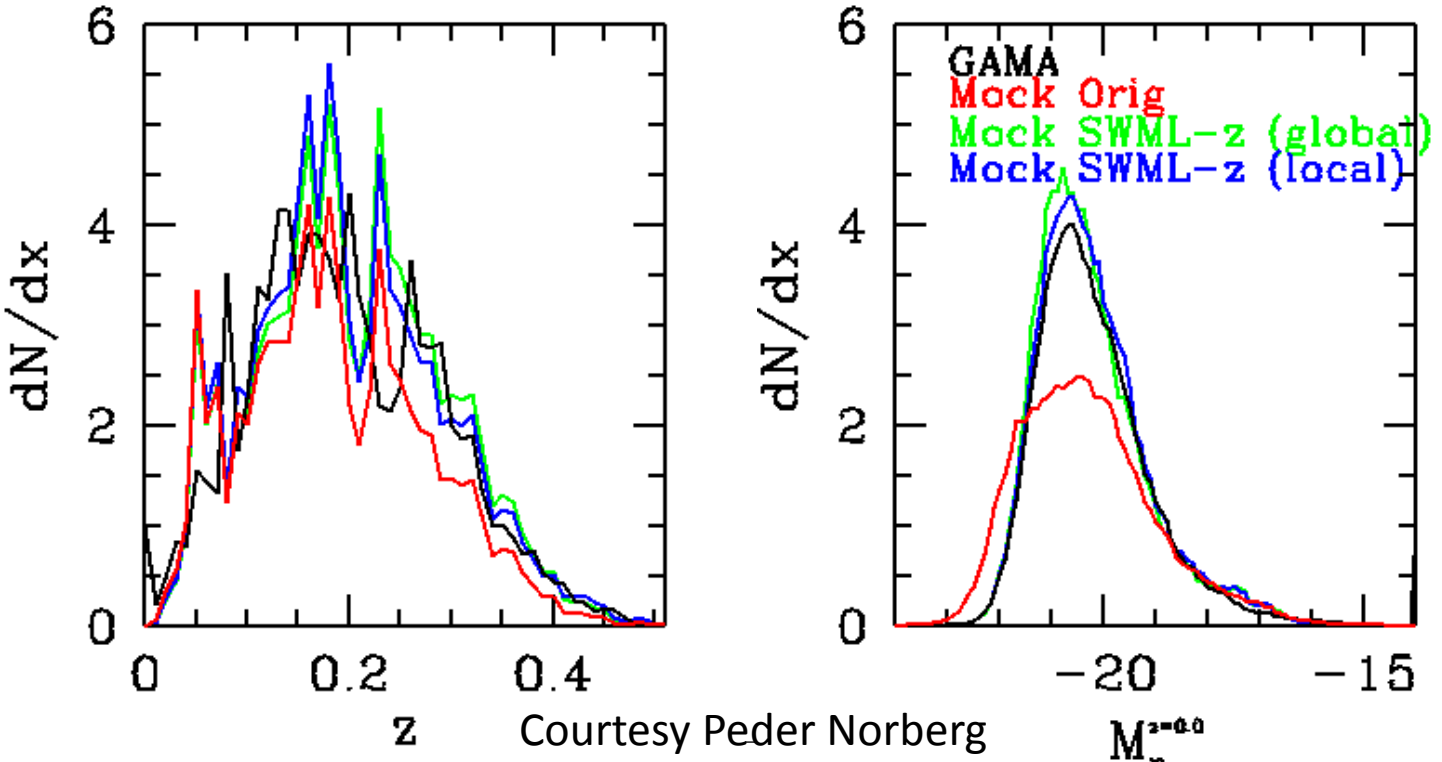






What lightcones are available currently?

- However these lightcones are ‘un-processed’.
- If you are not using them to test the GALFORM models but to say train statistic you may want to ‘tune’ the lightcone to your observations e.g.



Courtesy Peder Norberg

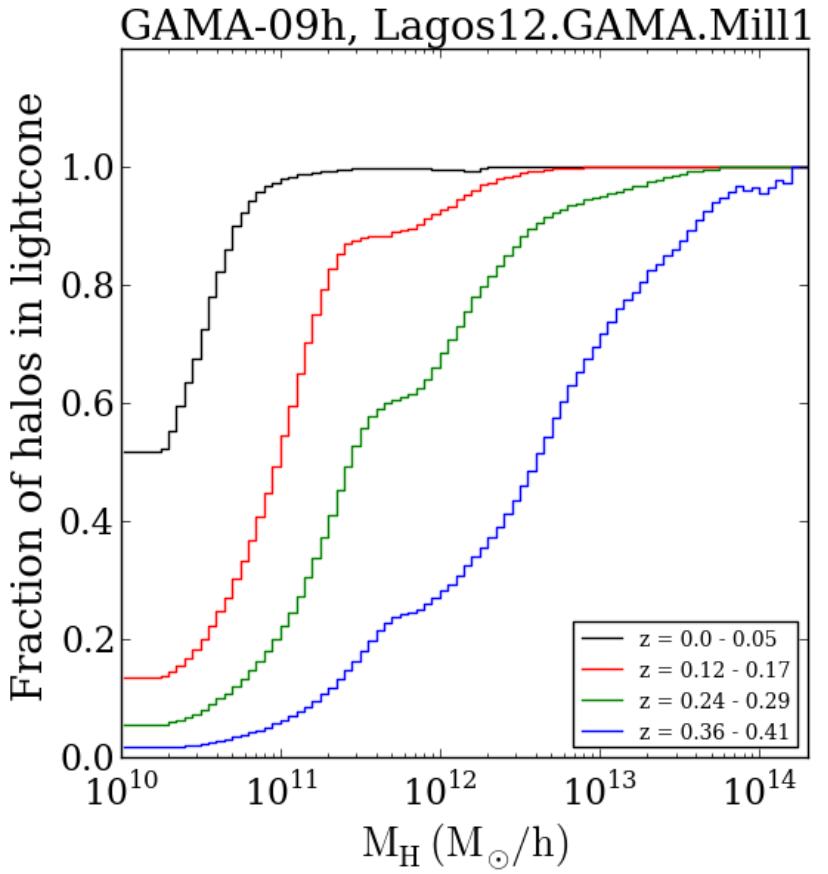
3 Lightcone developments

- Including more useful observational quantities:
  - M_{200}/M_{500} values rather than the dhalo mass
- These are currently ‘perfect’ mocks. Plans for post processing of the lightcones include:
  - Photometric redshifts
    - previously included using HyperZ code with Bruzual & Charlot (1993) templates
  - Pertrosian magnitudes + noise
    - currently using just point source magnitudes

Lightcone developments

- Generating ‘database’ of lightcones from different models
  - Not just for testing GALFORM but testing sensitivity of the mock.
- Halo Lightcones
  - same lightcone methodology
  - no survey specific restrictions
  - complementary information

    e.g. to understand completeness of halos in the lightcone.



Lightcone developments

- Spectra
  - the selection of galaxies by emission lines within a specified wavelength range
- Image pipeline
  - Example produced by Daniel Farrow for PanSTARRS
- Lensing
  - plan to incorporate into lightcone


Daniel Farrow & Alex Merson

Lightcone developments

- Making file easier to deliver
  - new database distribution format
  - file type converter for hdf5 to fits
  - also can do ascii (but small areas to test)
  - Splitting up hdf5 by projected area
  - reducing file sizes by having core file plus additional files for survey specific magnitudes
- More emphasis on reducibility
  - Combining GALFORM runs if extra bands required.

Summary

- Lightcone synthetic ”mock” catalogues
  - Constructed from Millennium N-body simulations + GALFORM models
- Recent/ongoing developments:
  - Adding M200/M500 masses
  - Halo lightcones
  - Selection by emission lines
- Future developments
  - Image processing
  - Photo-zs and magnitude errors
  - Gravitational lensing