Evidence for baryon acoustic oscillations from galaxy–ellipticity correlations

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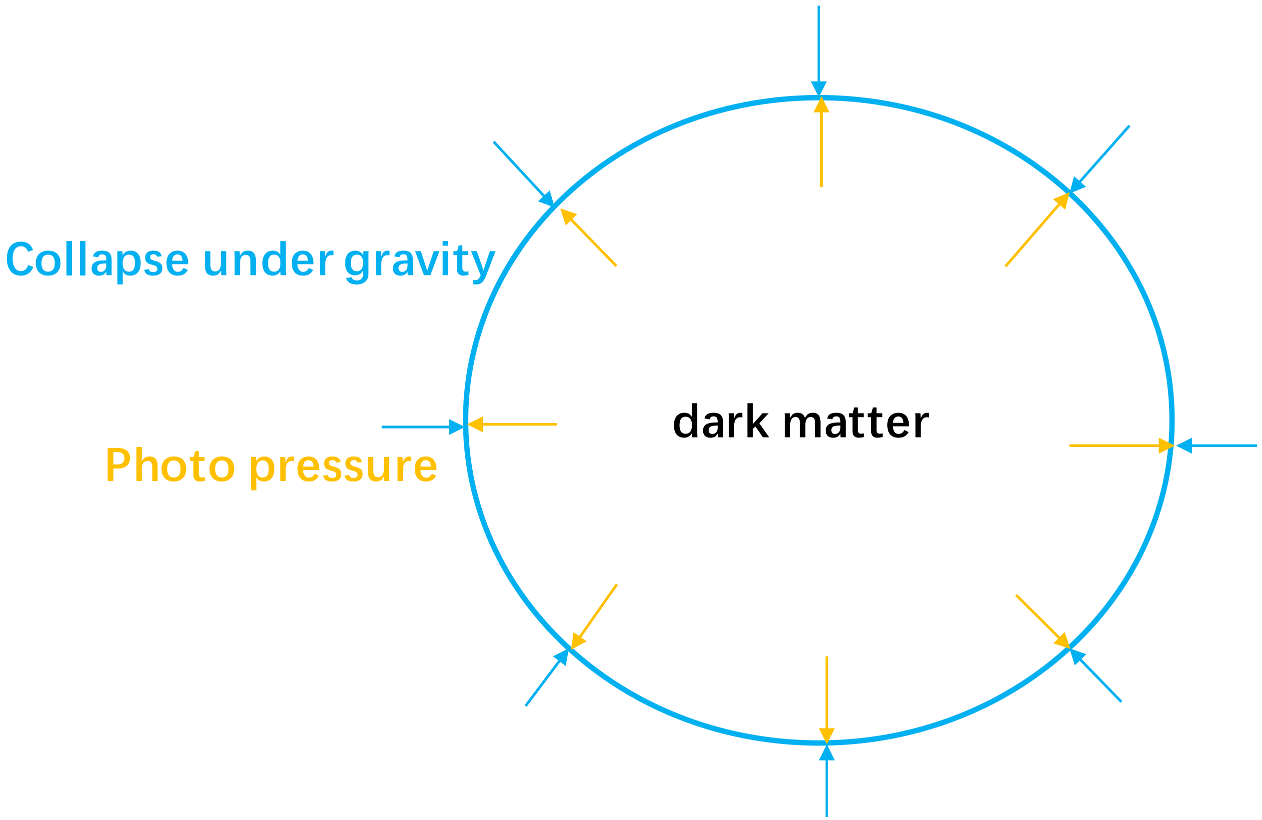
Baryon acoustic oscillations (BAO)

Distance Measurement → Expansion of universe

Standard Ruler: Supernova, BAO,

Early universe (hot): dense plasma of electrons and baryons

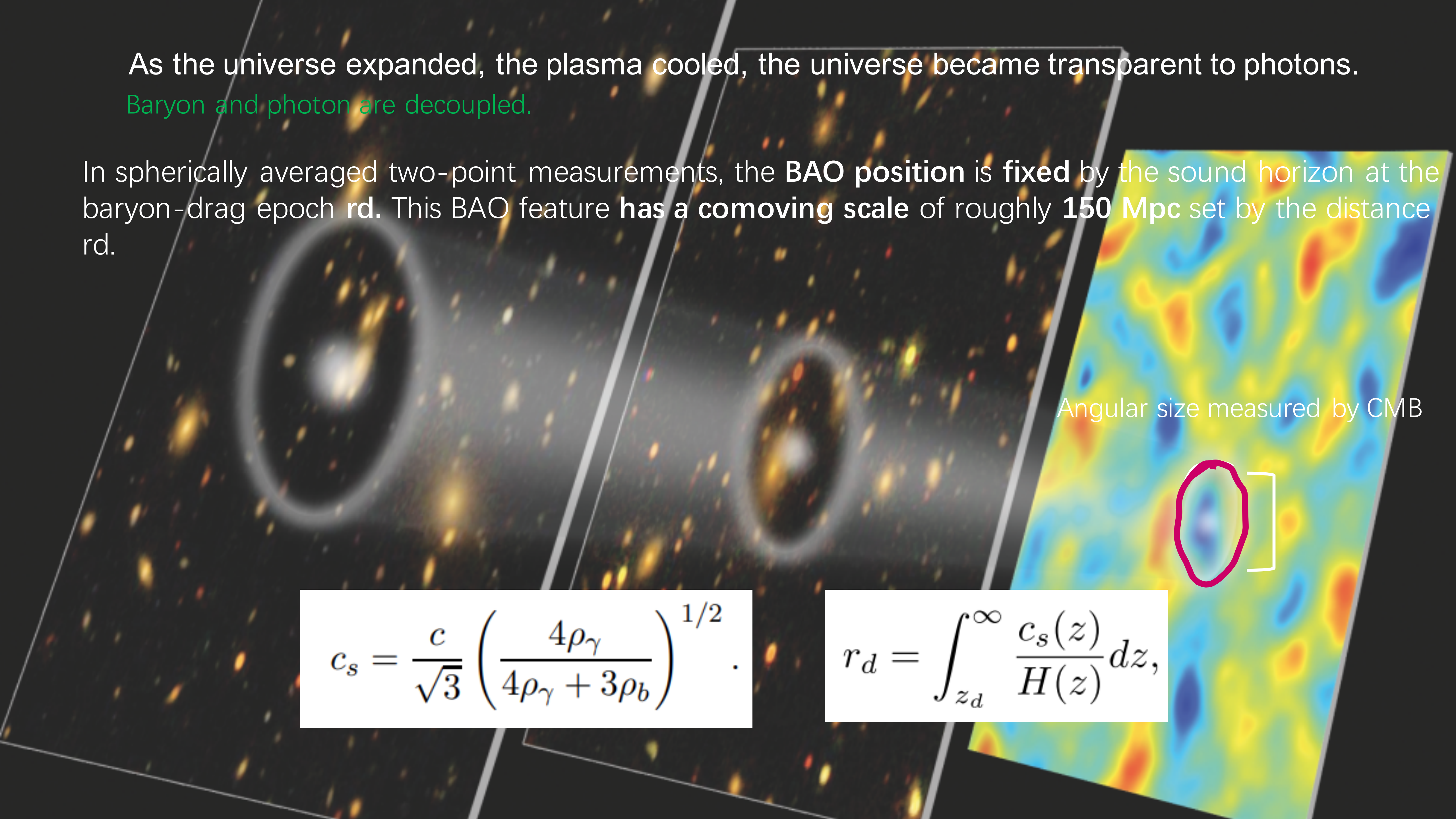


Baryon and photon are coupled due to Thomson scattering.

As the universe expanded, the plasma cooled, the universe became transparent to photons.

Baryon and photon are decoupled.

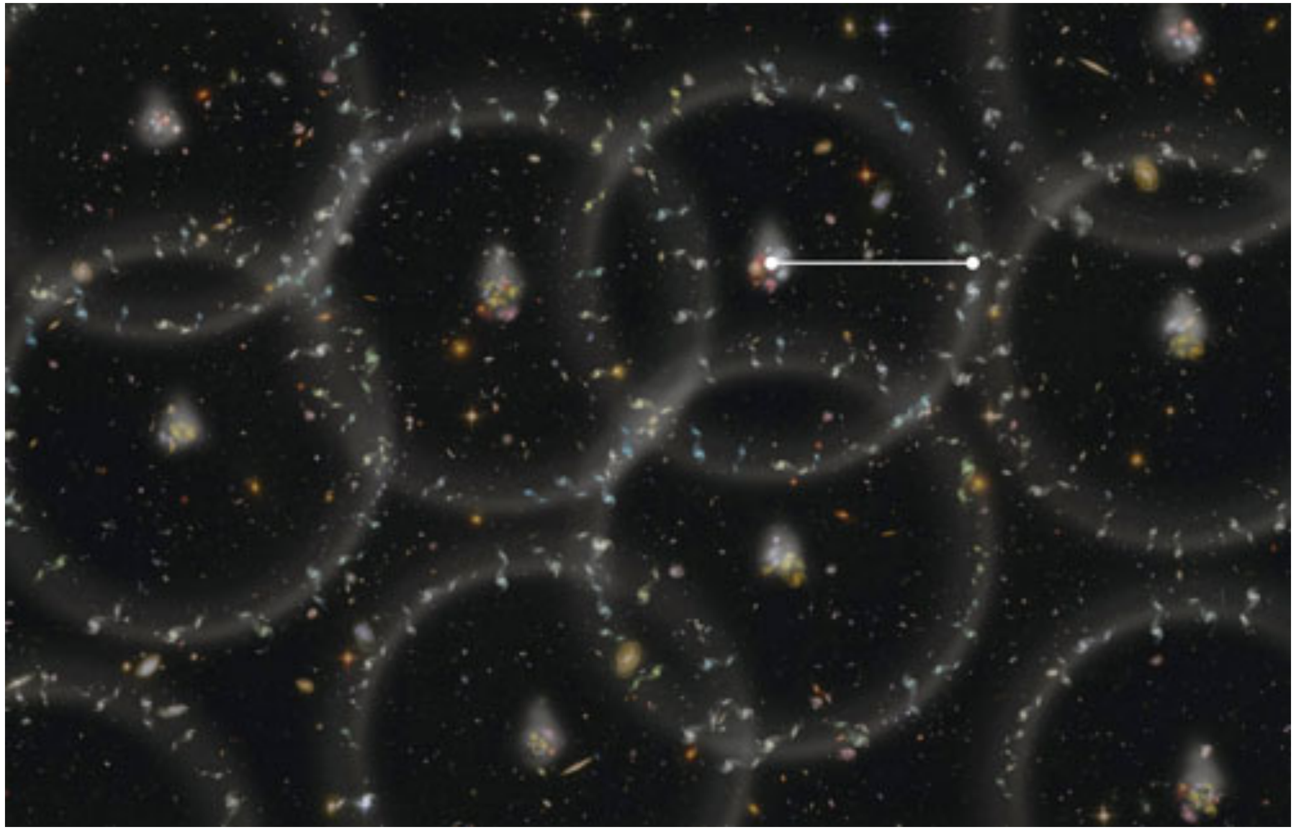
In spherically averaged two-point measurements, the **BAO position** is **fixed** by the sound horizon at the baryon-drag epoch **rd.** This BAO feature **has a comoving scale** of roughly **150 Mpc** set by the distance rd.

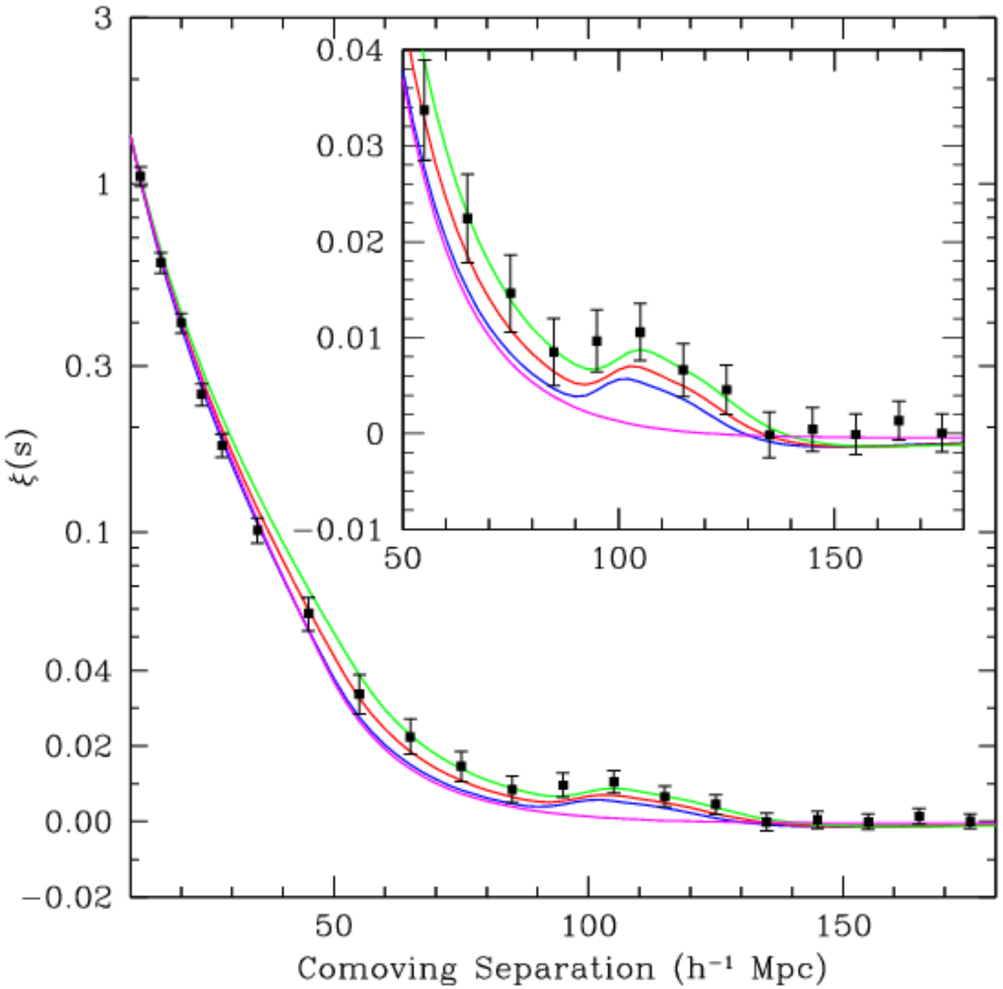


$$c_s = \frac{c}{\sqrt{3}} \left(\frac{4\rho_\gamma}{4\rho_\gamma + 3\rho_b} \right)^{1/2} .$$

$$r_d = \int_{z_d}^{\infty} \frac{c_s(z)}{H(z)} dz,$$

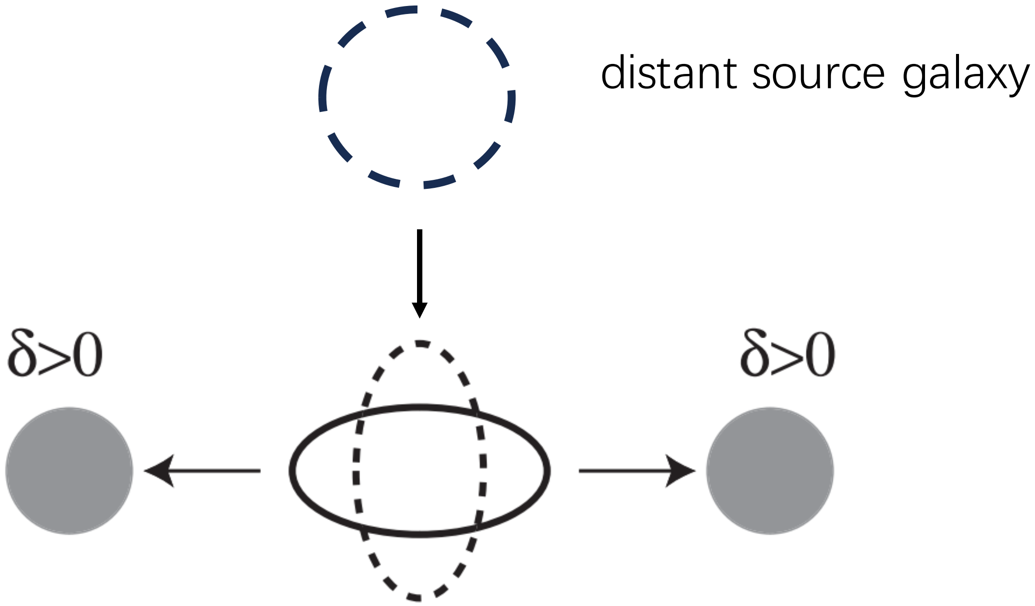
“Galaxy-Galaxy”





$$D_V(z) \equiv \left[cz(1+z)^2 D_A(z)^2 H^{-1}(z) \right]^{1/3},$$

The intrinsic alignment (IA) of galaxies: a contaminant in weak-lensing analysis



Measured shape in obs:

$$\varepsilon \simeq \varepsilon^{s} + \gamma,$$

FIG. 1: The effect of the density-intrinsic shear correlation on the shear power spectrum. Density fluctuations in the nearby plane (gray masses) induce a tidal field (arrows). A source galaxy in a more distant plane (dashed ellipse) is gravitationally sheared tangentially to these masses. If the intrinsic shears of galaxies in the nearby plane (solid ellipse) are aligned with the stretching axis of the tidal field, then this results in an anti-correlation between the shears of galaxies at different redshifts, i.e. $C_\ell^{EE,GI} < 0$. (The opposite case, $C_\ell^{EE,GI} > 0$, results if galaxies are preferentially aligned with the compressing axis of the tidal field.)

In this work, IA is actually a promising cosmological probe and contains valuable information.

“Intrinsic alignment-lensing interference as a contaminant of cosmic shear”

Data

use the CMASSLOWZTOT Large-Scale Structure catalogue in BOSS DR12 and adopt a redshift cut of $0.43 < z < 0.70$ to select the CMASS sample with an effective redshift $z_{\rm eff} = 0.57$.

extraction on pixel-level data. We use shape_e1 and shape_e2 in the Legacy Surveys DR9 catalogues (https://www.legacysurvey.org/dr9/catalogs/#ellipticities) as the shape measurements for each CMASS galaxy. These two quantities are then converted to the ellipticity defined

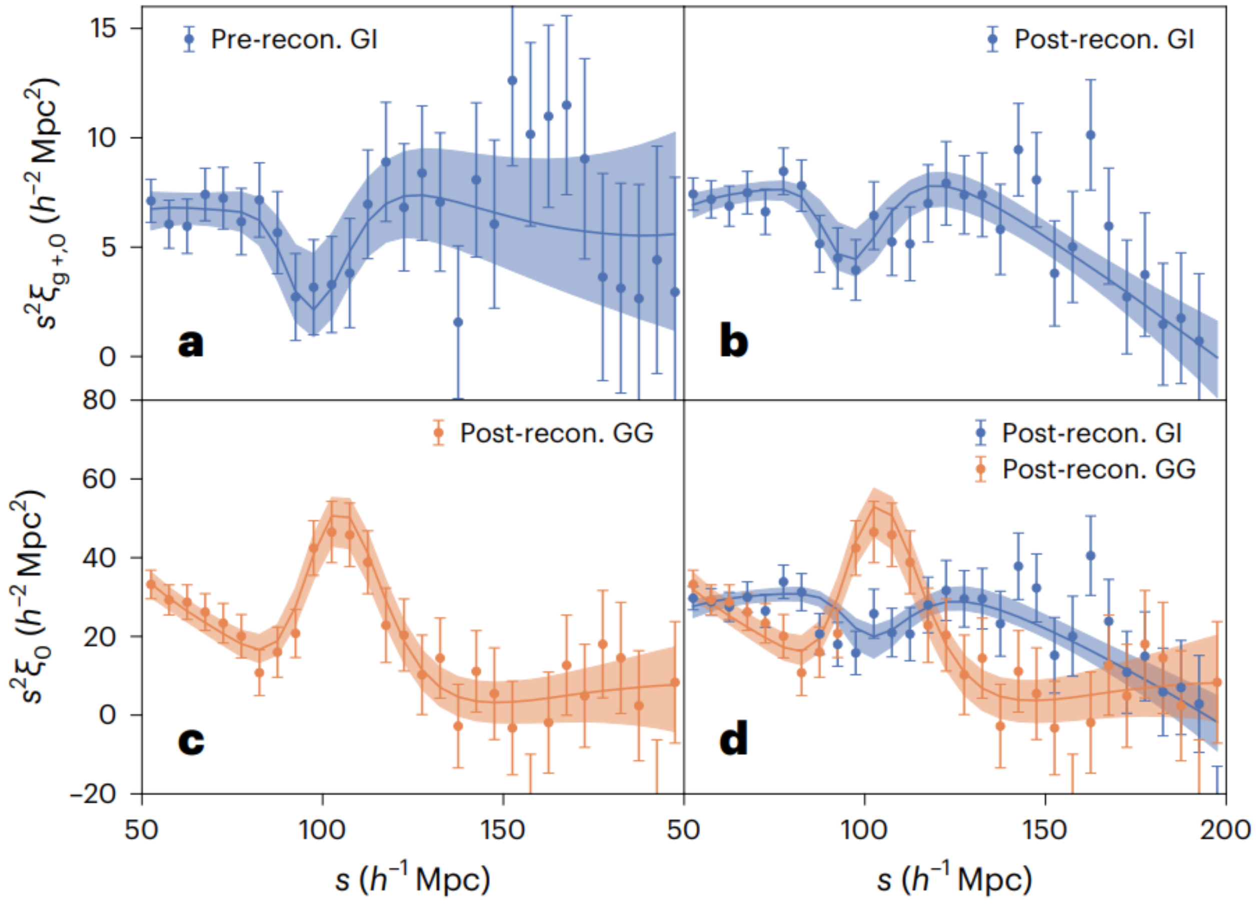


Fig. 1 | Measurements and modelling of GI and GG correlation functions. **a**, Pre-reconstruction GI correlations. **b**, Post-reconstruction GI correlations. **c**, Post-reconstruction GG correlations. **d**, Post-reconstruction combined modelling (GI multiplied by 4 for better illustration). Points and error bars show the mean and s.e.m. of clustering measurements. Errors are from the diagonal elements of the jackknife covariance matrices estimated using 400 subsamples. Lines and shading are the best-fit models and 68% confidence-level regions derived from the marginalized posterior distributions.

notice, Reconstruct: undo the BAO smoothing caused by non-linear

notice:zdrag= 1059.57±0.46 光子脱离重子拖曳

$$\alpha \equiv \frac{D_V(z) r_{d,\mathrm{fid}}}{D_{V,\mathrm{fid}}(z) r_d},$$

Model:

$$P_{\mathrm{damp}}(k) = P_{\mathrm{nw}}(k)\left[1 + \left(\frac{P_{\mathrm{lin}}(k)}{P_{\mathrm{nw}}(k)} - 1\right) \mathrm{e}^{-(1/2)k^2\Sigma_{\mathrm{nl}}^2}\right],$$

$$\xi_{g+,0}(s) = B\int_0^\infty \frac{k^2\,\mathrm{d}k}{2\pi^2} P_{\mathrm{lin}}(k) j_2(\alpha k s),$$

$$\xi_{g+,0}^{\mathrm{mod}}(s) = \xi_{g+,0}(s) + \frac{a_1}{s^2} + \frac{a_2}{s} + a_3.$$

Likelihood:

$$\chi^2 = \frac{N_{\mathrm{JK}} - N_{\mathrm{bin}} - 2}{N_{\mathrm{JK}} - 1} \sum_{i,j} [\xi_i^{\mathrm{mod}} - \xi_i^{\mathrm{obs}}]\, C_{ij}^{-1}\, [\xi_j^{\mathrm{mod}} - \xi_j^{\mathrm{obs}}],$$

in $50 < s < 200\ h^{-1}$ Mpc

Results

The constraint on α, which represents the deviation from the fiducial cosmology (Methods), is $1.050^{+0.030}_{-0.028}$ and $1.057^{+0.035}_{-0.036}$ using the pre- and post-reconstructed samples, respectively. Both results are in good agreement (within 2σ) with the fiducial Planck18 (ref. 22) results (TT, TE, EE + lowE + lensing + BAO), which assumes a Λ cold dark matter model (where Λ is the cosmological constant) cosmology. We find that the constraint is not improved after reconstruction for the GI correlations, which may be due to the fact that we only reconstruct the density field and keep the shape field unchanged. The result may be further improved in principle if the shape field is also reconstructed, which is left for a future study.

1)

2)

conclusion

In this work, we obtain a 2–3σ measurement of the BAO dip feature in GI correlations, although the constraints on the distance from GI are only around one-third of those from GG, much weaker than predicted by Taruya and Okumura[21] using the LA model. The reason may be that the galaxy–halo misalignment[24] can reduce the IA signals and weaken the BAO constraints, which may not be considered appropriately by Taruya and Okumura[21]. According to Okumura and Jing[24], on taking into account the misalignment the GI signals can be reduced by two- to

threefold, which is consistent with our results. Moreover, since realistic mock catalogues for galaxy shapes are unavailable as yet, the covariance matrices in this study are estimated using the jackknife resampling method. Employing more reliable error estimation techniques could potentially improve the accuracy of the results, and is left for a future study. Nevertheless, the results are already promising. With the next-generation spectroscopic and photometric surveys including the Dark Energy Spectroscopic Instrument (DESI)[23] and the Legacy Survey of Space and Time[25], we will have larger galaxy samples and better shape measurements. We expect that the IA statistics can provide much tighter constraints on cosmology from BAO and other probes[26,27].

Thank you!