INVESTIGATING THE IMPRINT OF QUINTESSENCE IN COSMIC MAGNIFICATION

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GENERAL INTRODUCTION:

WHAT IS COSMIC MAGNIFICATION & WHY IT MATTERS?

The **amplification** of flux or angular size of distant cosmic sources (e.g., galaxies) due to intervening large-scale structure.

- Analyzes and understands **cosmic distances**.
- Probes **dark energy theories** through a new observational window.
- Constrains **cosmological parameters**.
- Sensitive to **large-scale structure** geometry and distribution.

INTRODUCTION TO QUINTESSENCE MODELS

Dynamical dark energy models where a **scalar field** drives the accelerated expansion of the Universe, offering alternatives to the cosmological constant.

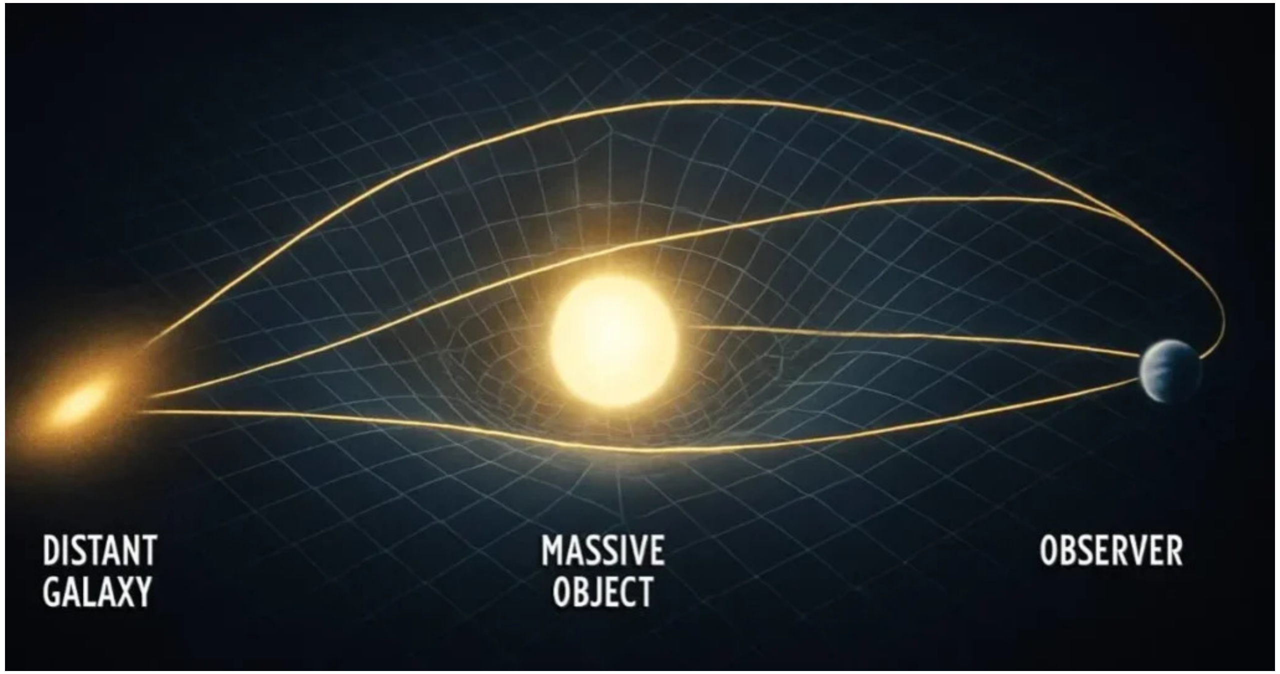
PHYSICAL CAUSES OF MAGNIFICATION

> **Weak Lensing:** Bending of light by gravitational fields of massive structures [2].

> **Doppler Effect:** Velocity-induced change in the apparent size and flux of sources [3].

> **Time Delay:** Photons passing through gravitational potentials take extra time [4].

> **ISW Effect:** Energy change of photons as they traverse time-varying potentials [5].



Conceptual diagram of gravitational lensing and magnification [6].

QUINTESSENCE MODELS & EOS EVOLUTION

MODELS ANALYZED

> Ratra–Peebles (RP), SUGRA Potential, and Double Exponential (DExp).

LOW REDSHIFT ($Z \lesssim 1$)

> **DExp** gives the highest w_φ, followed by **RP**, then **SUGRA**.

> Deviation from $\mathbf{w_\Lambda = -1}$ indicates the strength of quintessence evolution.

> Larger deviation from -1 → stronger quintessence dynamics, leading to higher quintessence contribution to background energy density and lower matter density.

HIGH REDSHIFT ($Z > 1$)

> The three models **converge toward** $\mathbf{w_\Lambda = -1}$.

> Implies similar evolution in the early Universe.

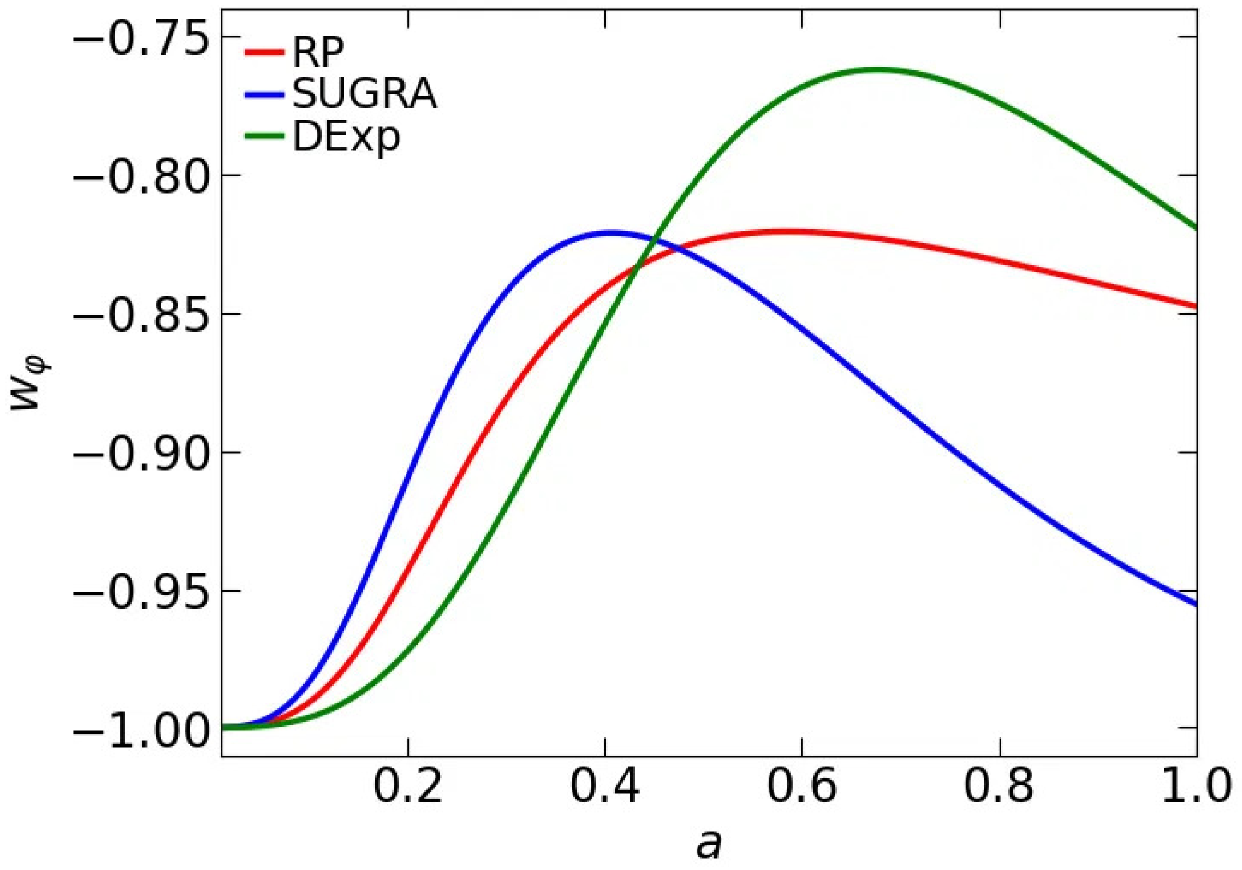


Fig. 1: Evolution of wφ for quintessence models.

RESULTS: TOTAL MAGNIFICATION POWER SPECTRUM

> In general, **cosmic variance dominates** over the magnification angular power spectra of all models on all scales.

> Angular power spectra (C_ℓ and $C_\ell^{lensing}$) for different models appear **indistinguishable** on all scales at given z_S.

> At z_S = 3 and 4.5, lensing magnification coincides with total magnification on scales **ℓ > 10** for all models.

> Lensing magnification **deviates** from total magnification on scales **ℓ ≲ 10** at all source redshifts.

> Scales **ℓ ≲ 10** are suitable for investigating **relativistic (non-lensing) effects** in cosmic magnification.

> At $z_S \leq 0.5$, the lensing-magnification signal will not overlap with the total magnification in observational data.

> At $z_S > 0.5$, large-scale cosmic variations can cause the total-magnification signal to overlap with the lensing signal.

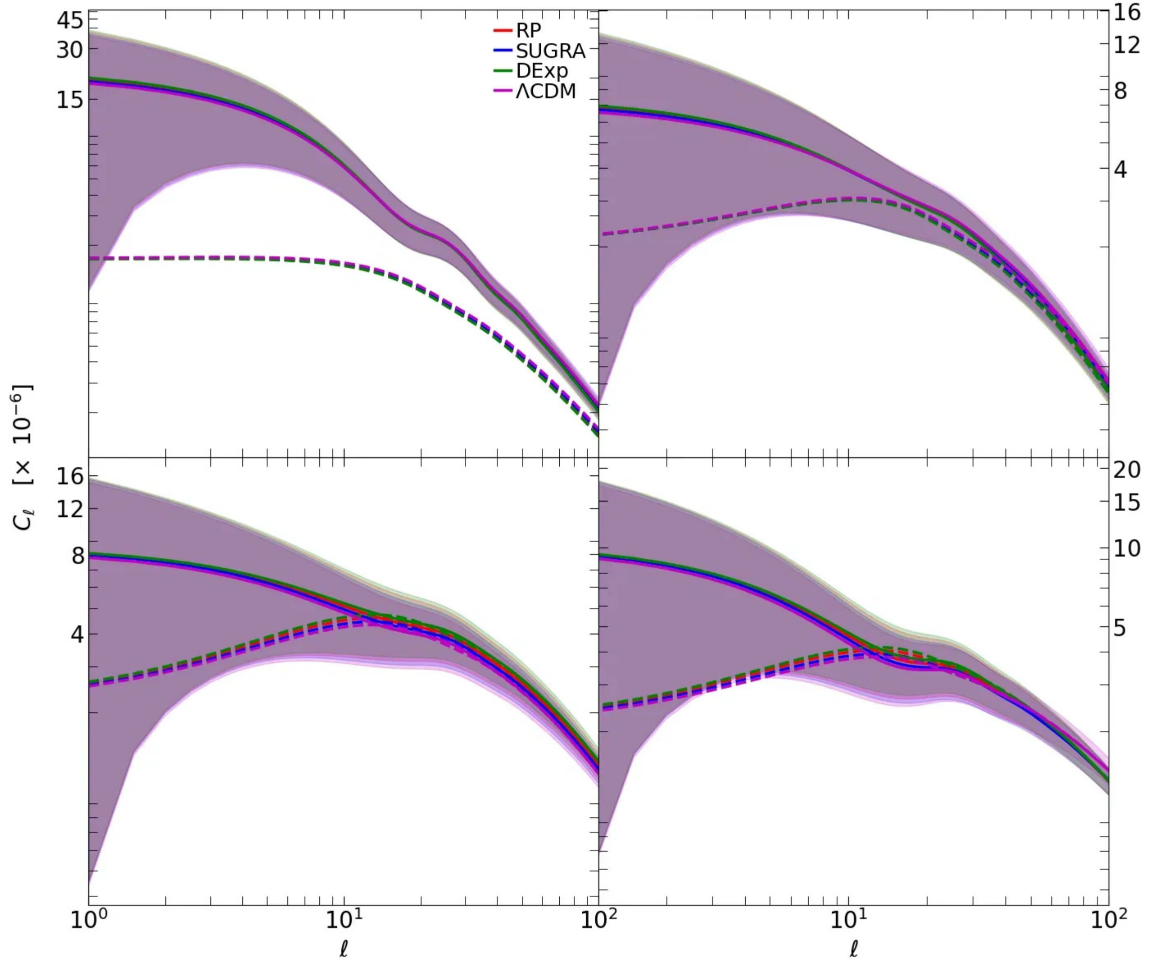


Fig. 2: Total magnification angular power spectrum vand the lensing magnification angularpower spectrum

RESULTS: FRACTIONAL DIFFERENCE FROM ΛCDM

> Separation between lines measures the **difference between models**, indicating the possibility of distinguishing them.

> Percentage value measures similarity to ΛCDM; **closer to zero** means more difficult to distinguish from ΛCDM.

> At $z_S \leq 1$, total magnification is **more sensitive** to the underlying dark energy model than lensing magnification.

> Lensing magnification angular power spectrum percentage differences **approach zero** on the largest scales at $z_S \leq 1$.

> At $z_S \geq 3$, either lensing or total magnification can be used to distinguish quintessence from ΛCDM.

> At $z_S \leq 1$, total-magnification signal **gradually dominates** over lensing on the largest scales ($\ell \leq 10$).

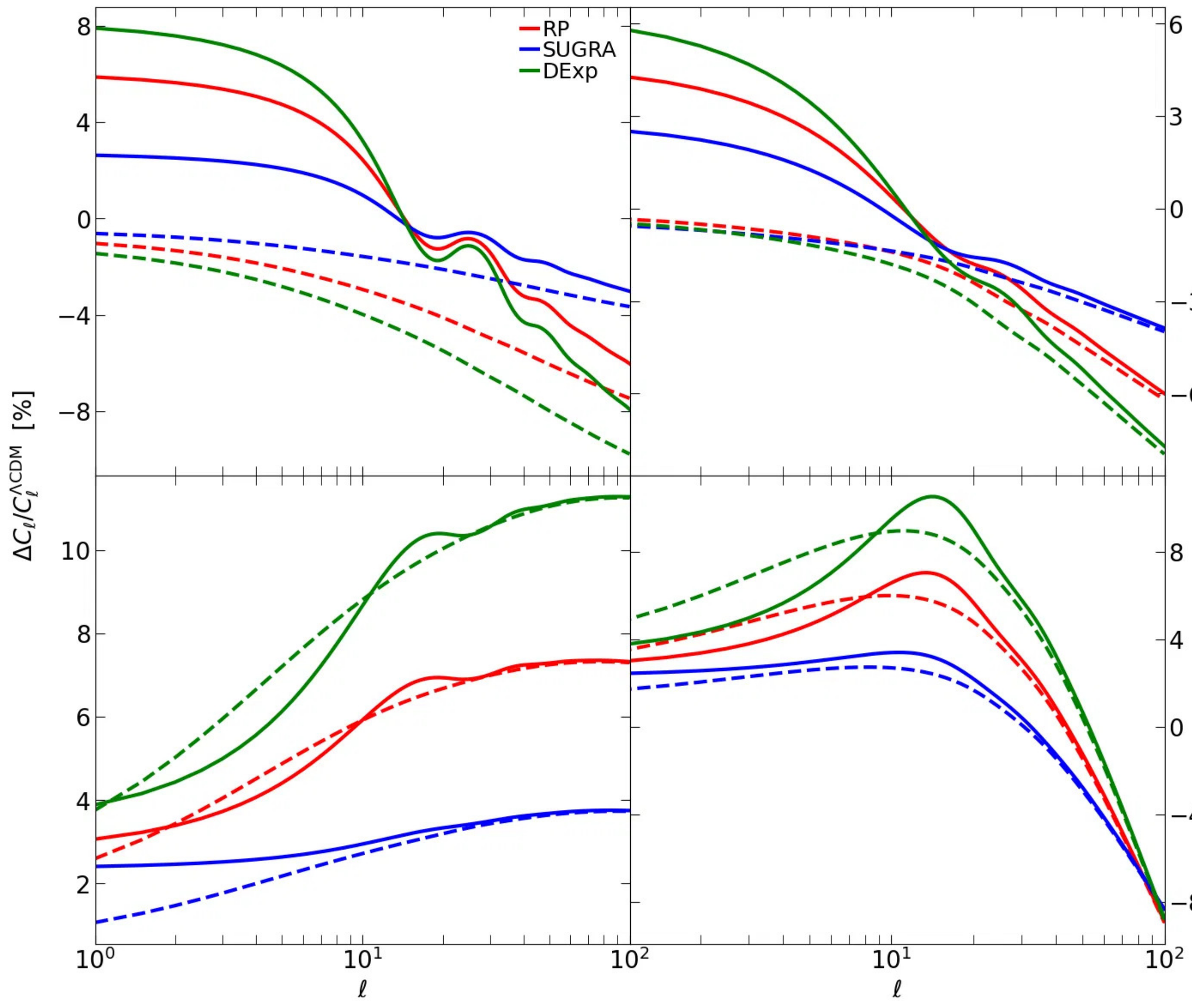


Fig. 3: Fractional difference of quintessence models from ΛCDM.

RESULTS: TOTAL RELATIVISTIC SIGNAL

> These fractions measure the **total relativistic signal** in the magnification angular power spectrum for φCDM and ΛCDM.

> From high to low redshifts (z_S = 4.5 to 0.5), the amplitude of the total relativistic magnification signal **increases**.

> The total relativistic signal is **higher at low source redshifts (z_S ≤ 0.5)** than at high source redshifts in both φCDM and ΛCDM.

> The signal gradually becomes significant relative to **cosmic variance** as z_S decreases, only surpassing it at **z_S = 0.5**.

> At **z_S ≤ 0.5**, neglecting cosmic variance in quantitative analysis will not lead to significant estimation deviations.

> At **z_S > 0.5**, advanced methods like **multi-tracer methods** are required to isolate the signal from cosmic variance.

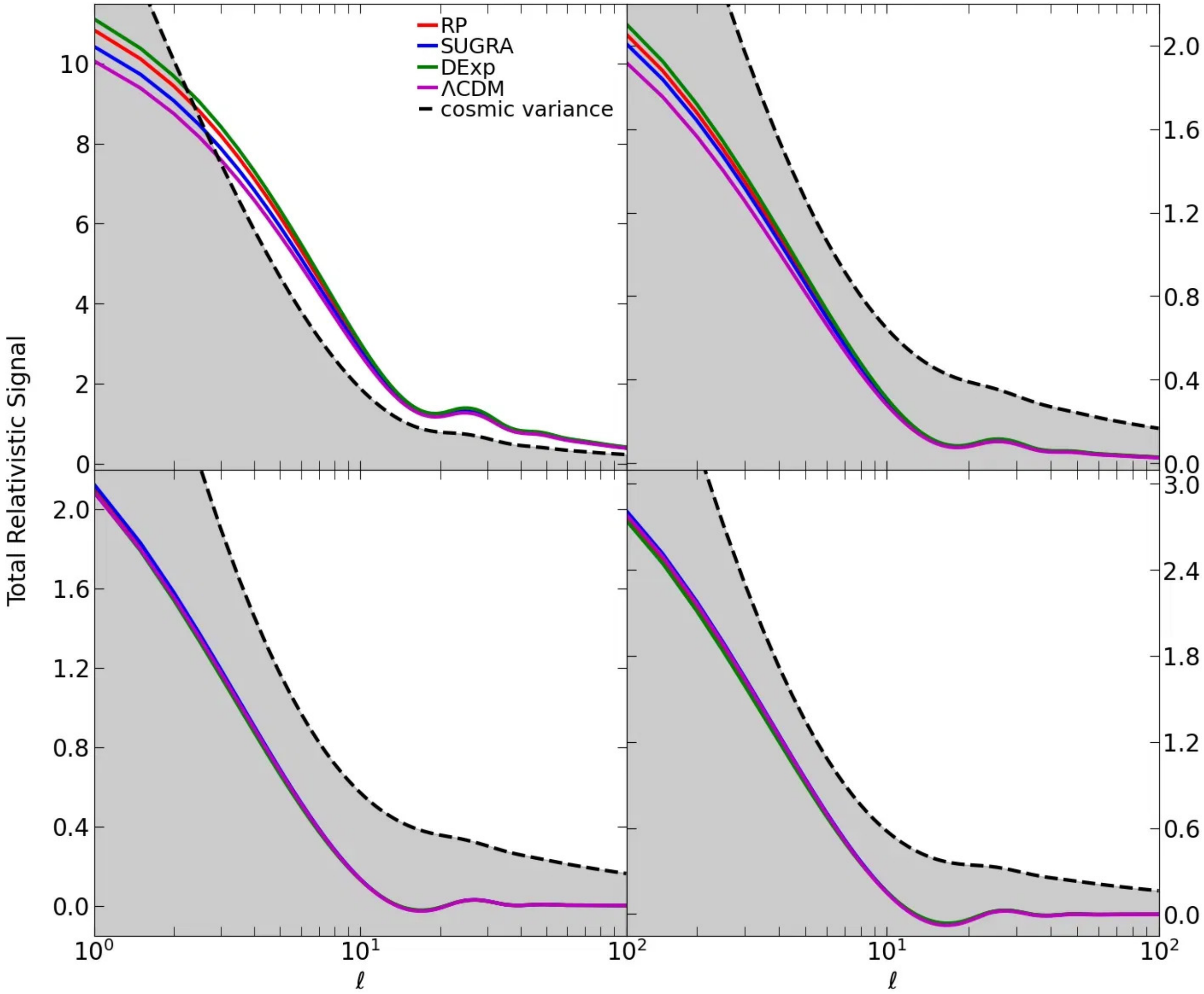


Fig. 4: Total relativistic magnification signal vs cosmic variance.

RESULTS: DOPPLER MAGNIFICATION SIGNAL

> Plots show the **fractional change** in the total magnification angular power spectrum owing solely to the **Doppler-effect correction**.

> These fractions measure the **Doppler signal** for φCDM and ΛCDM at source redshifts $z_S = 0.5, 1, 3, 4.5$.

> The Doppler magnification signal is **almost identical** to the total relativistic magnification signal, but with a relatively lower amplitude.

> The results suggest that the **Doppler signal dominates** the total relativistic magnification signal at low source redshifts (**$z_S \leq 0.5$**).

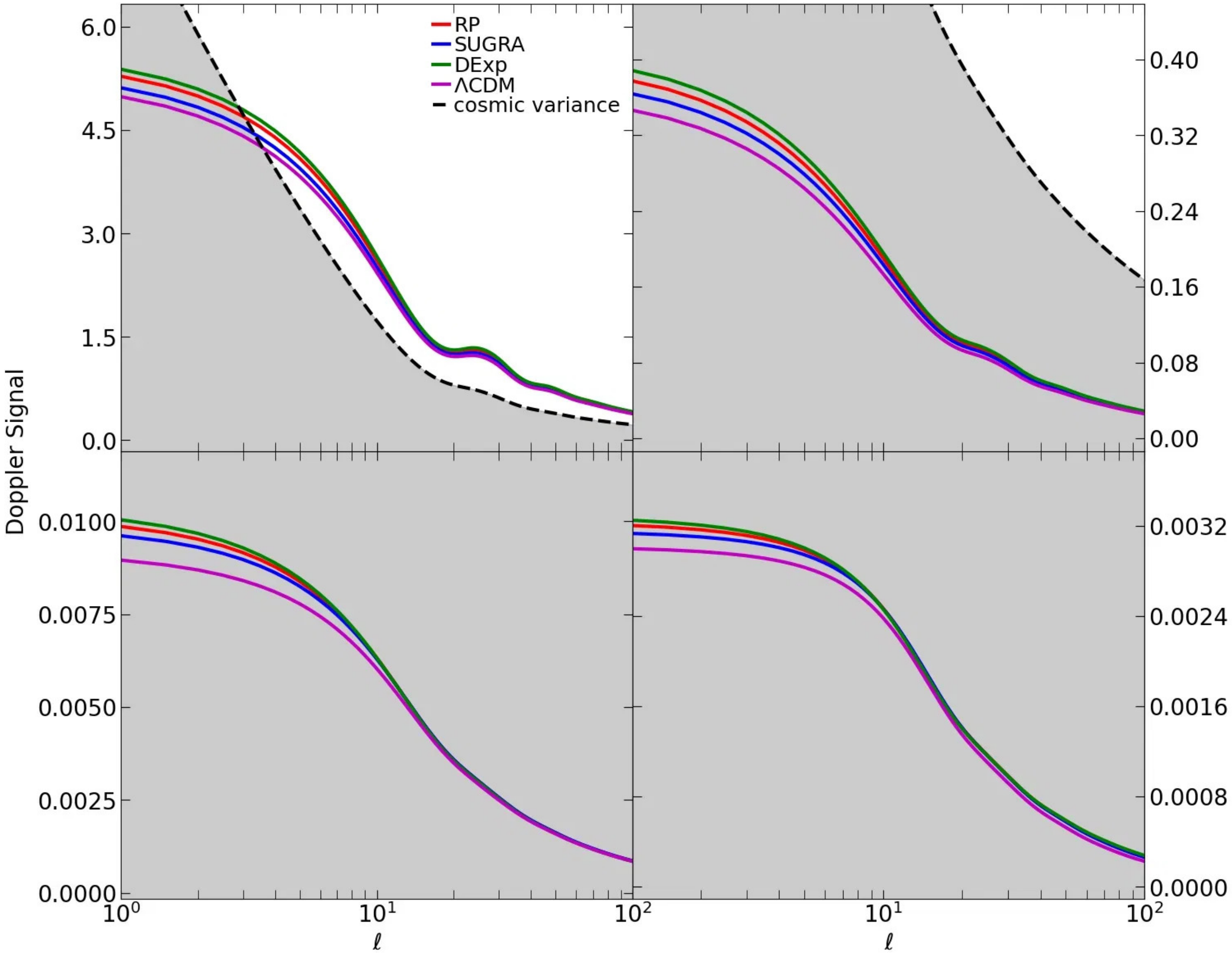


Fig. 5: The Doppler magnification signal vs cosmic variance.

RESULTS: ISW MAGNIFICATION SIGNAL

> Plots show the **ISW signal** fractional change in the total magnification angular power spectrum for φCDM and ΛCDM.

> The signal is **below cosmic variance** on all scales and at all source redshifts (z_S = 0.5, 1, 3, 4.5).

> Contrary to unified dark energy results, the ISW signal here remains **insignificant** relative to cosmic variance even at $z_S \geq 3$.

> Extracting the ISW magnification signal for quintessence will be **difficult** without advanced methods like multi-tracer analysis.

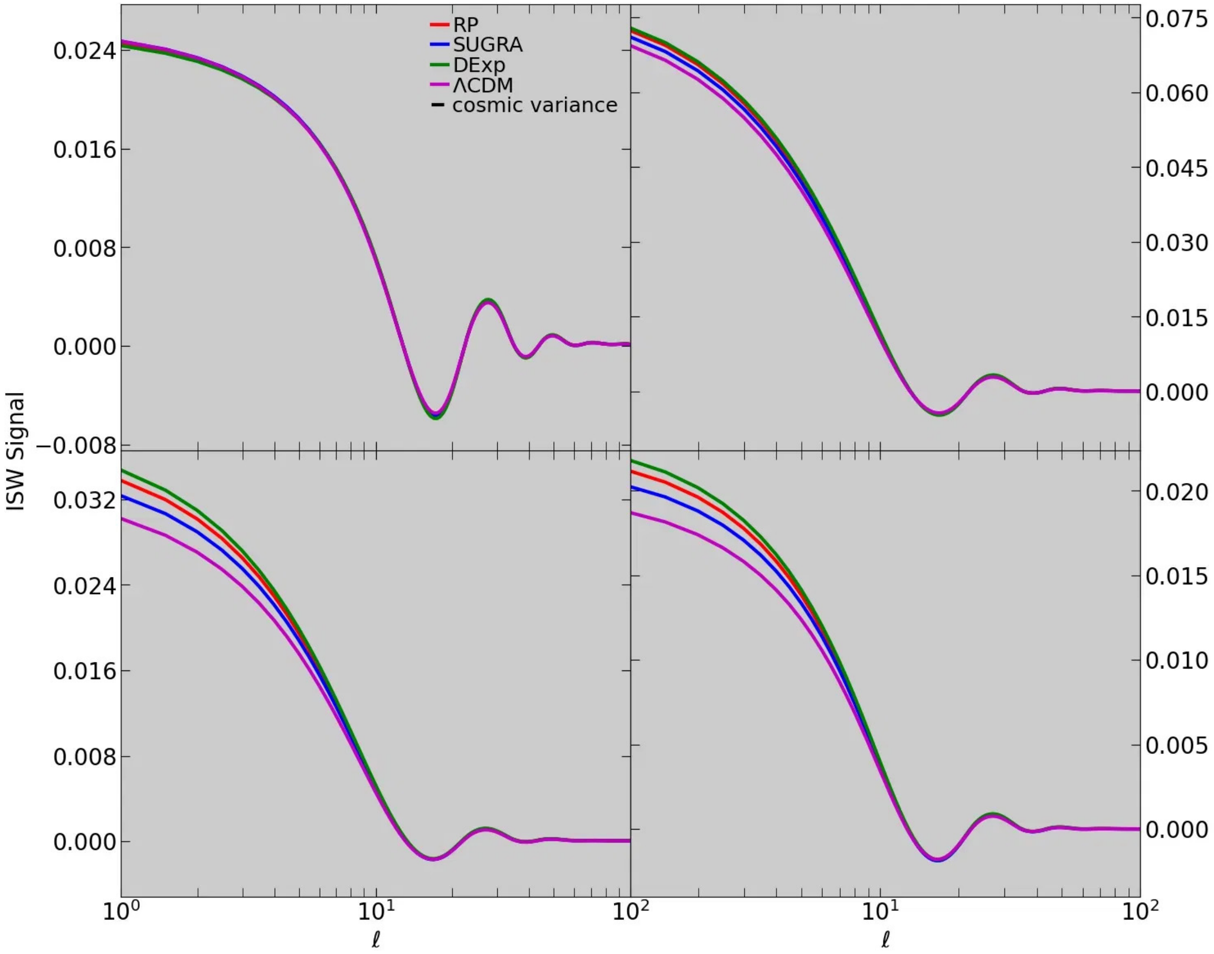


Fig. 6: The ISW magnification signal vs cosmic variance.

RESULTS: TIME-DELAY MAGNIFICATION SIGNAL

> Plots show the **time-delay magnification signal** fractional change for φCDM and ΛCDM at source redshifts z_S = 0.5, 1, 3, 4.5.

> The signal exhibits **similar behavior** to the ISW magnification signal (Fig. 6) across all redshifts.

> The primary difference is in the **amplitudes**: time-delay signals are larger relative to ISW signals at all redshifts.

> Quantitative analysis of the time-delay signal will require **advanced methods** like multi-tracer analysis.

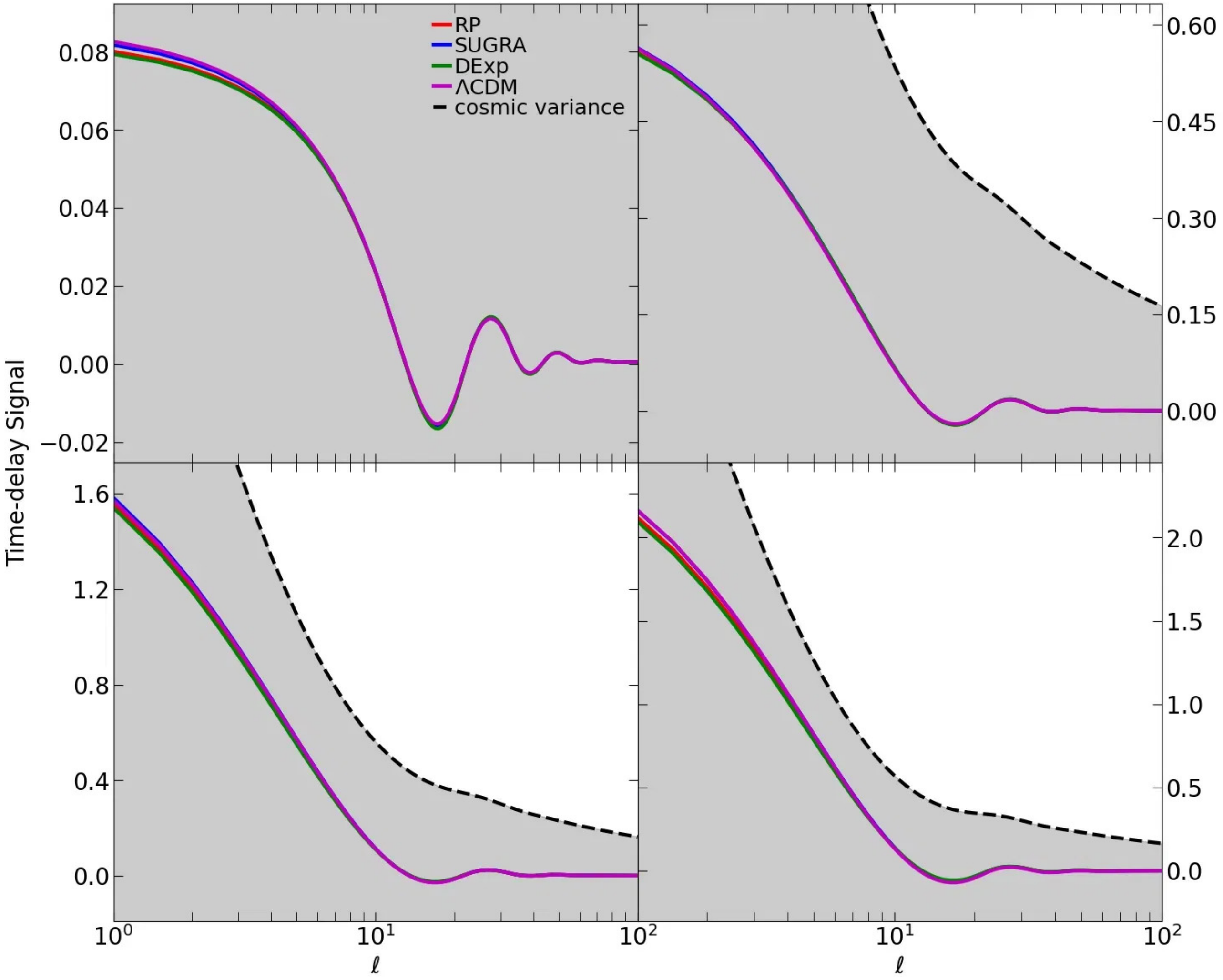


Fig. 7: The time-delay magnification signal vs cosmic variance.

CONCLUSION

- Distinguishing between quintessence models from ΛCDM is **difficult using lensing magnification alone** at redshifts zs ≤ 1.
- Including **relativistic effects** in total magnification helps differentiate models at redshifts below z_s = 1.
- At high redshifts ($z_s \geq 3$), lensing magnification becomes a **good approximation** of the total magnification signal.
- Total relativistic and Doppler signals are **stronger than cosmic variance** at $z_s \leq 0.5$, making them potentially observable.
- ISW and time-delay signals remain **weaker than cosmic variance** at all scales up to $z_s = 4.5$.
- The signal from the **gravitational potential is zero** in our results.
- This is the **first study** of total magnification with all relativistic effects for quintessence or any dark energy model.

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