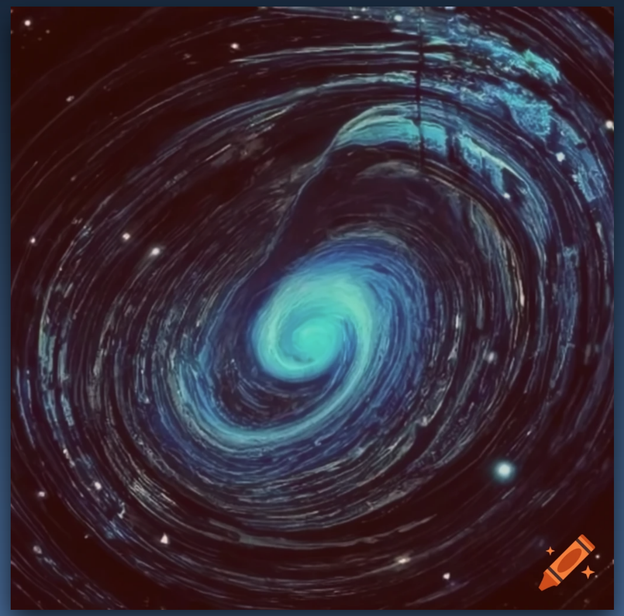
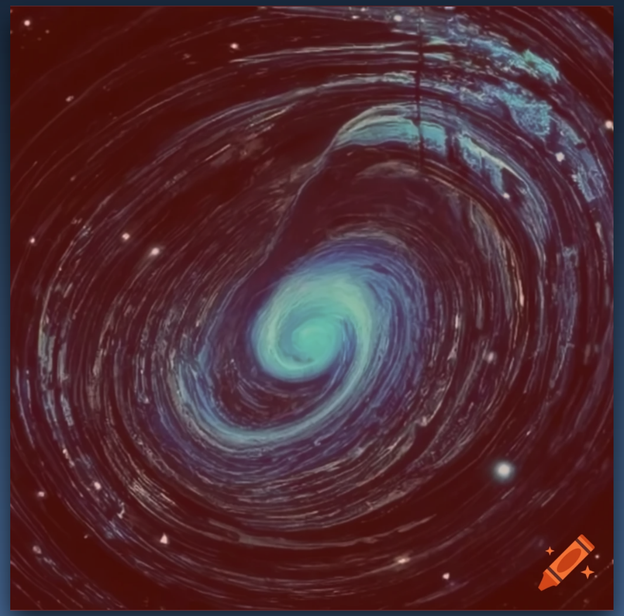
Gravitational redshift from SKA2 as a test of fundamental physics

Sveva Castello

EoI with L. Amendola, C. Bonvin, L. Dam, N. Grimm, M. Mancarella, D. Sobral Blanco, Z. Zheng

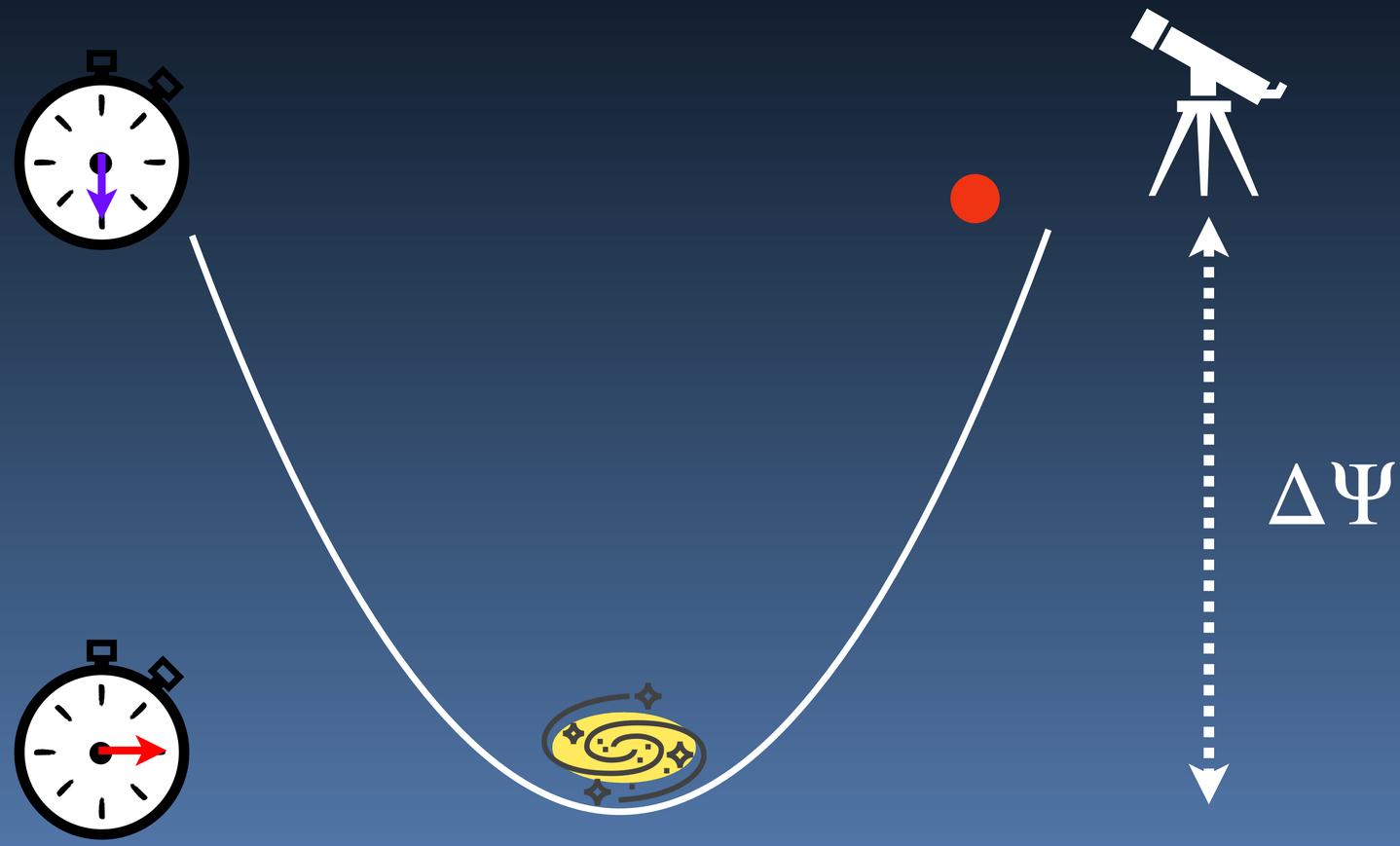
UNIVERSITÉ DE GENÈVE
FACULTÉ DES SCIENCES

SKA Cosmology SWG meeting 2024

Nice, November 6th, 2024

European Research Council
Established by the European Commission

Gravitational redshift



→ <u>On cosmological scales</u>: extracted from galaxy clustering

Galaxy clustering observables

Fluctuations in galaxy number counts

$$\Delta(z, \mathbf{n}) = b\,\delta_{\rm m} - \frac{1}{\mathscr{H}}\partial_r(\mathbf{V}\cdot\mathbf{n})$$

Matter density x galaxy bias

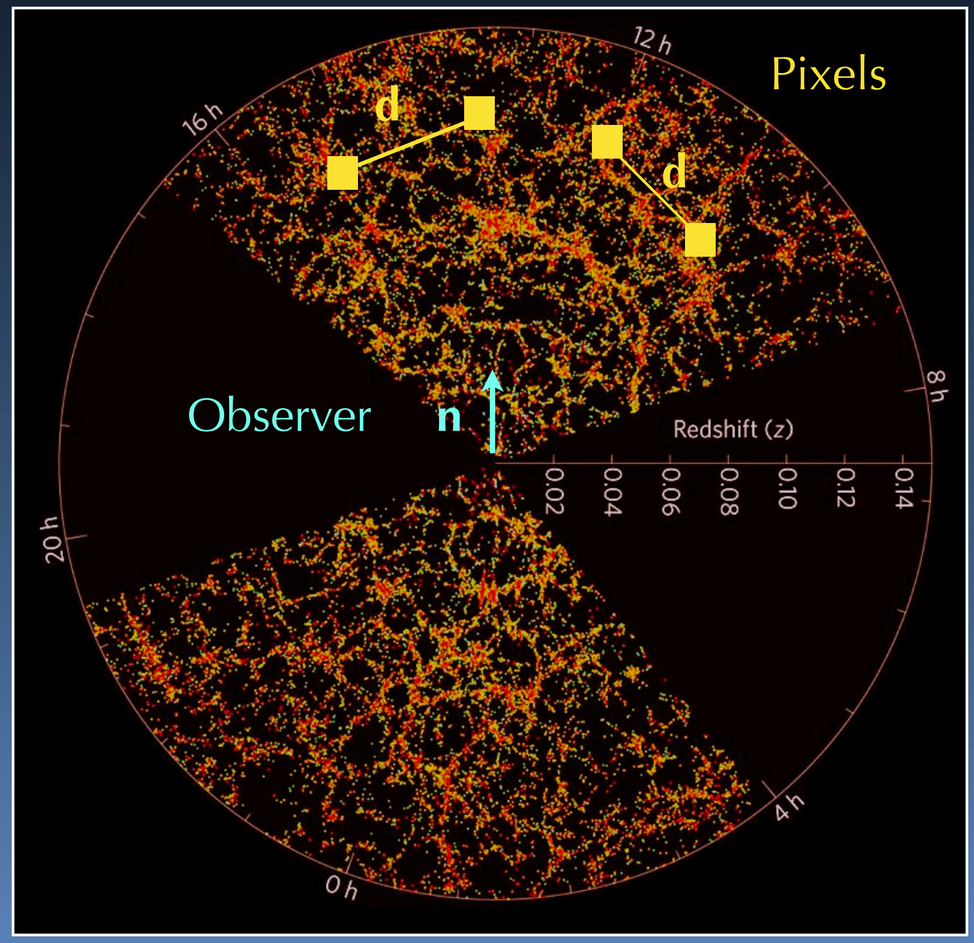
Redshift-space distortions (RSD)

Two-point correlation function

$$\xi \equiv \langle \Delta(z, \mathbf{n})\Delta(z', \mathbf{n}')\rangle$$

→ **Even multipoles** ($\ell = 0,2,4$)

Kaiser (1987)
Hamilton (1992)



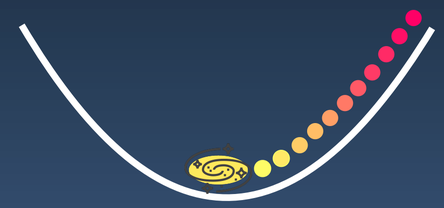
Credits: M.Blanton, SDSS

What we really observe

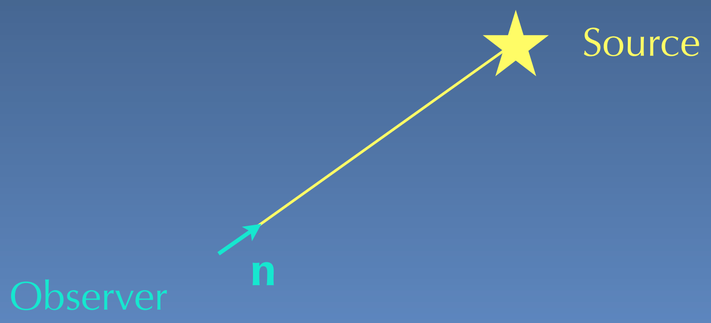
Yoo et al. (2010)
Bonvin and Durrer (2011)
Challinor and Lewis (2011)
Jeong, Schmidt and Hirata (2012)

$$\Delta(\mathbf{n}, z) = b\,\delta_{\rm DM} - \frac{1}{\mathscr{H}}\partial_r(\mathbf{V}\cdot\mathbf{n})$$

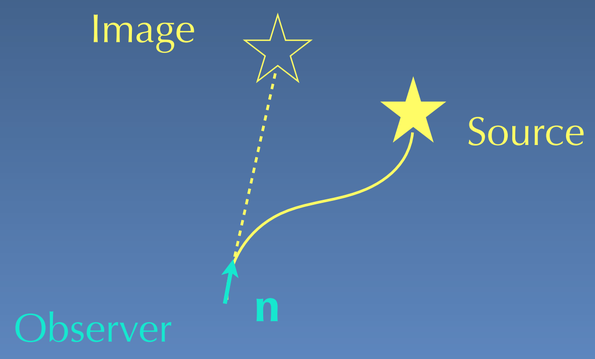
+ relativistic corrections ⟷ Including gravitational redshift $\Delta_{\rm gr} = \frac{1}{\mathscr{H}}\partial_r\Psi$



Homogeneous Universe



Inhomogeneous Universe



Galaxy clustering observables

Fluctuations in galaxy number counts

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+ relativistic corrections

Two-point correlation function

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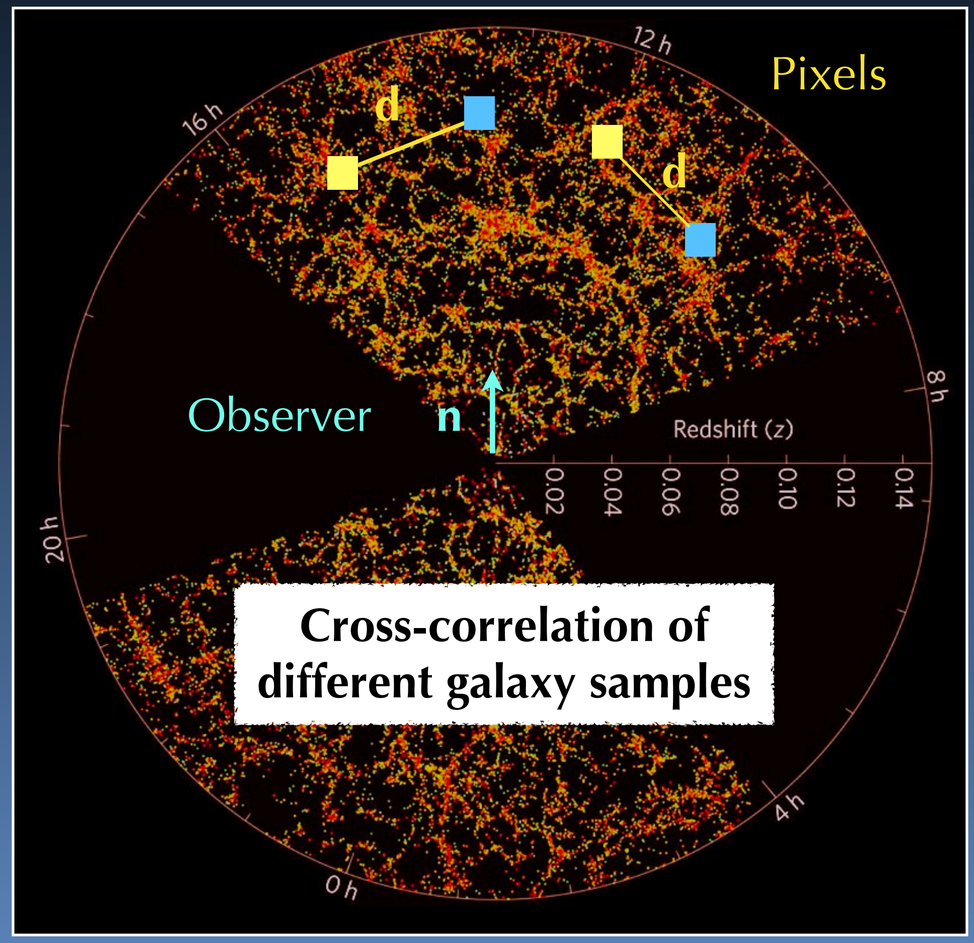
→ **Even multipoles** ($\ell = 0,2,4$)

→ **Odd multipoles** ($\ell = 1,3$)

Bonvin, Hui and Gaztanaga (2014)



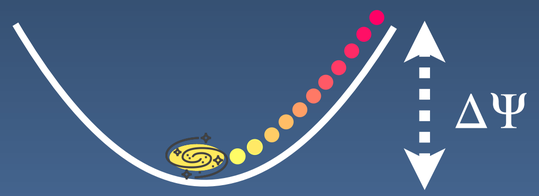
Credits: M.Blanton, SDSS

Isolating gravitational redshift with SKA2

δ +RSD $\times$ relativistic corrections $=$ Dipole ($\ell = 1$)

→ **Cumulative S/N with SKA2 HI galaxies reaches 80**
($z = 0.15 - 1.55$ and $d = 20 - 160$ Mpc/h)

Sobral Blanco & Bonvin (2022)
SC, Mancarella et al. (2024)



→ **Isolate Ψ combining different multipoles**

Sobral Blanco & Bonvin (2021, 2022)

Redshift	0.35	0.45	0.55	0.65	0.75	0.85	0.95
Constraints	23%	24%	28%	33%	40%	48%	60%

Isolating gravitational redshift with SKA2

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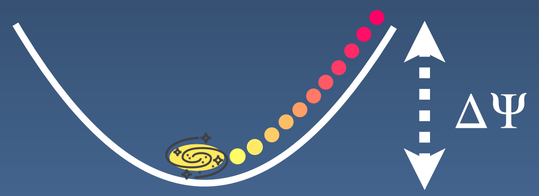

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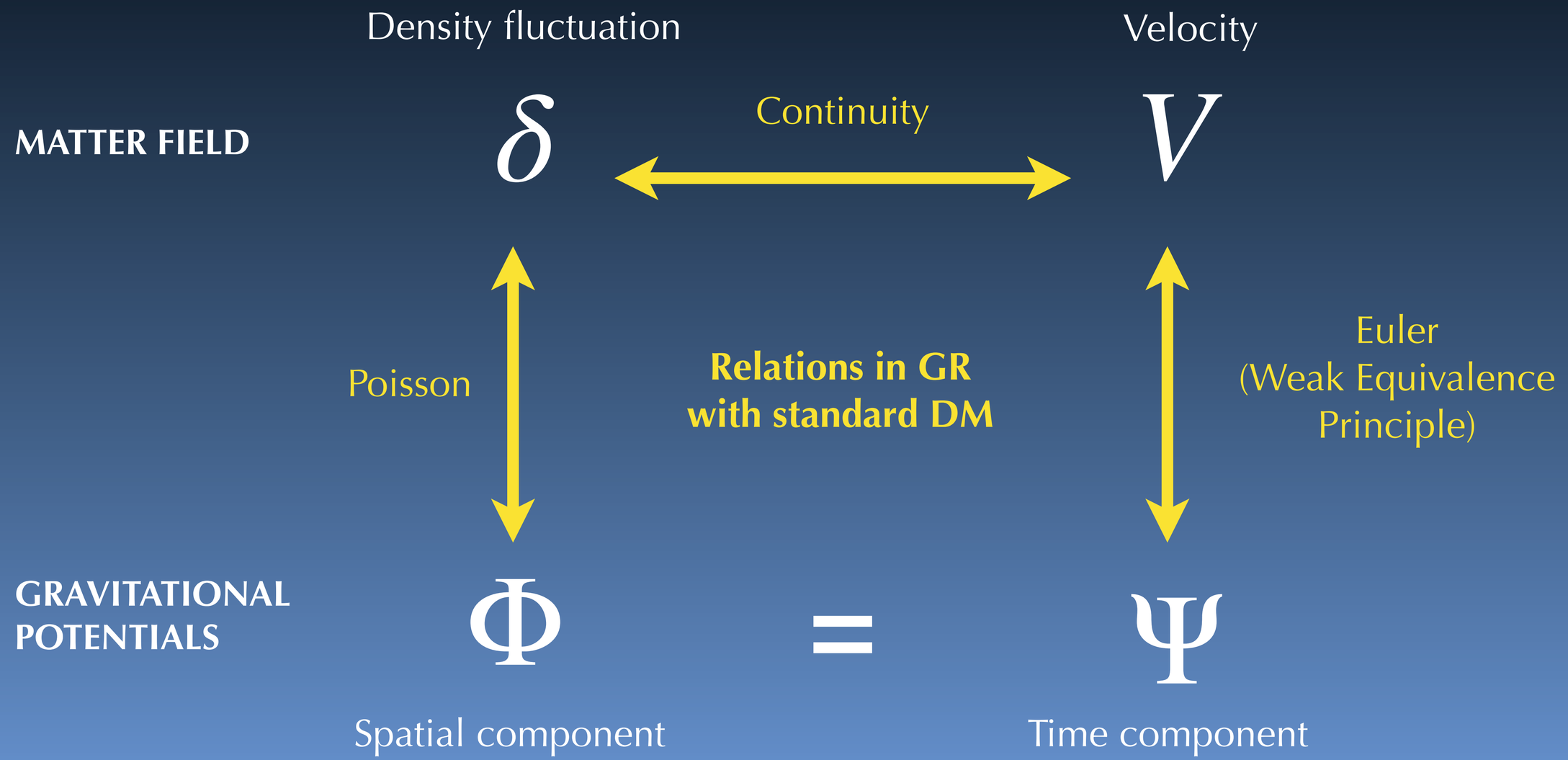
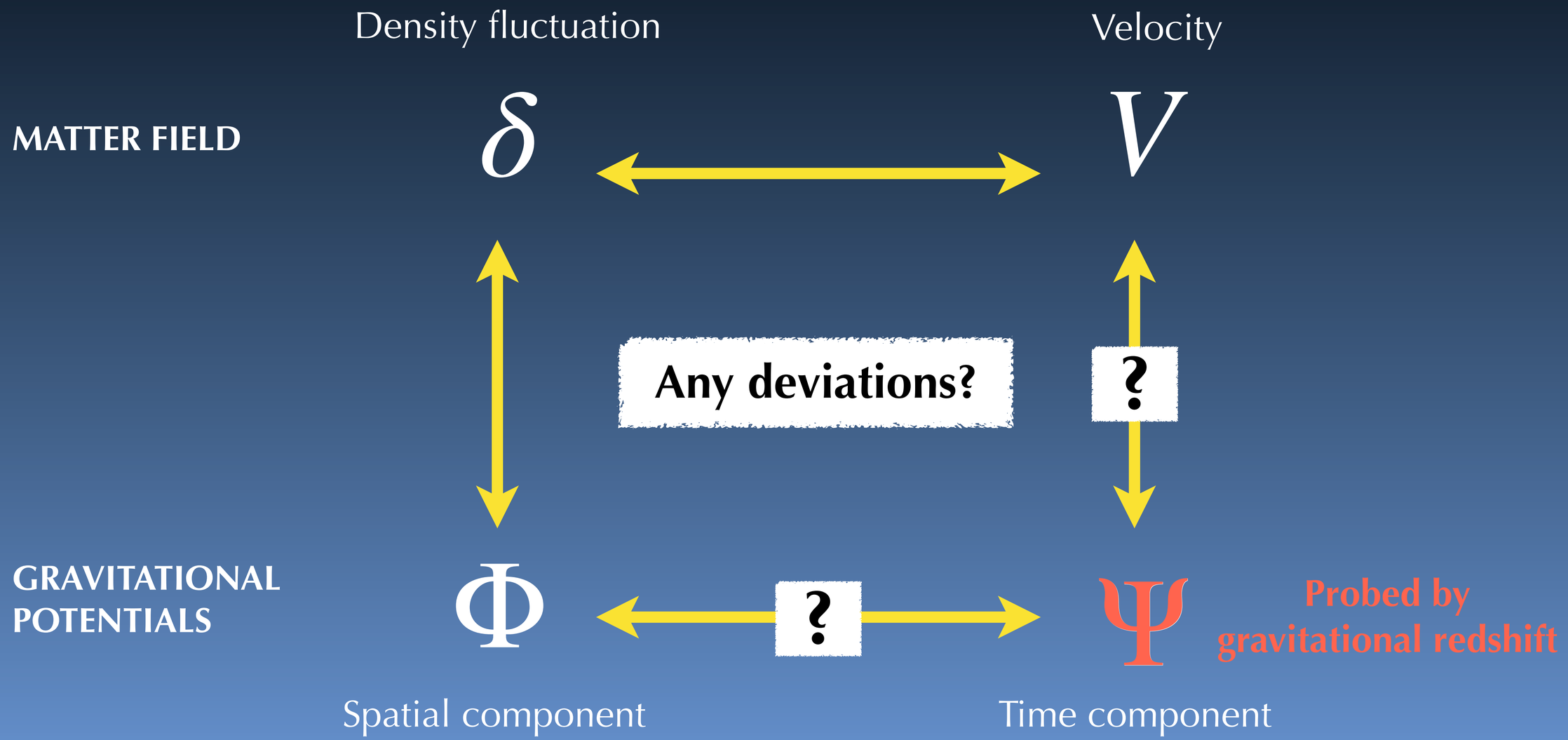
Why is this interesting?

Model-independent tests of fundamental physics

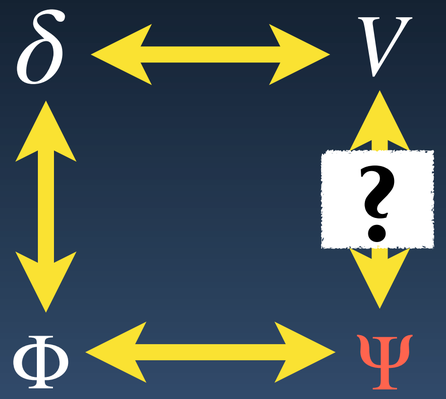


Model-independent tests of fundamental physics



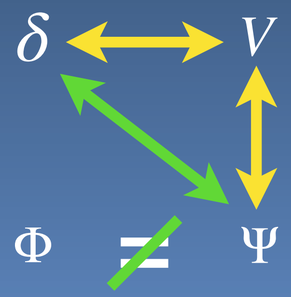
Test of the equivalence principle

SC, Grimm & Bonvin (2022)
Bonvin & Pogosian (2022)
SC, Mancarella et al. (2024)
SC et al. (2024)



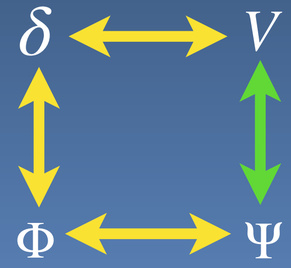
- **Gravitational redshift:** Ψ
- **RSD:** V

Gravity modifications



VS

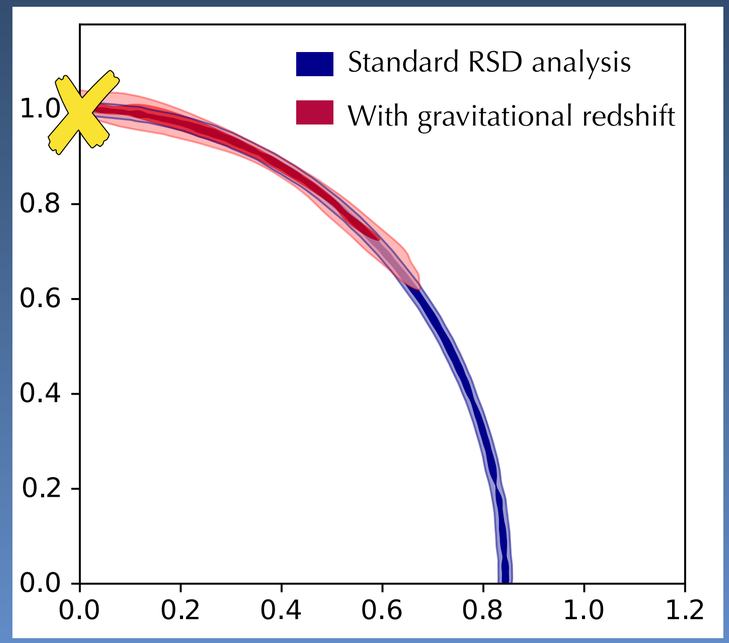
Dark sector interactions



(DM only)

Fiducial model

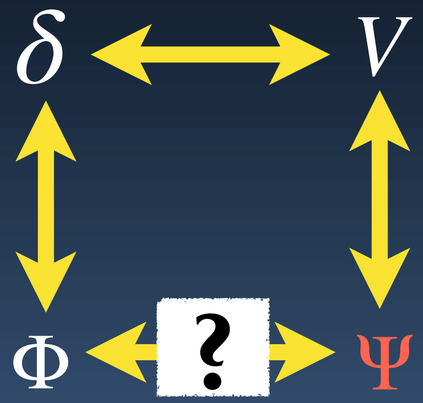
Dark sector interactions



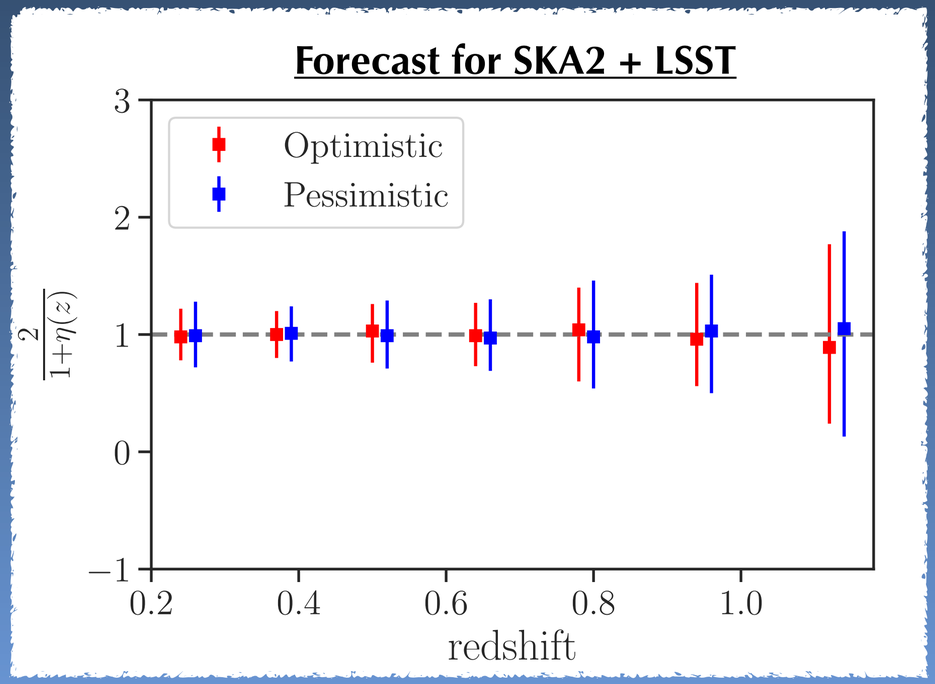
Modified gravity

Anisotropic stress $\eta = \frac{\Phi}{\Psi}$

Tutusaus, Sobral Blanco & Bonvin (2022)



- **Gravitational redshift:** Ψ
- **Gravitational lensing:** $\Phi + \Psi$



Proposing gravitational redshift in the SKAO book

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