Aix*Marseille université
Socialement engagée

Cosmology with type Ia supernovae velocities

Carreres Bastien

- CPPM Seminar October 2022 -

CENTRE DE PHYSIQUE DES PARTICULES DE MARSEILLE
CPPM

Current cosmological model

What we observe : a flat universe in accelerated expansion

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General Relativity + ΛCDM

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$$G_{\mu\nu} = 8\pi G T_{\mu\nu}$$

Space-Time

Universe content

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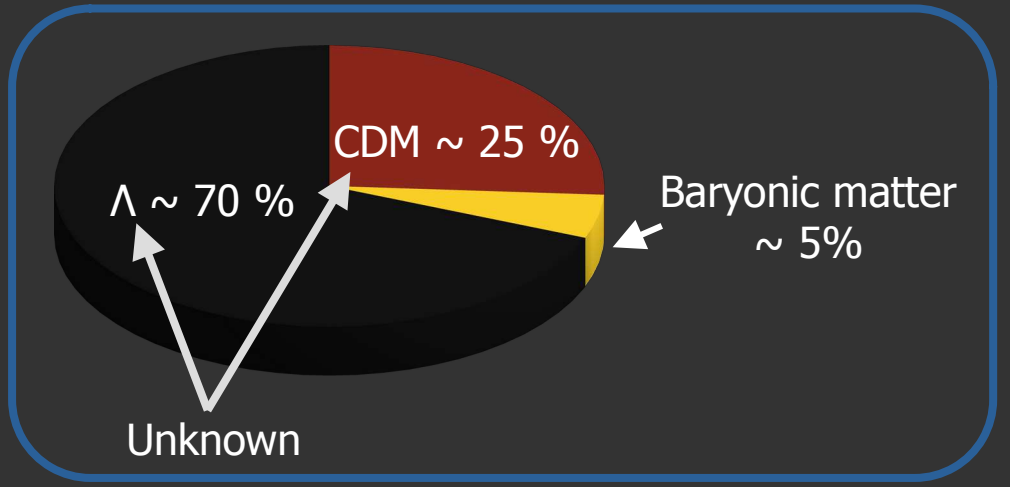

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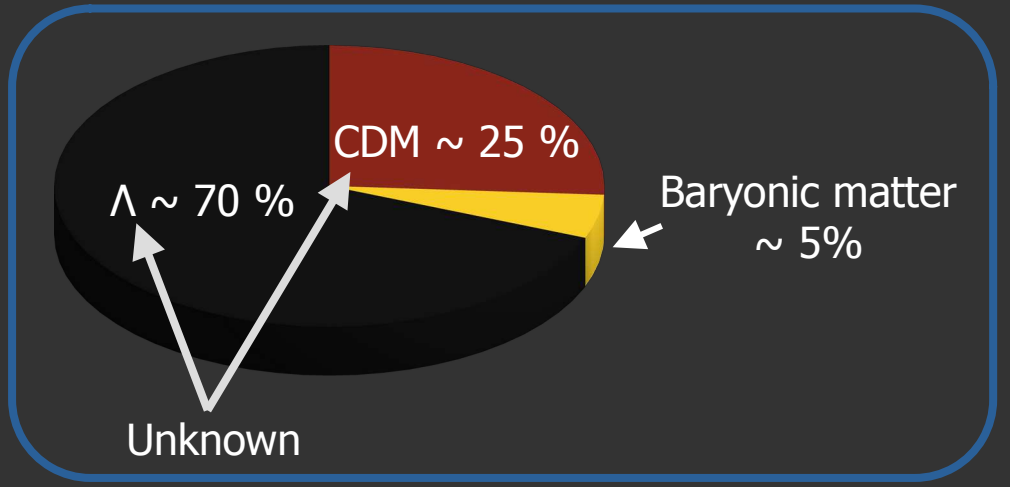
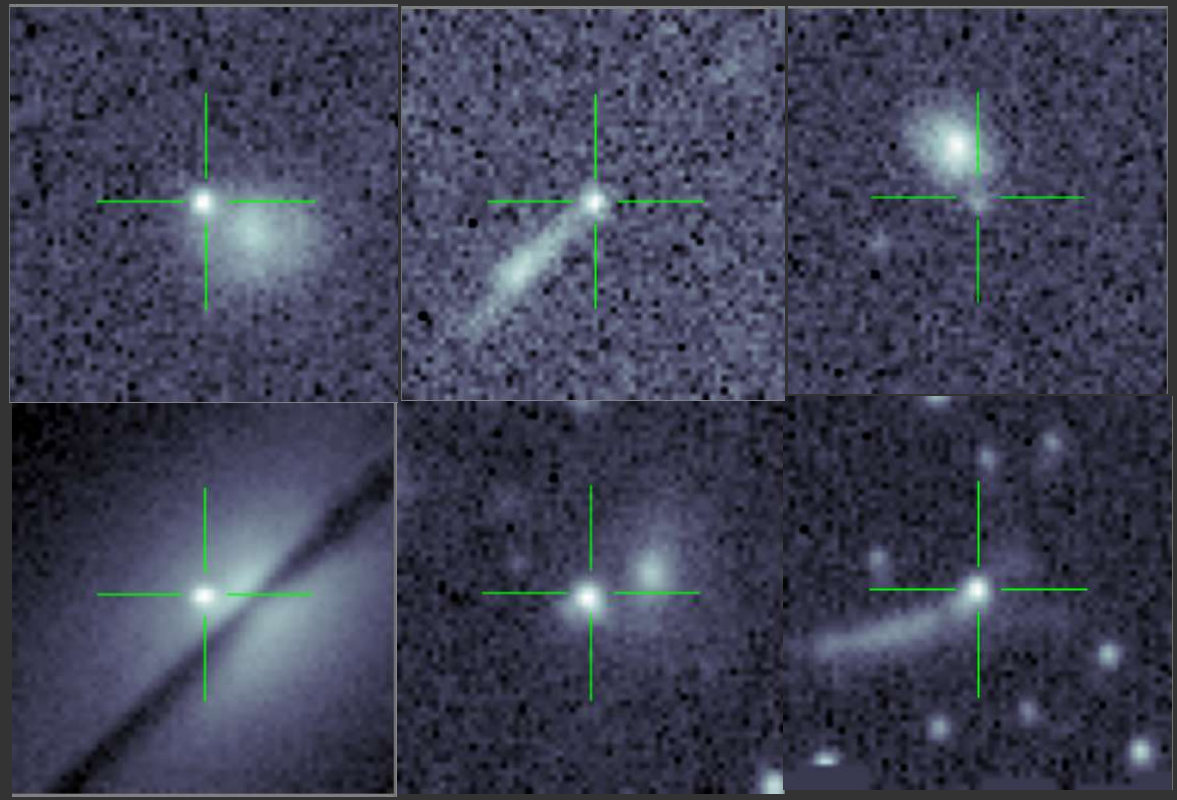
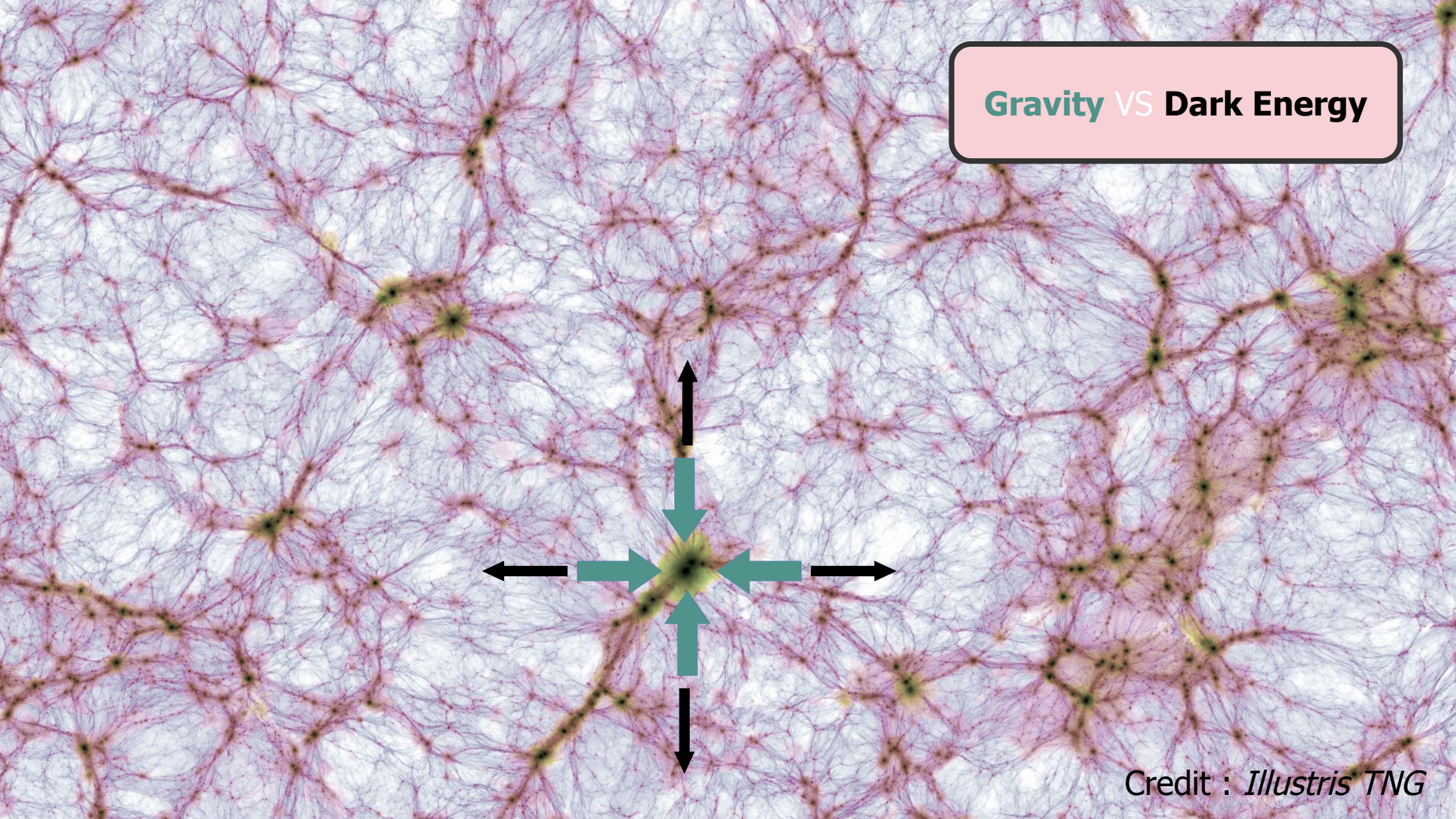
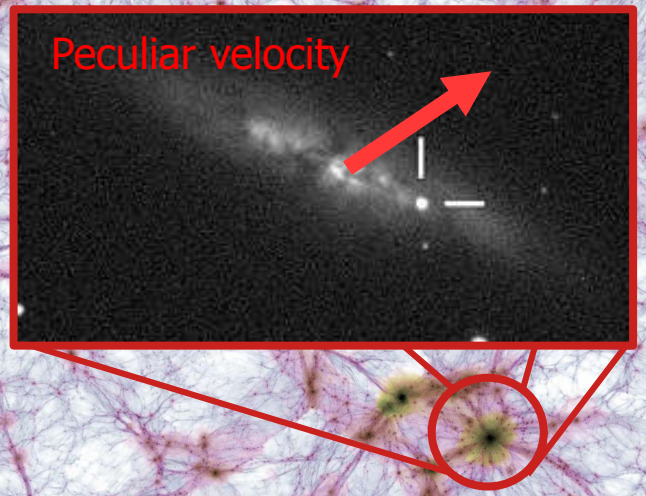


Is dark energy just a cosmological constant?
or a more complex fluid? or some deviation to GR?

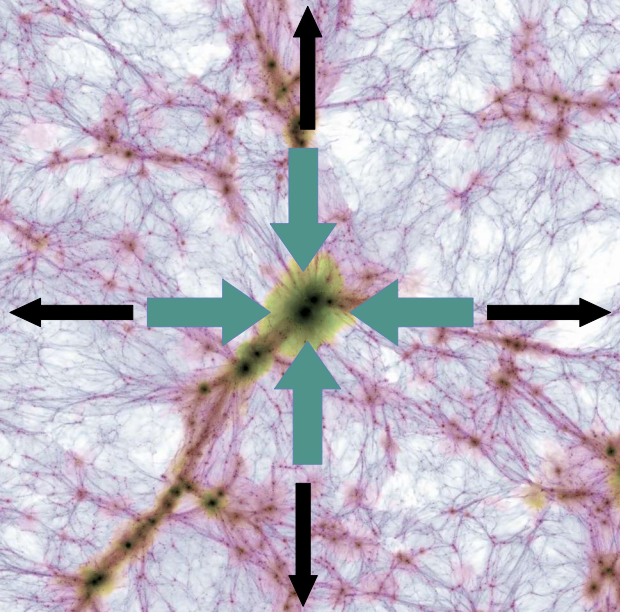
My thesis : use the huge sample of SN Ia observed by ZTF to test alternatives to General Relativity




Gravity VS Dark Energy
Credit : *Illustris TNG*



Gravity VS **Dark Energy**



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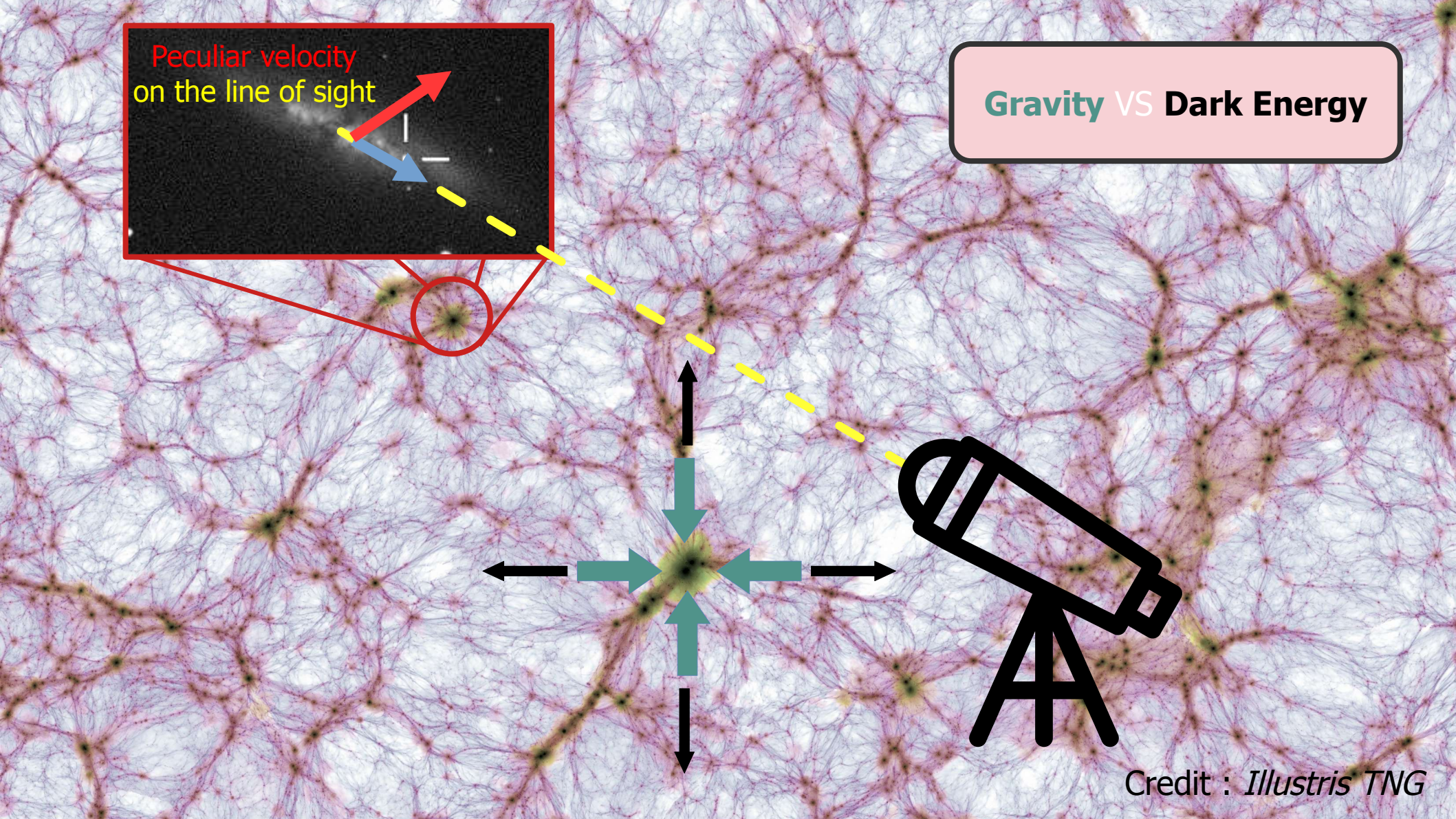
Peculiar velocity
on the line of sight
Gravity VS Dark Energy
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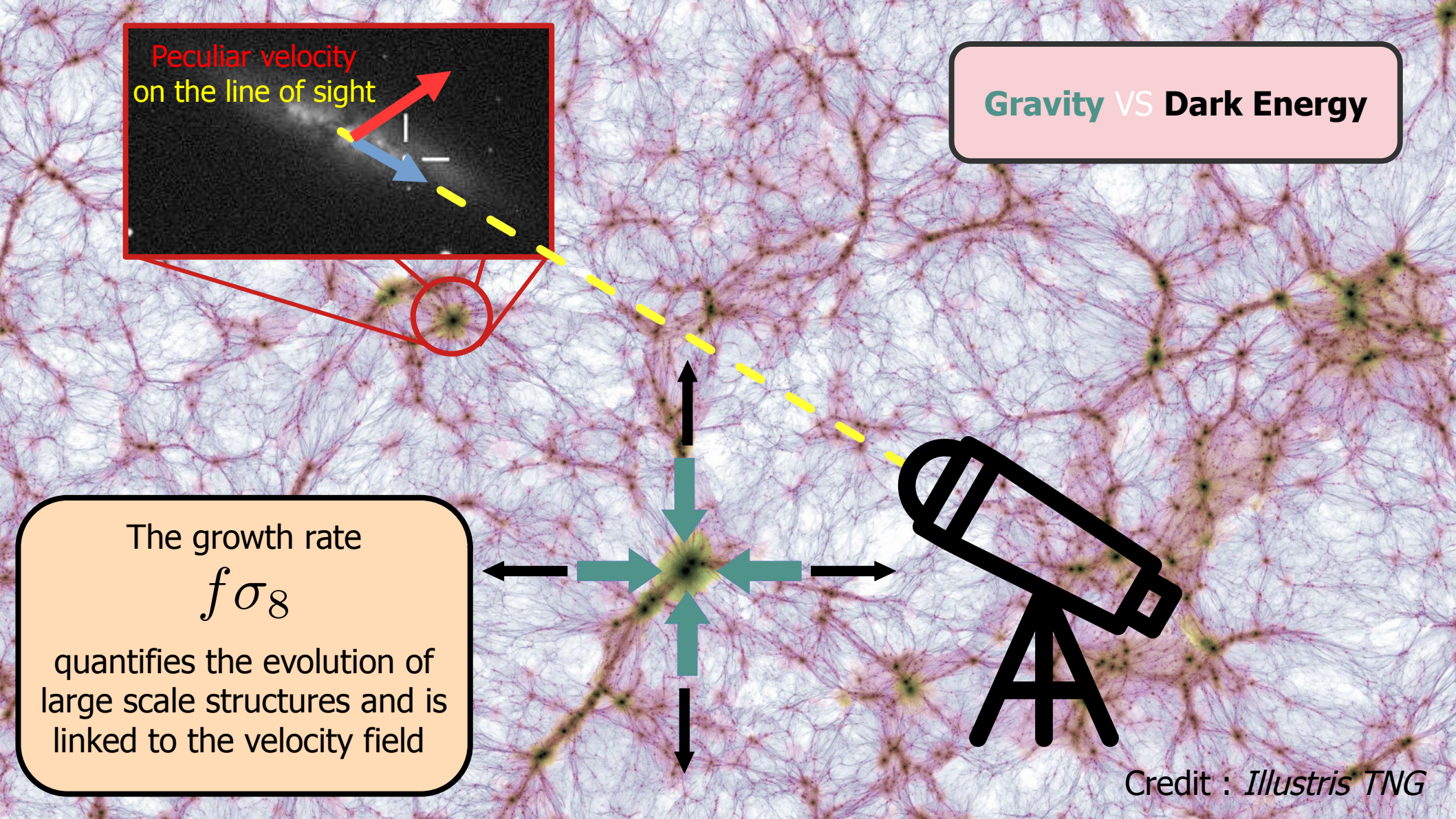
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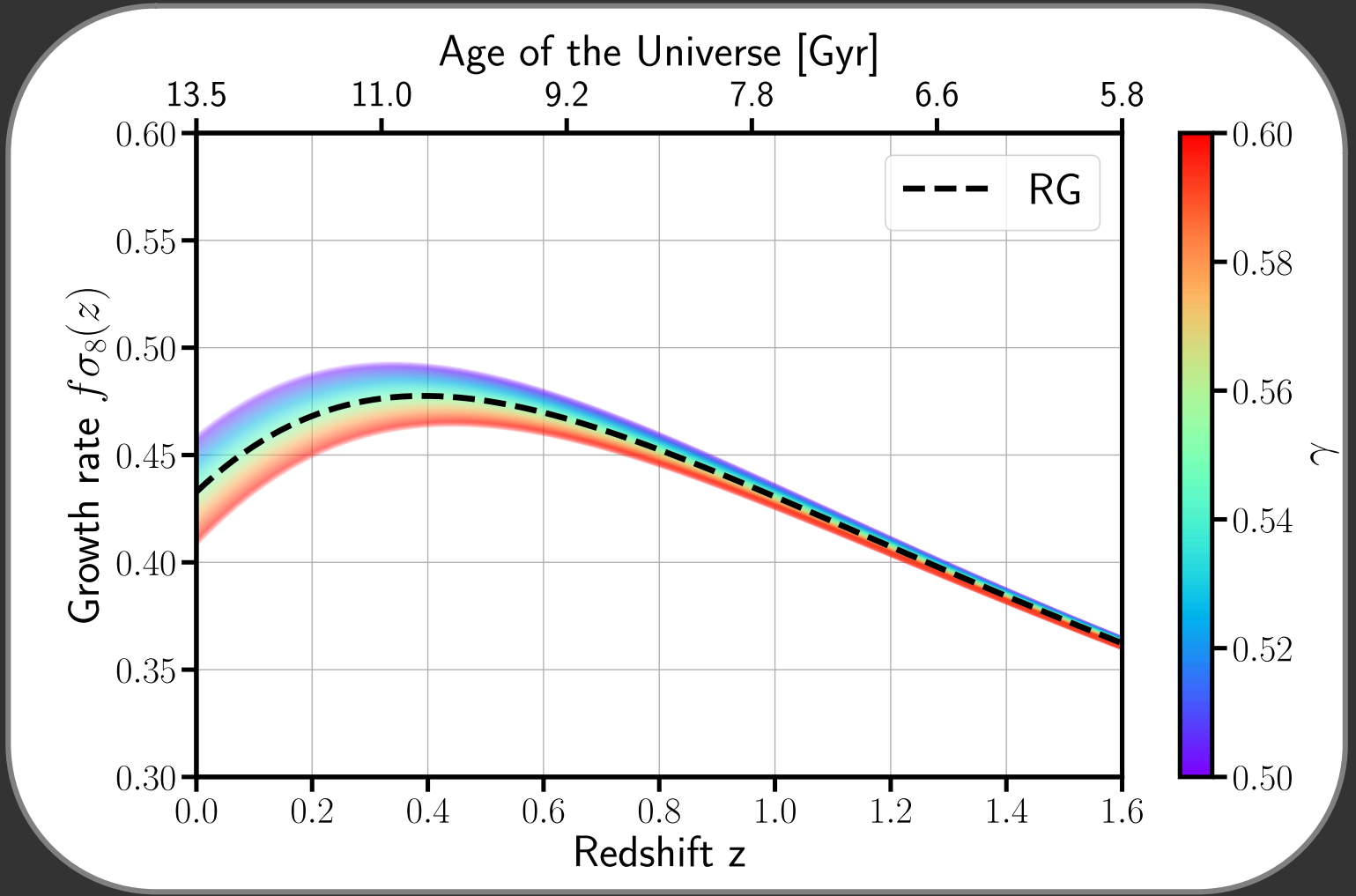
Gravity VS Dark Energy
The growth rate
$f\sigma_8$
quantifies the evolution of large scale structures and is linked to the velocity field
Credit : *Illustris TNG*

$f\sigma_8$: a probe of dark energy and general relativity

$$f\sigma_8 \simeq (1-\Omega_\Lambda)^\gamma$$

Ω_Λ
Dark energy density

γ
Gravitational growth index :
allows to quantify deviation to GR



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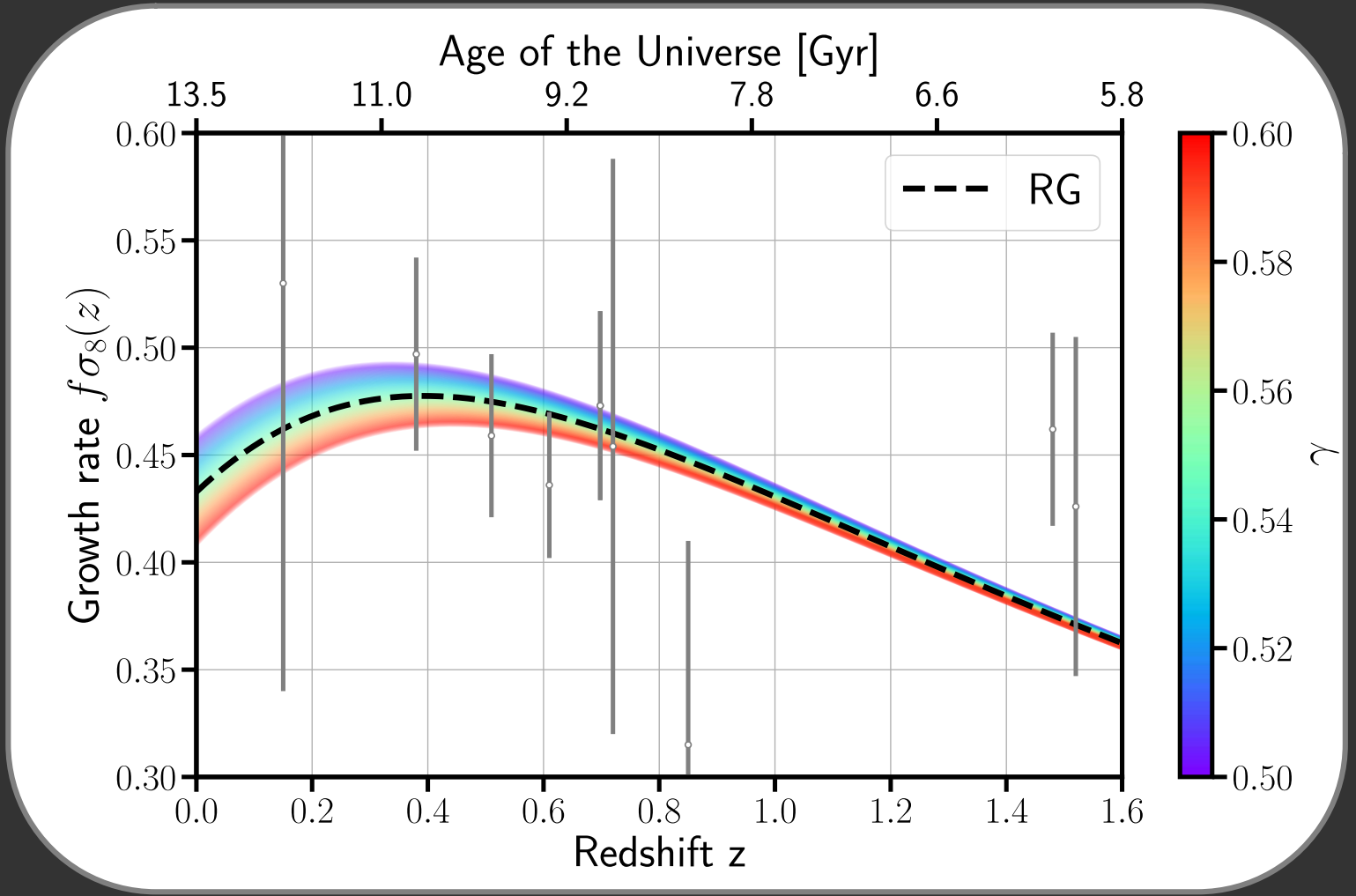

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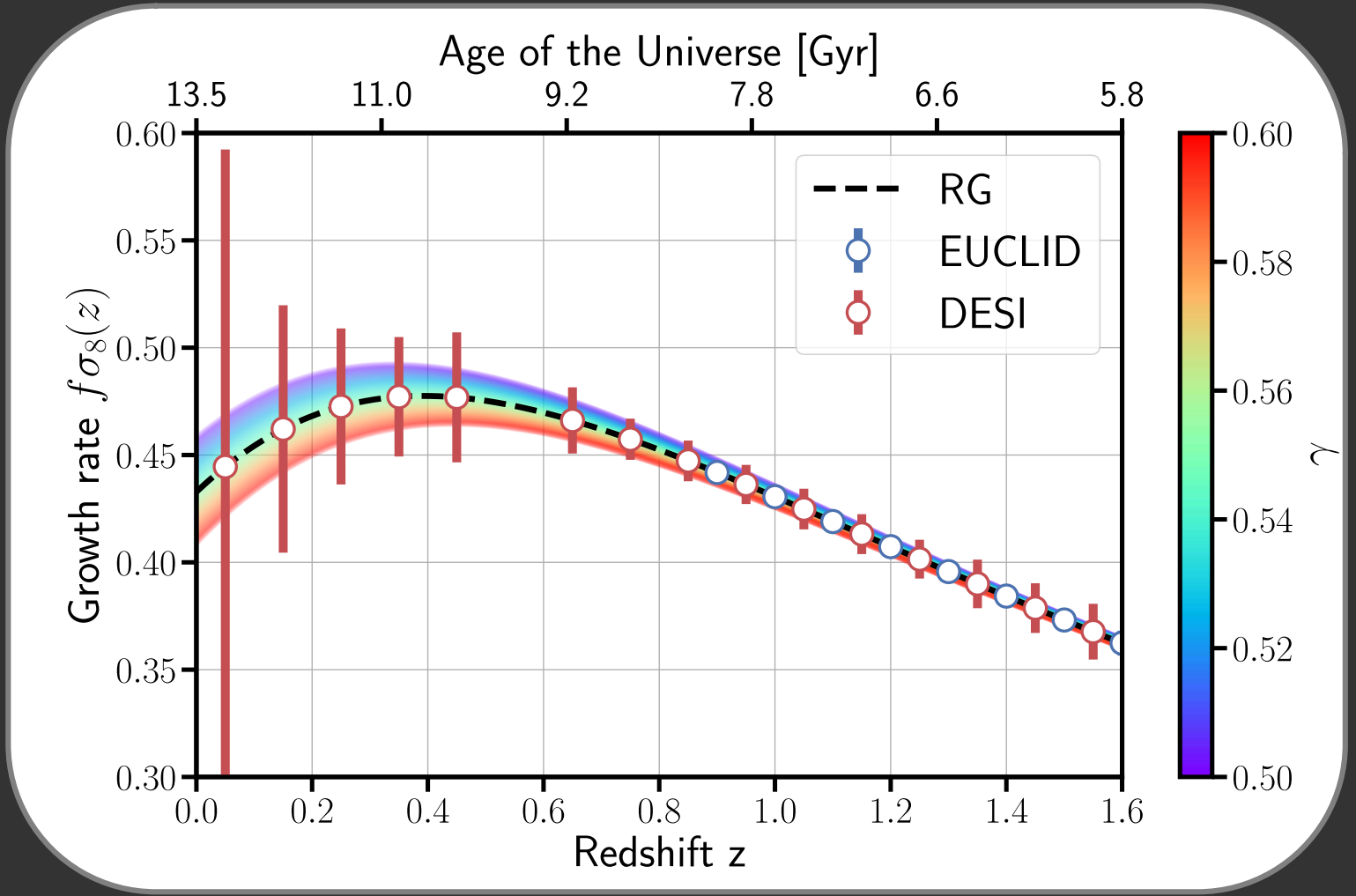

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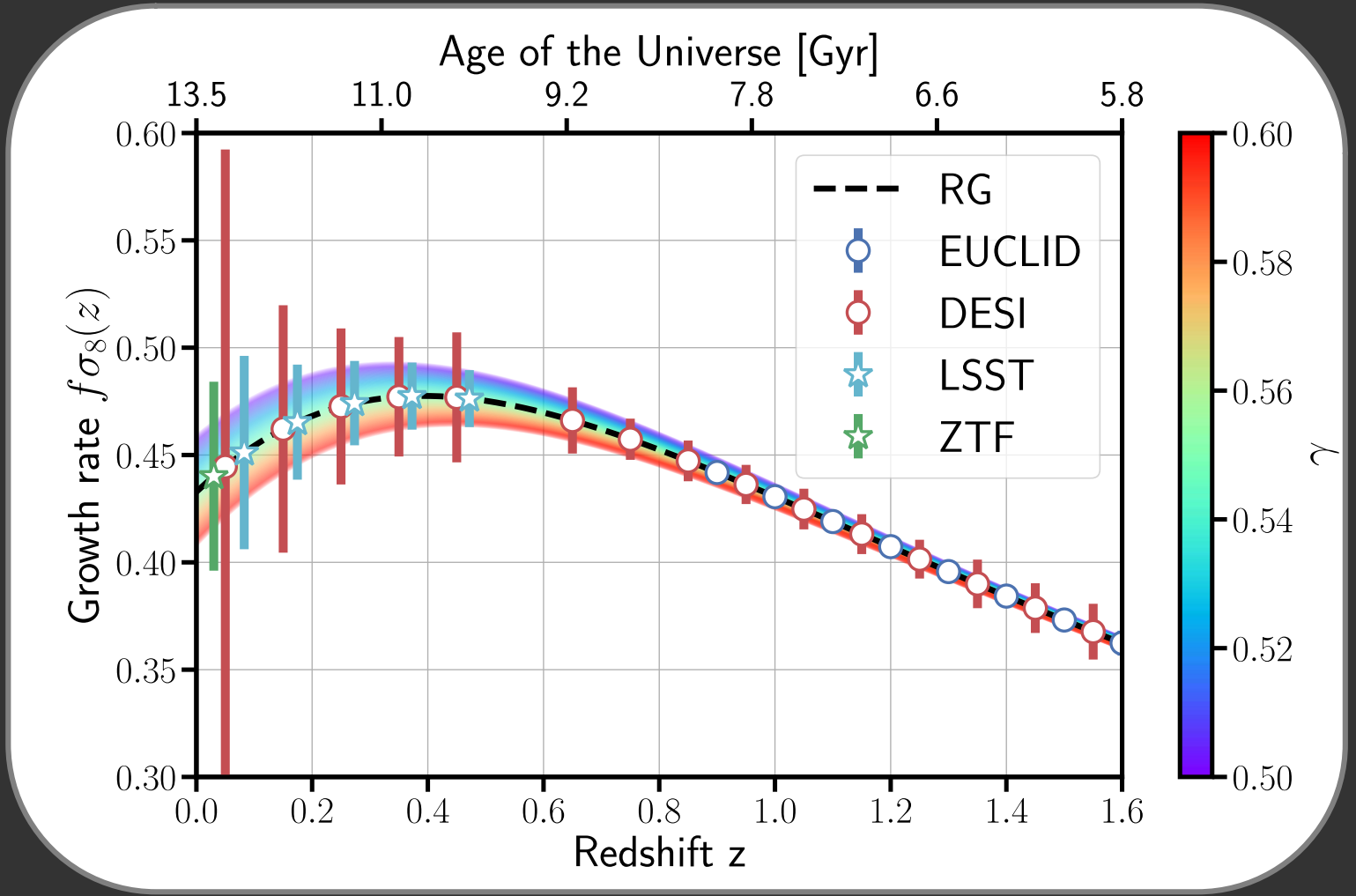

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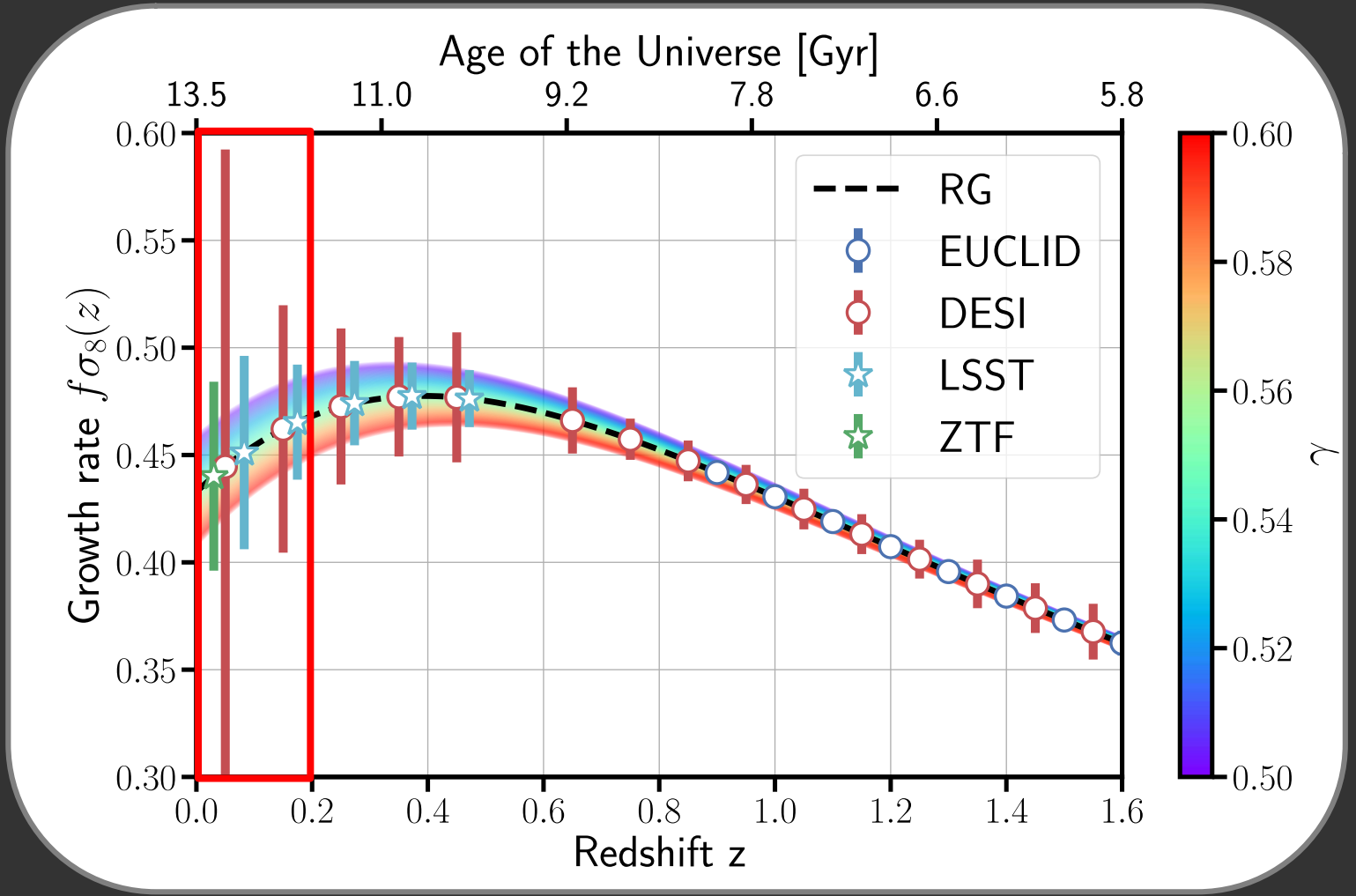

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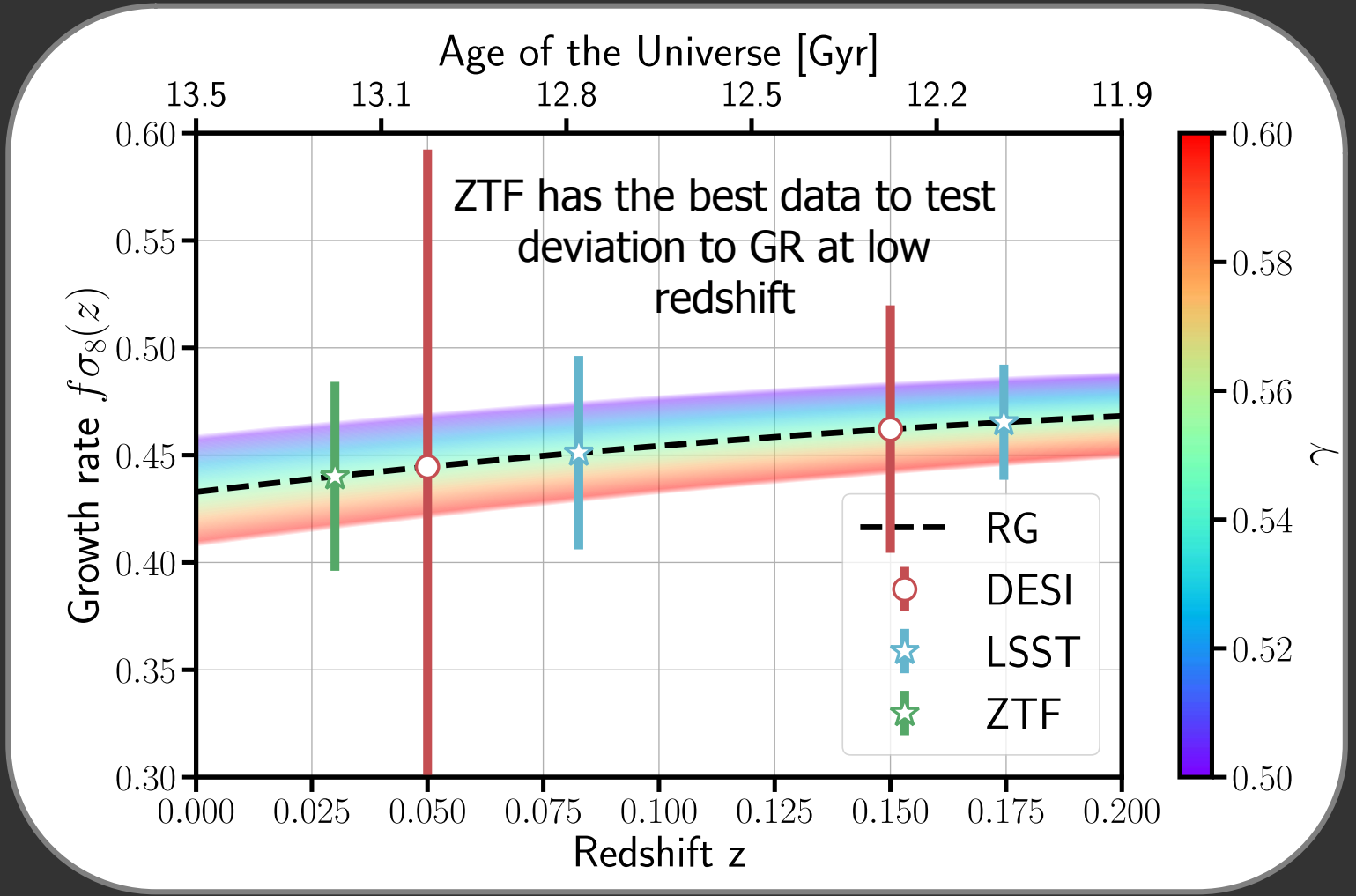

SN Ia : build the Hubble diagram

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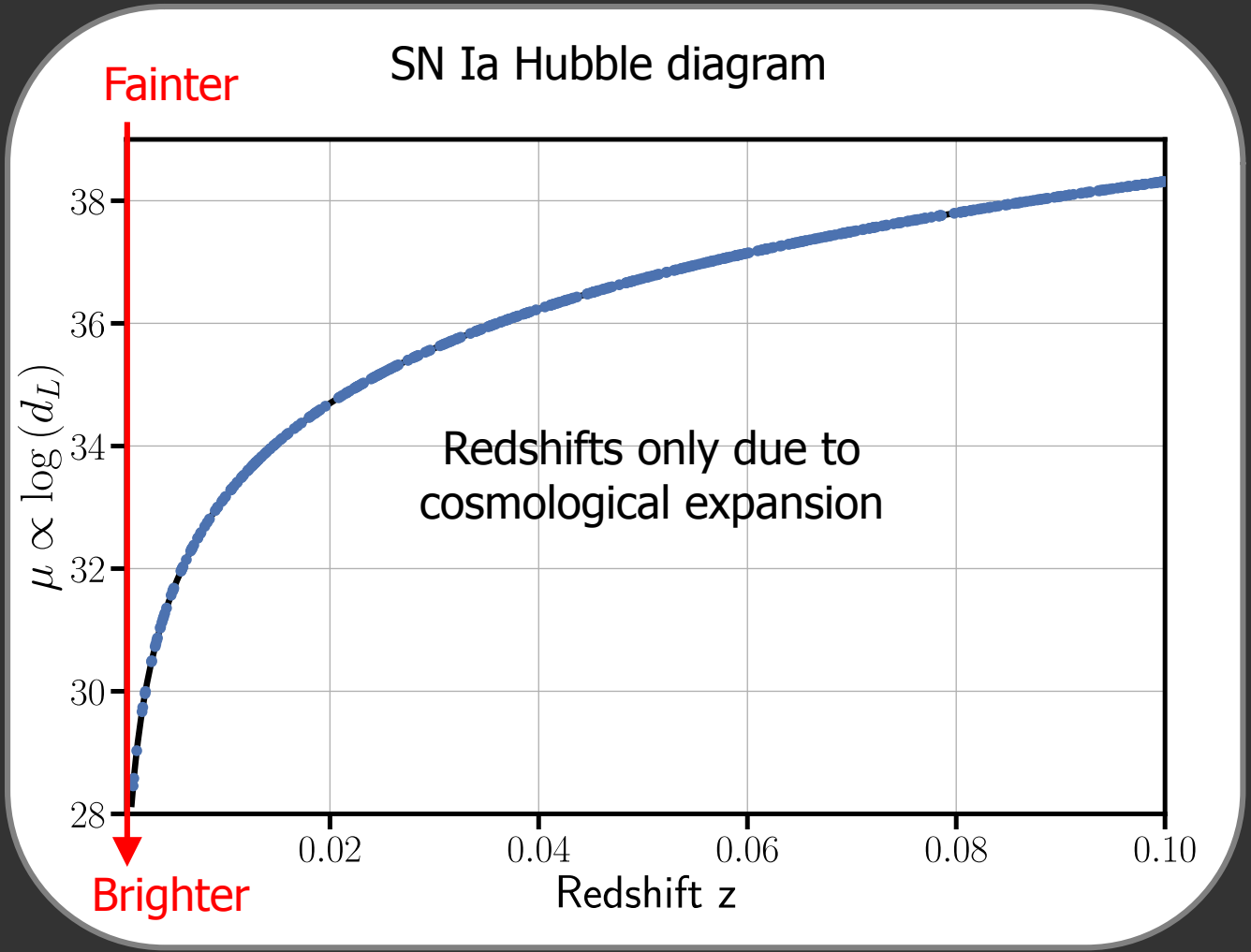

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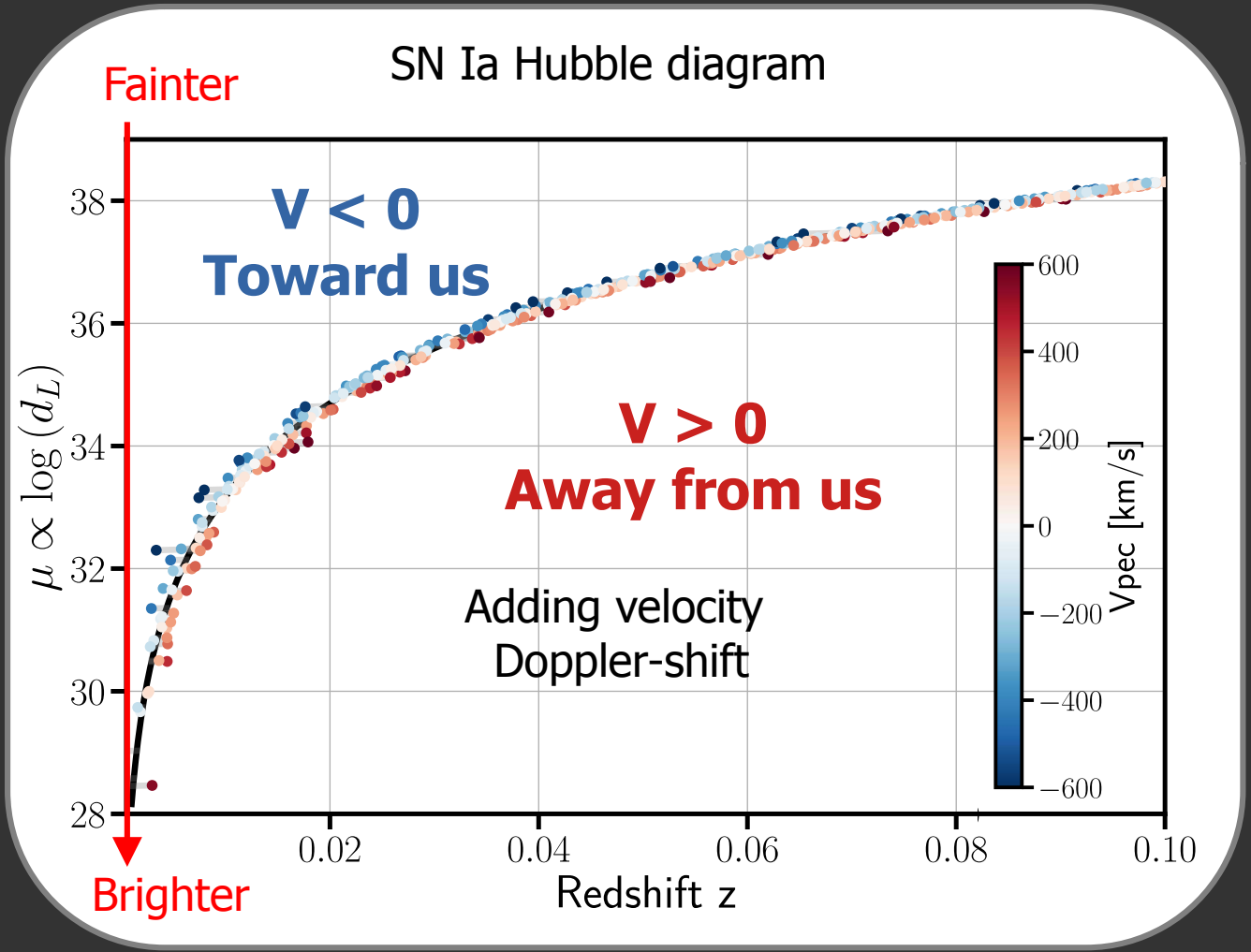

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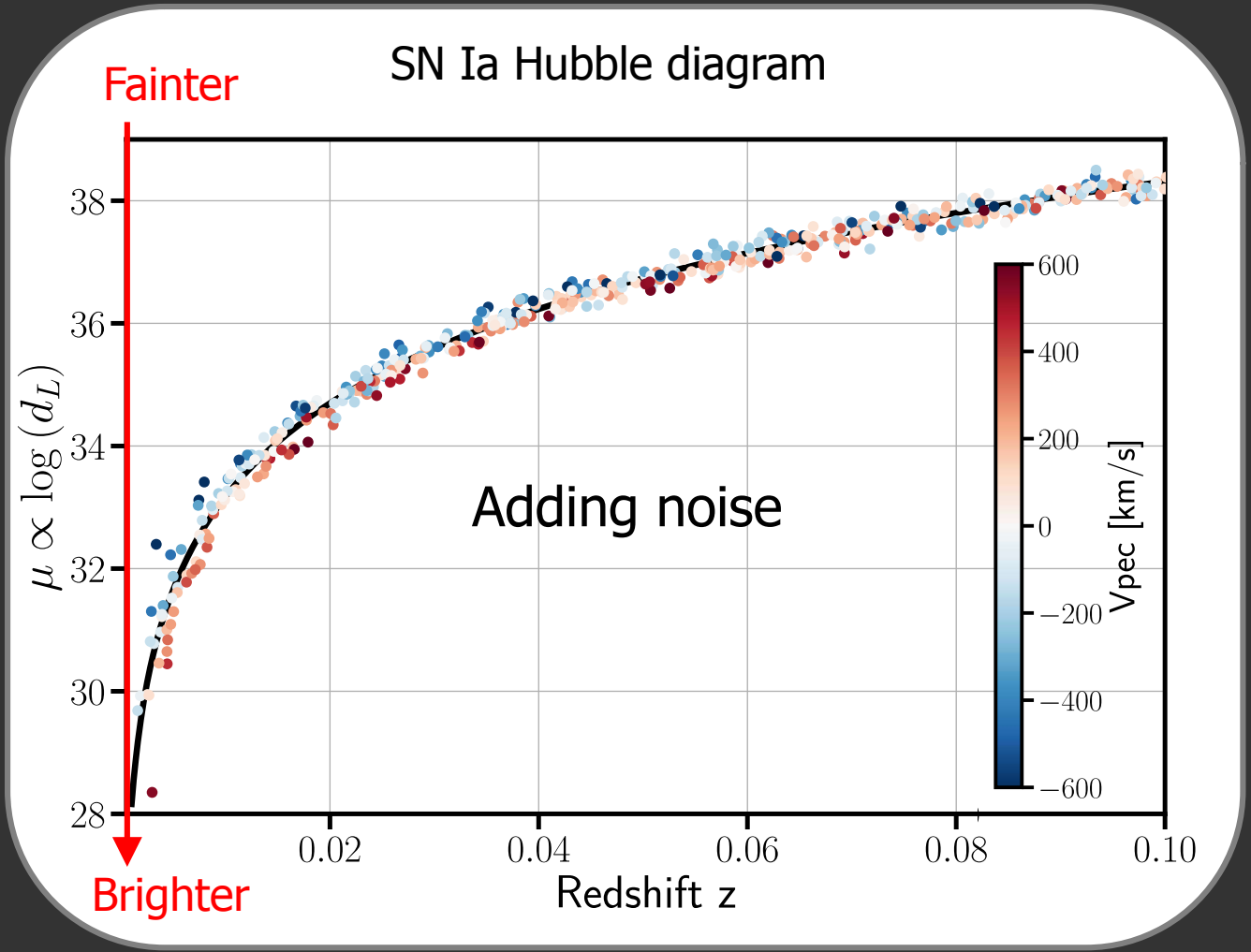
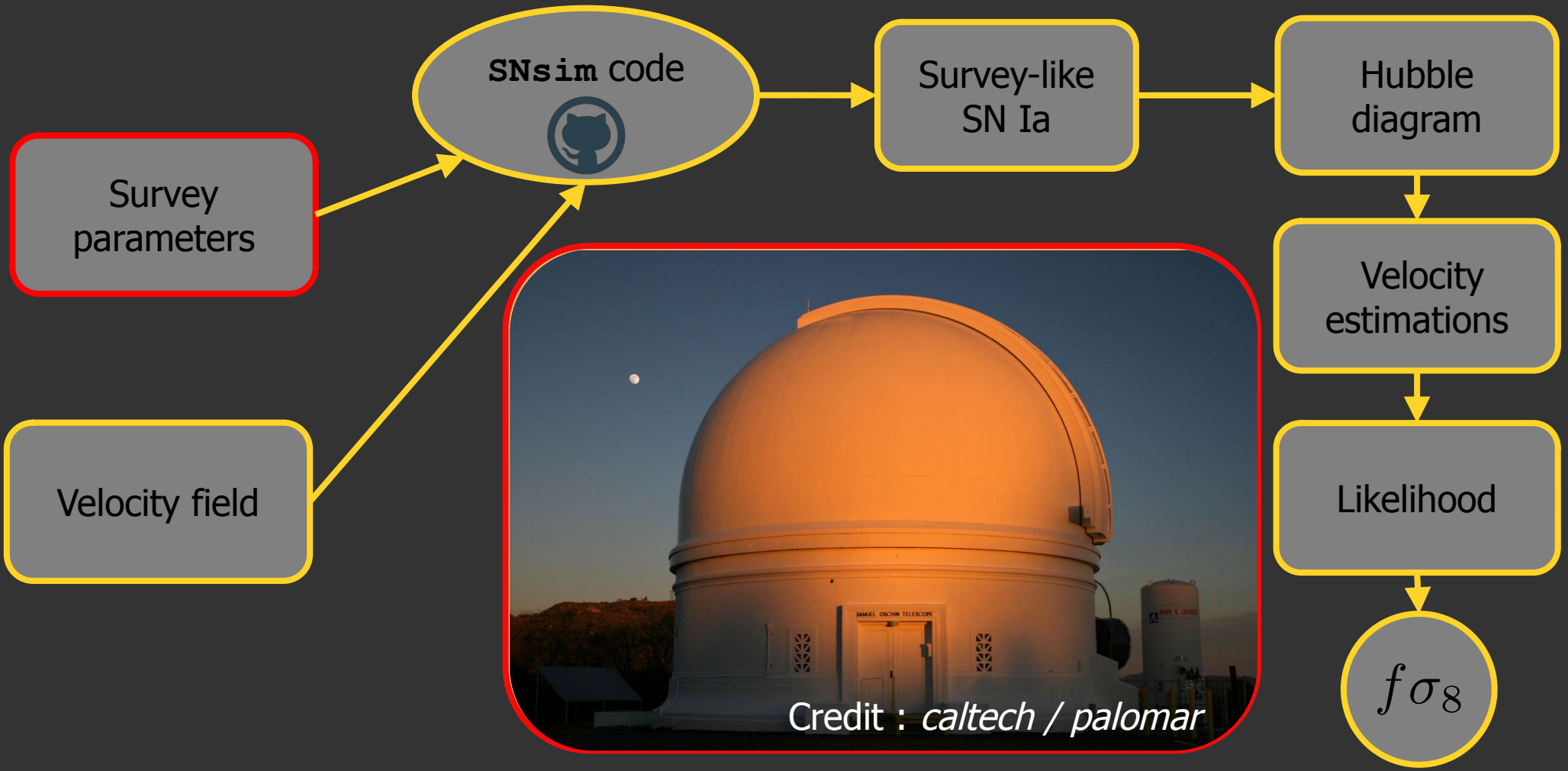


Using simulations to prepare the $f\sigma_8$ analysis



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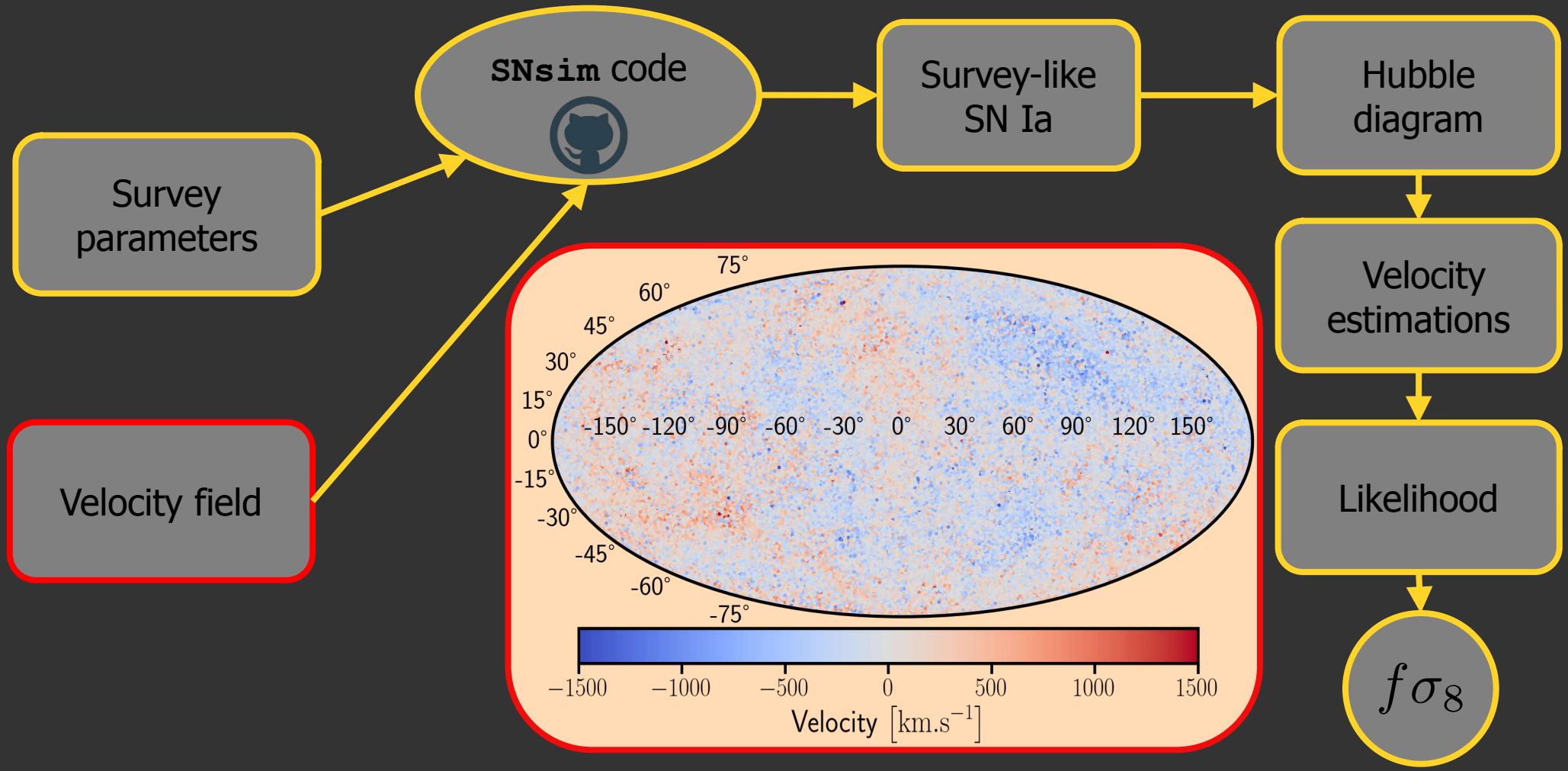

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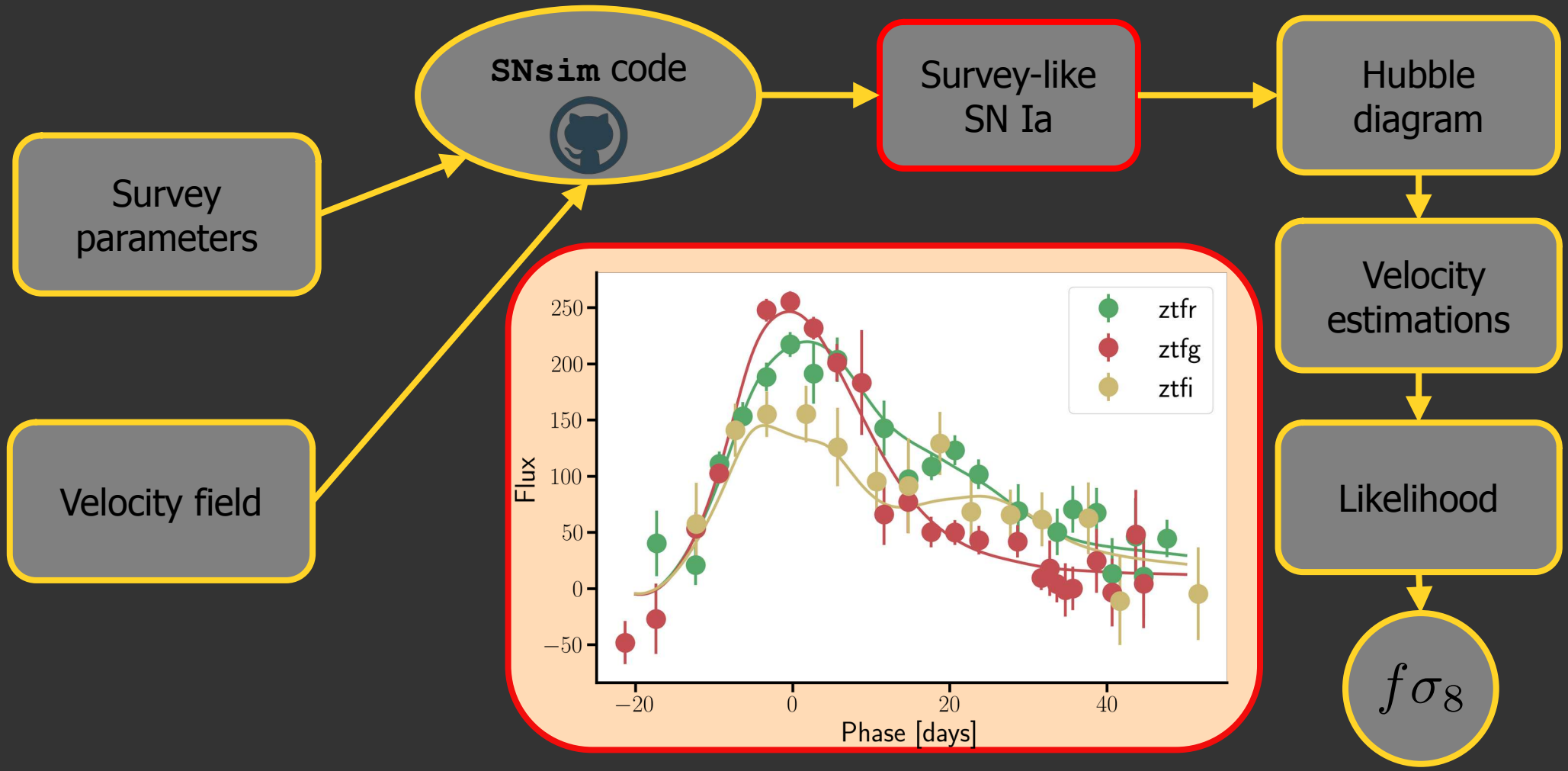

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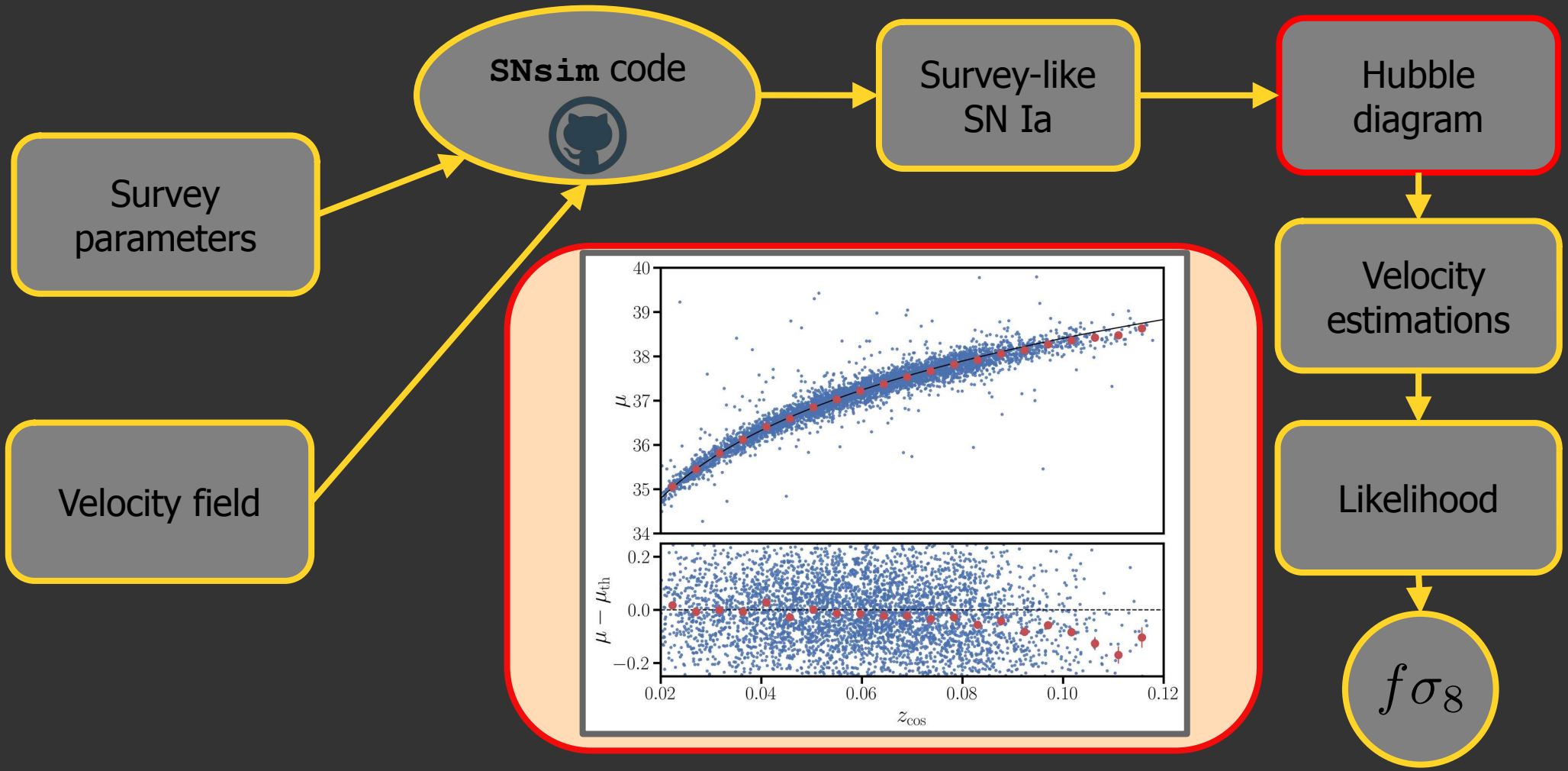

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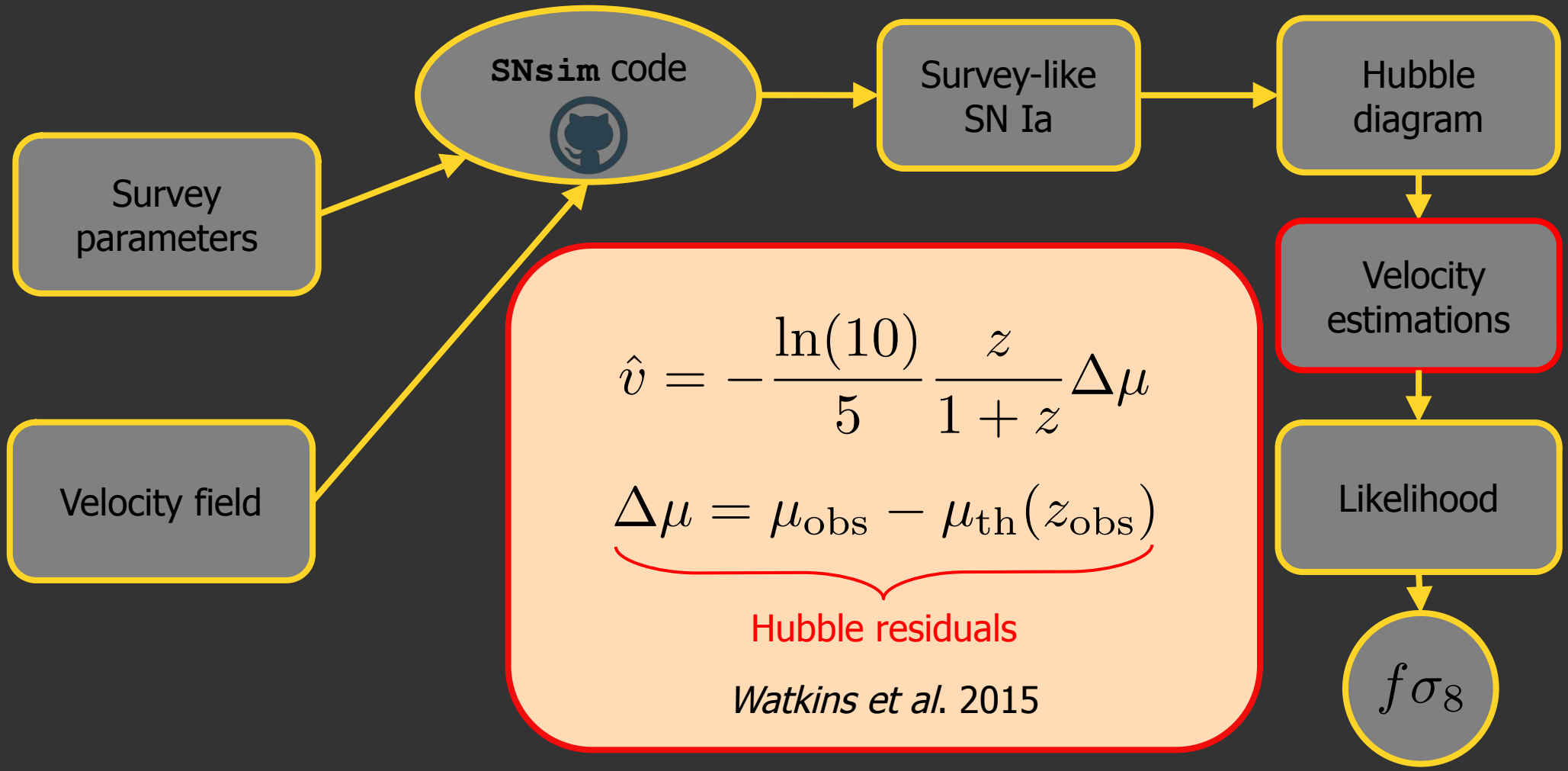

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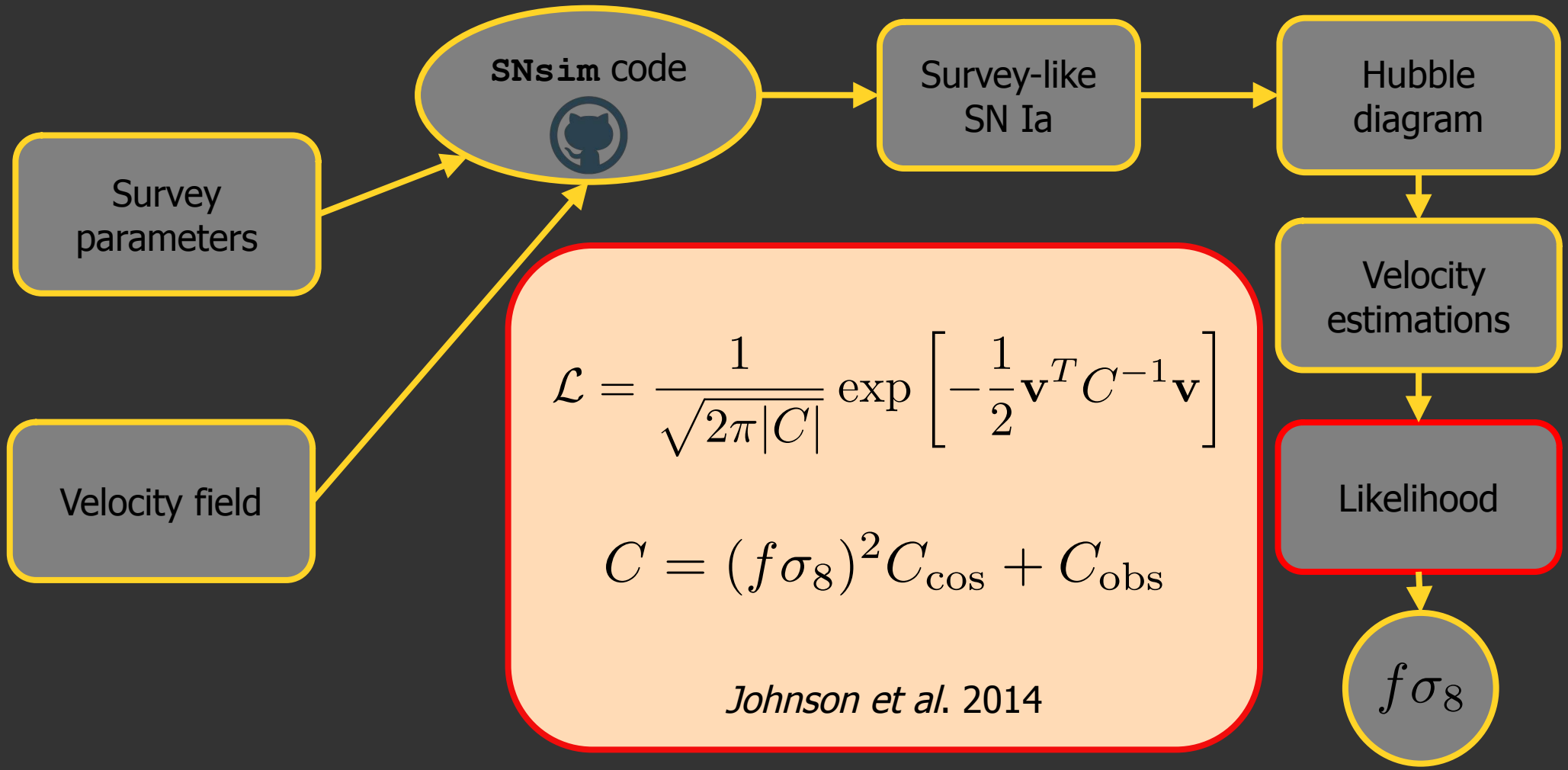
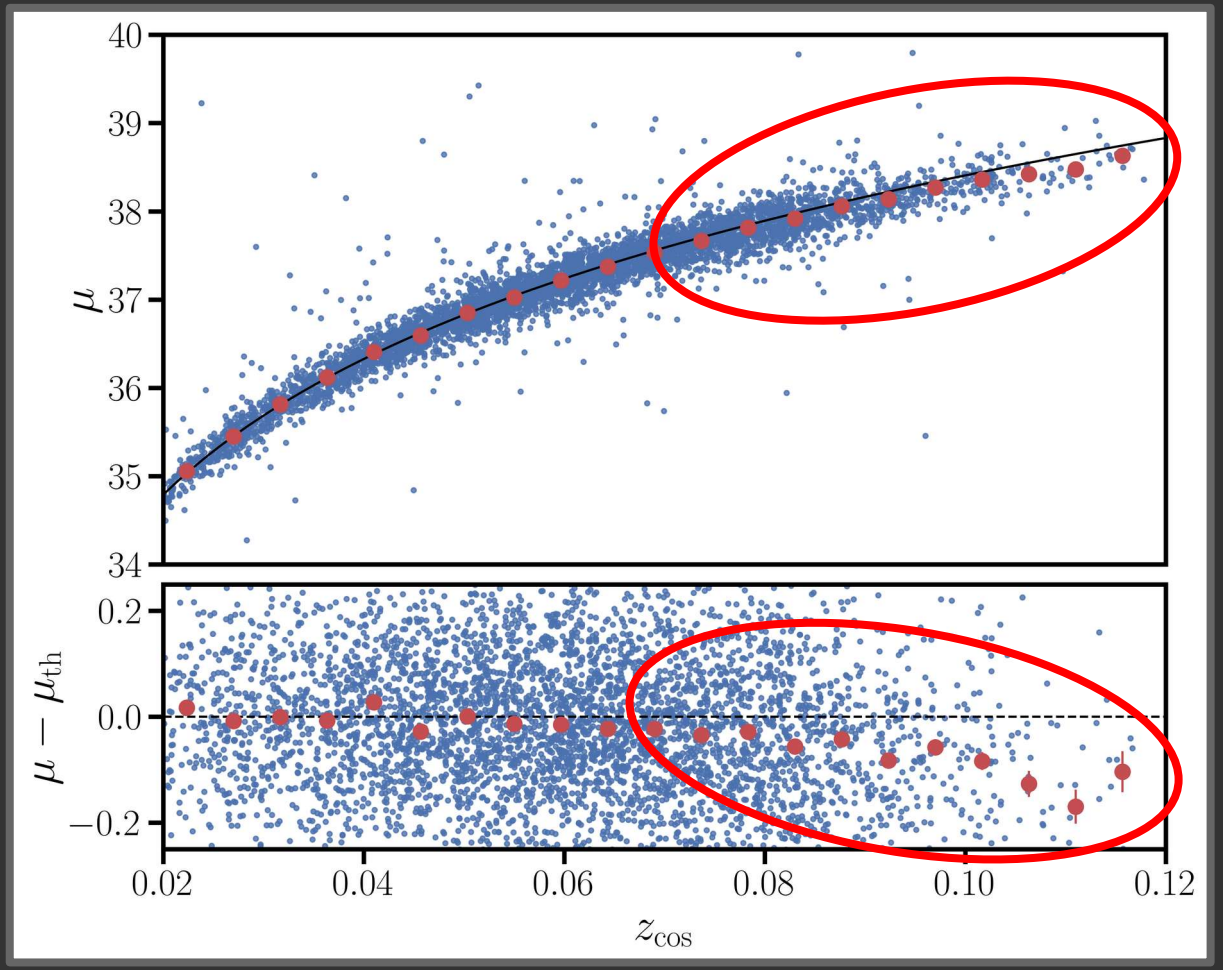


Example of bias : sample selection

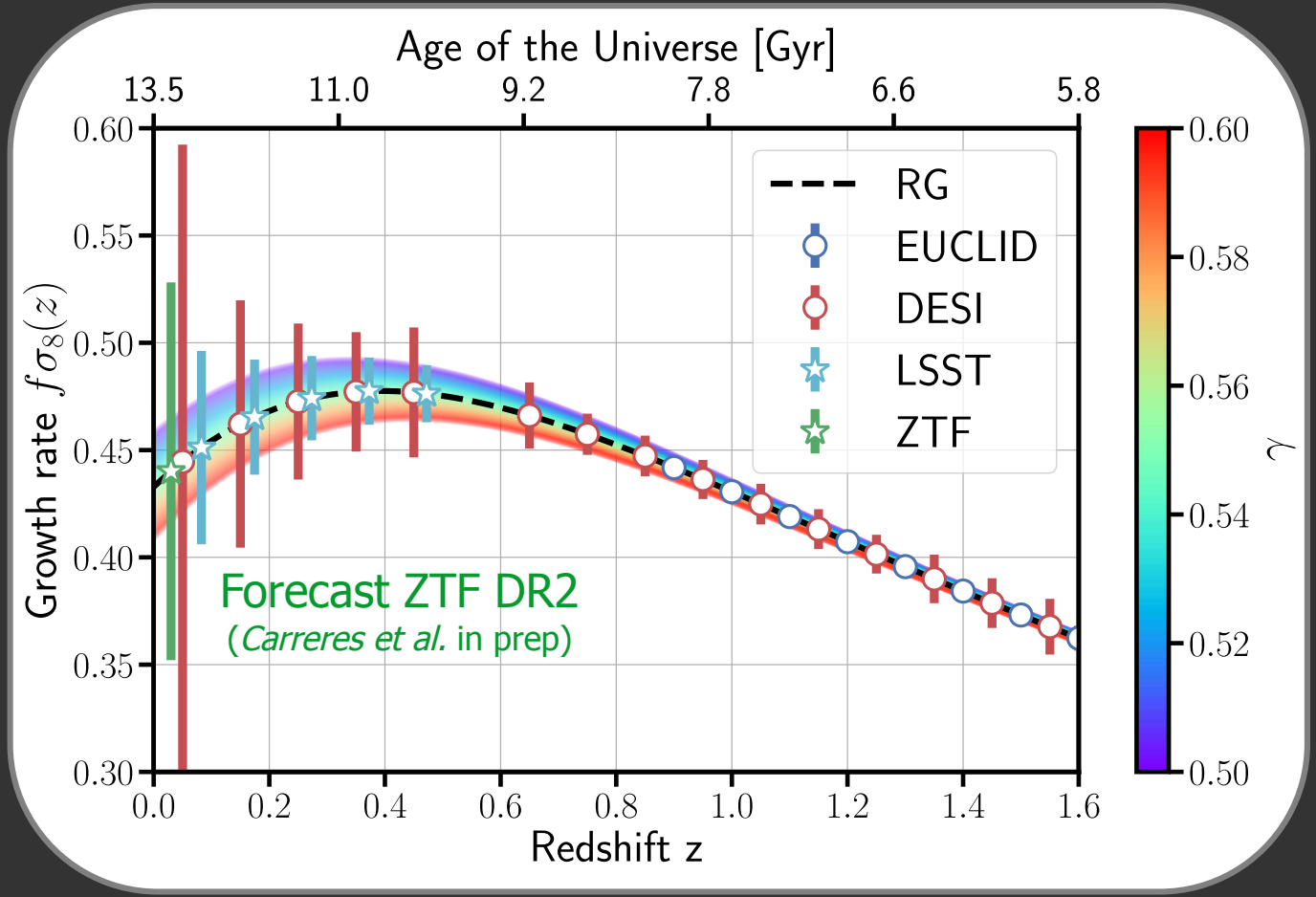
For distant objects only bright ones are detected, leading to a **selection bias**



The sample selection bias : growth rate results

Results for the **growth rate** :

- Bias appear when including SN Ia with a redshift z > 0.08
- For z > 0.08 the relative bias increase up to ~ 70 %
- With sample at z < 0.06 no bias and relative error of ~ 20 %



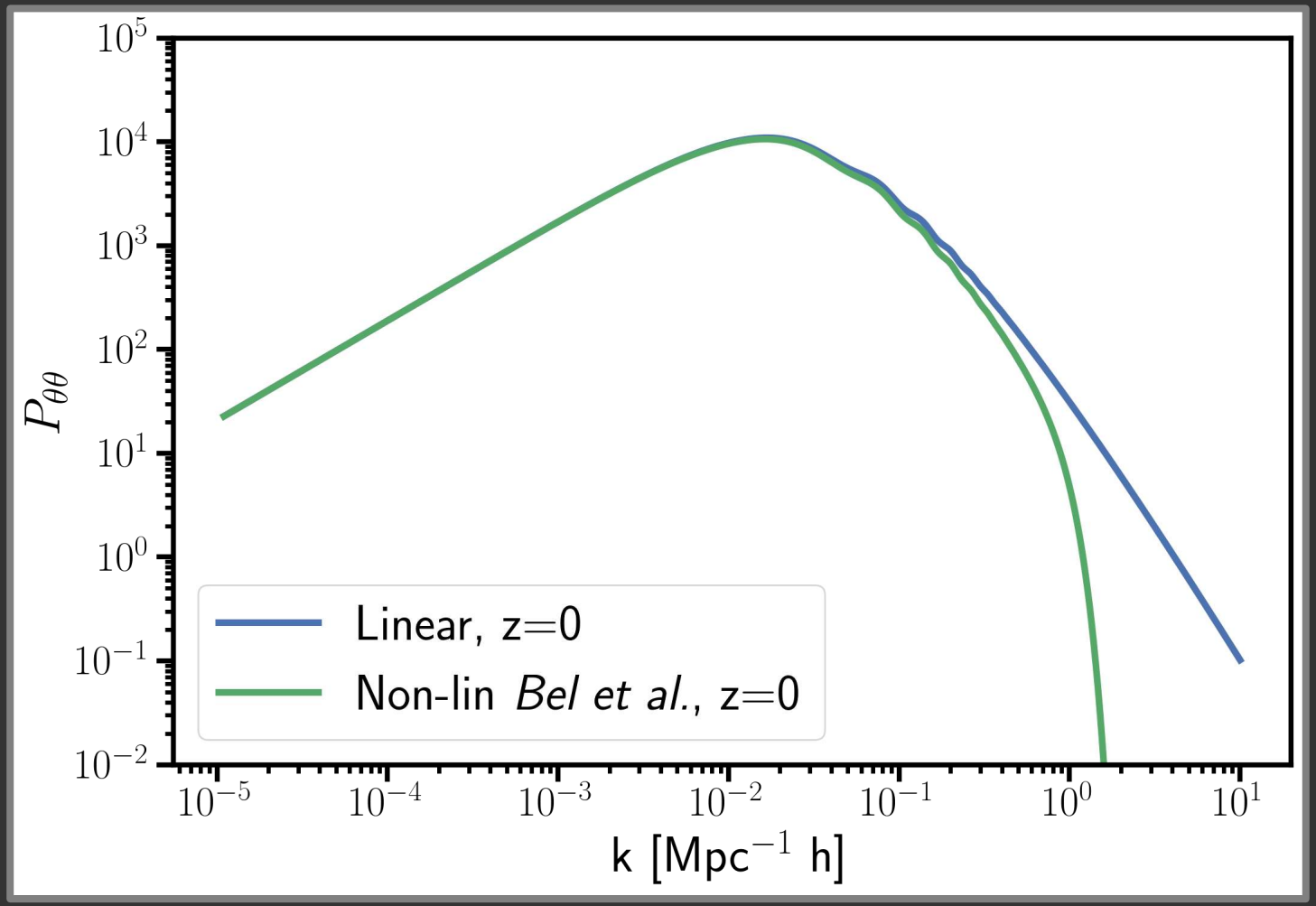
Conclusion

- The growth rate of structure $f\sigma_8$ is a good way to probe dark energy and deviation to GR
- SN Ia survey such as ZTF or LSST will allow to measure more precisely this parameter at low redshift, where the deviation is largest

Thank you for your attention

BACKUP

Power spectrum



Line of sight velocity covariance

$$C_{ij}^{vv} = \frac{(H_0 f \sigma_8)^2}{2\pi^2} \int P_{\theta\theta}(k) W_{ij}(k; \mathbf{r}_i, \mathbf{r}_j) dk$$

True velocities in simulated sample