Probing feedback with the shear-, magnitude-, and colour-position correlation functions

Project F6, SFB1491

Angus H Wright, 02-06-22

GCCL
GERMAN CENTRE FOR COSMOLOGICAL LENSING

RUB

erc
European Research Council
Established by the European Commission

DFG Deutsche Forschungsgemeinschaft

CIM Research Questions

Research question (3): What are the connections between the cosmic signatures of baryonic and dark matter, moving down to the lowest halo masses and out to large galactocentric distances?

Project F6: Dark Matter & Gas in Galaxies

The Work Plan

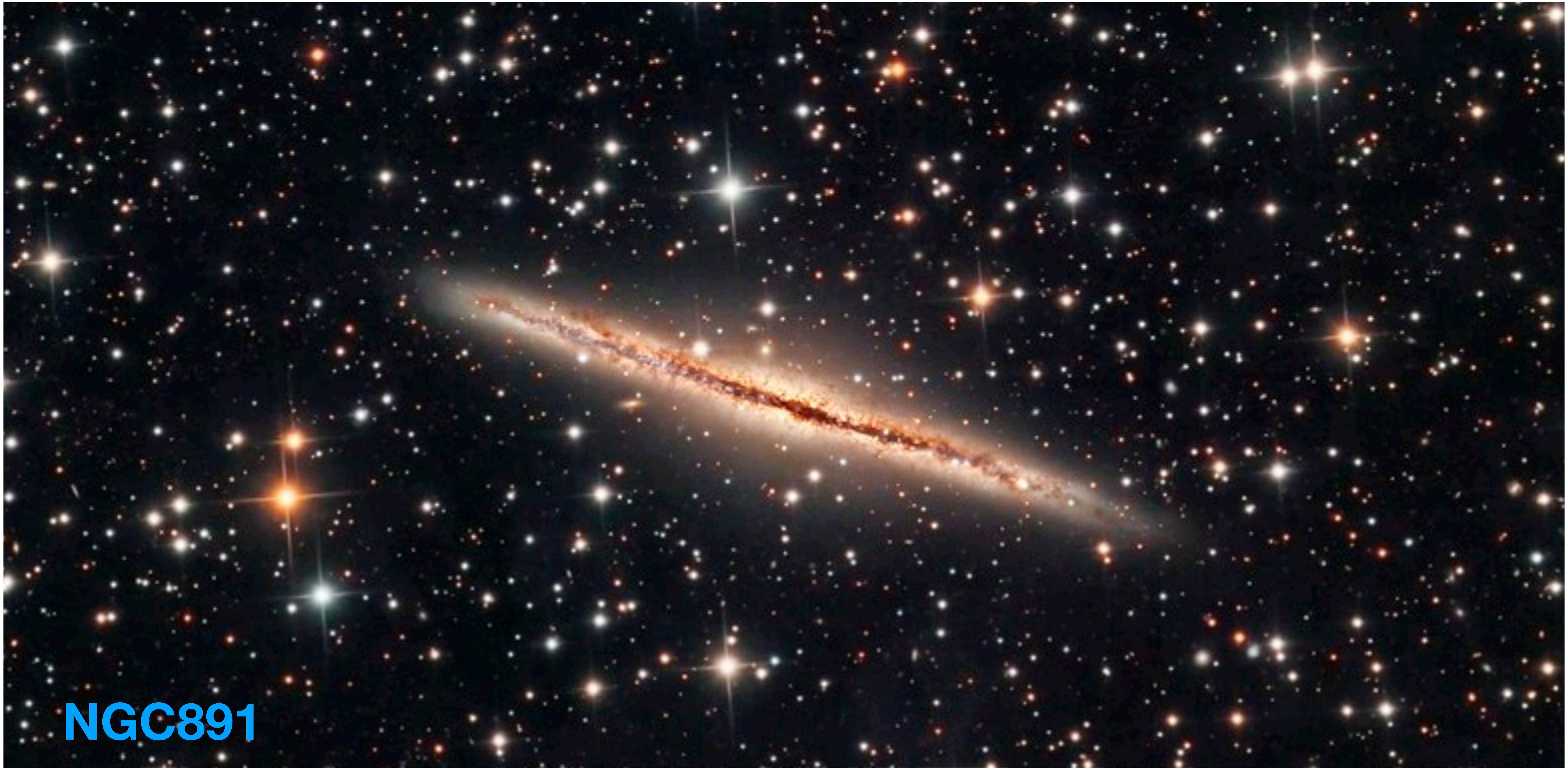
- i) Perform a base-line study of the 100 largest edge-on galaxies (in terms of angular extent on-sky) in existing imaging data from KiDS to determine **the profile and extent of dust** in low-redshift galaxy halos. **[Standard-Crayons]**

- ii) Improve the Ménard et al. (2010) experiment with photometrically selected background galaxies, allowing for better spatial resolution and for us to split the foreground galaxies by star-formation properties, thereby allowing **investigation into the origin and transport mechanism of the dust** [Correlation Functions]

- iii) Determine the ratio of dark to visible matter in low-mass, strongly star-forming, and post-starburst galaxies, and **how this ratio evolves as a function of redshift** and intrinsic galaxy properties such as stellar mass **[Mass-to-Light Ratios]**

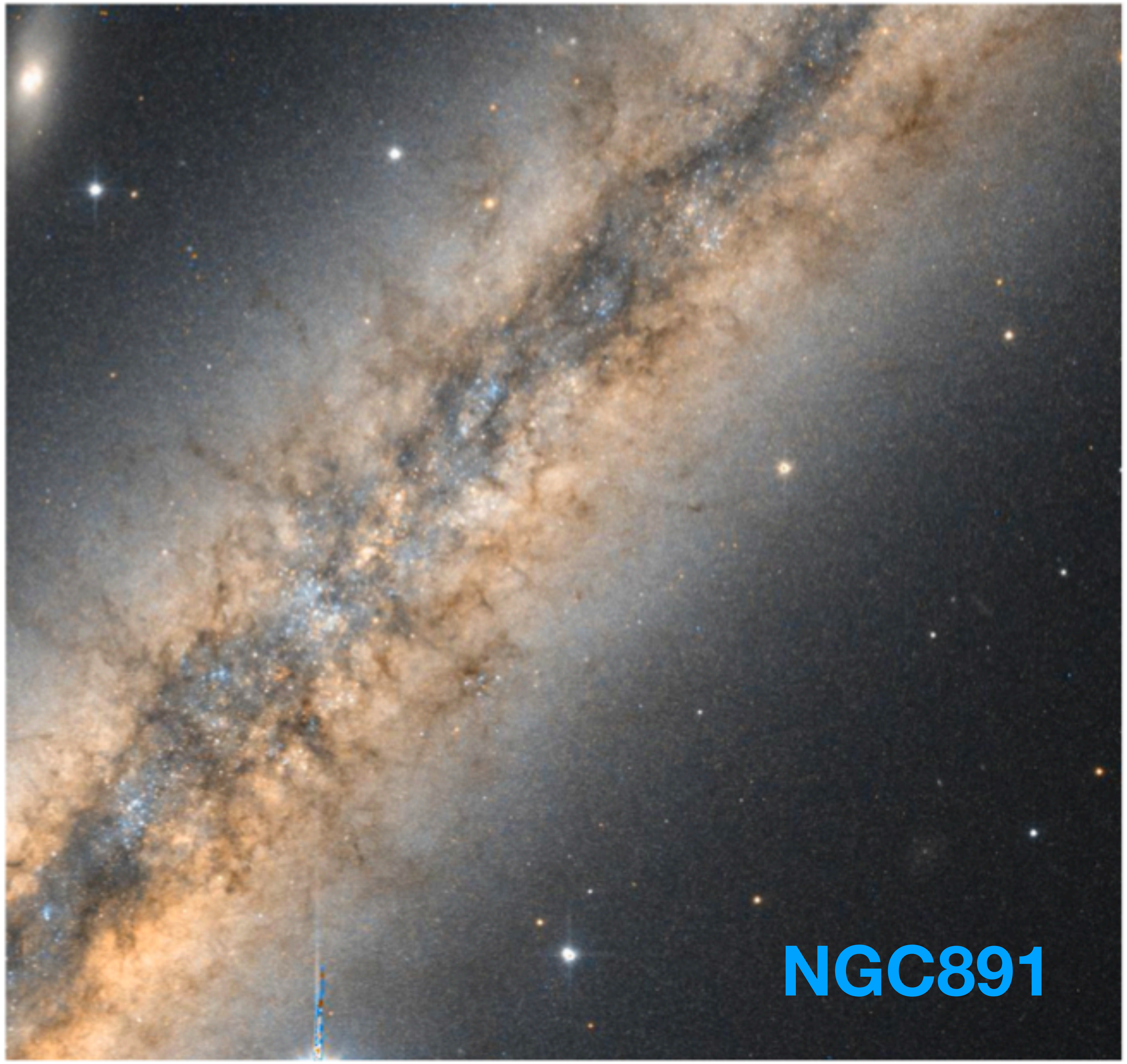
- iv) **Measure the asphericity of dark-matter halos** compared to the galaxy light and satellite galaxy distribution by GGL in comparison to the extent and projected shape of gaseous halos of galaxies **[Axially Asymmetric Galaxy-Galaxy Lensing]**

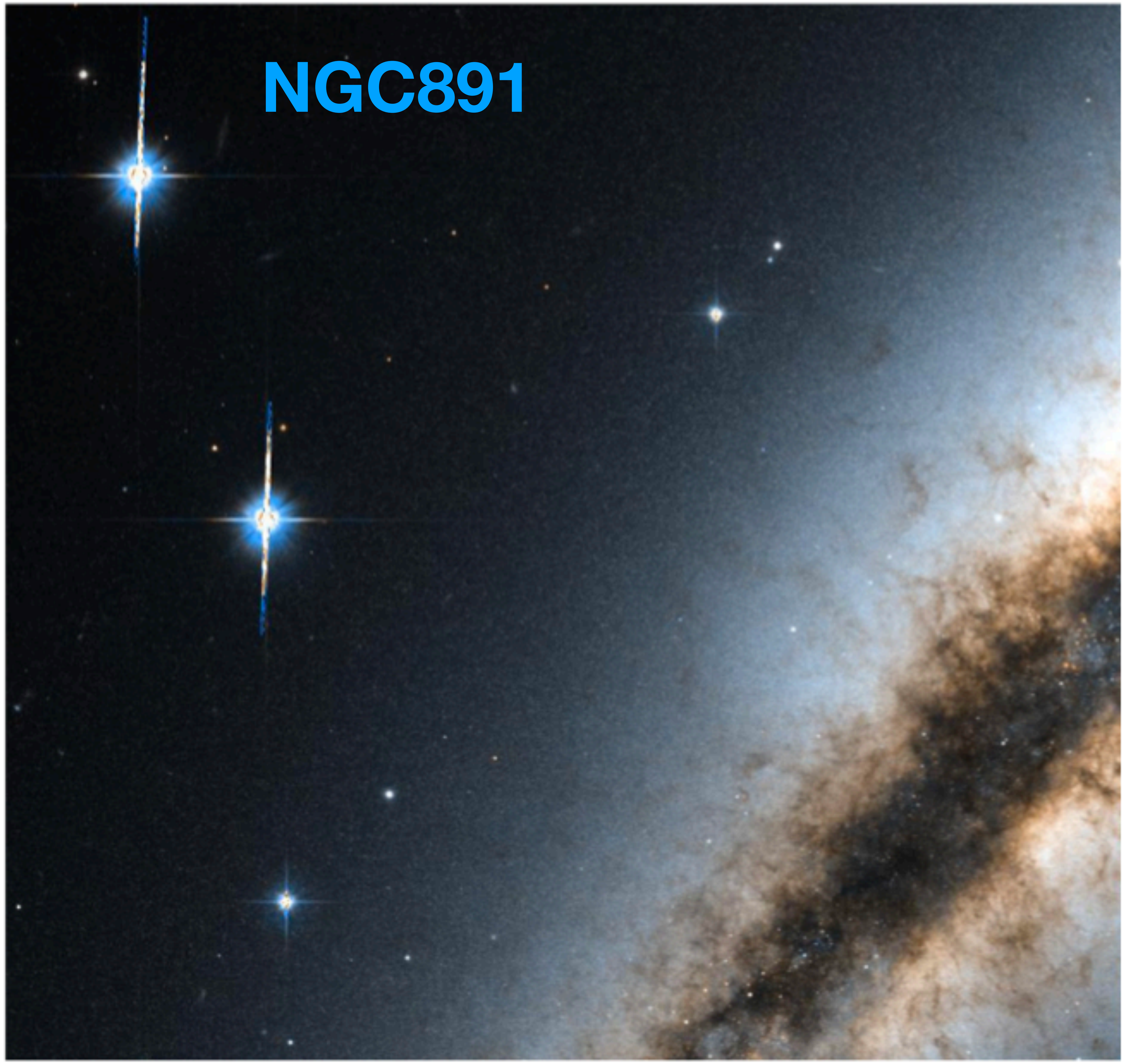
Dust is a tracer of ejected halo baryons



Credit: Paddy Gilliland 2016

Dust is a tracer of ejected halo baryons





Measuring Feedback with Galaxy Surveys

Using 3 cross-correlation functions

The goal is to measure the distribution of dust in the halo of dwarf galaxies, as a proxy for the overall baryonic mass distribution of the halo.

To do this, we need to know:

1. the total (i.e. dark + baryonic) mass of the galaxies, and
2. the distribution function of baryons and dark matter (i.e. the profiles)

Shear-Position Correlation:

- Sensitive to Total Mass

Magnitude-Position Correlation:

- Sensitive to Total Mass & Dust

Colour-Position Correlation:

- Sensitive to Dust

Multi-probe analyses can help to break degeneracies and constrain parameters further/better.

The [Something]-Position Correlation Function

Calculating joint variation in observables

- In statistics, the **X-Y correlation** describes the amount of mutual information contained in the two variables **X** and **Y**

- In astronomy, the **X-Y correlation function** describes the change in the X-Y correlation as a function of spatial separation (either angular or physical)

- Auto-correlations are very powerful tools (i.e. **X-X correlation functions**)
    - ➡ Shear-Shear correlation function (“cosmic shear”)
    - ➡ Position-Position correlation function (“galaxy clustering”)
    - ➡ Magnitude-Magnitude correlation function
    - ➡ Colour-Colour correlation function

The [Something]-Position Correlation Function

Calculating joint variation in observables

- In statistics, the **X-Y correlation** describes the amount of mutual information contained in the two variables **X** and **Y**

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- Auto-correlations are very powerful tools (i.e. **X-X correlation functions**)

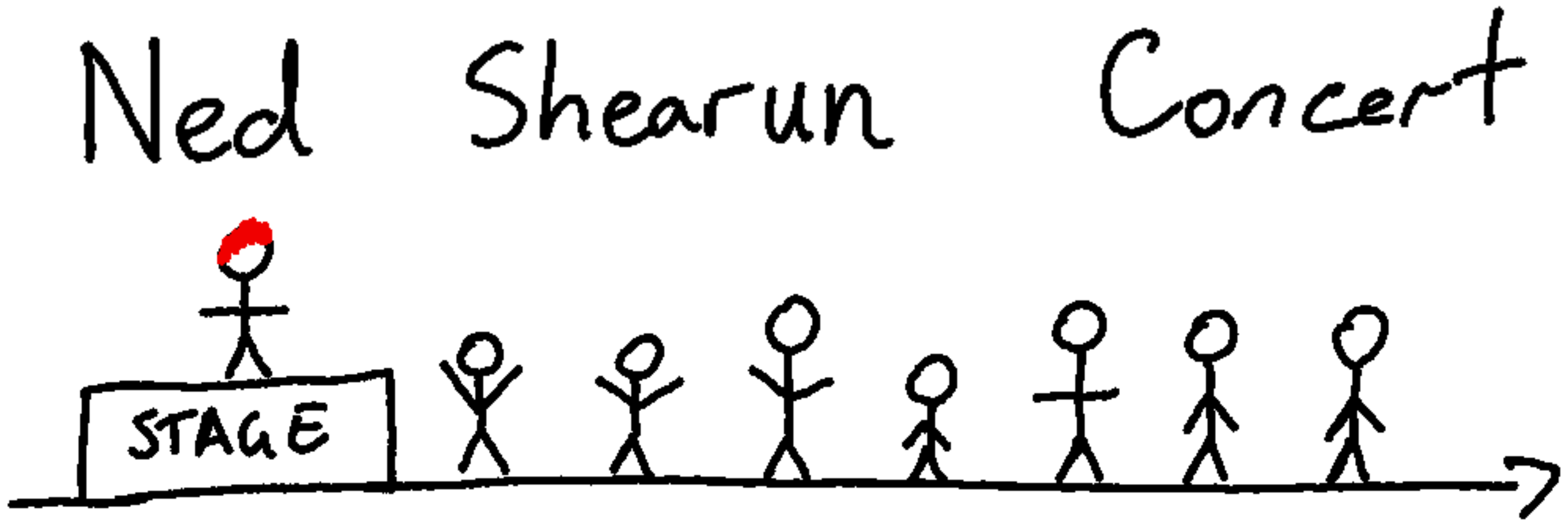
- But for this talk we're exclusively going to focus on 3 **cross-correlations:**
    - ➡ The **Shear-Position** correlation function ("galaxy-galaxy lensing")
    - ➡ The **Magnitude-Position** correlation function
    - ➡ The **Colour-Position** correlation function

The Enjoyment-Position Correlation Function

A simple example

- Consider a totally hypothetical concert, given by a totally hypothetical artist
- In this concert, we can use the audience to calculate the:

Enjoyment-Position Correlation Function



The Enjoyment-Position Correlation Function

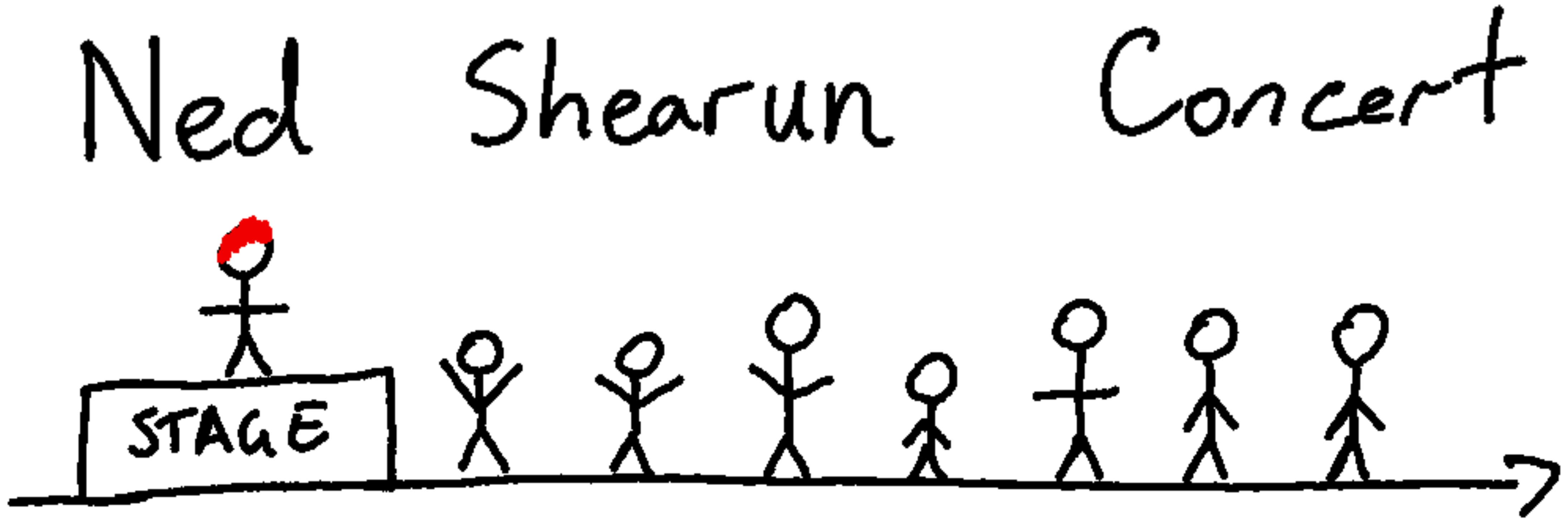
A simple example

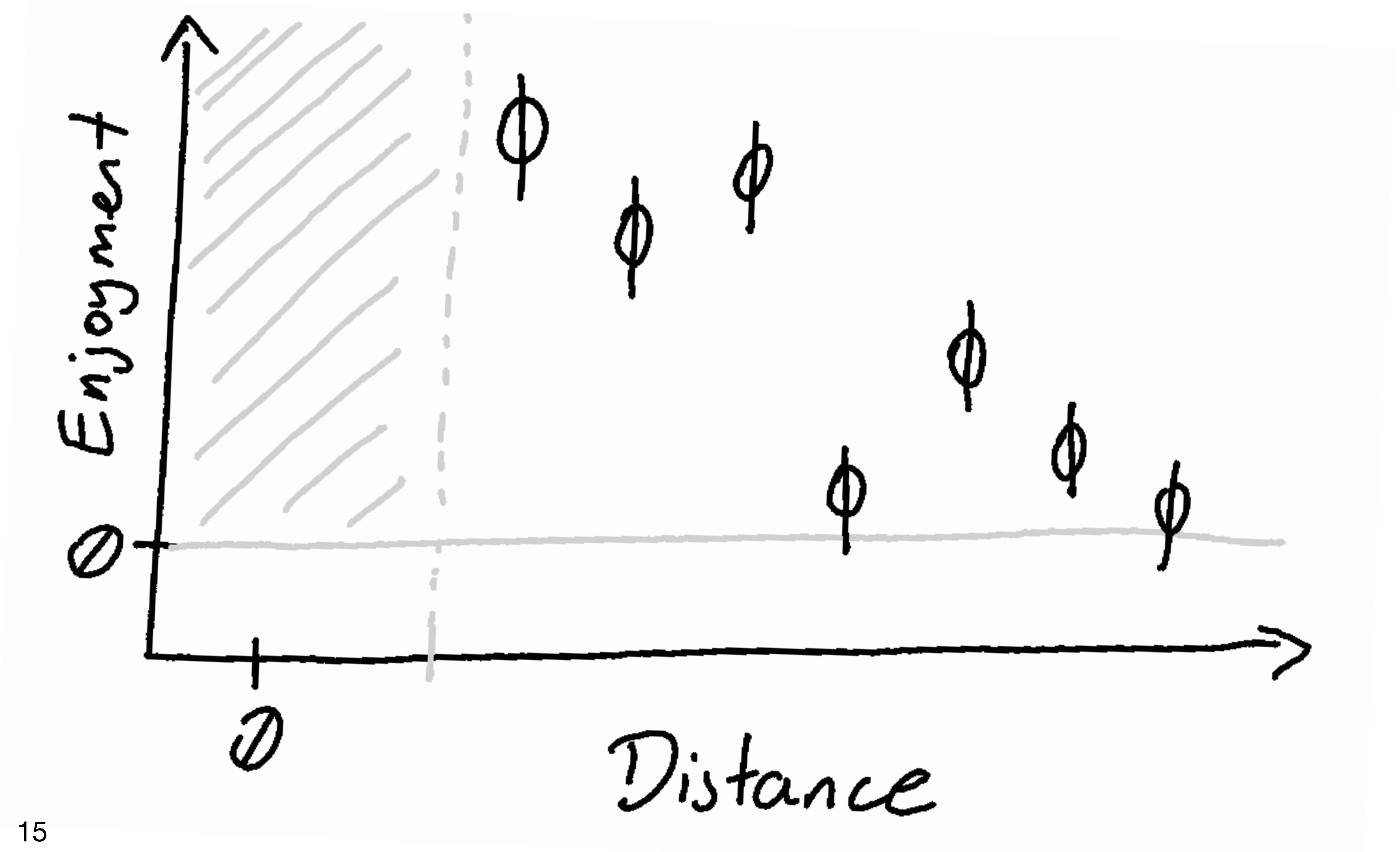
- Consider a totally hypothetical concert, given by a totally hypothetical artist

- In this concert, we can use the audience to calculate the:

Enjoyment-Position Correlation Function

- There is a strong signal, and we could use this signal to infer details about the concert

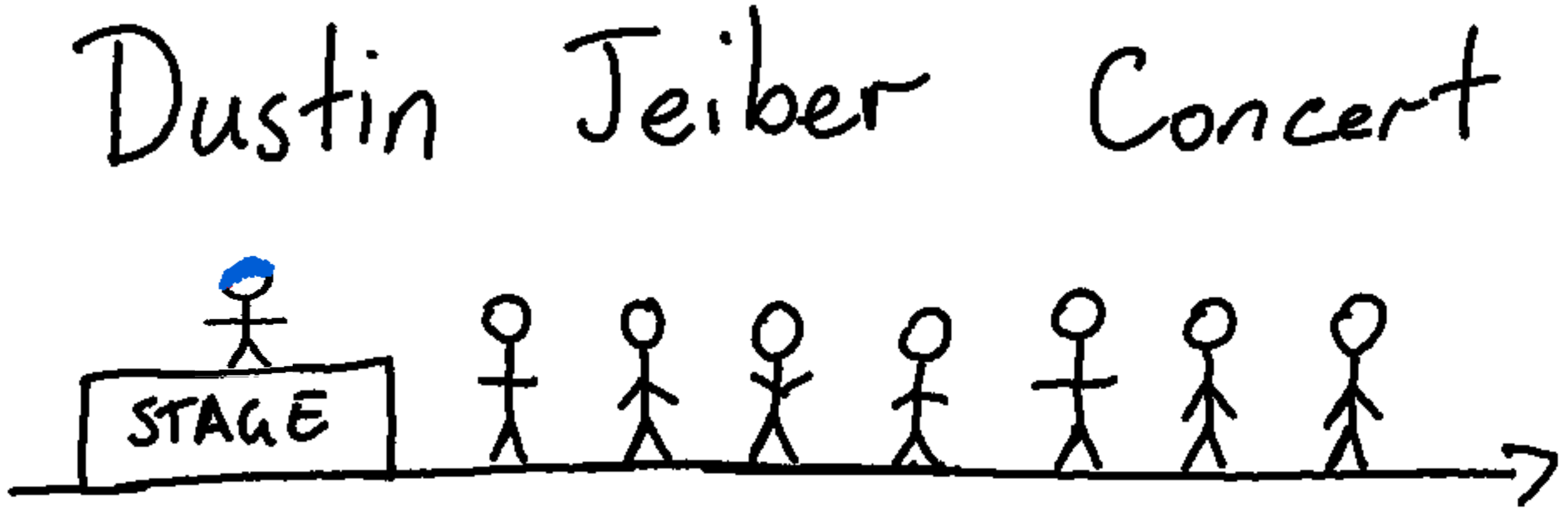




The Enjoyment-**Position Correlation Function**

A simple example

- Taking the analogy further: Consider another totally hypothetical concert, given by another totally hypothetical artist



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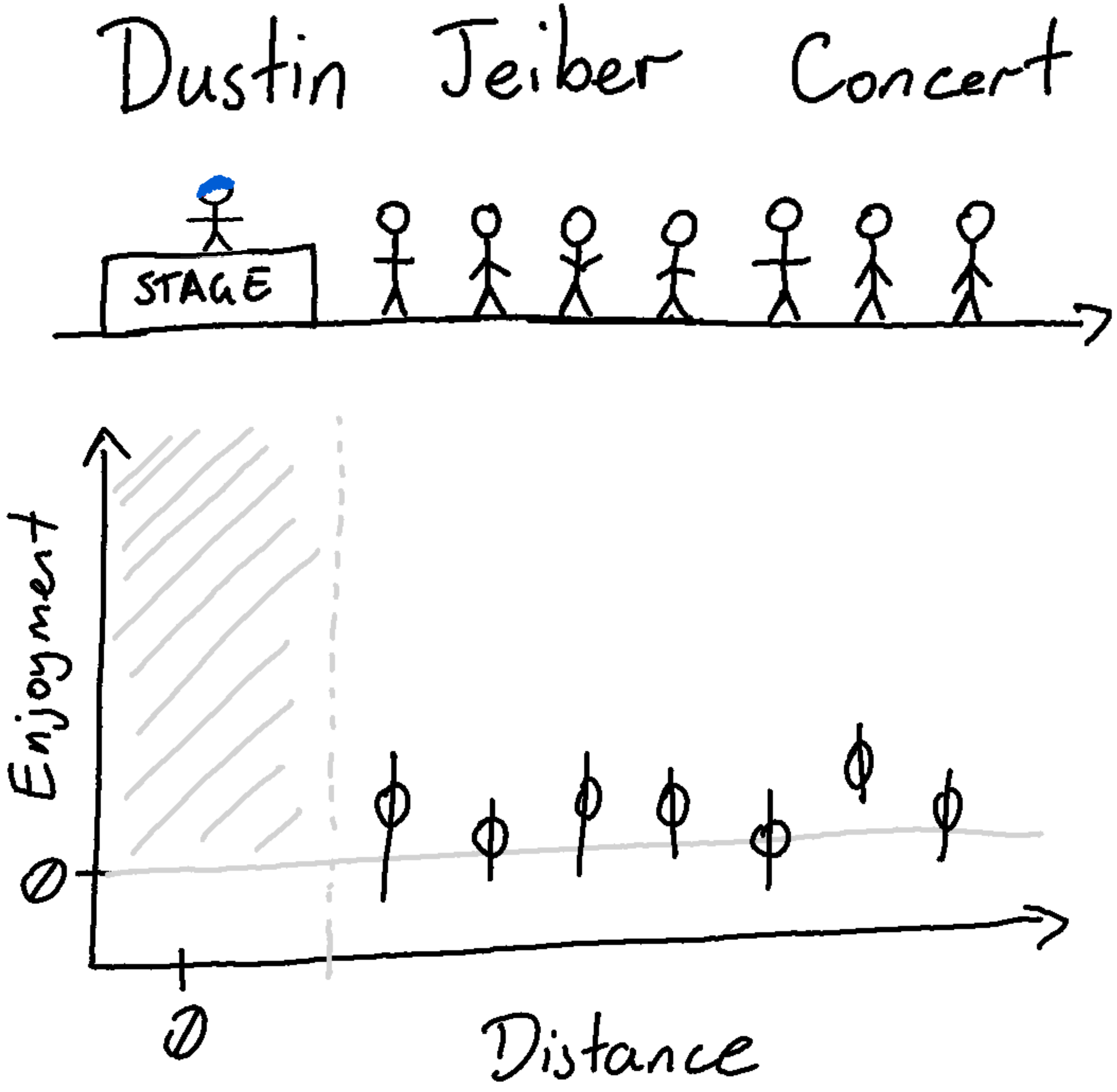
- Taking the analogy further: Consider another totally hypothetical concert, given by another totally hypothetical artist
- This artist has a much weaker influence on their audience



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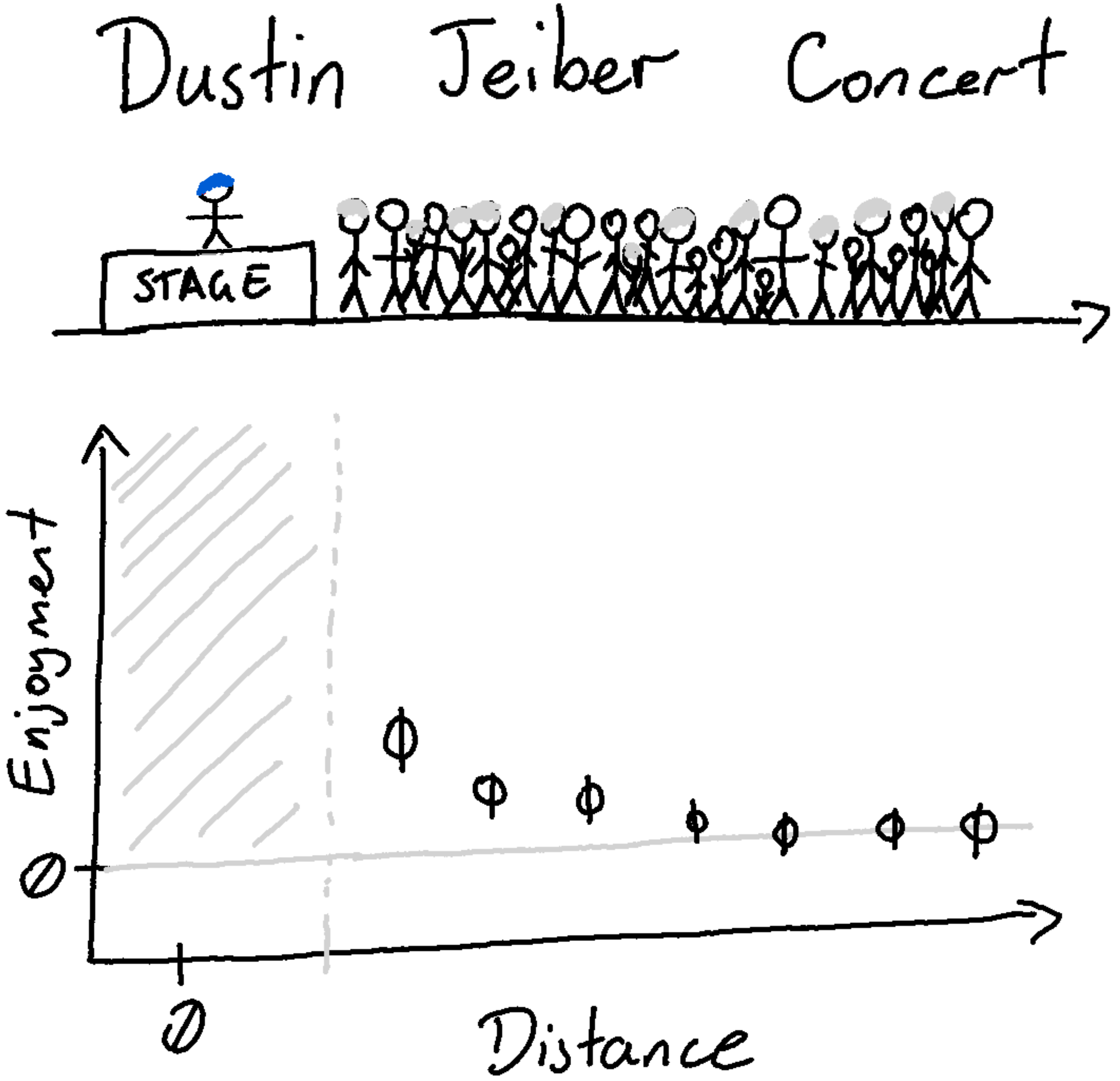
A simple example

- Taking the analogy further: Consider another totally hypothetical concert, given by another totally hypothetical artist
- This artist has a much weaker influence on their audience
- To determine a signal, we would need:

➡ a much larger audience, or



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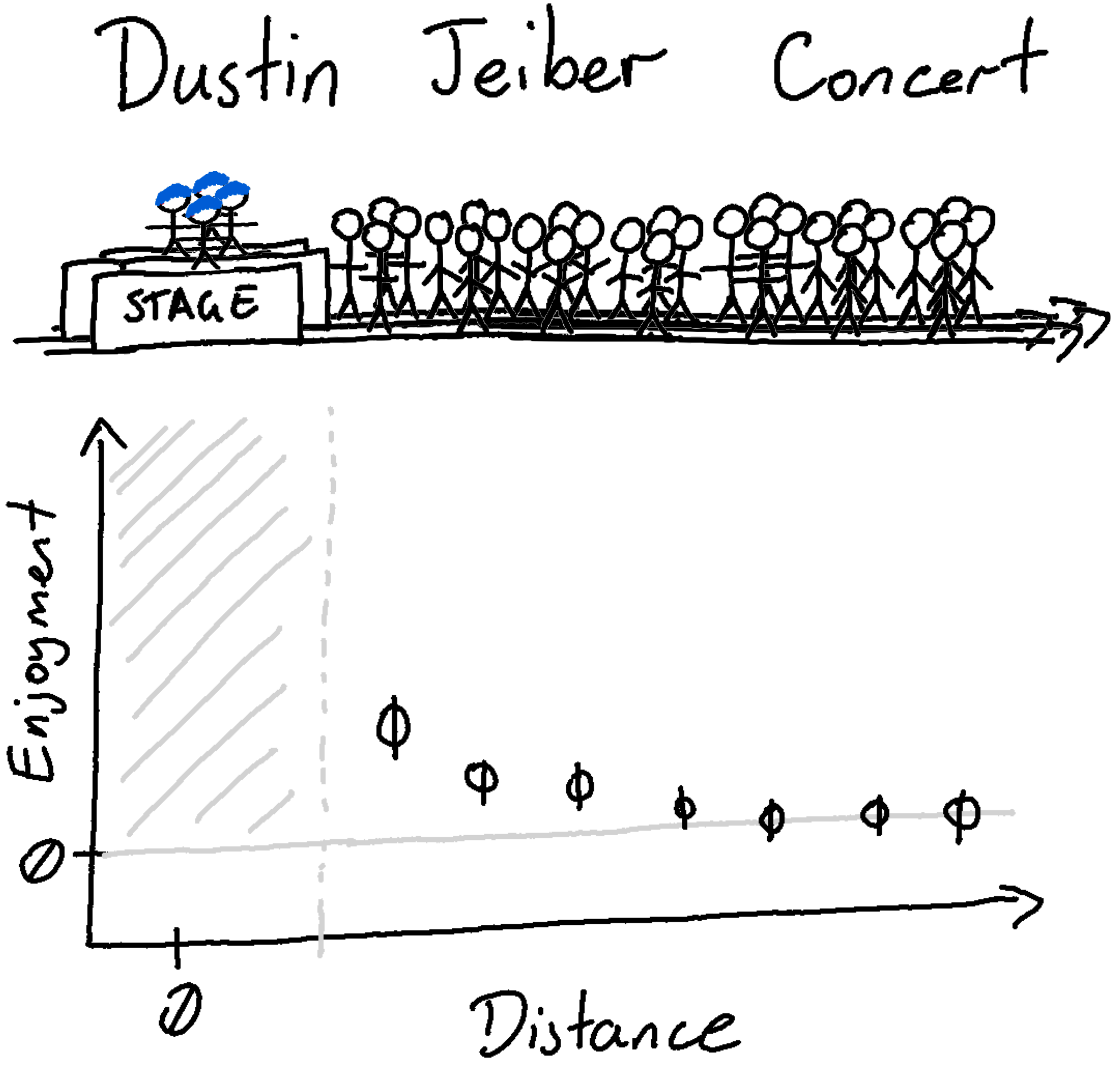
A simple example

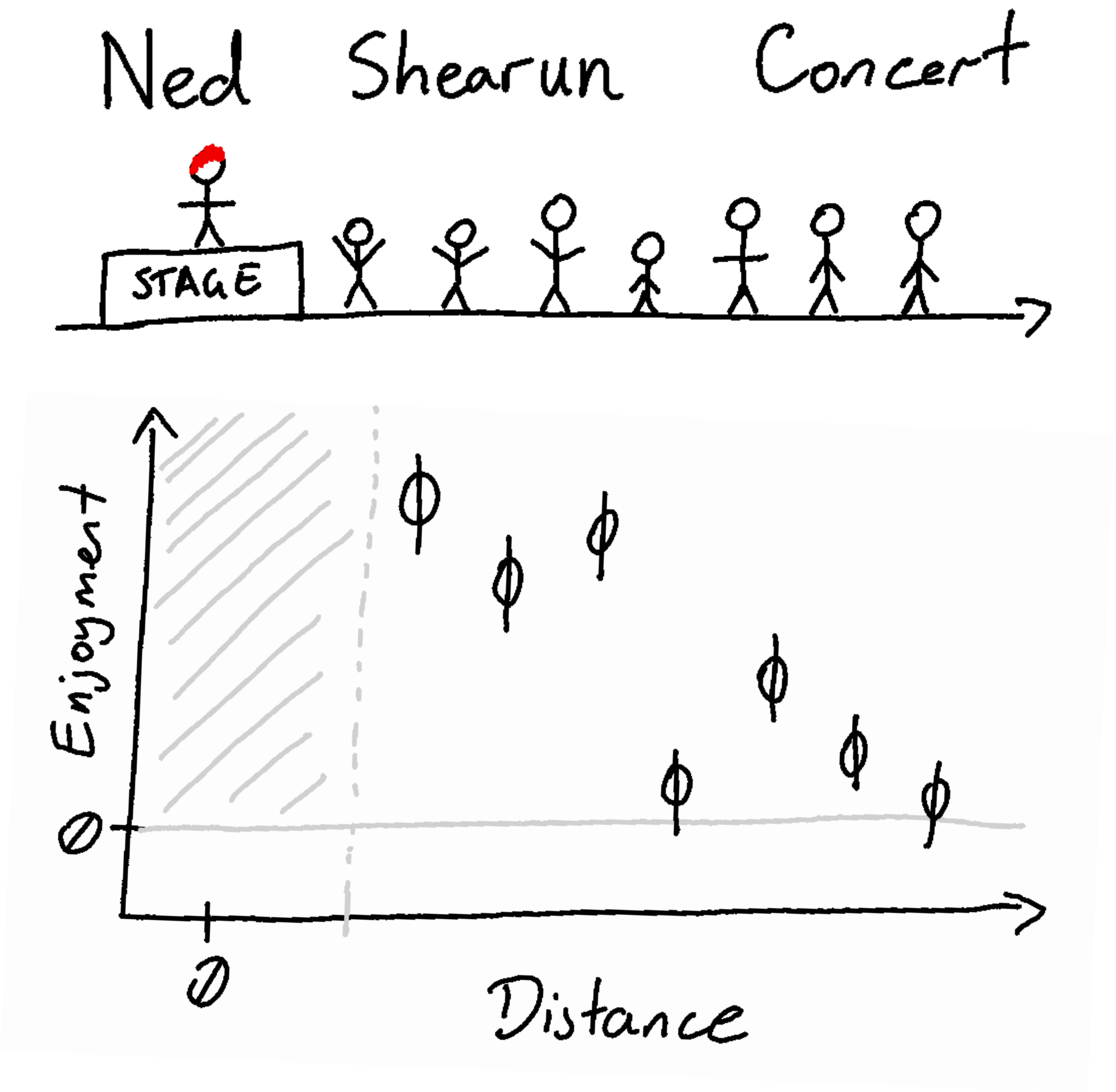
- Taking the analogy further: Consider another totally hypothetical concert, given by another totally hypothetical artist
- This artist has a much weaker influence on their audience
- To determine a signal, we would need:

➡ a much larger audience, or

➡ analyse multiple concerts at the same time (with assumptions)

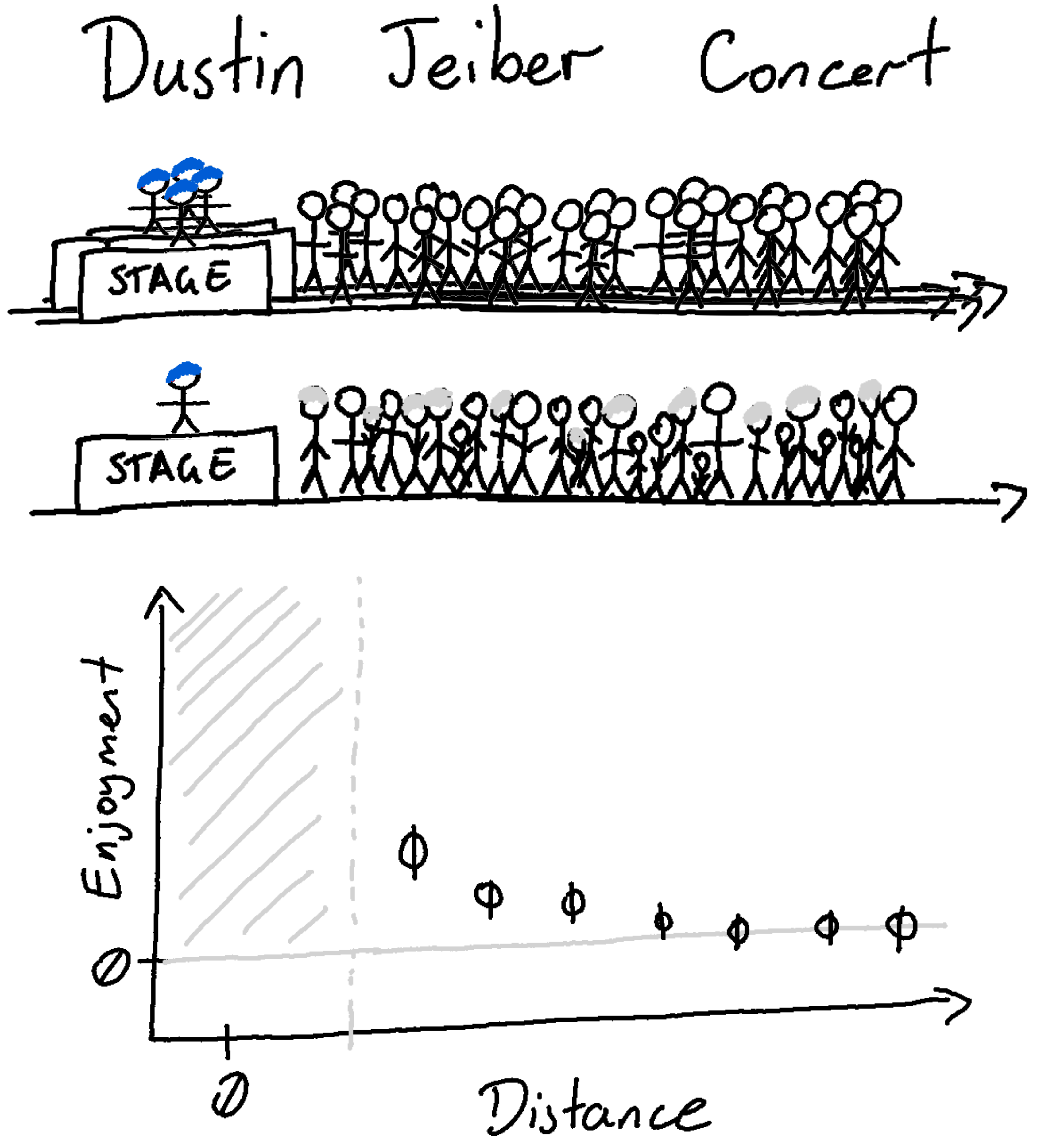


The Enjoyment-Position Correlation Function



Large, Red Target

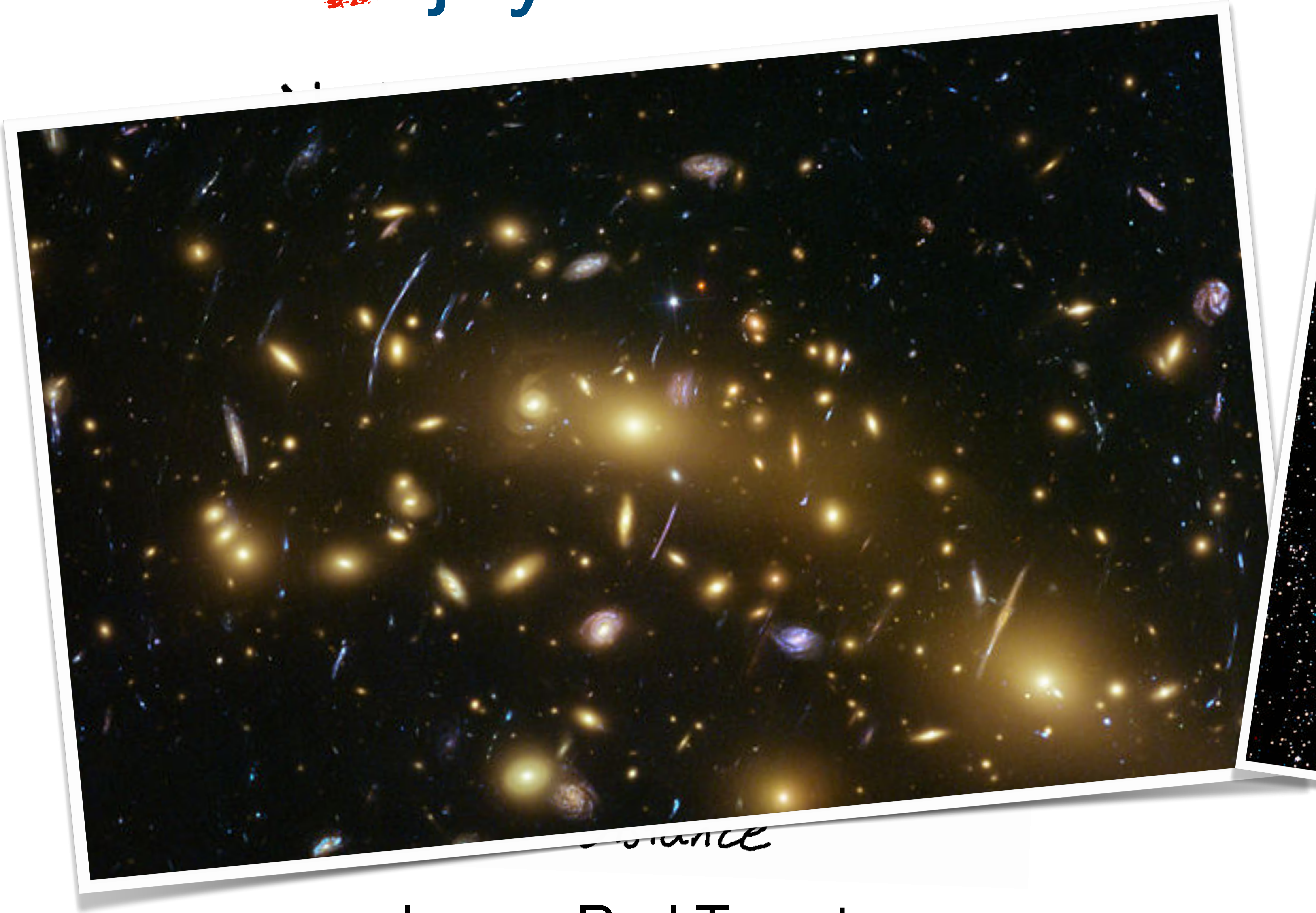
Sources show a strong signal, detectable with one/few sources



Small, Blue Target

Sources show a weak signal, but one that is detectable with large samples

The ~~Enjoyment~~ Shear-Position Correlation Function



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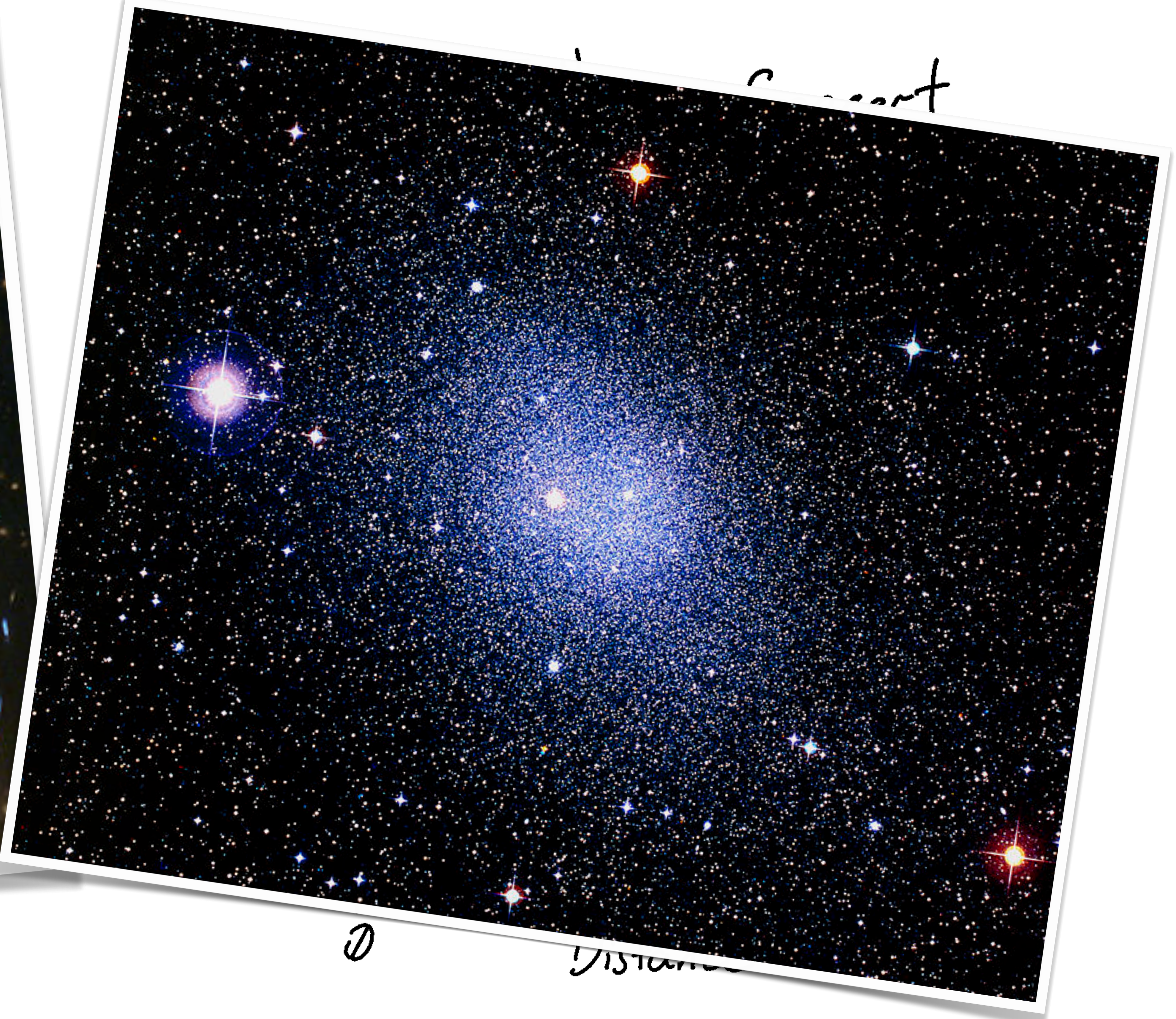


Small, Blue Target

Sources show a weak signal, but one that is detectable with large samples

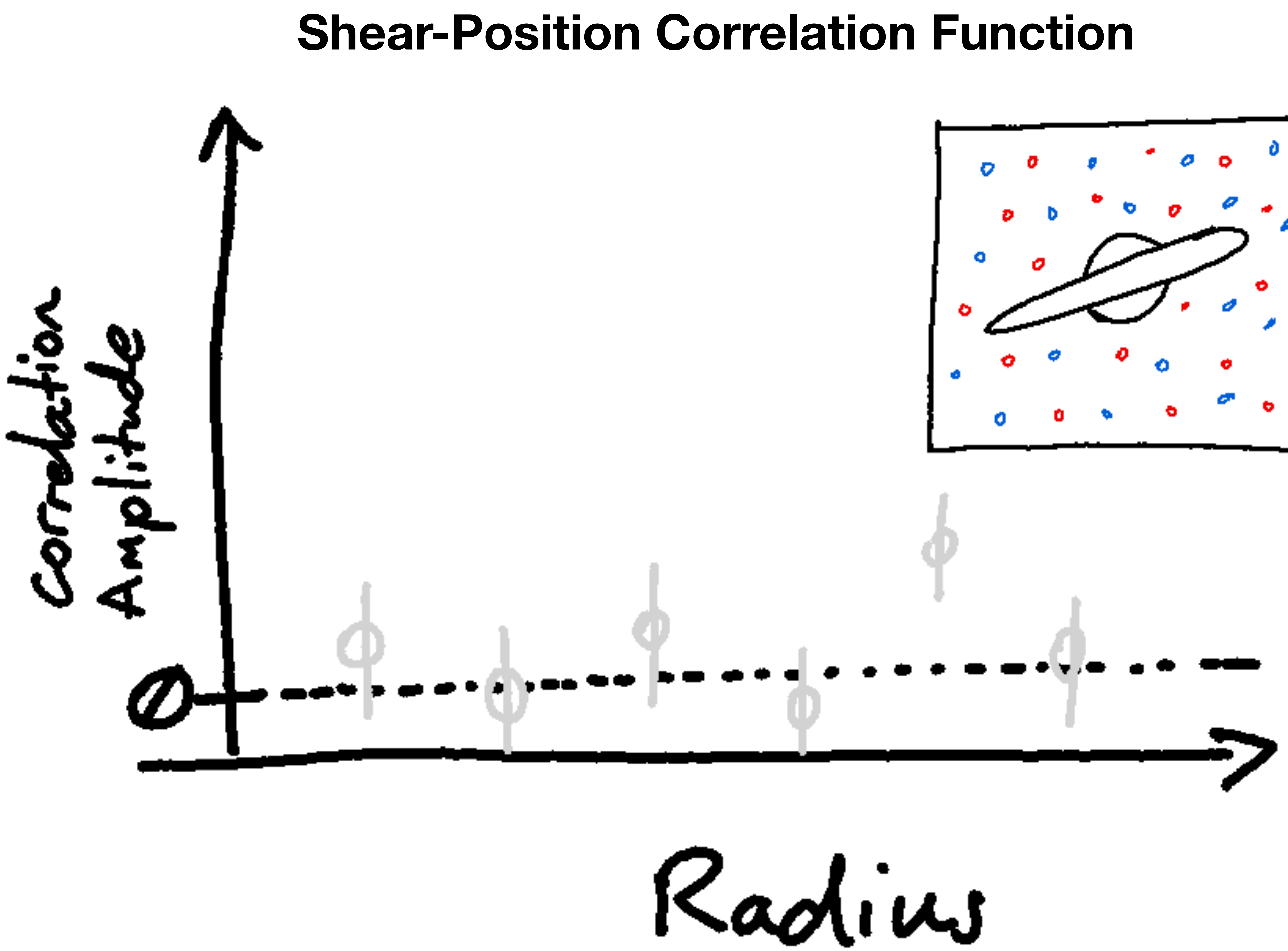
The [Something]-Position Correlation Function

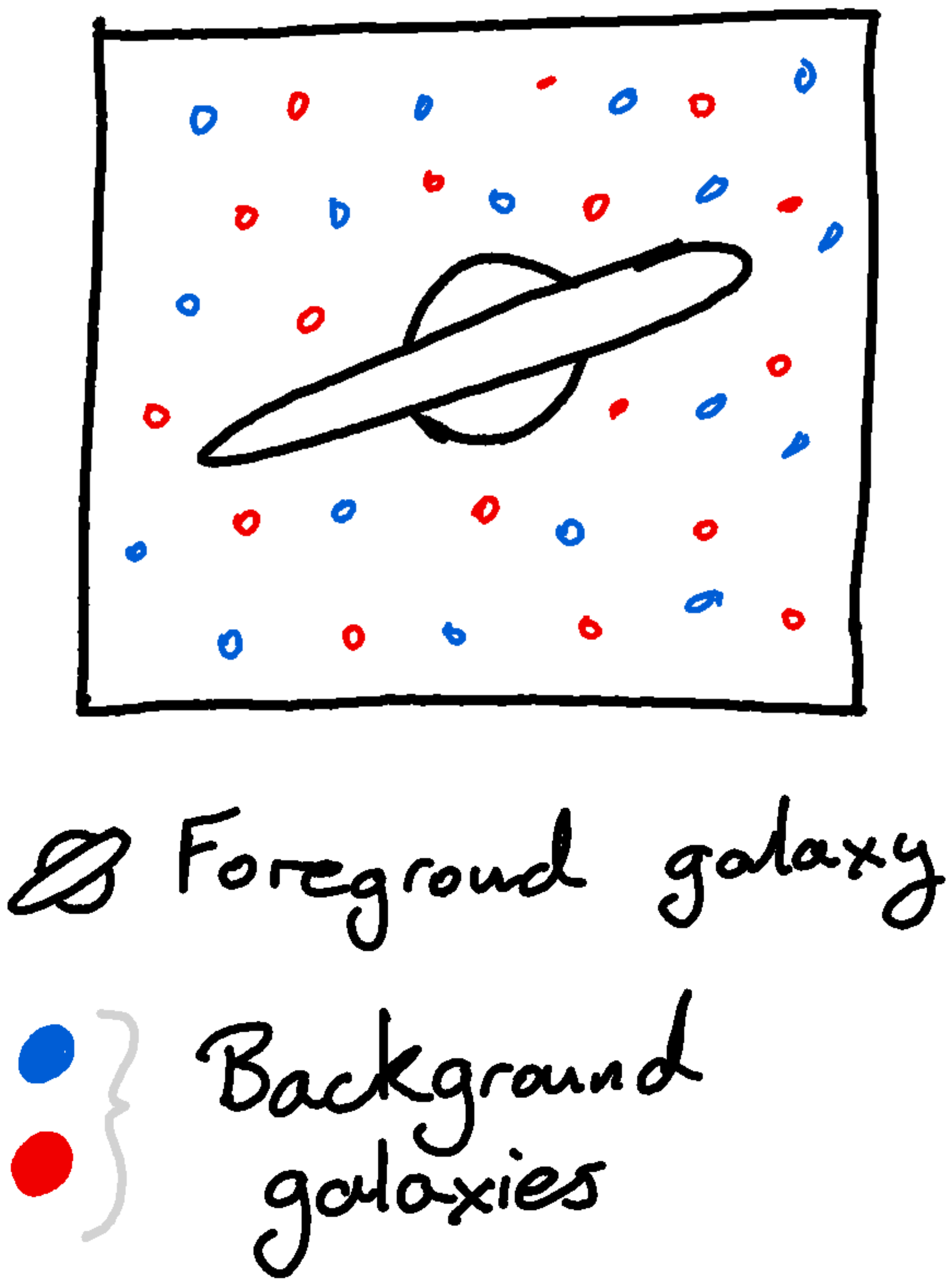
Now onto Galaxies

- Let’s now take exactly the same approach to explore the 3 cross-correlations:
  - ➡ The **Shear-Position** correlation function (“galaxy-galaxy lensing”)
  - ➡ The **Magnitude-Position** correlation function
  - ➡ The **Colour-Position** correlation function

The Shear-Position Correlation Function

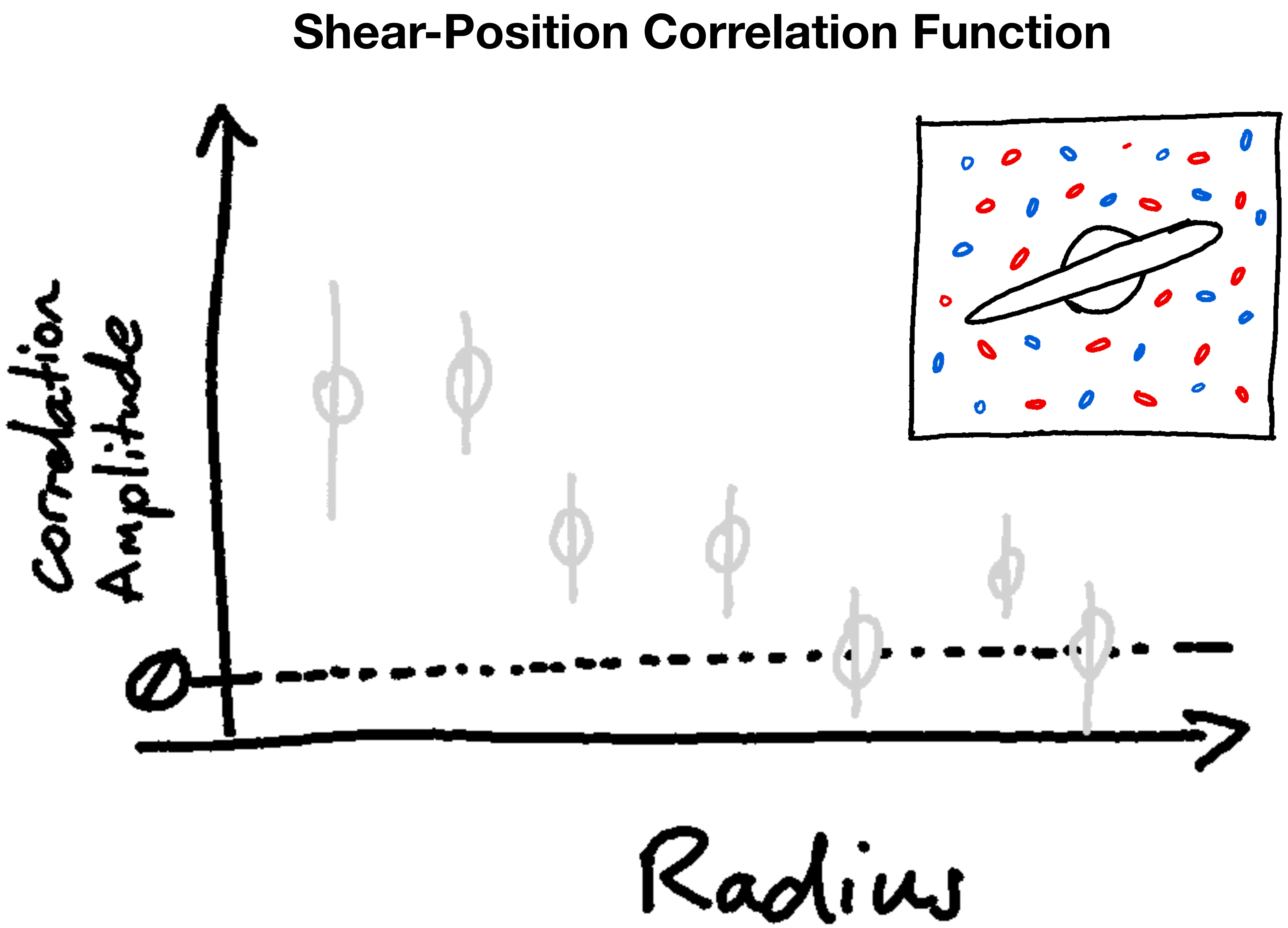
Without Gravitational Lensing

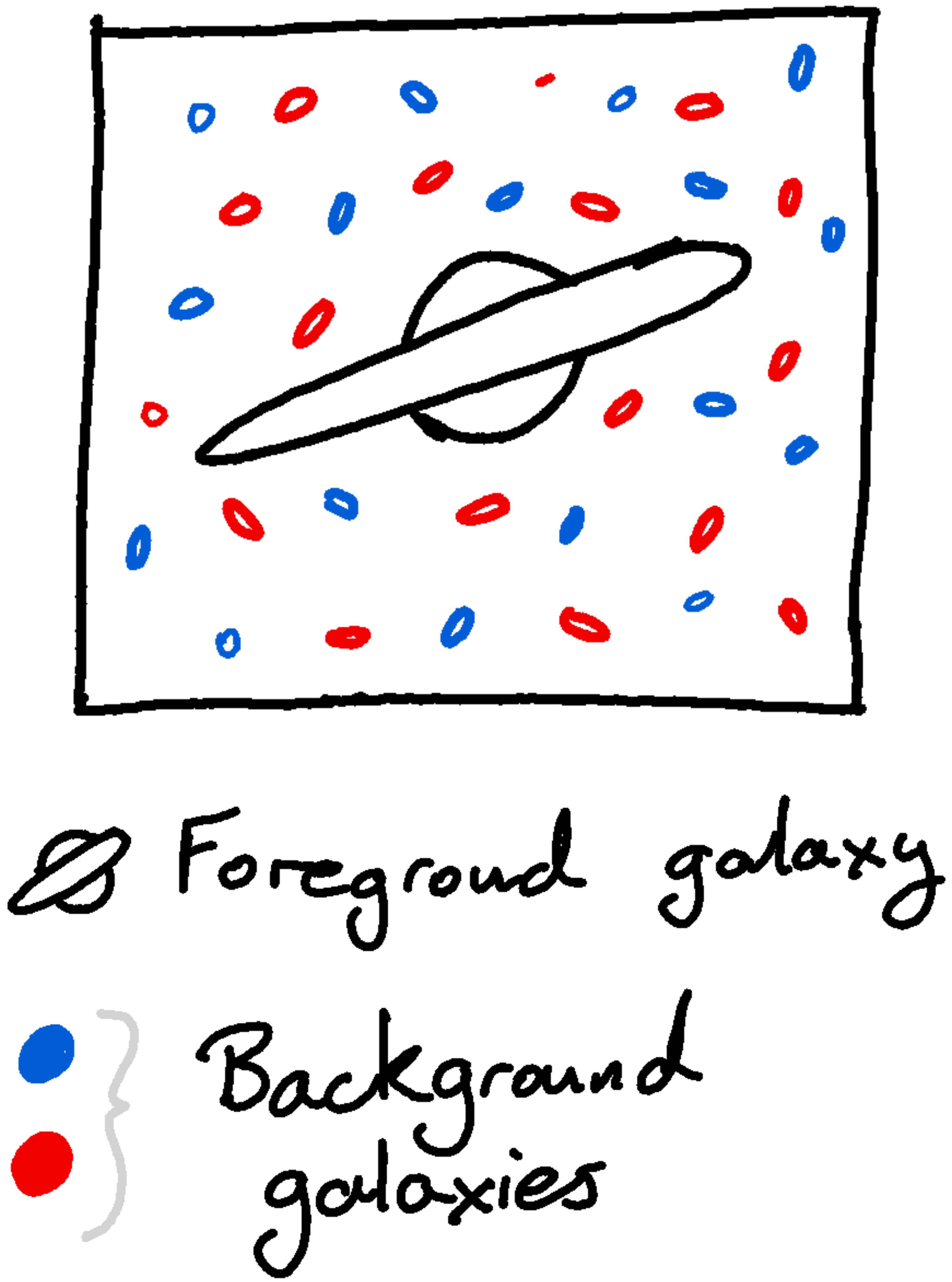




The Shear-Position Correlation Function

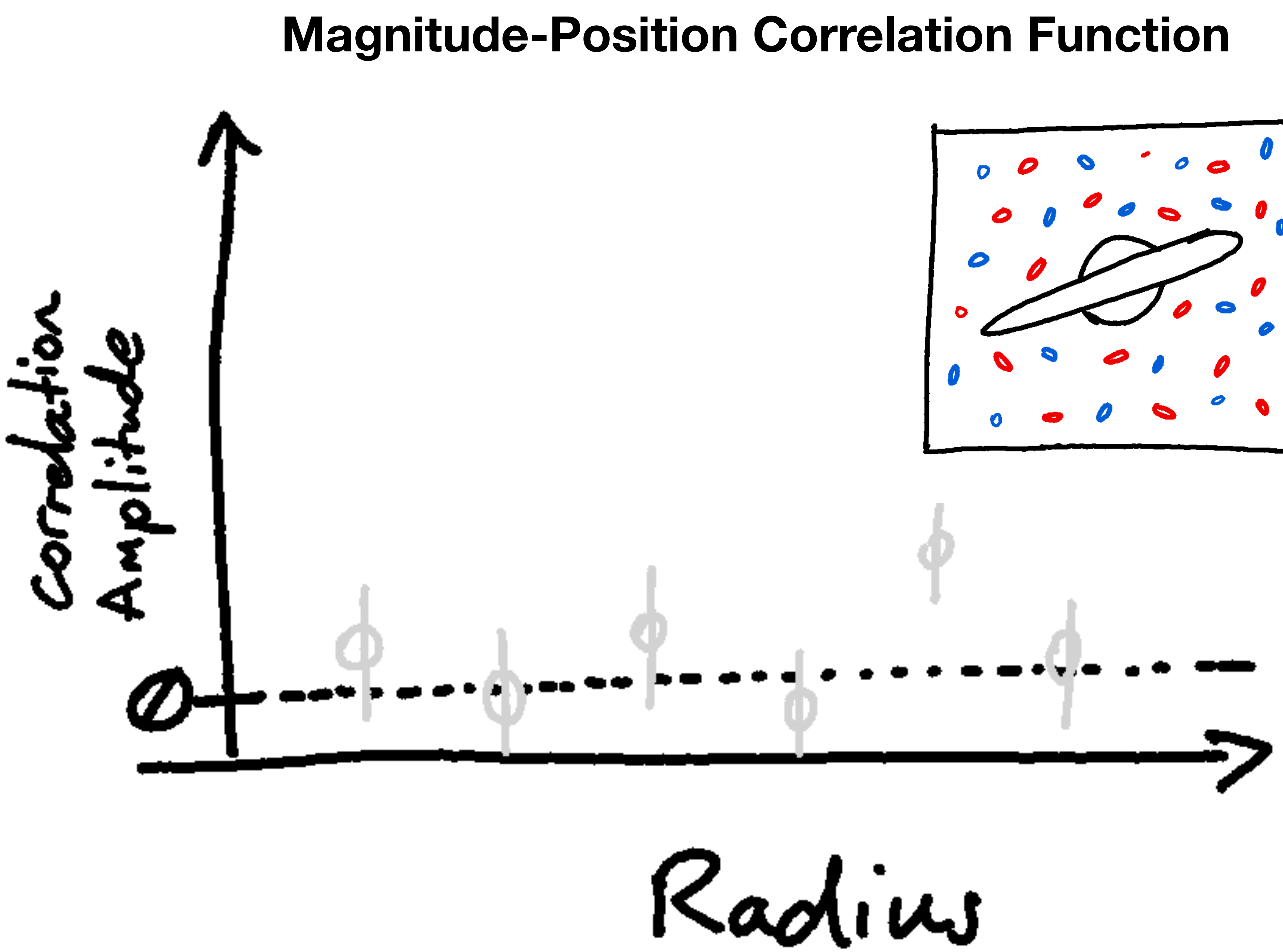
With Gravitational Lensing

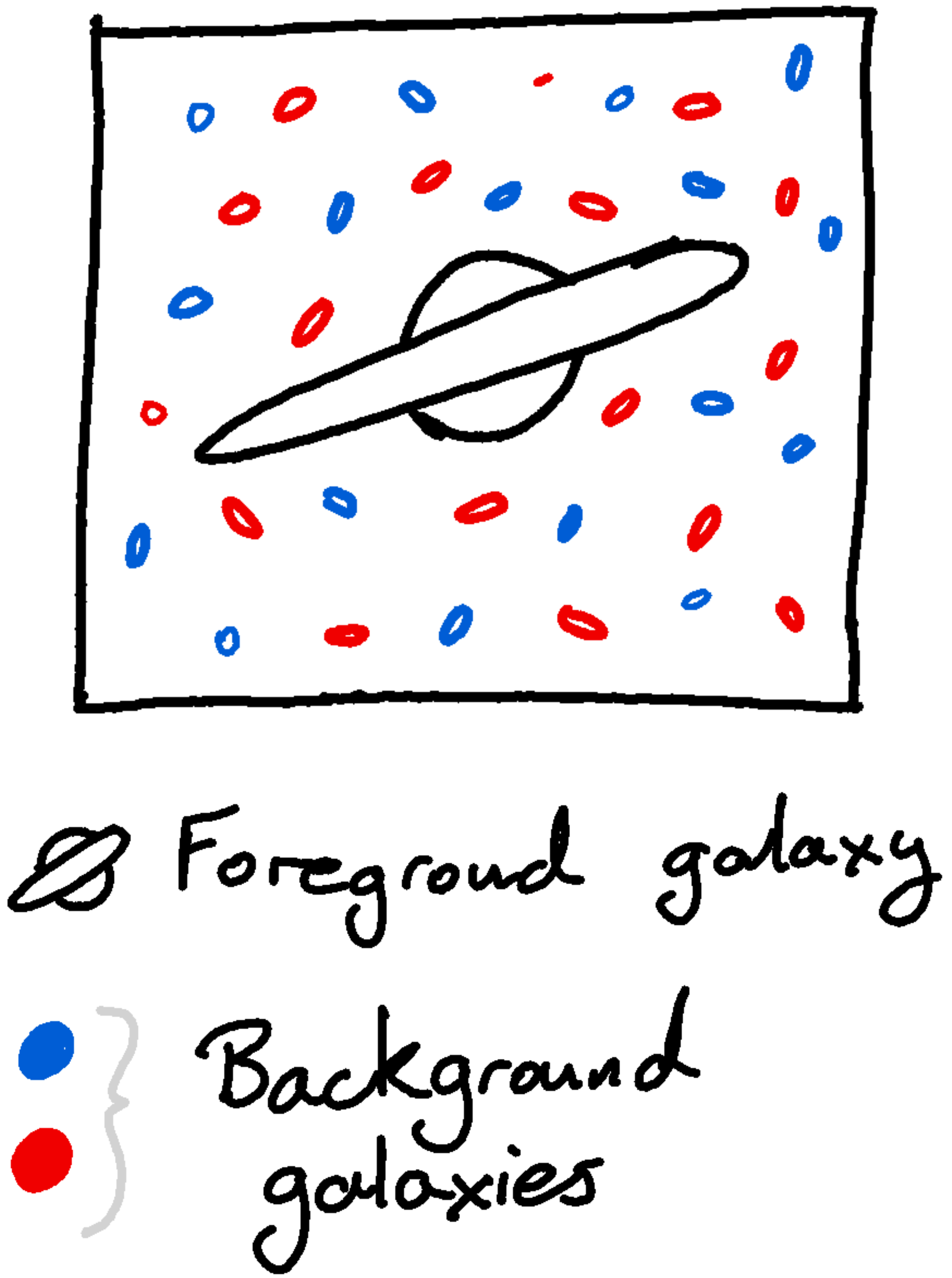




The Magnitude-Position Correlation Function

Without Halo Dust Obscuration





The Magnitude-Position Correlation Function

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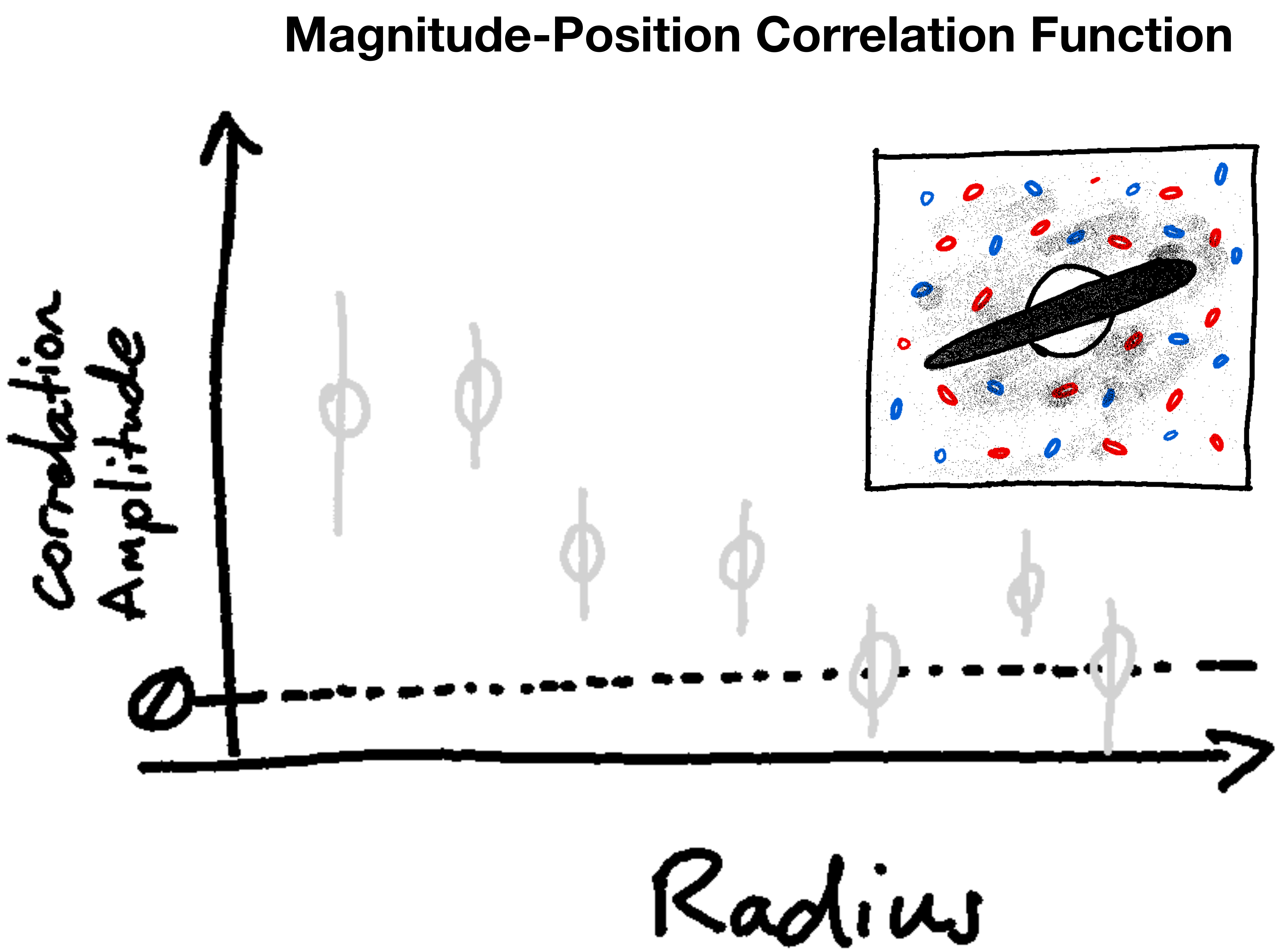
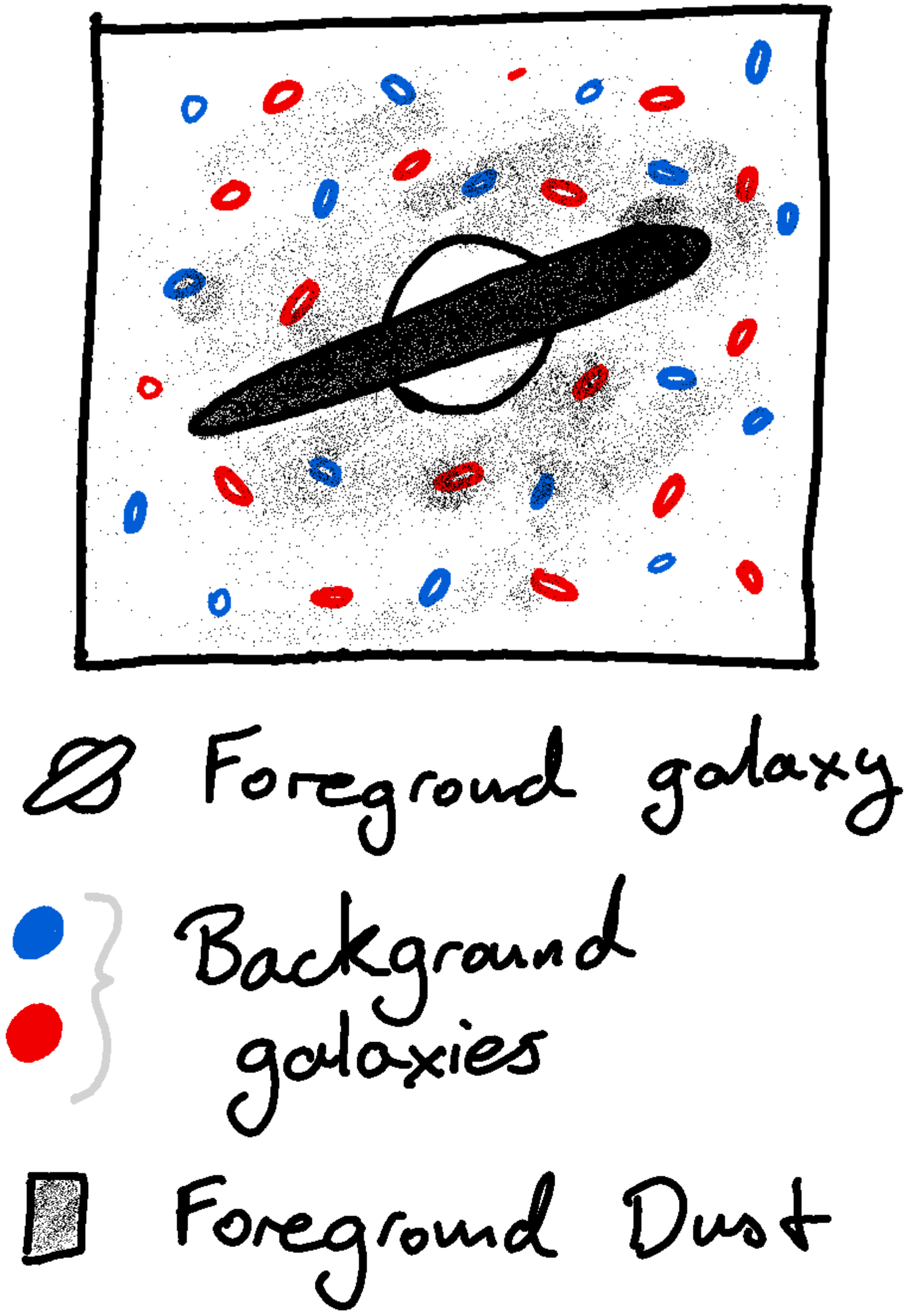


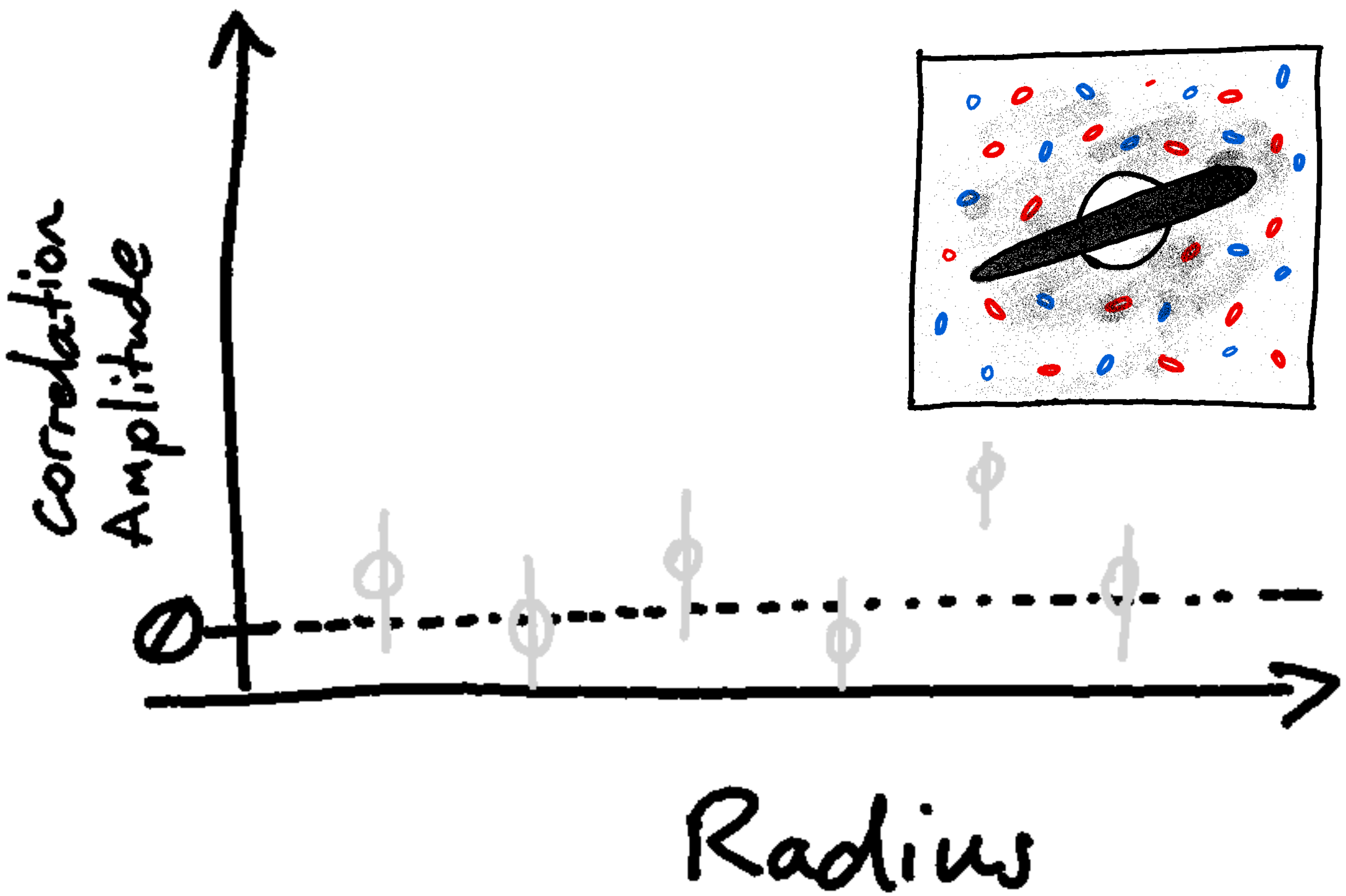


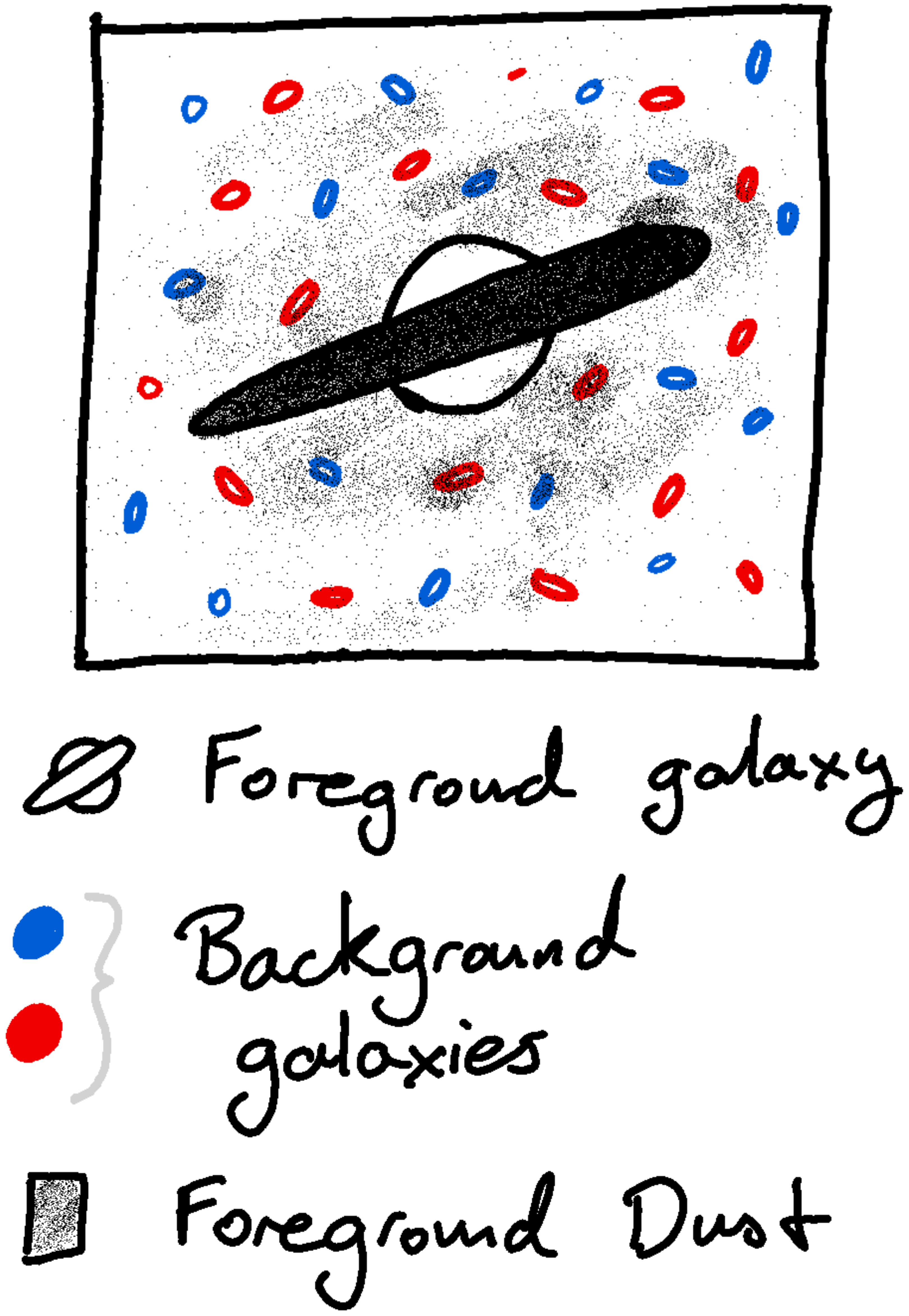
m = -2.5*log10(flux) + ZP

The Colour-Position Correlation Function

Without Halo Dust Extinction

Colour-Position Correlation Function

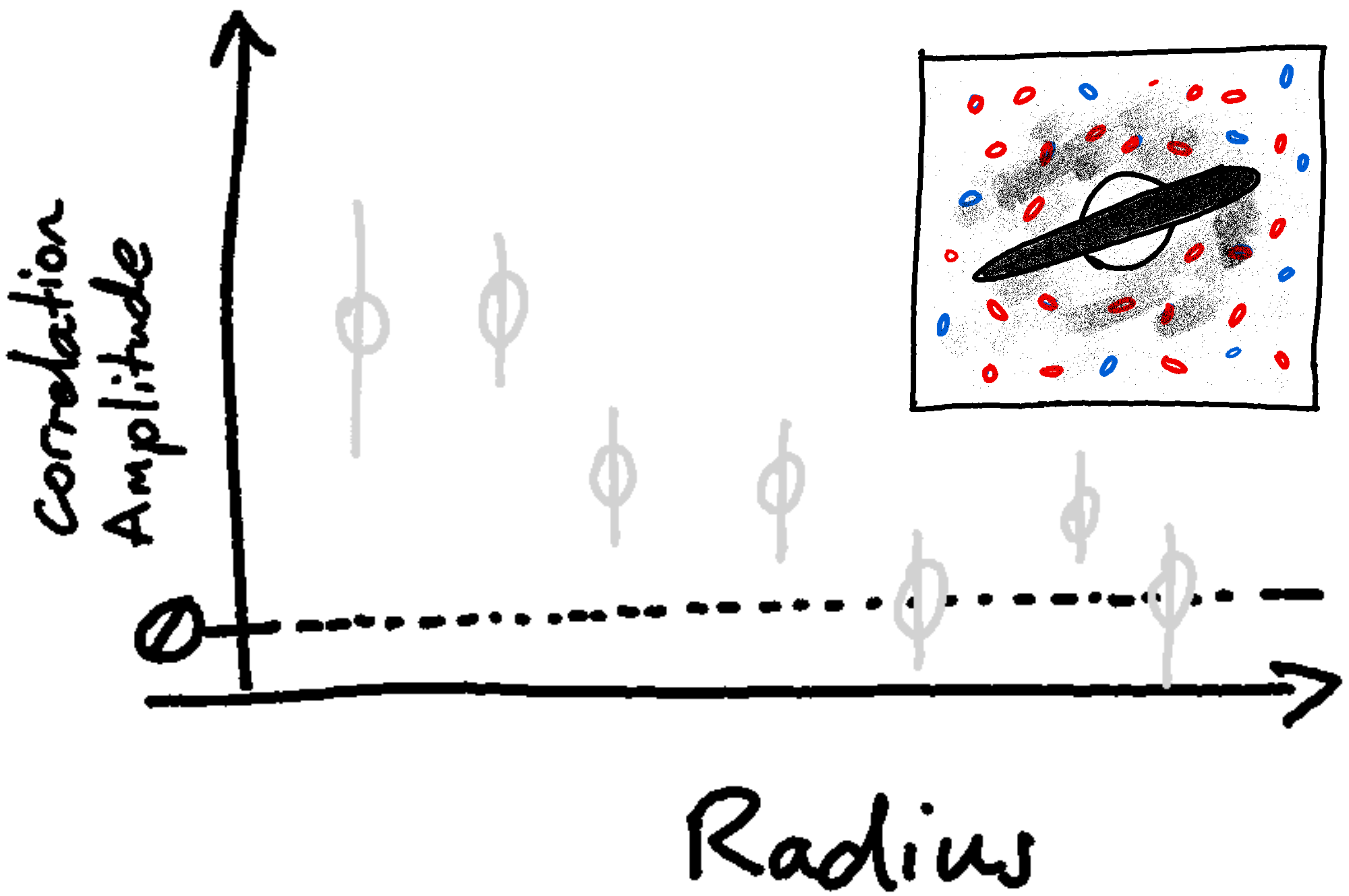


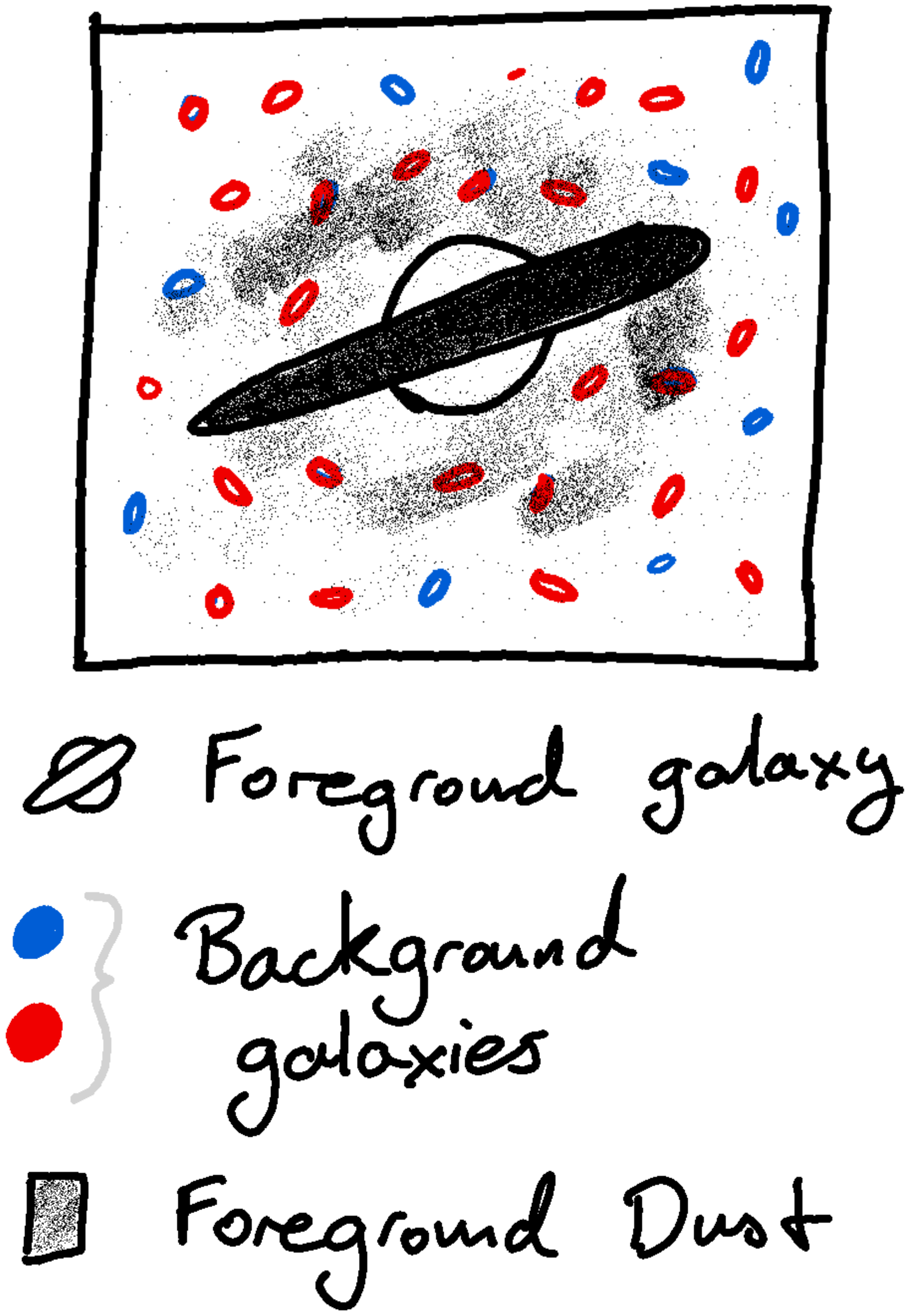


The Colour-Position Correlation Function

With Halo Dust Extinction

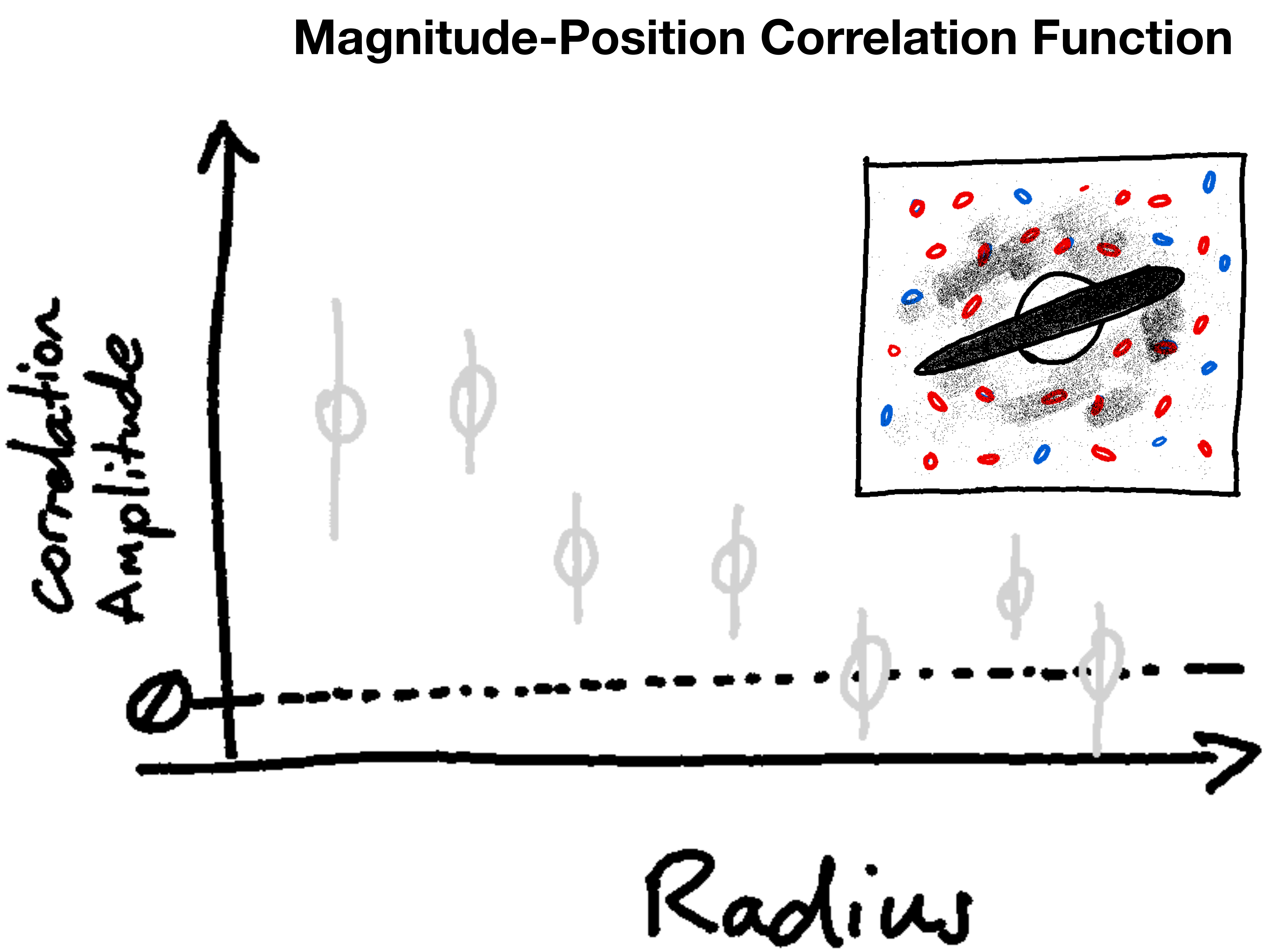
Colour-Position Correlation Function

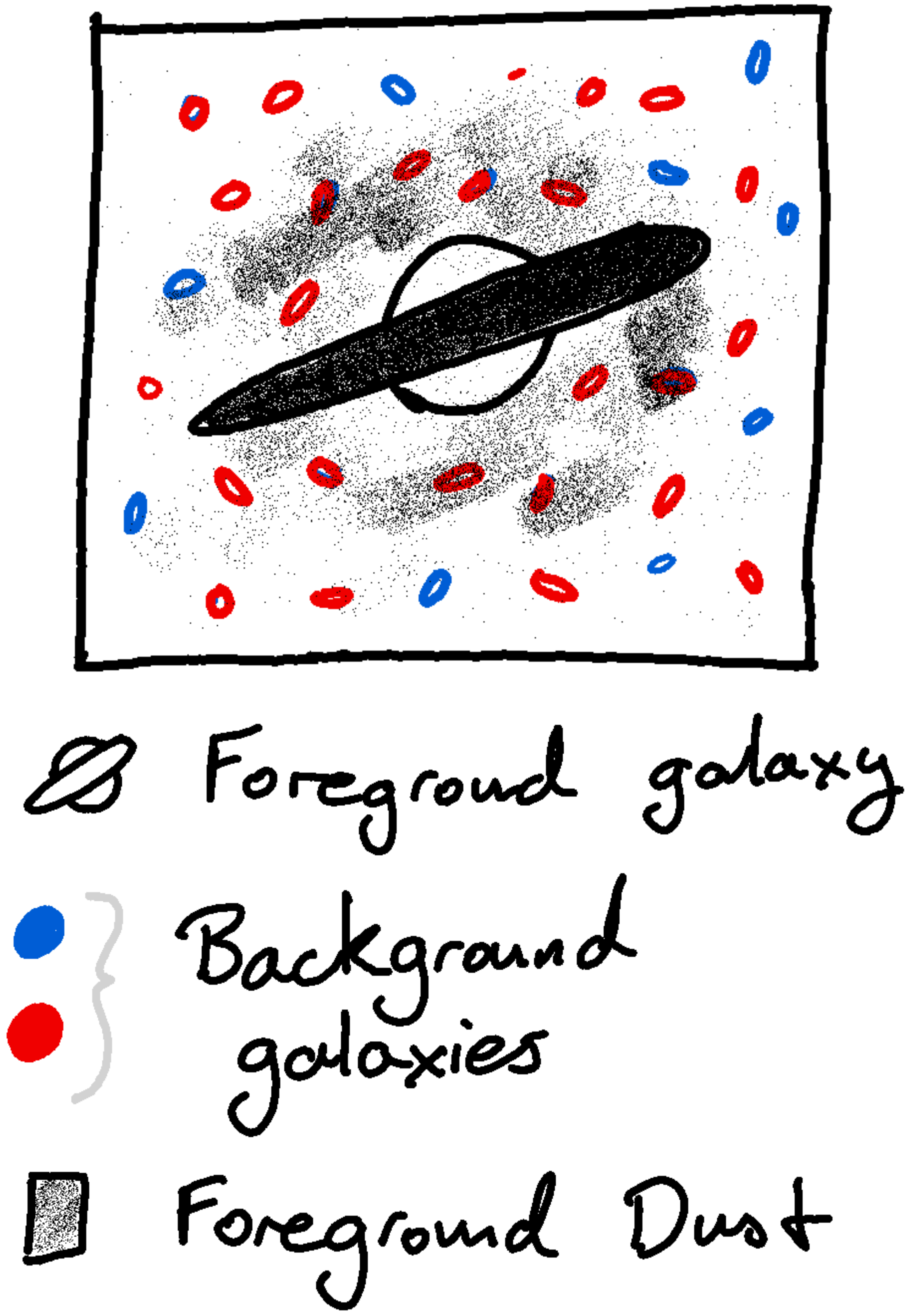




The Magnitude-Position Correlation Function (again)

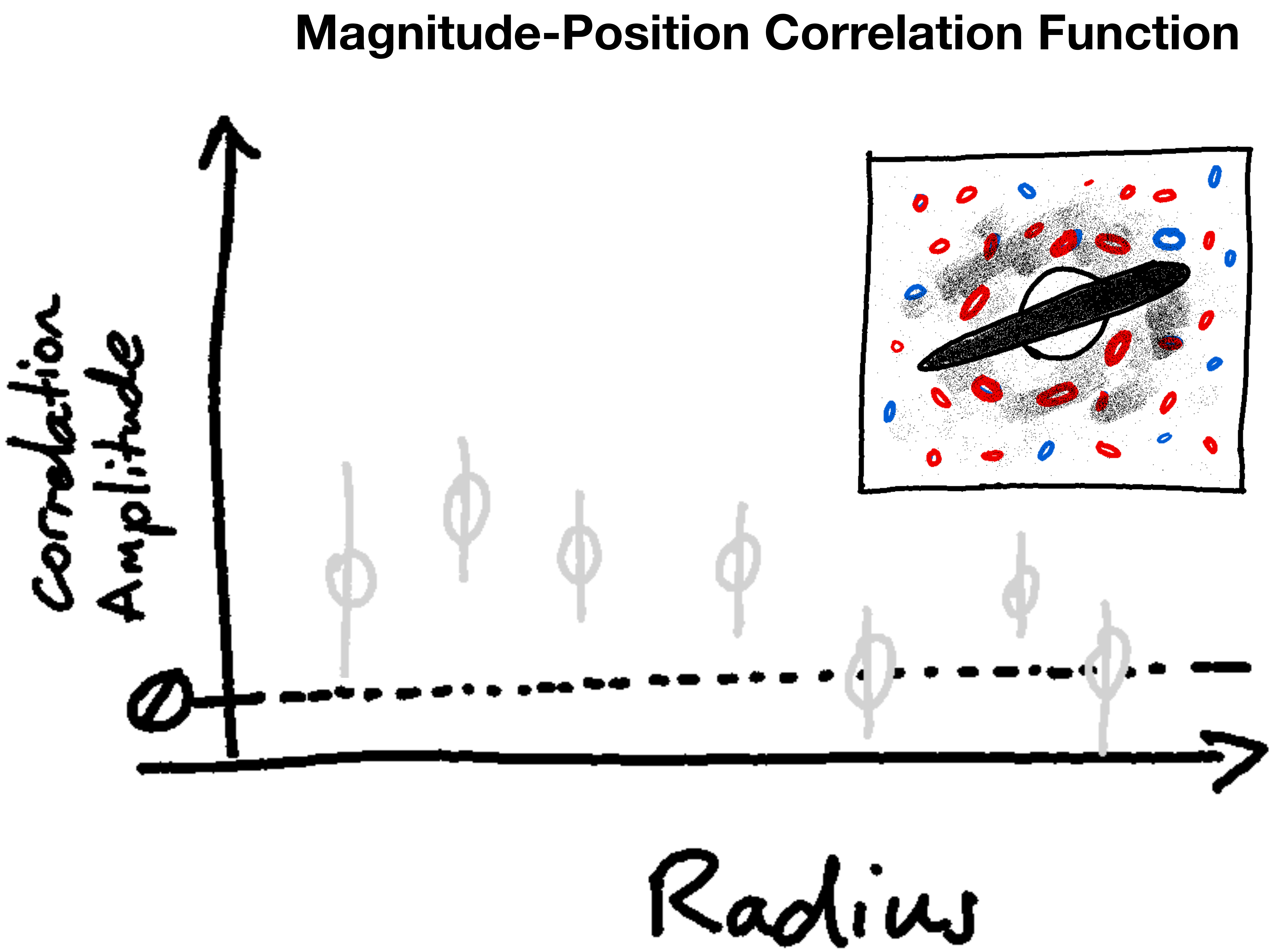
Without Gravitational Magnification

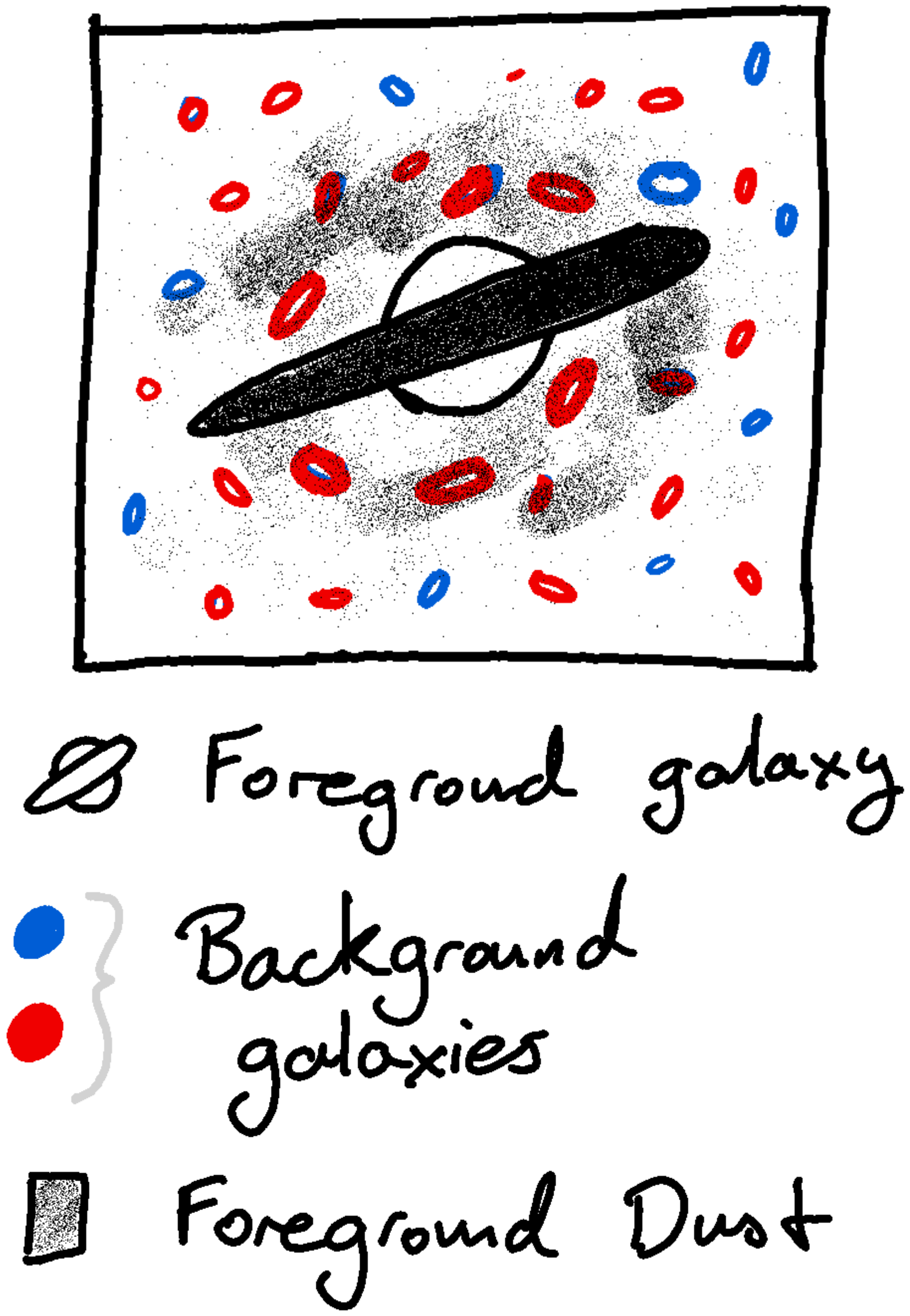




The Magnitude-Position Correlation Function (again)

With Gravitational Magnification

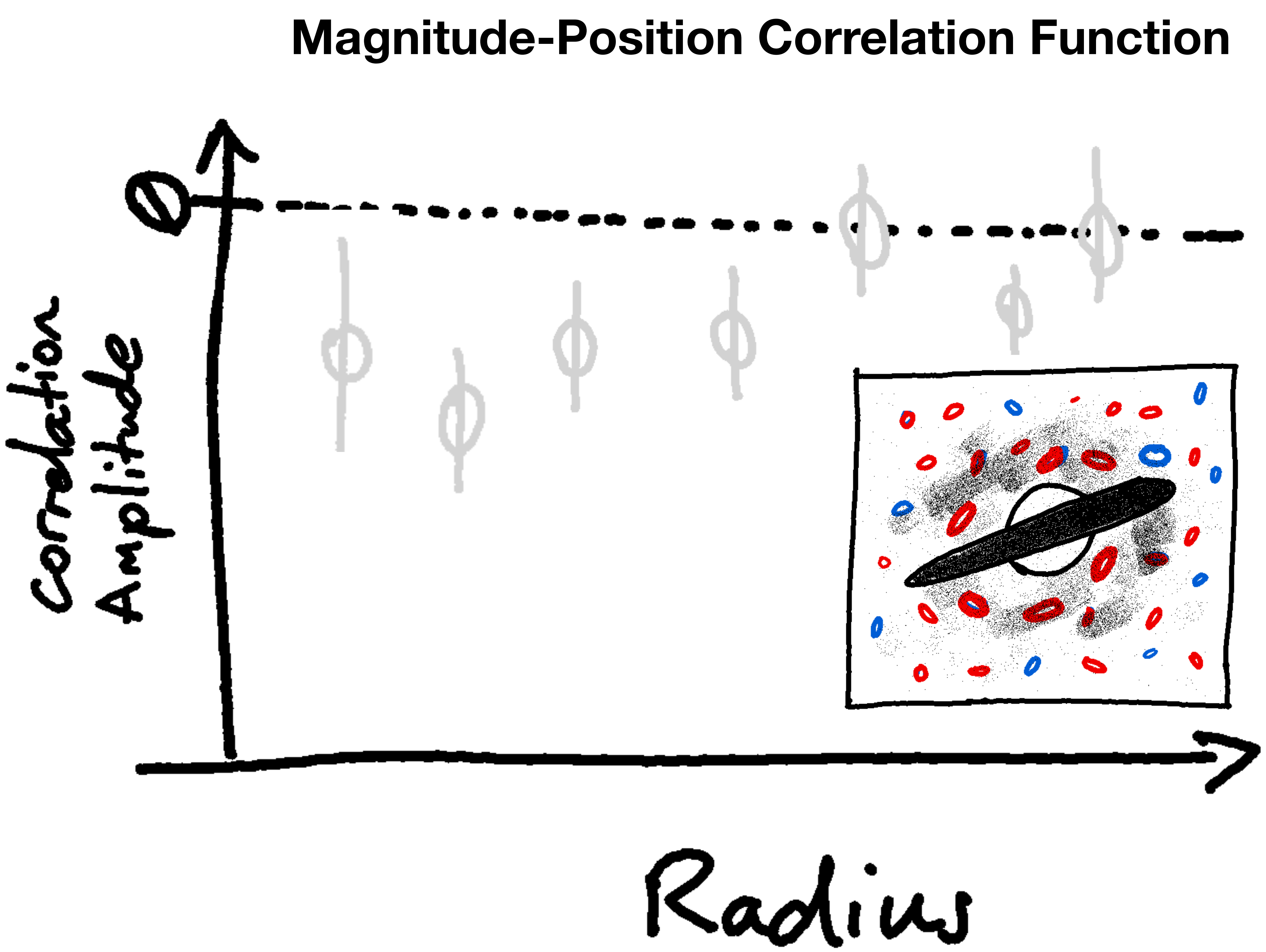


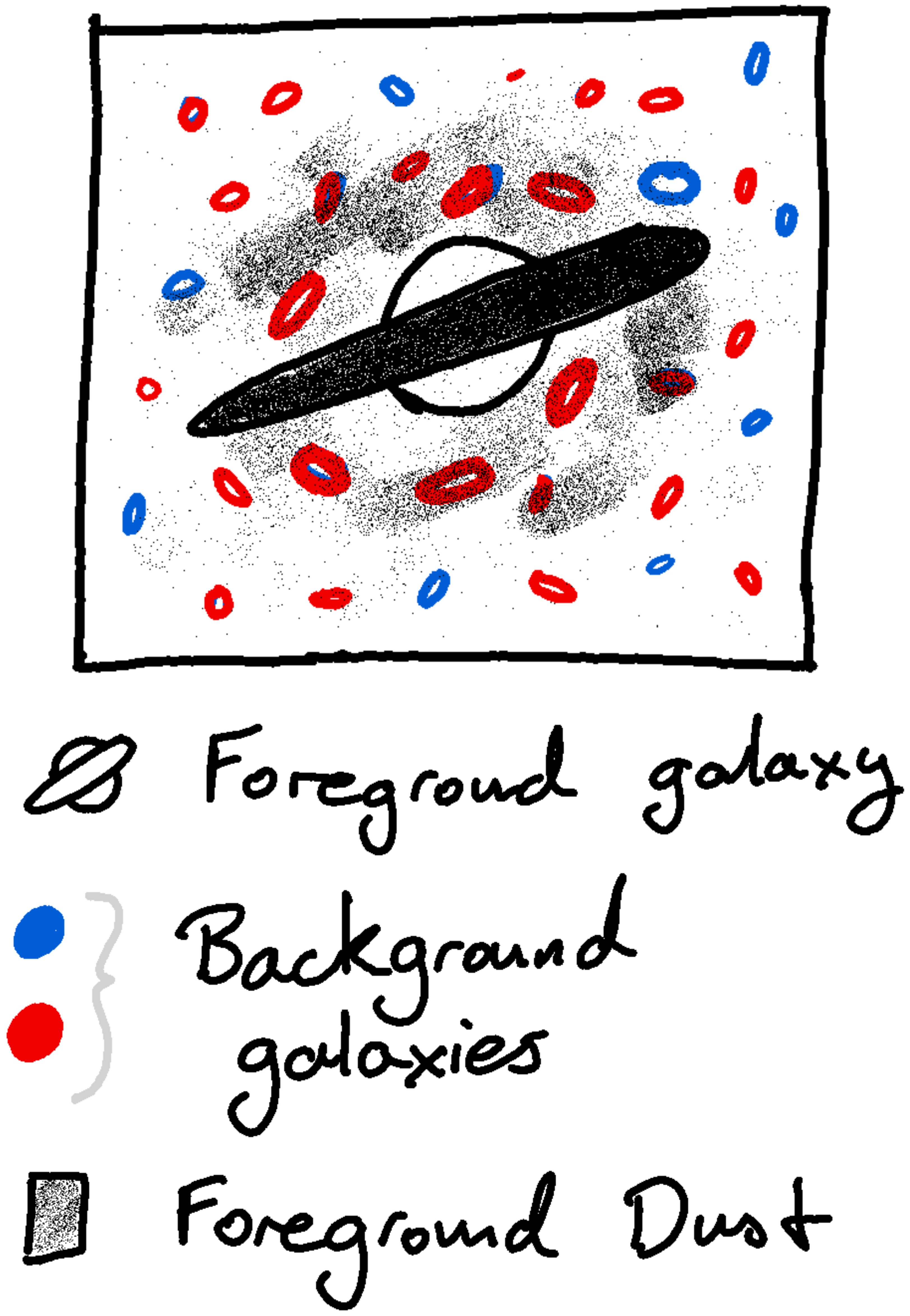


(Extinction dominated)

The Magnitude-Position Correlation Function (again)

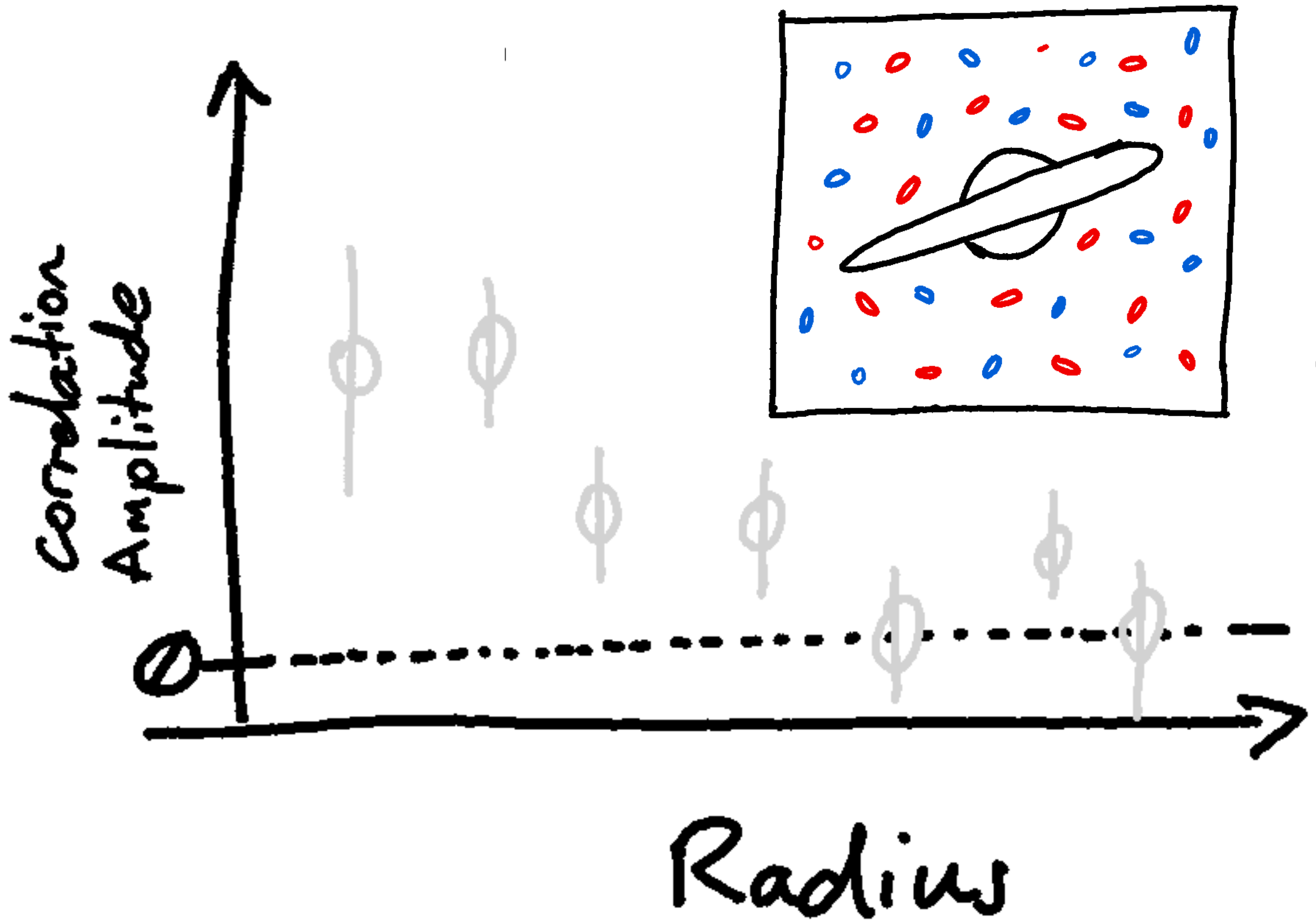
With Gravitational Magnification

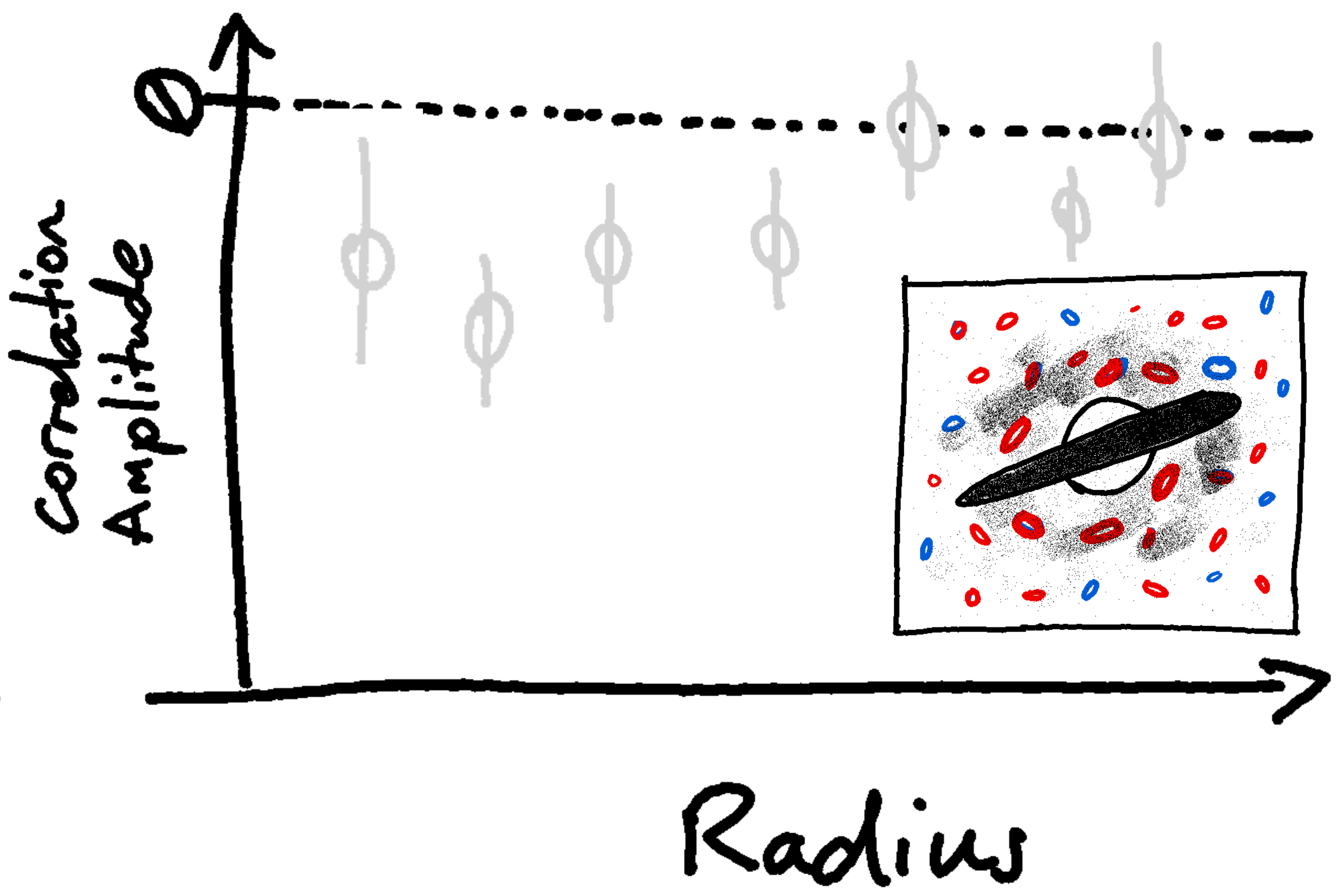


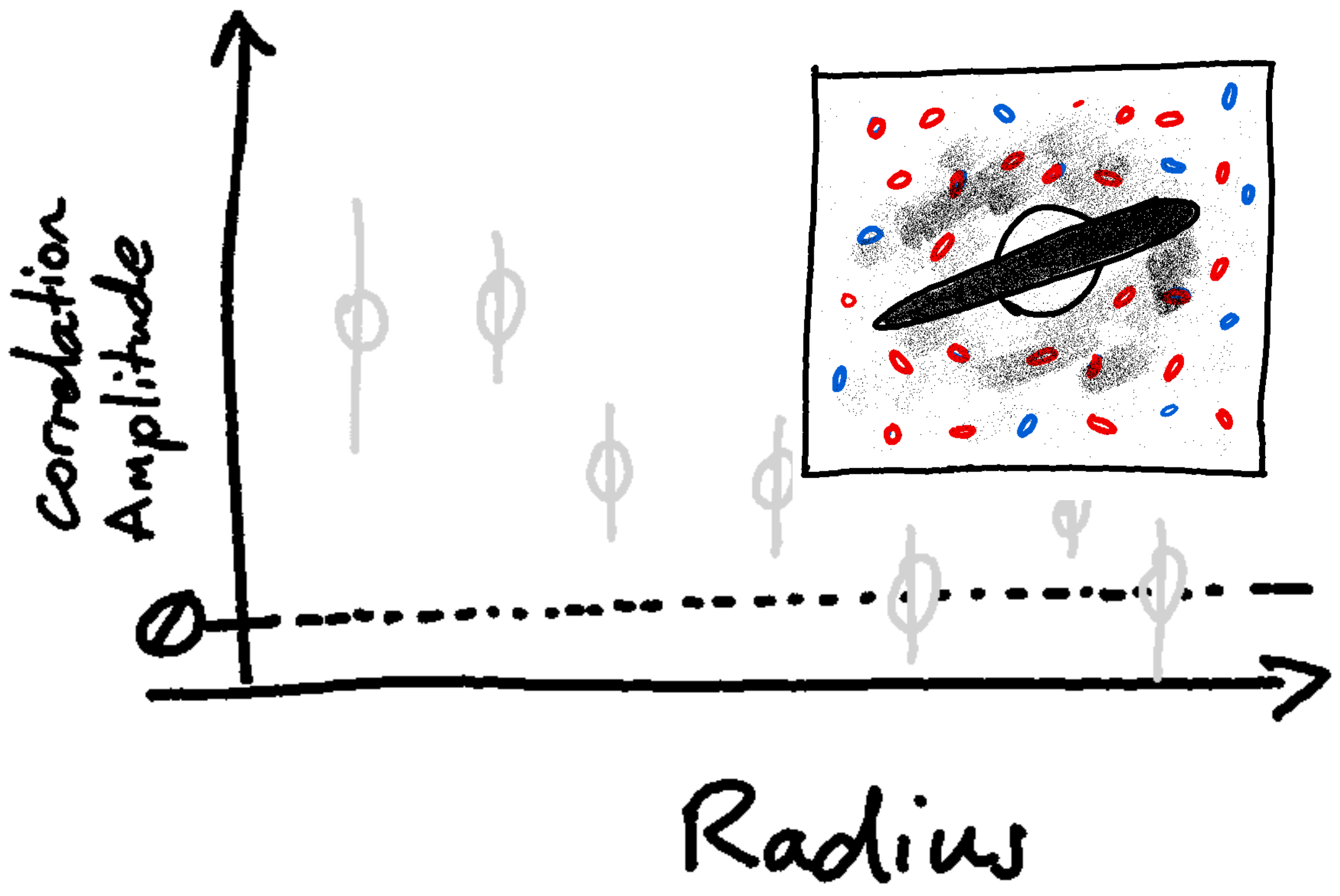


(Magnification dominated)

Our 3 [Something]-Position Correlation Functions







Shear-Position

Sensitive to Mass

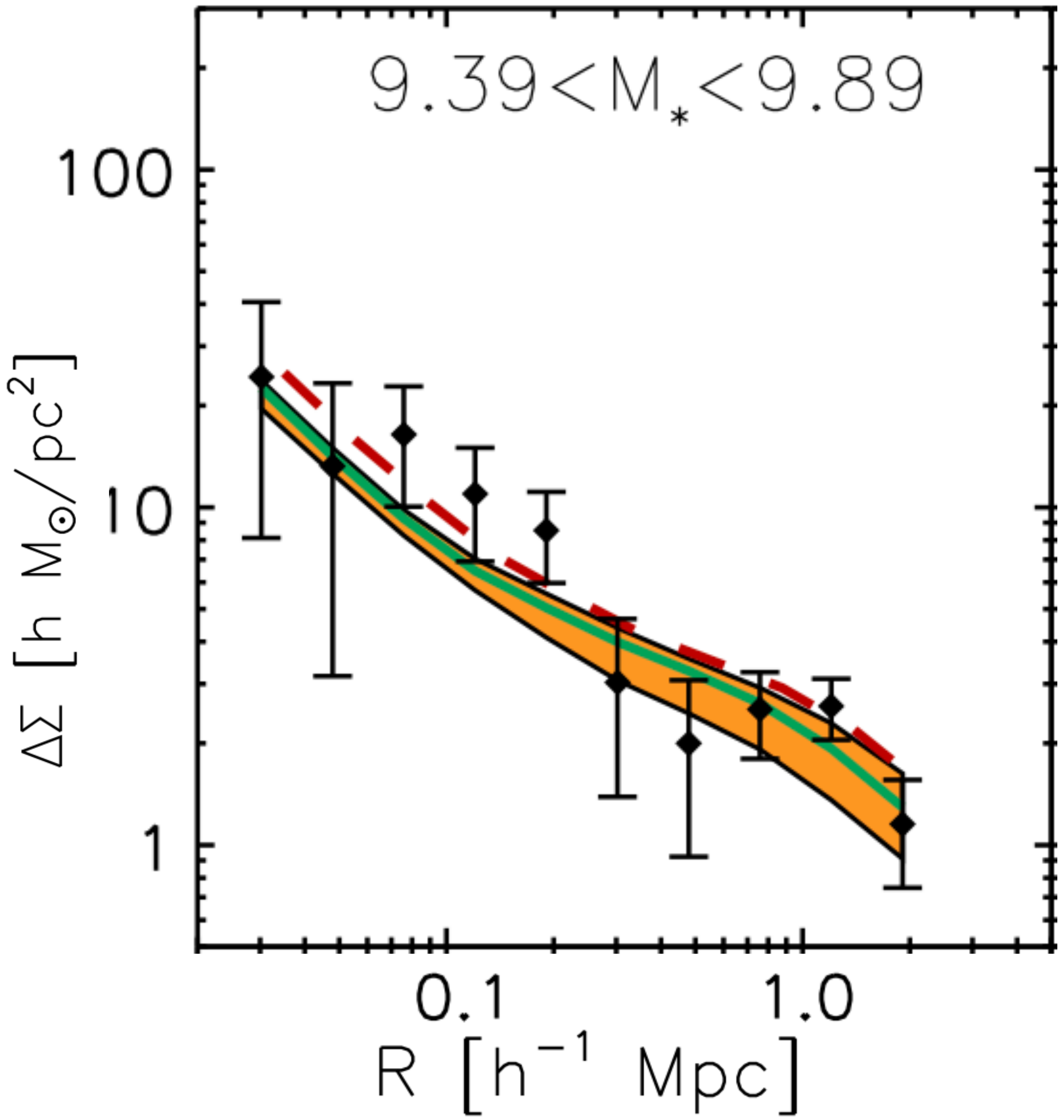
Magnitude-Position

Sensitive to Mass
& Dust

Colour-Position

Sensitive to Dust

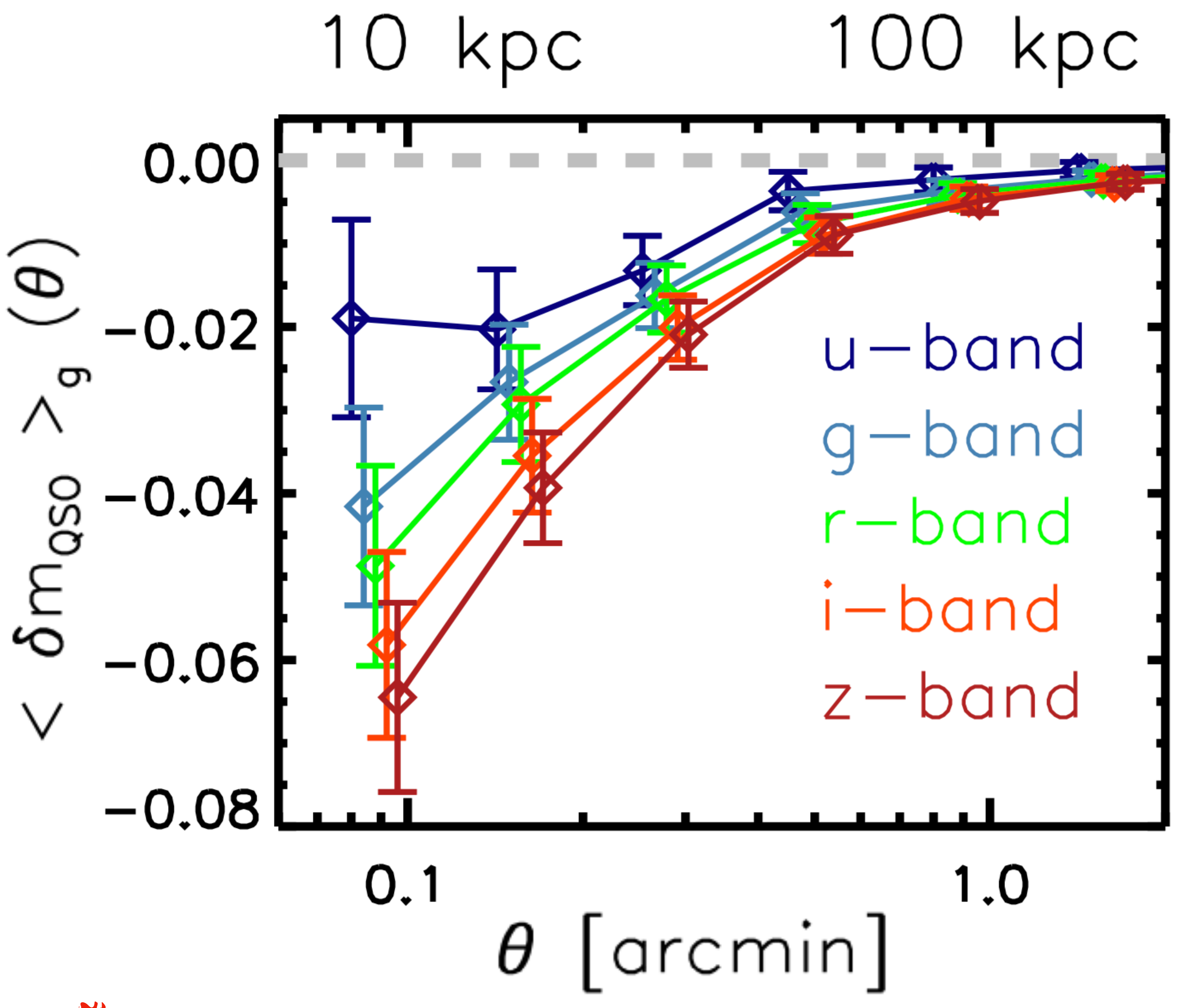
Previous Work on these Correlation Functions



Shear-Position

Sensitive to Mass

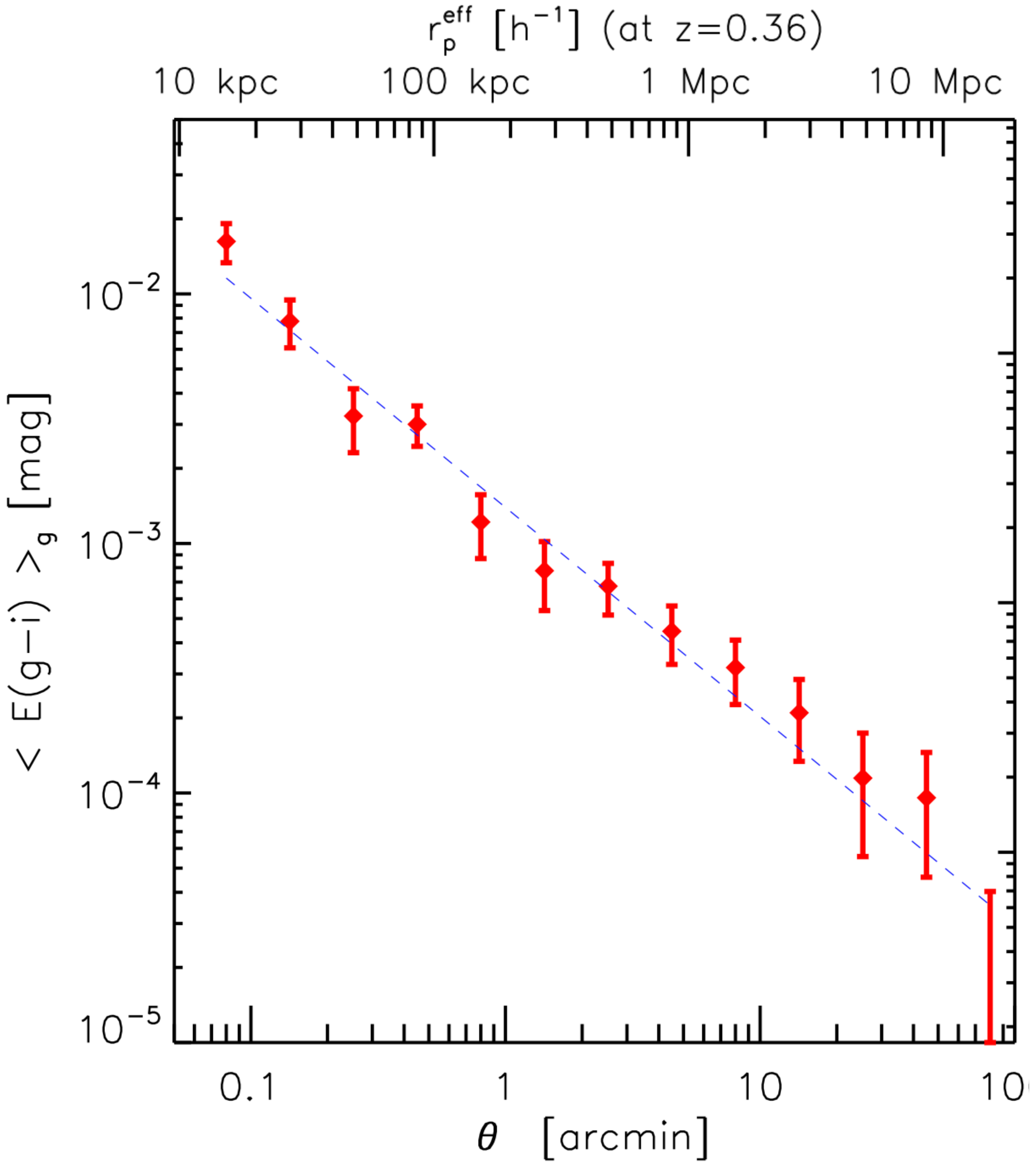
Van Uitert et al (2018)



Magnitude-Position

Sensitive to Mass
& Dust

Ménard et al (2010)



Colour-Position

Sensitive to Dust

Ménard et al (2010)

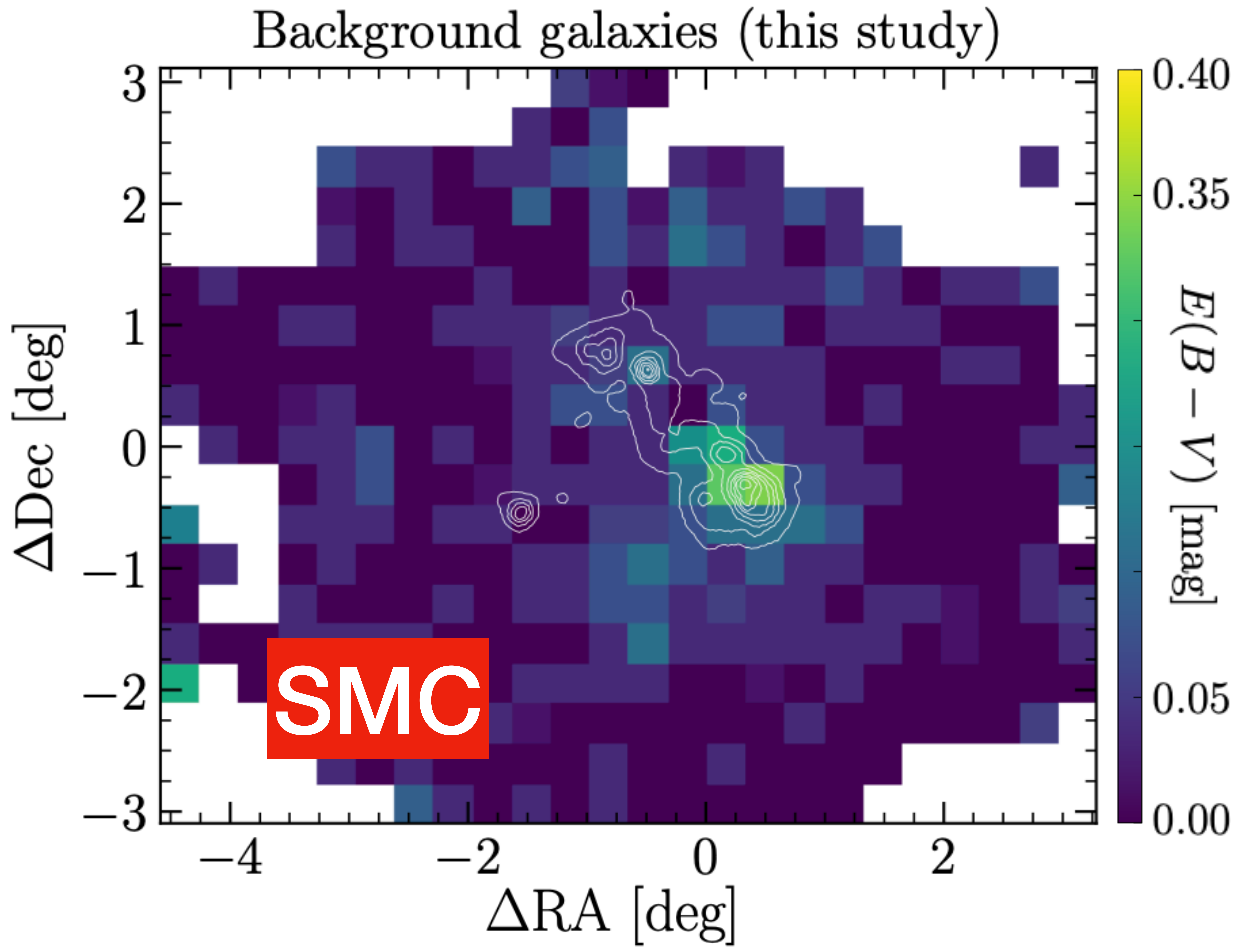
How will we improve on this? What have we already done?

- Using wide-area surveys for target (lens) definition allows us to read much lower masses, and create finer bins **[Demonstrated]**
- Using background galaxy samples (not QSOs) gives a significant improvement in statistical power per-target, but adds complications **[Demonstrated]**
- Performing detailed mock analyses will allow us to better understand the systematic limitations of this analysis **[Planned]**
- Using the same sample of galaxies for all measurements allows degeneracy breaking multi-probe analyses **[Planned]**

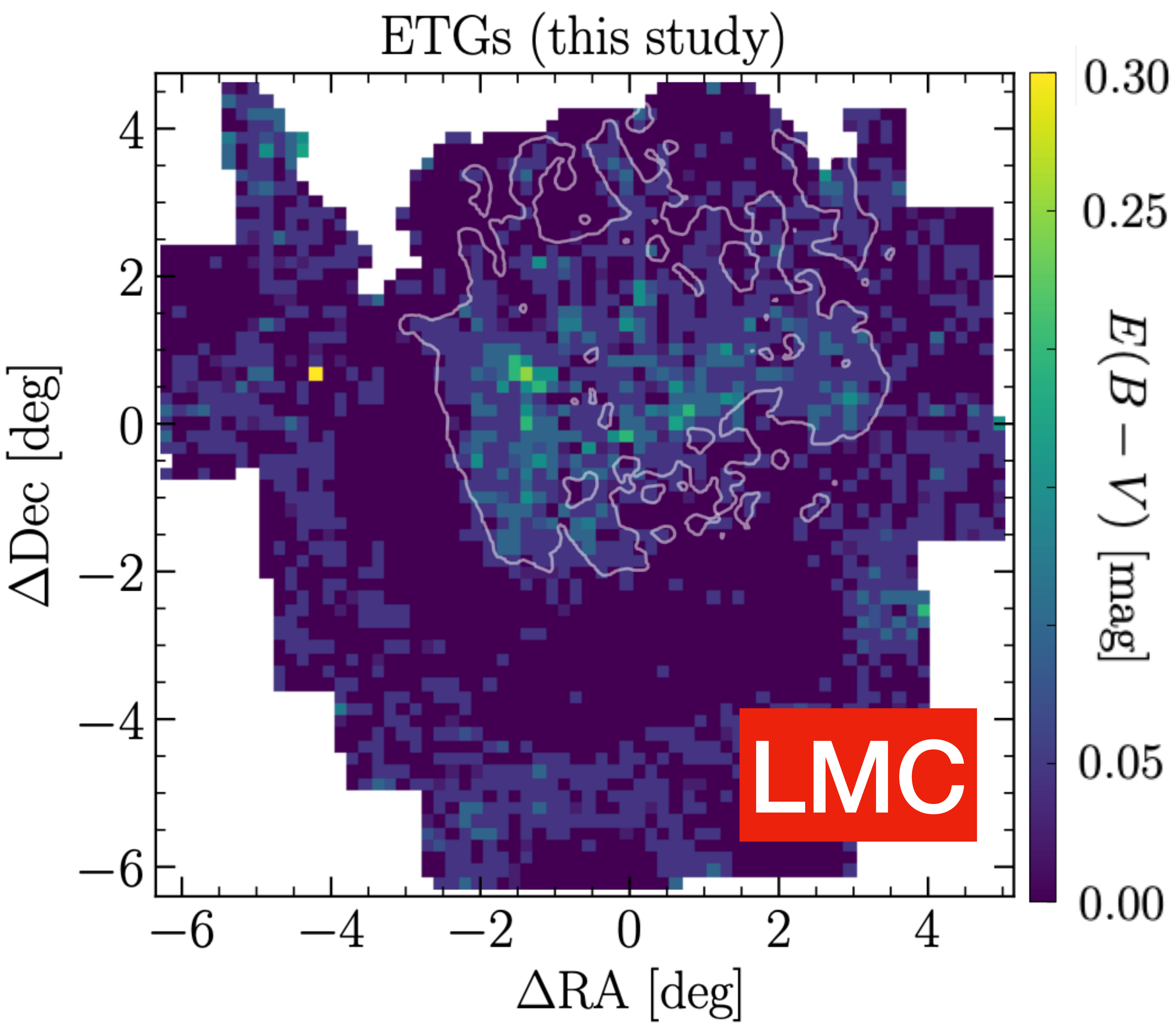
Shear-Position	**Magnitude-Position**	**Colour-Position**
Sensitive to Mass	Sensitive to Mass & Dust	Sensitive to Dust

Direct Measurement of Dust in SMC/LMC

Demonstration of the "Standard Crayon" concept with galaxies



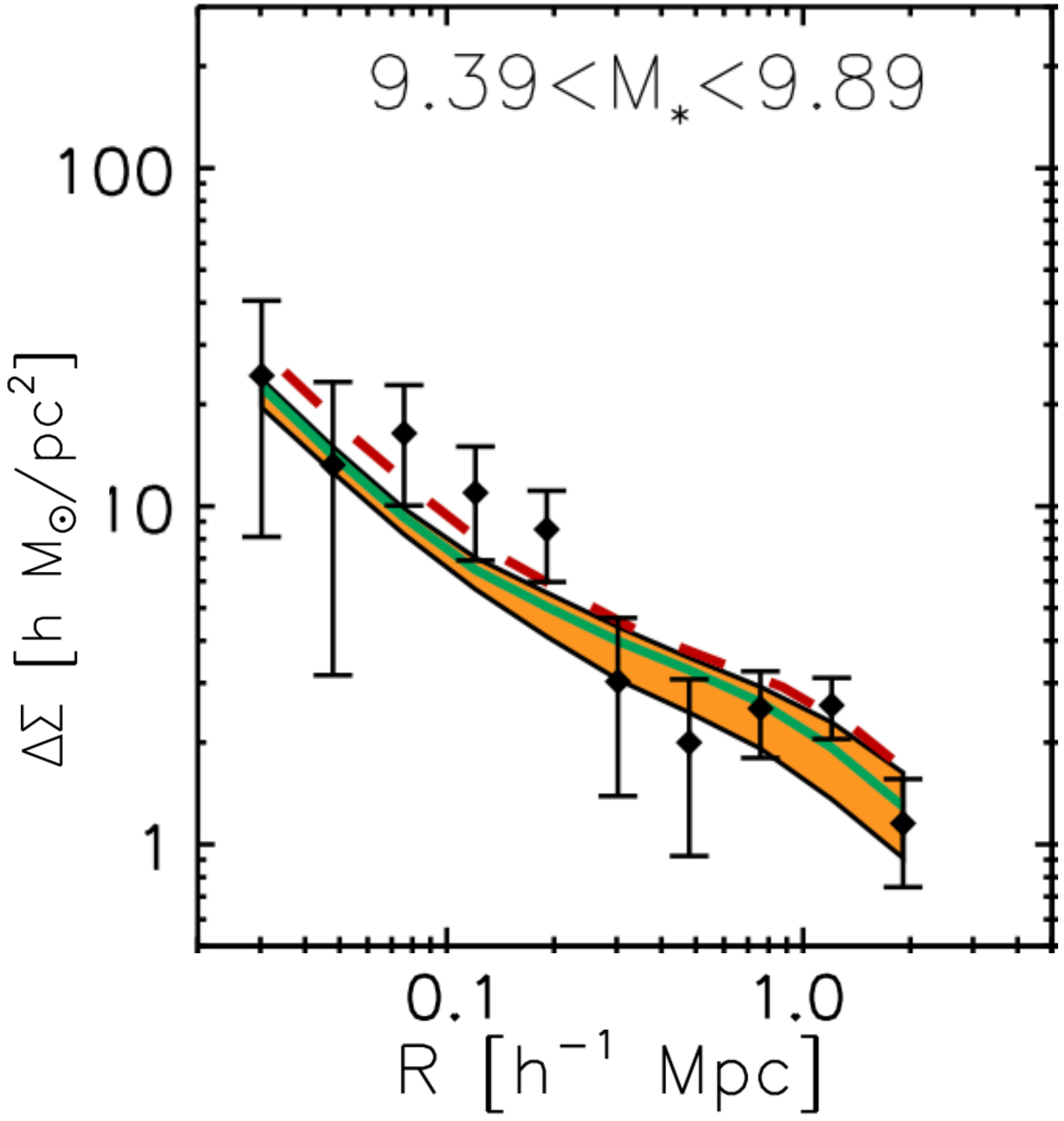
Bell, Cioni, Wright, et al (2021)



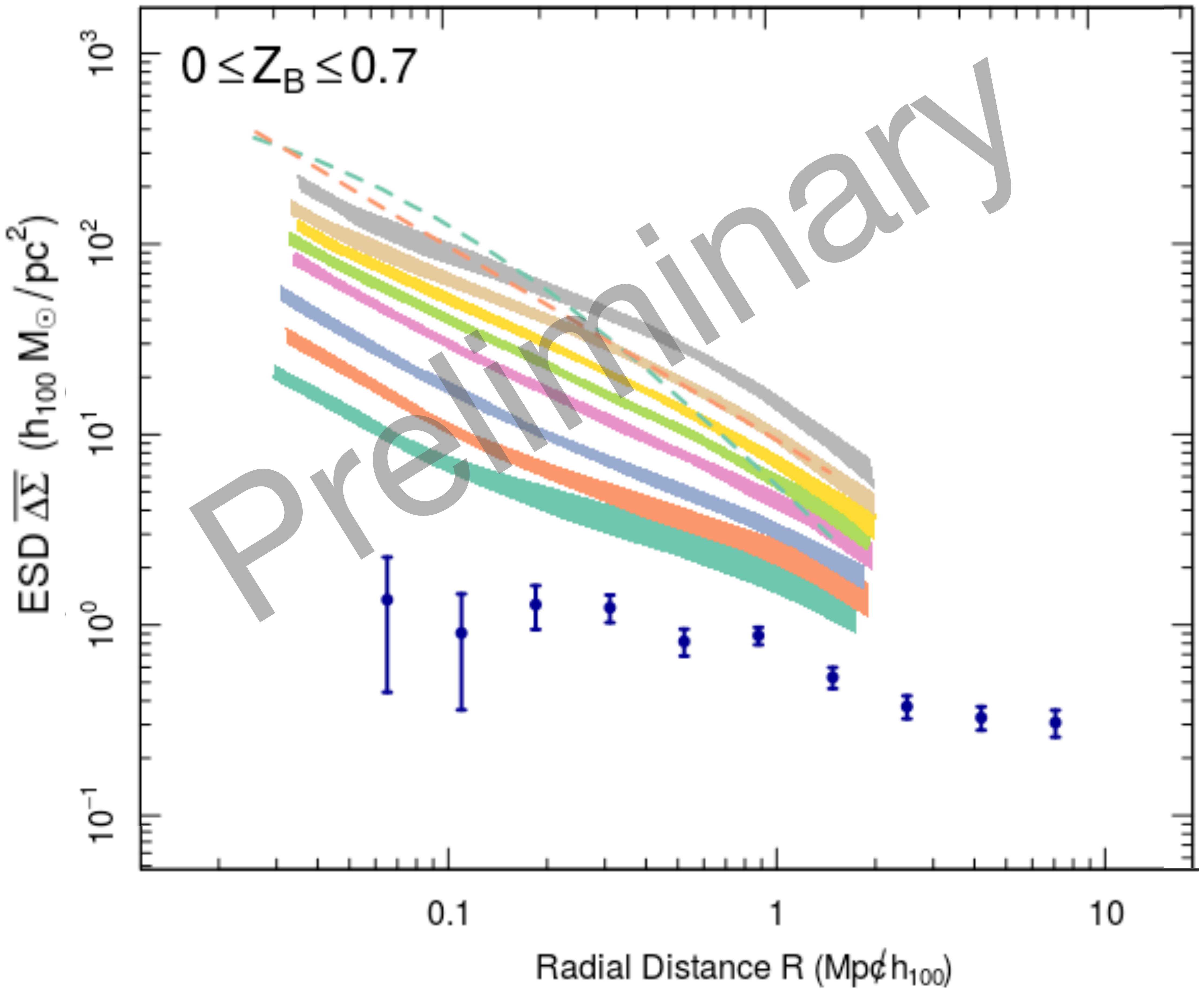
Bell, Cioni, Wright, et al (2022)

Shear-Position Correlation Functions for low-mass galaxies

Significant detections of extremely low-mass starburst sources



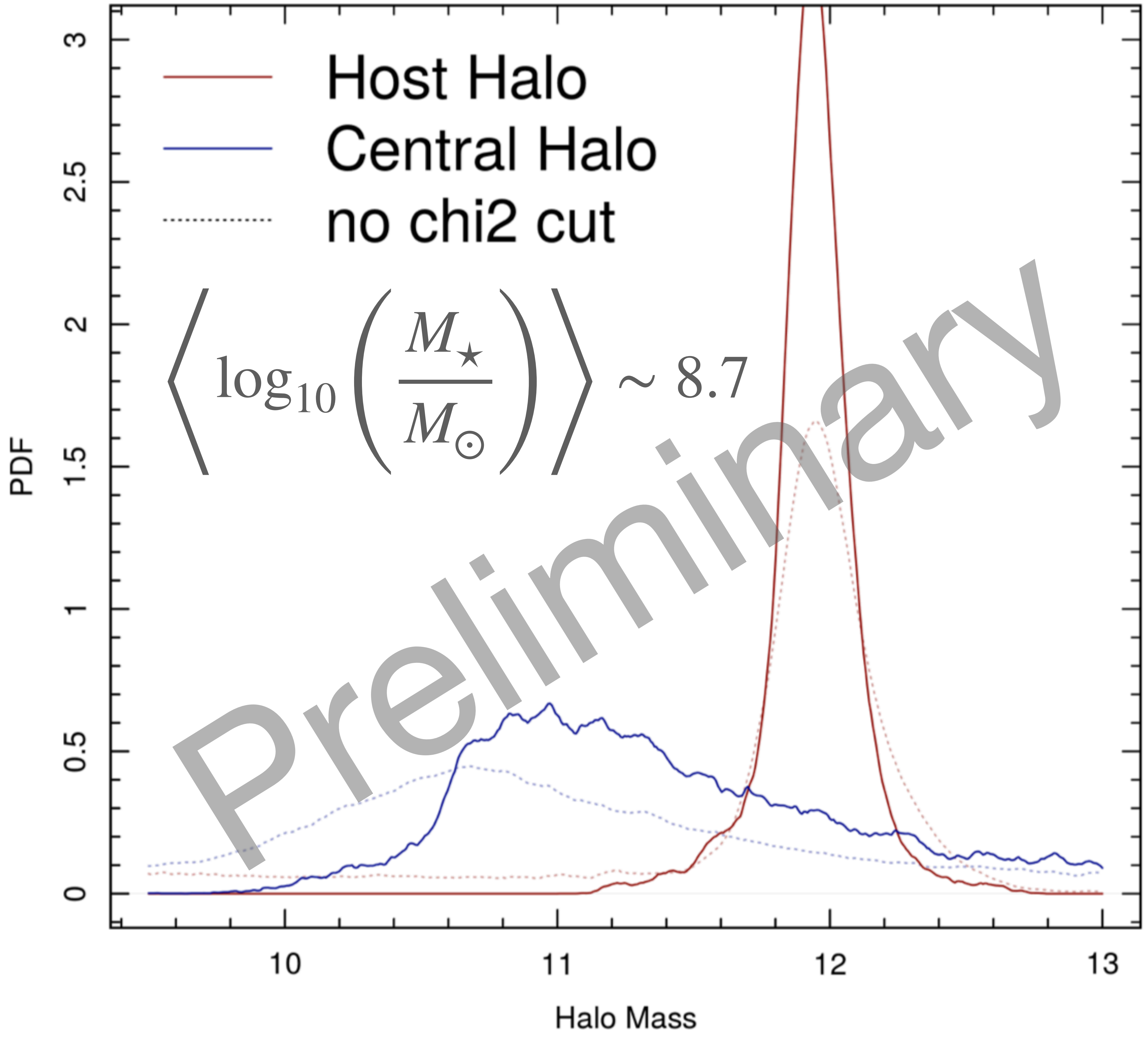
Van Uitert et al (2017)



Masters work by Anna Enders (RUB)

Shear-Position Correlation Functions for low-mass galaxies

Stellar and Halo Mass Estimates from “Halo Modelling”…



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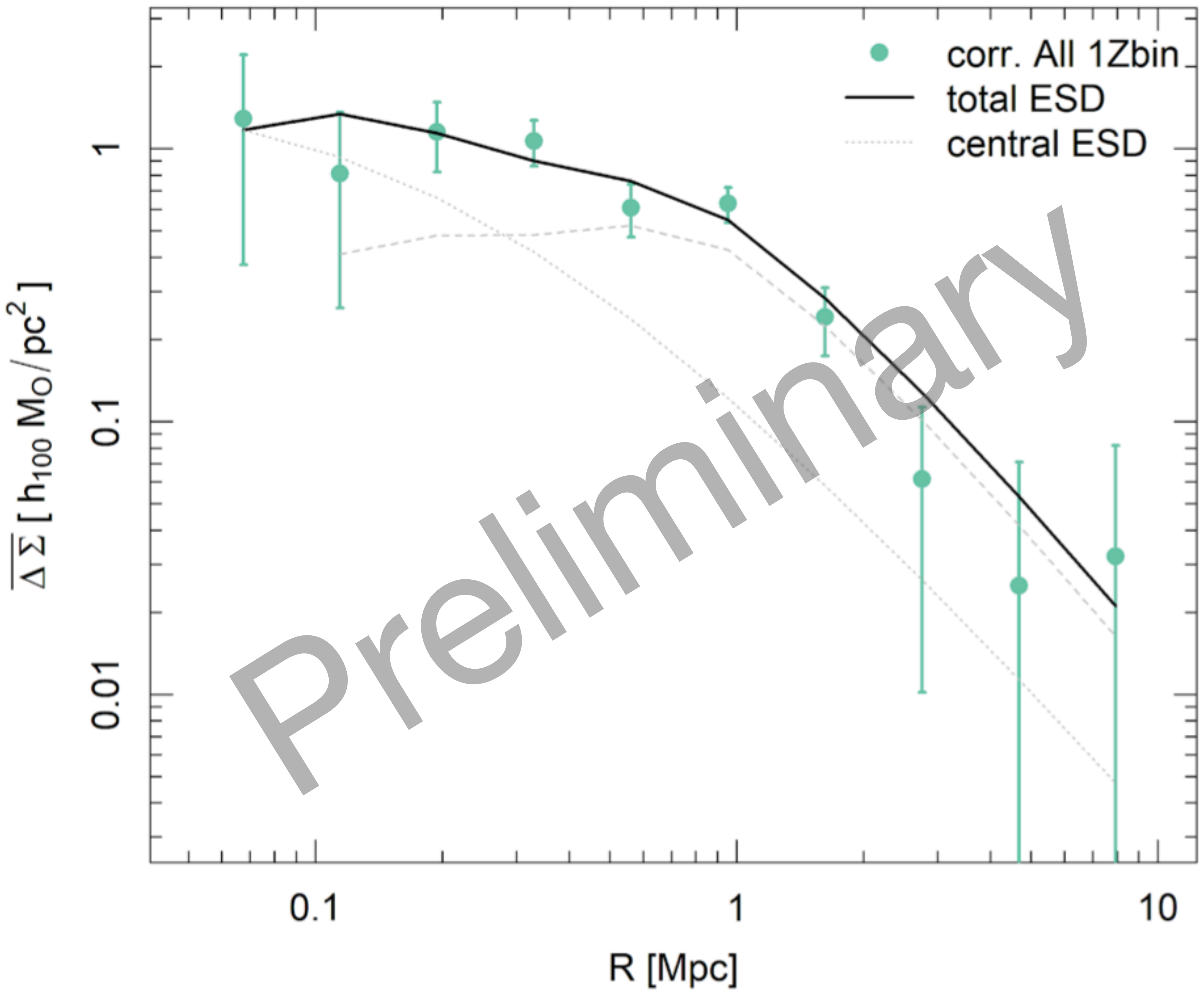

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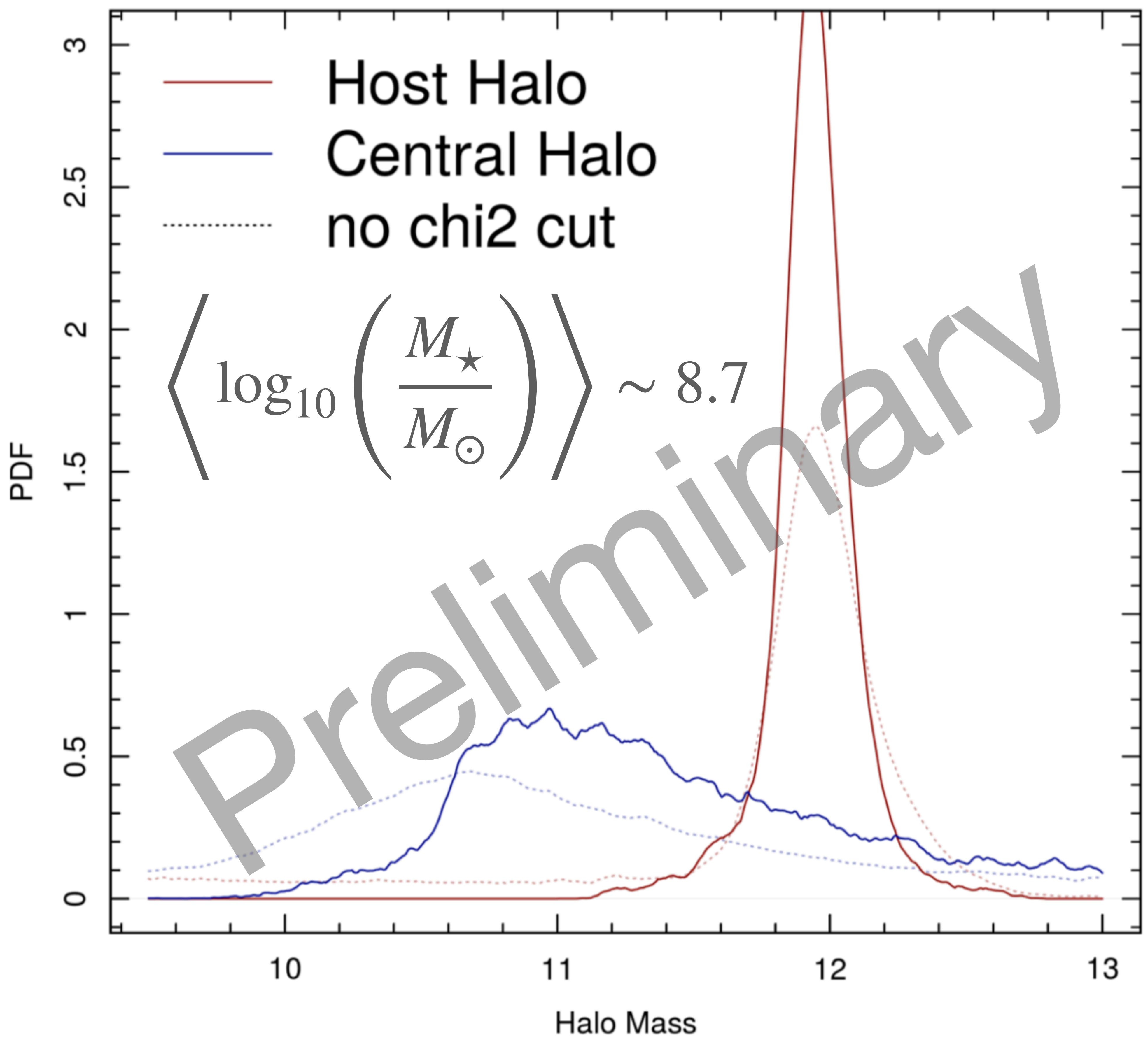
Shear-Position Correlation Functions for low-mass galaxies

… allows us to check whether these sources follow expected trends!



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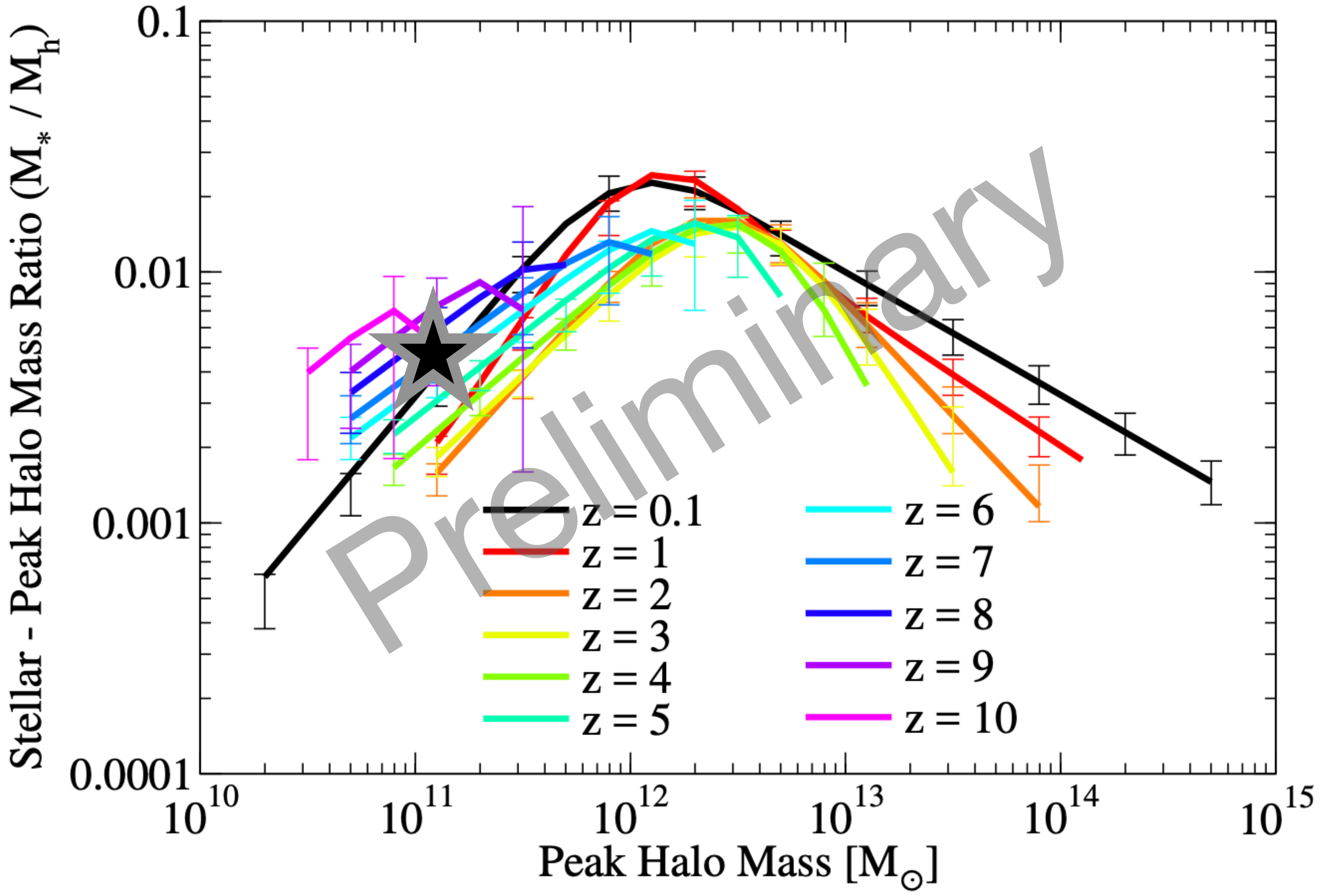

Behroozi et al (2019)

Project F6: Dark Matter & Gas in Galaxies

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