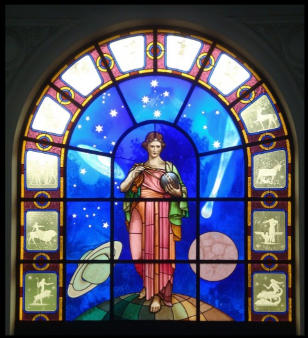
São Paulo/ Brazil - FAPESP projects for LSST @ Vera Rubin Observatory

Eduardo Cypriano (IAG/USP)



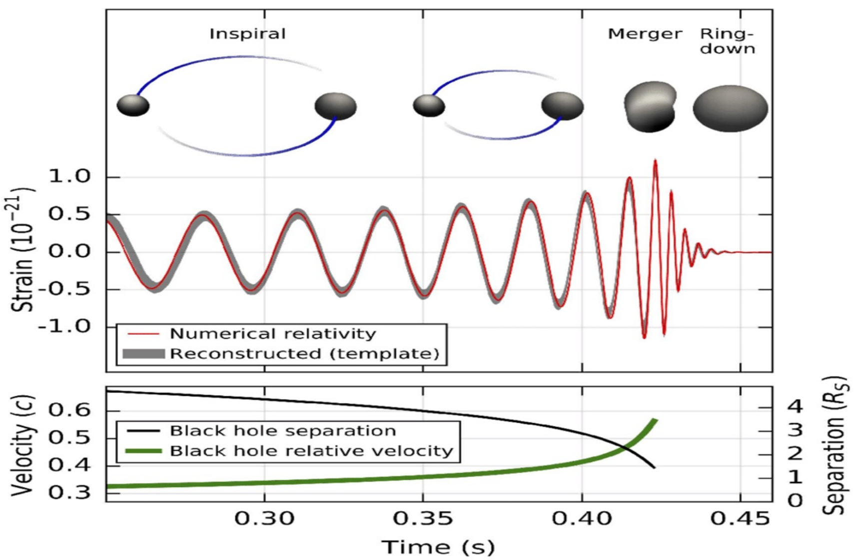
São Paulo/Brazil - FAPESP

- The state of São Paulo in Brazil via FAPESP is contributing to the LSST project through REDNESP

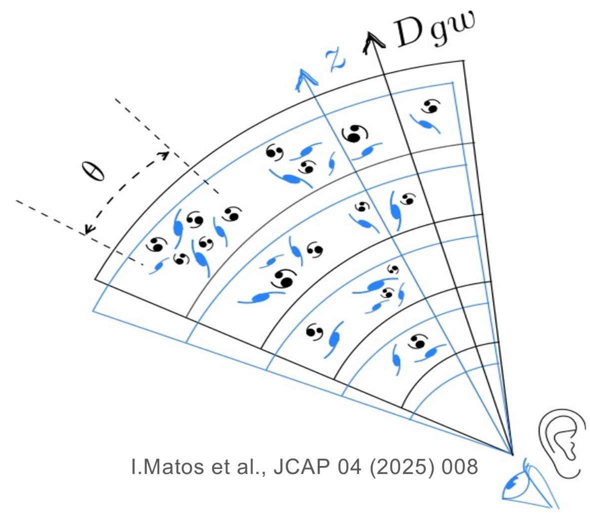
- On that account LSST granted 5 PI positions (+4 JAs each)
  - 3 - Department of Astronomy - IAG/USP
  - 1 - Physics Institute - USP
  - 1 - Theoretical Physics Institute - UNESP

Gravitational waves originating from mergers of compact objects (neutron stars and/or black holes) at astrophysical/cosmological distances (sources with sizes of ~ km)

Correlações nos aprendem sobre evolução cósmica



LIGO/Virgo PRL 116 (2016) 6



I.Matos et al., JCAP 04 (2025) 008

LSST: Brazilian Participation Group

Peak Sirens and LSST:
measuring H_0 through the cross-correlations of gravitational wave sources and LSST galaxies

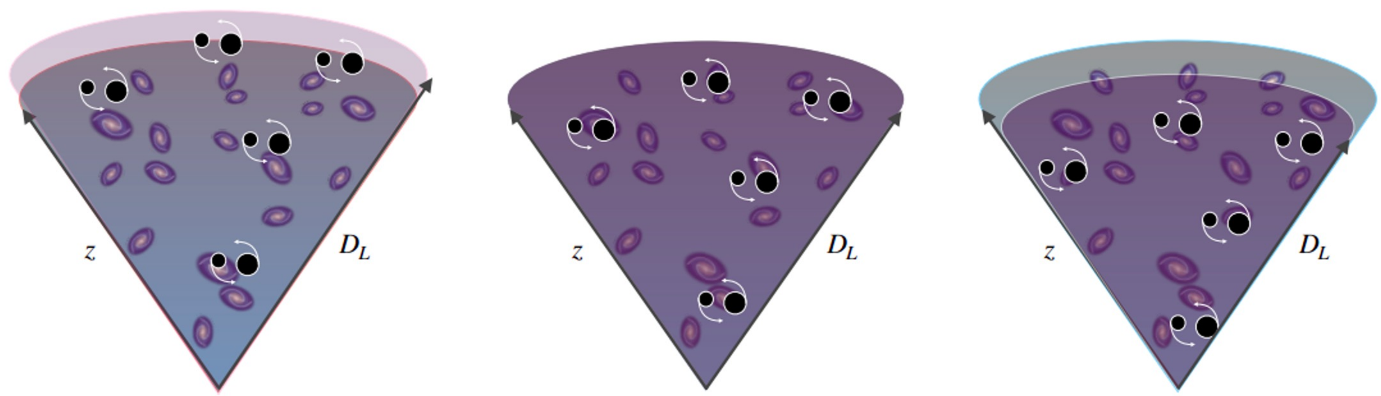
Project inside the DESC Working Group on
Models and Combined Probes

Raul Abramo (Physics Inst., São Paulo Univ.)
Isabela Santiago de Matos, Tessa Baker (Portsmouth)**,**
Riccardo Sturani, Bernardo Veronese (IFT/UNESP)**, …**

FAPESP
FUNDAÇÃO DE AMPARO À PESQUISA
DO ESTADO DE SÃO PAULO

Combining dark sirens and galaxies

- Gravitational waves from mergers of binary black holes are "**dark sirens**": we can infer their (luminosity) **distances**, but we do not know their redshifts.
- Galaxies have known **redshifts**, but their distances are unknown
- By **combining** the two observations we can measure directly H_0 (as well as Ω_m , etc.)



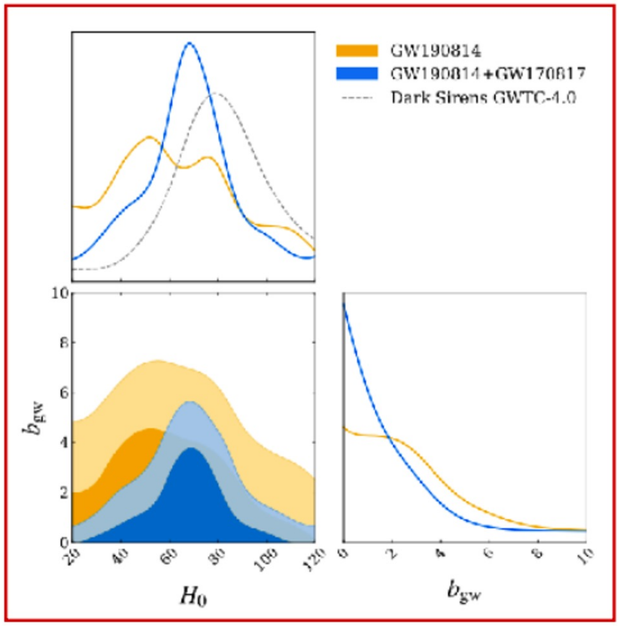
$D_L > D_L(z)$
correlations ↓

✓ : $D_L = D_L(z)$
correlations ↑

$D_L < D_L(z)$
correlations ↓

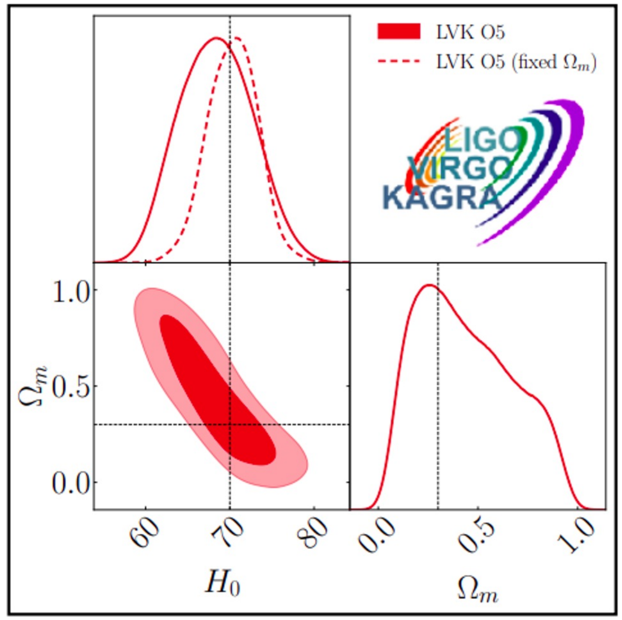
See also **Oguri 2016**
Mukherjee, Wandelt 2018
Bera + 2020

Peak Sirens — Ferri et al. 2412.00202 (JCAP 2025); Santiago de Matos et al. 2512.15380



5.9 σ detection of a cross-correlation

$H_0 = 67^{+18}_{-15}\ \mathrm{km\,s^{-1}\,Mpc^{-1}}$



- **Forecast: LIGO-Virgo-Kagra Run O5: 4% in H_0**

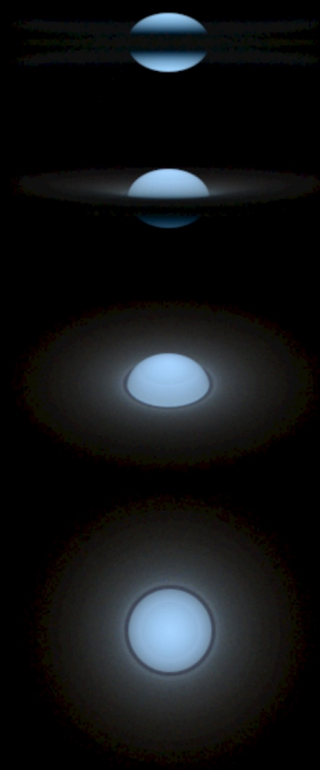
  Network of the current GW detectors LIGO (both Hanford and Livingston), Virgo and KAGRA; 3 years of observations (2028-2030), ~ 300 BBHs up to z ~1

VERA C. RUBIN OBSERVATORY

Machine Learning Identification of Be stars in LSST

Be stars as probes of massive-star evolution

- Rapidly rotating B-type stars with circumstellar decretion disks;
- Possible products of binary interaction and mass transfer;
- Exhibit long-term photometric variability associated with disk formation and dissipation cycles.



Why Rubin LSST?

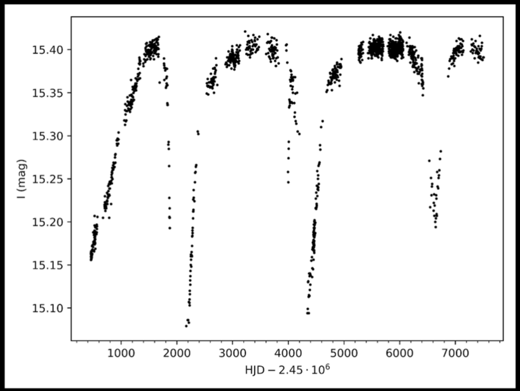
- Deep multi-band time-domain survey with long temporal coverage;
- Ideal for detecting long-term Be-star variability and disk cycles;
- Enables large-scale discovery and population studies in the Milky Way and Magellanic Clouds.

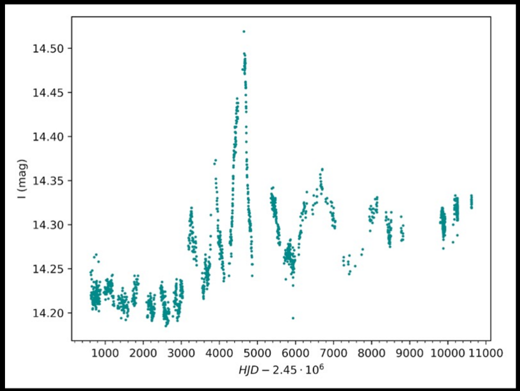
Machine Learning Identification of Be stars in LSST

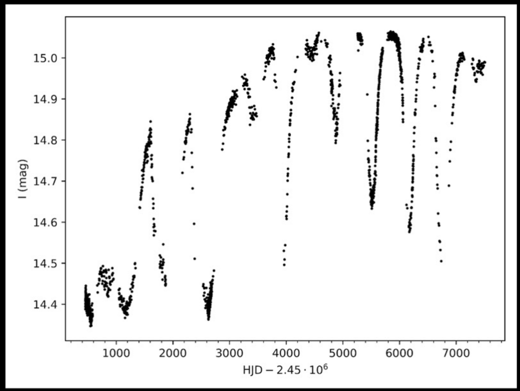
From Current Surveys to Rubin LSST

- Current surveys such as OGLE provide long-term monitoring of Be-star variability;
- However, multi-band temporal sampling remains sparse and uneven, with limited coverage beyond the I-band;
- Rubin LSST will provide dense multi-band time-domain coverage at unprecedented scale and depth.

Examples of long-term Be-star variability in OGLE I-band photometry







Machine Learning Identification of Be stars in LSST

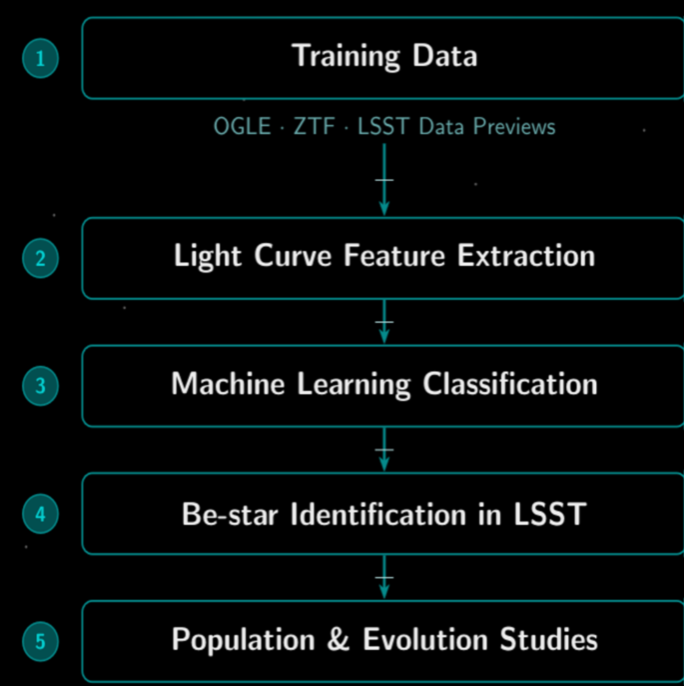
Scientific Goals

- Automated identification of Be stars;
- Population studies across different metallicity environments;
- Investigating the role of binary interaction in Be-star populations.

Expected Impact

- Large homogeneous Be-star samples (from thousands to hundreds of thousands known stars);
- Scalable ML pipelines for LSST time-domain astronomy;
- Improved constraints on massive-star and binary evolution.

Pipeline:



Pilot project: bulge–disc decomposition for the LSST era

Objective: Characterize Transition galaxies, which are galaxies with properties in between early and late-type galaxies that seem to have different evolutionary paths in groups and specially in compact groups.

WHY TRANSITION GALAXIES?

Our recent result:

Transition galaxies (those with low Sérsic index ($n<2.5$) and red colors ($u-r>2.3$)) show a strong environmental signal — **steeper mass–size slopes β and smaller sizes in groups and CGs** than in the field suggesting **accelerated morphological transformation** driven by bulge growth and/or disc fading.

Montaguth et al. 2026, ApJ 999, 160 ·
S-PLUS DR4 · $0.035 < z < 0.096$

FIELD

$\beta \simeq 0.24$

shallow slope, disk-like (0.2)

GROUPS & CGs

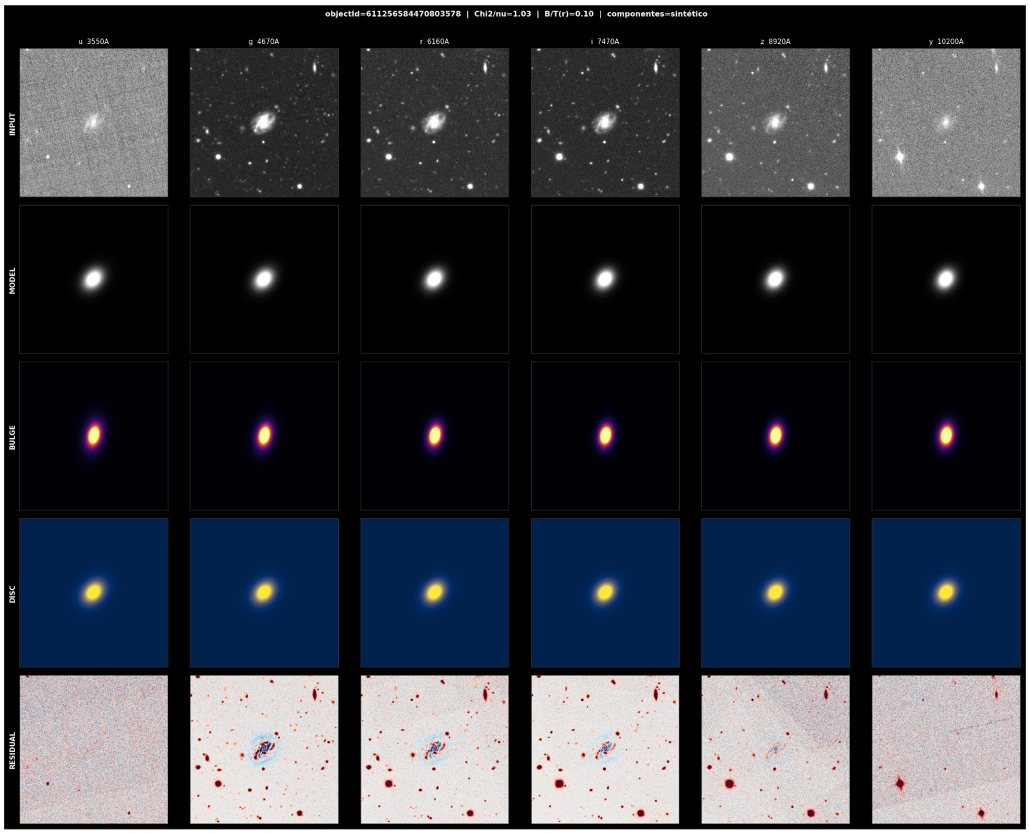
$\beta \simeq 0.43$

steeper, ETG-like (0.40–0.45)

Pilot project: bulge–disc decomposition for the LSST era

Specific Goal: Determine whether the steeper mass–size slope of Transition Galaxies in groups is driven by bulge growth, disc fading, or both

Testing the methodology on LSST DP1 galaxies while the full survey ramps up



Pilot test on an LSST DP1 galaxy. GALFITM multi-band Sérsic fit (6 bands). Rows: input, total model, bulge, disc, residual. **$\chi^2/\nu = 1.03$** · **B/T (r) = 0.10** — well-fit, disc-dominated system.

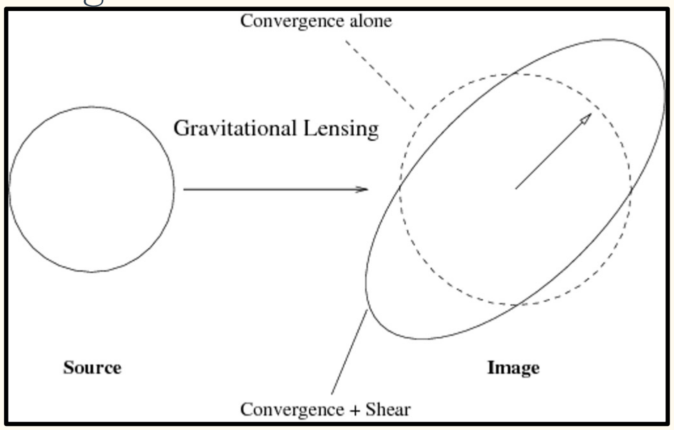
Why LSST?

- Only LSST combines the depth, the uniform 6-band coverage, and the wide-area imaging needed to characterise Transition Galaxies across every environment — recovering their faded outer discs and faint tidal features in a single homogeneous sample.

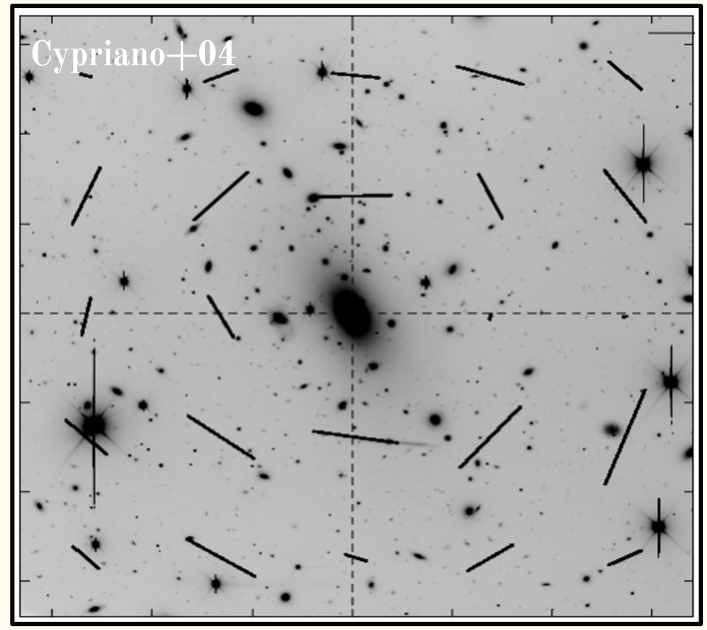
Strong & weak Lensing with LSST
E. Cypriano

Weak Gravitational Lensing

On its weak regime GL deforms the shape of distant galaxies images



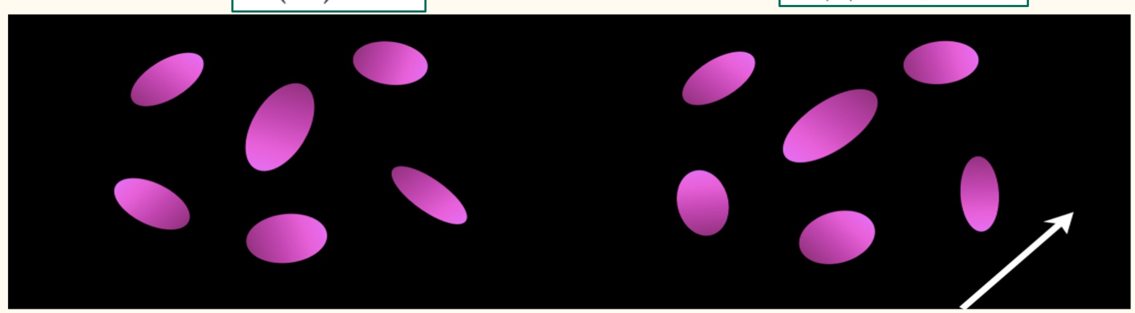
In cluster lensing background galaxy images are stretched (sheared) in the direction perpendicular to the cluster centre



- Intrinsic galaxy shapes are a huge noise source...
- ...but it is random, thus it can be beaten down by the use of large galaxy samples.

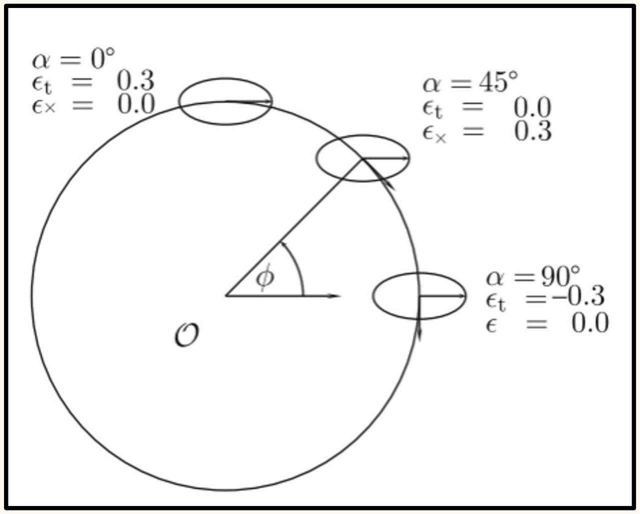
No lens $E(\epsilon^s) = 0$

$E(\epsilon) \approx g \approx \gamma$



Weak Gravitational Lensing

Tangential Shear

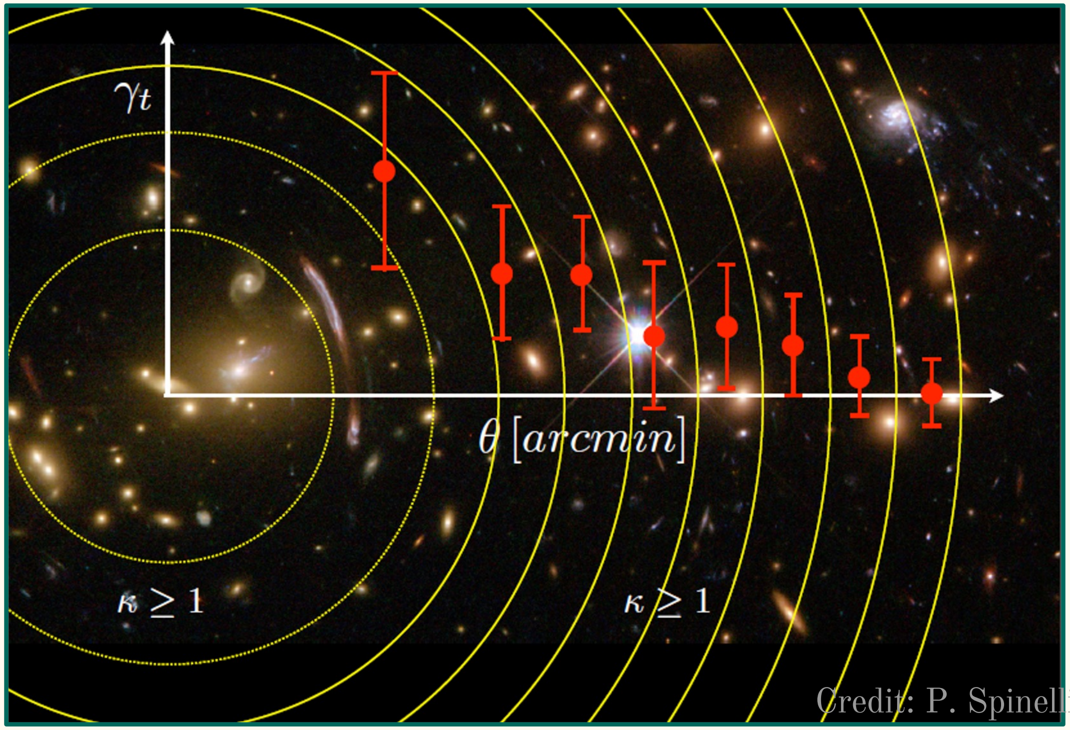


Schneider 05

Radial profiles of the tangential shear traces the cluster mass projected (over-)density

$$\gamma_t(\theta)\Sigma_{crit}(z_l, z_s) = \bar{\Sigma}(< \theta) - \Sigma(\theta)$$

$$\Sigma_{cr} = \frac{c^2}{4\pi G}\frac{D_{os}}{D_{ol}D_{ls}}$$

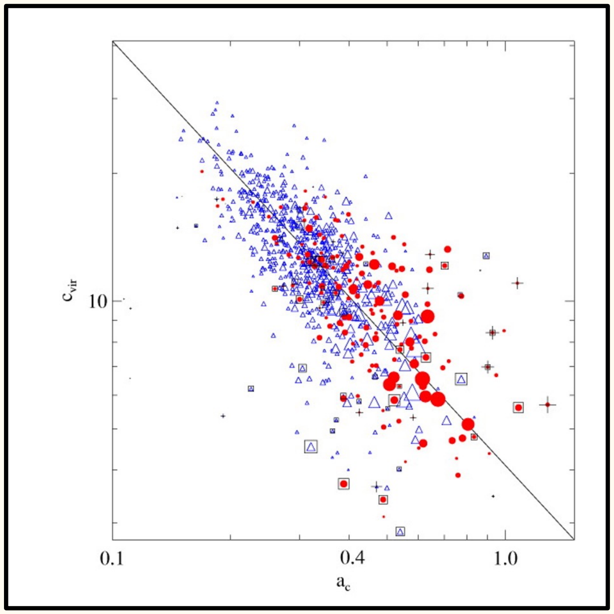


Credit: P. Spinelli

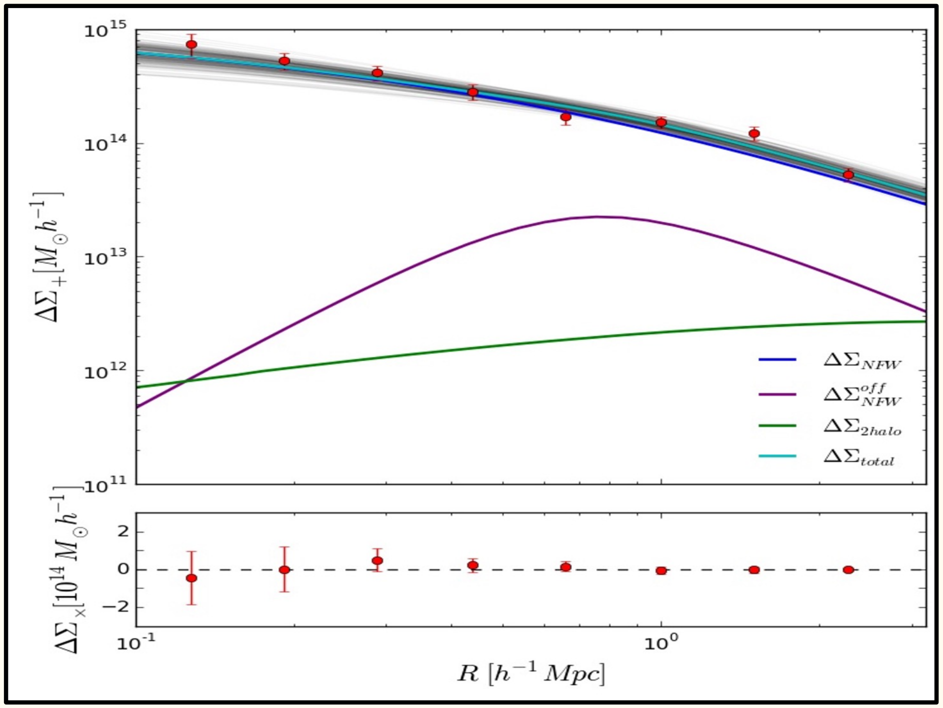
Weak-lensing profile analysis

$$\Delta\Sigma(R) = p_{cc}\Delta\Sigma_{NFW} + (1 - p_{cc})\Delta\Sigma^{sm} + \Delta\Sigma_{2h}$$

- Halo model:
- Main Halo: $\Delta\Sigma_{\rm NFW}$ → Mass & Concentration



The concentration is a "cosmic clock" for the halo formation

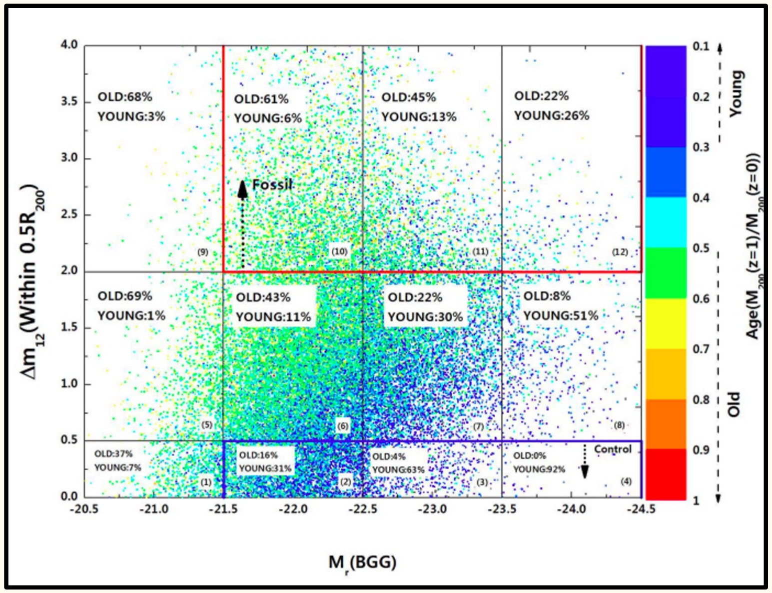


Weschler+02 - Concentrations of Dark Halos From Their Assembly Histories

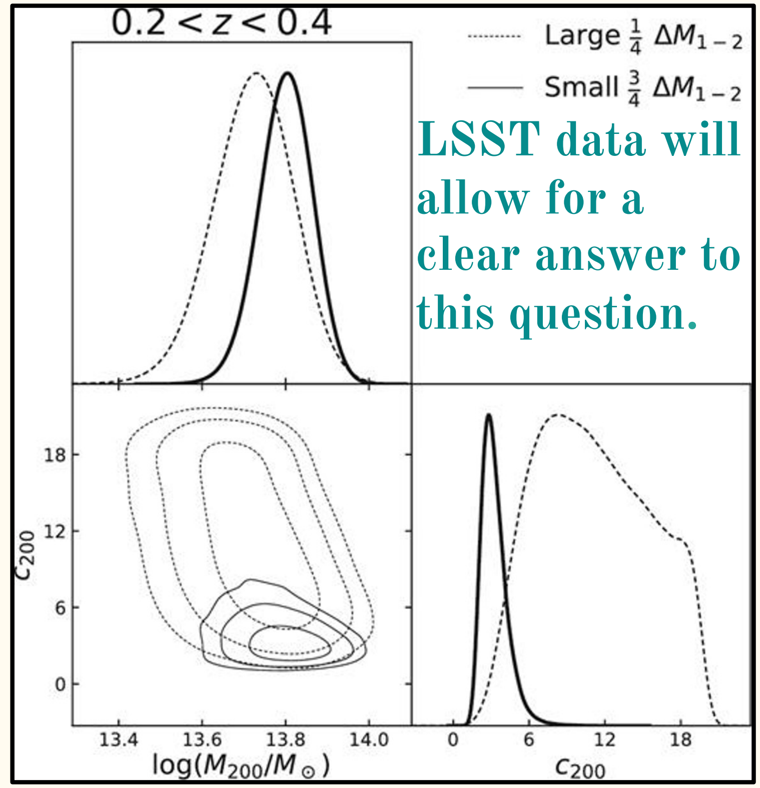
Cibirka, Cypriano+17 - Mass profile of z~0.5 galaxy clusters

Weak-lensing profile analysis

Project: Correlate mass profile concentration with cluster observables such as $\Delta m_{1,2}$ to check whether those are dependent of the assembly history as suggested by simulations



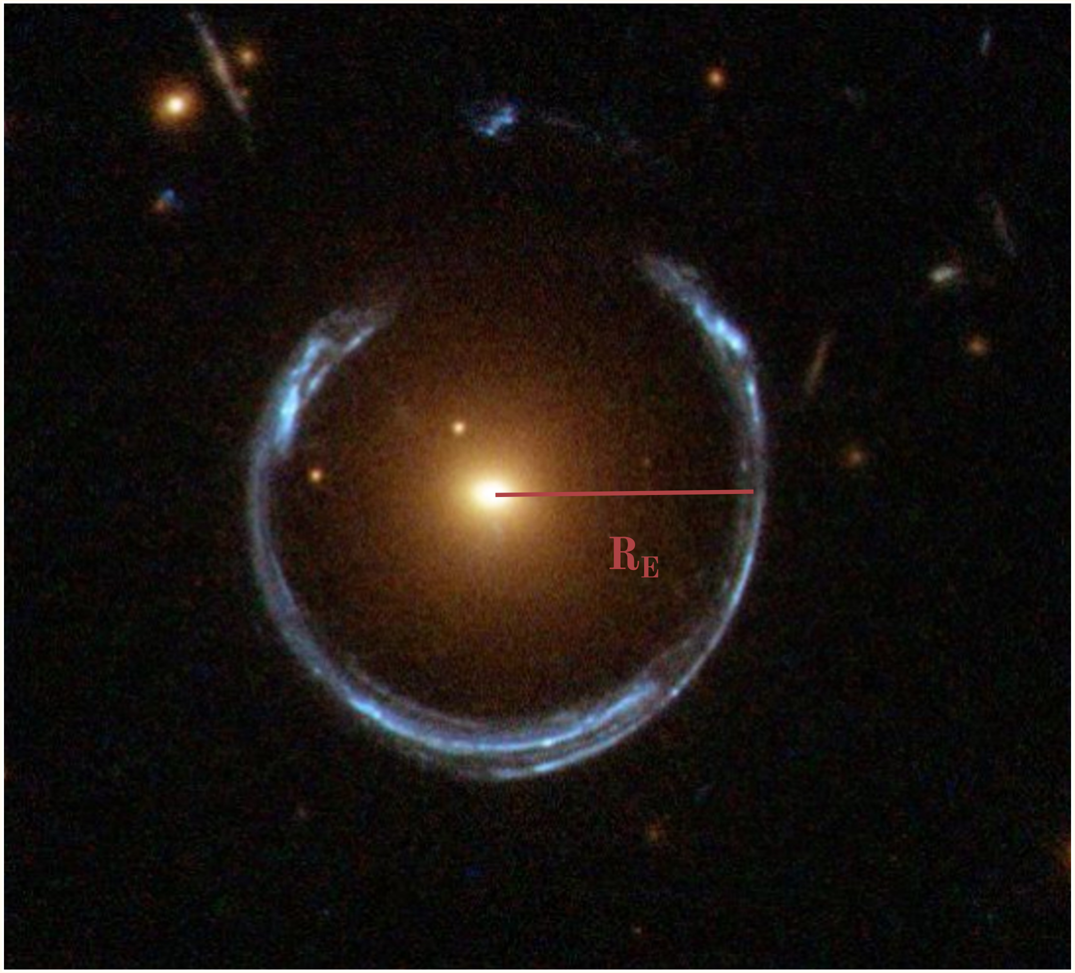
Raoulf+14 - Ultimate age-dating method for galaxy groups; clues from the Millennium Simulations



LSST data will allow for a clear answer to this question.

Vitorelli, Cypriano+17 - On mass concentrations and magnitude gaps of galaxy systems in the CS82 survey.

Strong Gravitational Lensing



General Relativity allow for the precise measurement of Strong Gravitational Lenses

$$M_{Lens} = \frac{c^2}{4G} \frac{D_S}{D_L\, D_{LS}} R_E^2$$

Galaxy dynamics also allows mass measurements

$$M_{Dyn} = \frac{R\, \sigma^2}{\alpha\, G}$$

By comparing both mass estimations on can test GR and the galaxy level scale.

Strong Gravitational Lensing

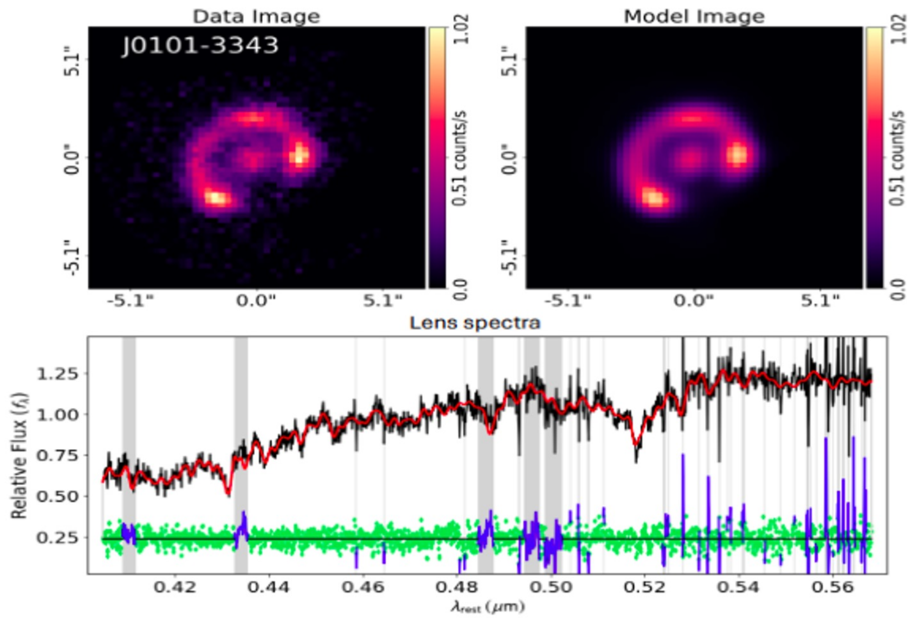
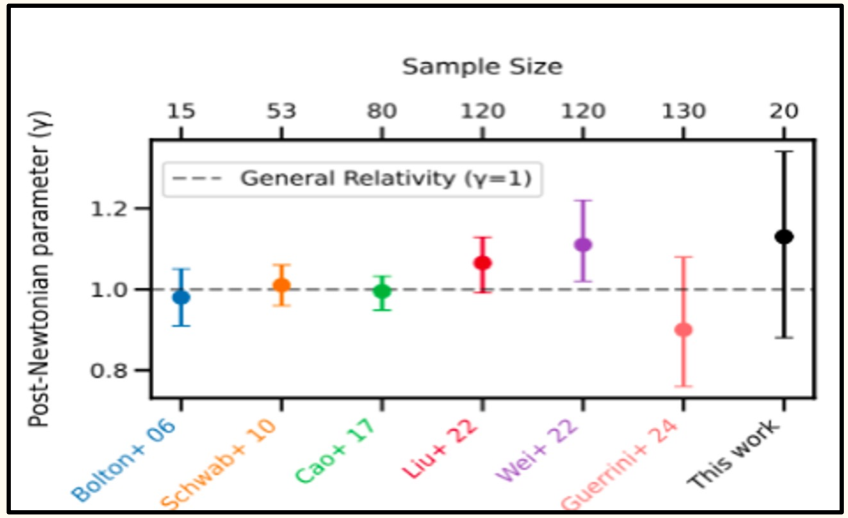


Figure 1. Necessary elements to estimate the post-Newtonian parameter in SL systems. The upper panel shows the data of the object J0101-3343 in the DES imaging survey (left) and respective modeling reconstruction (right) in $20'' \times 20''$. Modeling reconstructions for the 21 SL candidate systems in the sample were reported in JAIR-FOI I. The Bottom panel shows the lens spectra for the same object with the model fit (in red) and residuals in green. Noise data is represented in blue and was discarded. Lens velocity dispersion values were obtained from absorption lines, extracted from spectra.



França+26 (in prep.) - Joint Arc sample for Investigations into Relativity

Current results seems to agree with GR predictions - LSST data will take this experiment to another level.