XXIII IAP Colloquium

From giant arcs to CMB lensing: 20 years of gravitational distortion

2–6 July 2007, IAP, Paris, France

Cosmological parameters from strong gravitational lensing and stellar dynamics in elliptical galaxies

C. Grillo[*,†], M. Lombardi[*,†], and G. Bertin[*]

[*] European Southern Observatory, Garching, Germany

[†] Department of Physics, University of Milan, Italy

Recently, it has been recognized that the Universe is dominated by dark energy and dark matter. Although their physical nature is still unknown, the standard cosmological ΛCDM model with only few parameters fits well all current data: precision measurements of the anisotropies in the cosmic microwave background, the observed abundances of light elements, the large scale distribution of galaxies, and the luminosity-distance relationship for distant type Ia supernovae. Nevertheless, it must be noted that the estimates of different cosmological parameters from a single observational method are often correlated (hence degenerate) and show relevant uncertainties. This explains why complementary techniques are necessary to obtain precise measurements of the cosmological parameters. Although all the previous cosmological tests are already available, we show here a **new techinque** that, starting from **strong gravitational lensing** and **stellar dynamics** observations in **elliptical galaxies**, is able **to probe the geometry of the Universe** in a different and effective way.

The method

Elliptical *mass* estimates can be obtained from
- Strong lensing $M_{\mathrm{grl}} = \Sigma_{\mathrm{cr}} \pi \theta_{\mathrm{E}}^2$
- Stellar dynamics $M_{\mathrm{dyn}} = \alpha \sigma_0^2 \theta_{\mathrm{E}}$

1. Identifying the two *mass* measurements $M_{\mathrm{grl}} = M_{\mathrm{dyn}}$ and
1. assuming a homologous (isothermal) total density distribution for ellipticals $\rho \propto \frac{1}{r^2}$

$$\theta_{\mathrm{E}} = 4\pi \left(\frac{\sigma_{\mathrm{SIS}}}{\mathrm{c}} \right)^2 \frac{D_{ls}}{D_{os}}$$

1. Checking that $\sigma_{SIS} = \sigma_0$

$$\frac{c^2}{4\pi} \frac{\theta_{\mathrm{E}}}{\sigma_0^2} = \frac{D_{ls}}{D_{os}} = r(z_l, z_s; \Omega_m, \Omega_\Lambda)$$

Relation between observed quantities which depends on the values of the cosmological parameters.

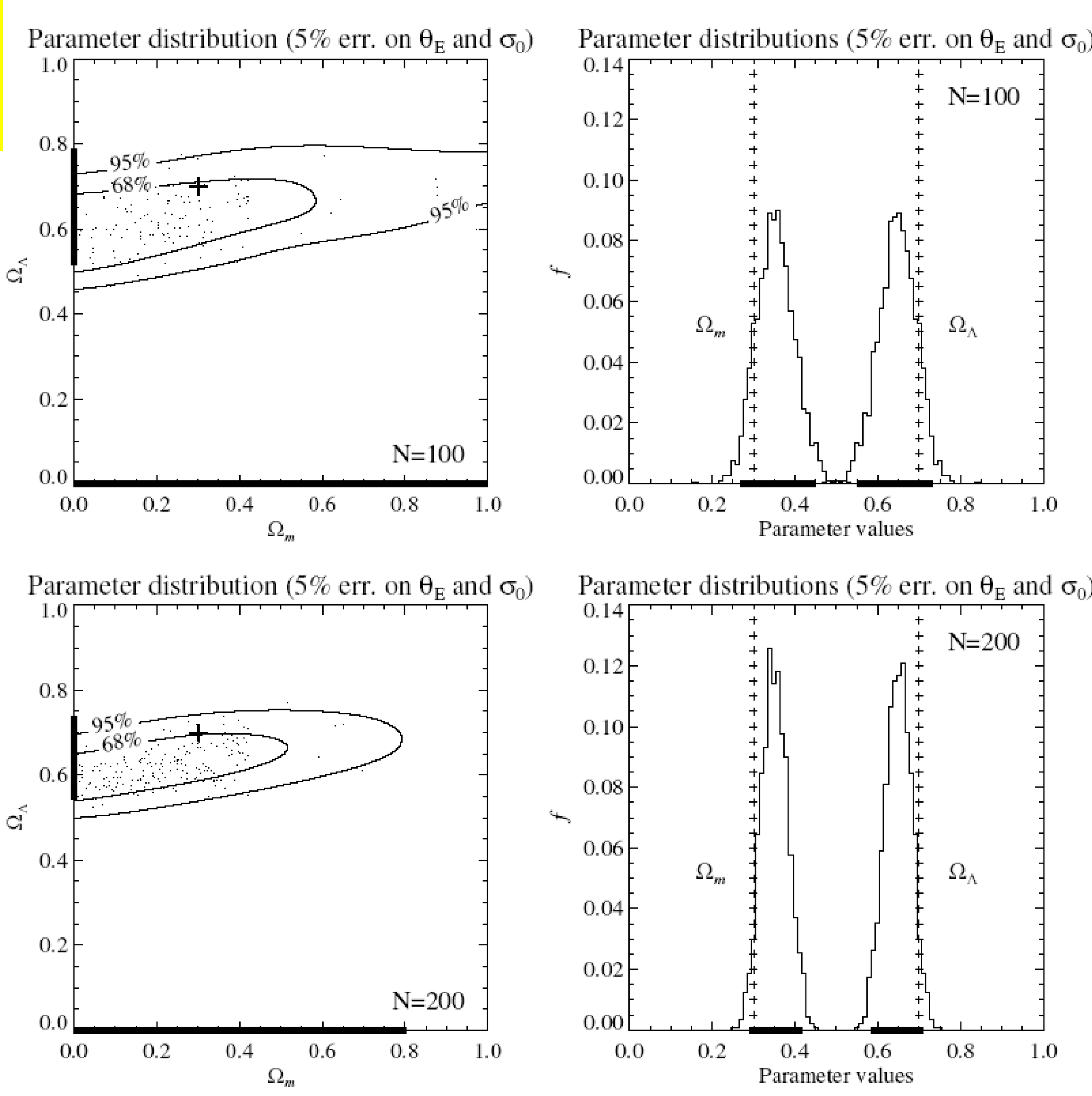
Simulated measurements

5% uncertainties on both θ_{E} and σ_{SIS} are considered

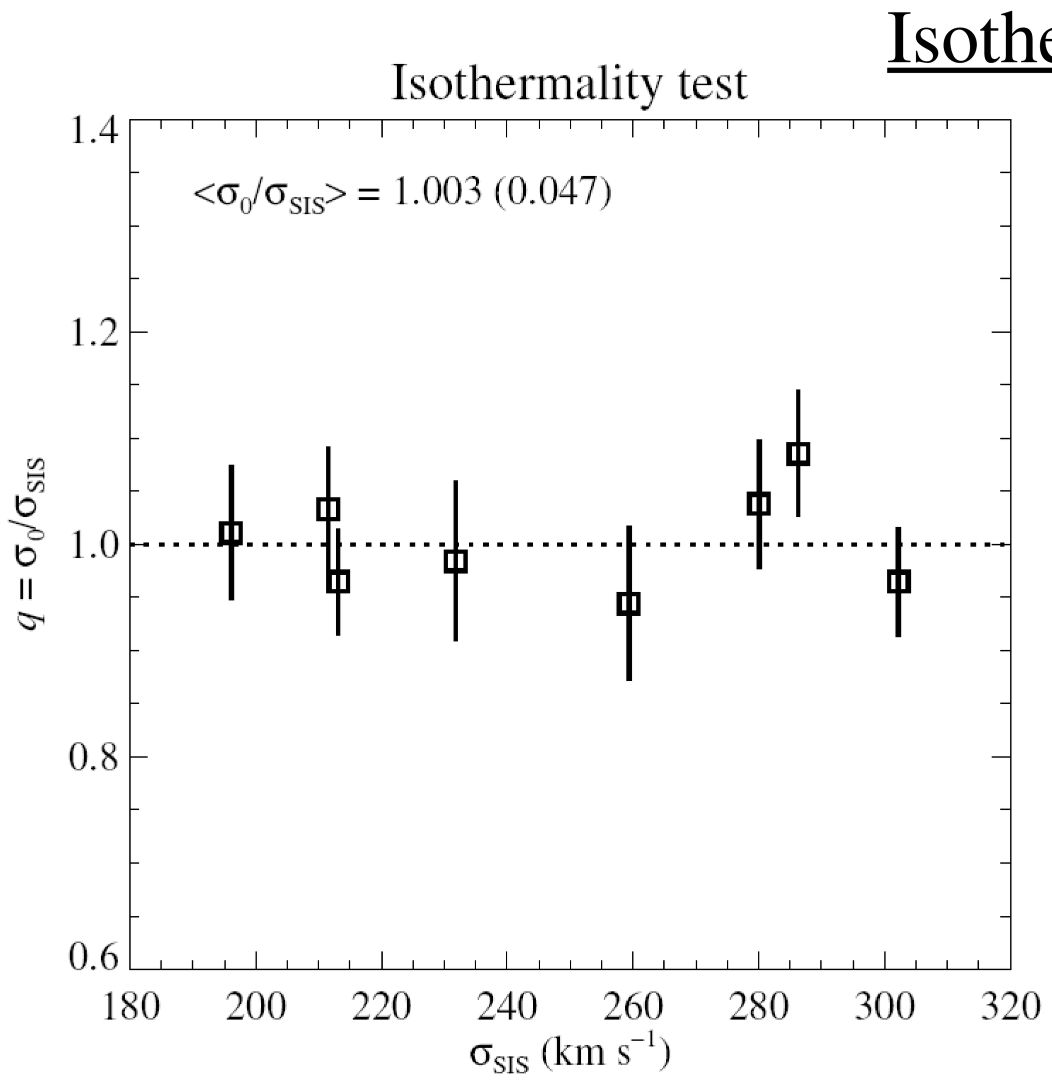
	Ω_m	Ω_Λ	Ω_m [a]	Ω_Λ [a]
N=100	[0.00, 1.12]	[0.52, 0.79]	[0.27, 0.45]	[0.55, 0.73]
N=200	[0.00, 0.80]	[0.54, 0.74]	[0.29, 0.42]	[0.58, 0.71]

[a] Flat cosmology: $\Omega_m + \Omega_\Lambda = 1$.

The method is well-suited to measure Ω_Λ



Isothermality and velocity dispersions



Sample of 8 bright, nearly round, local, early-type galaxies:
- σ_0 measured from kinematical data
- σ_{SIS} estimated from the best-fit two-component models

σ_0 is a good estimator of σ_{SIS}

Object	NGC 1404	NGC 1549	NGC 3379	NGC 4278
σ_0	245 ± 7	198 ± 6	219 ± 13	228 ± 9
σ_{SIS}	259	196	212	232
f_{DM}	0.58	0.59	0.40	0.18

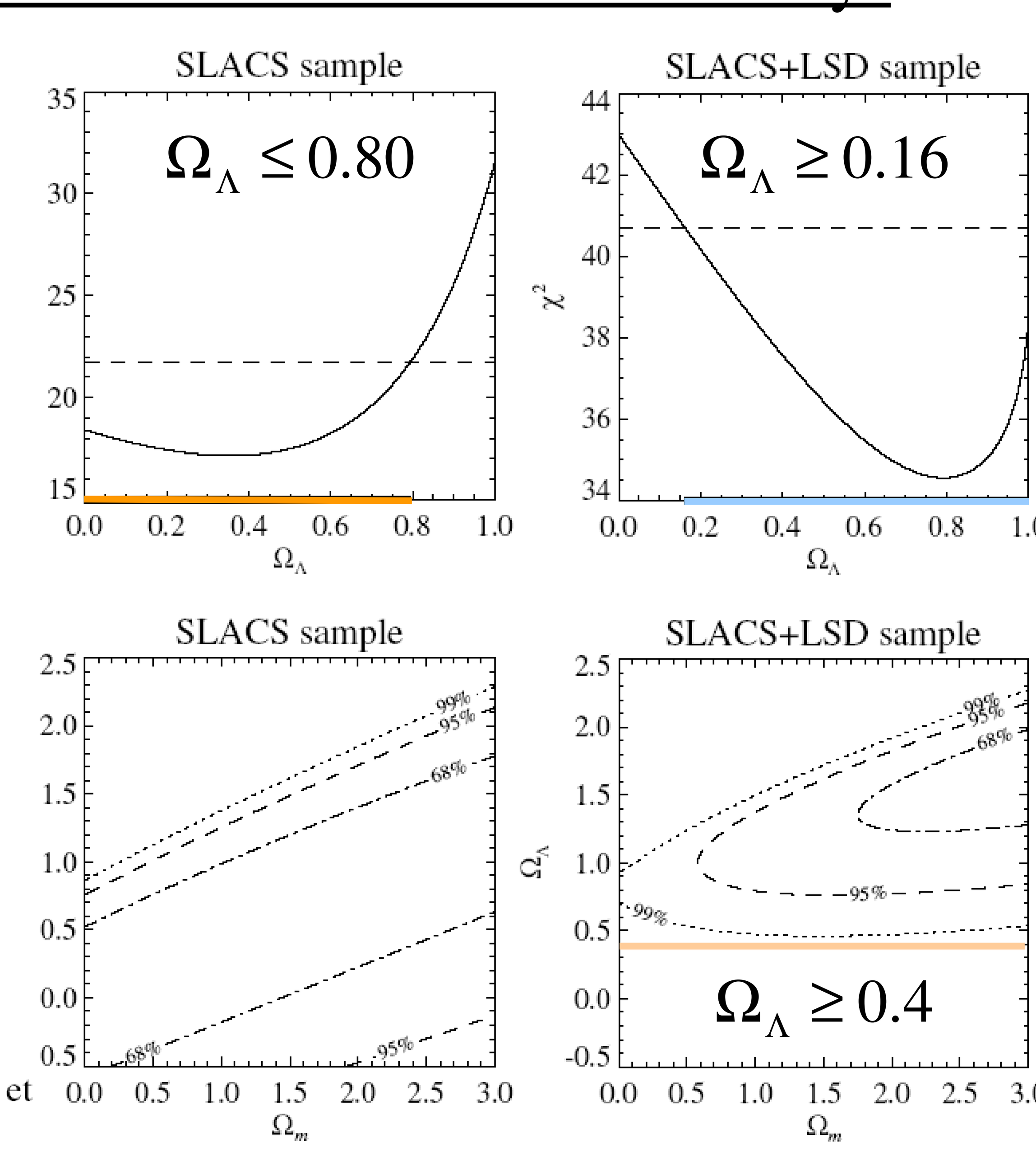
Object	NGC 4374	NGC 4472	NGC 4486	NGC 4636
σ_0	291 ± 6	292 ± 7	311 ± 3	206 ± 8
σ_{SIS}	280	302	286	213
f_{DM}	0.59	0.33	0.34	0.27

References – Davies & Birkinshaw (1988); Franx et al. (1989); Saglia et al. (1992).

Application of the method to the SLACS and LSD Surveys

#	z_l	z_s	θ_{E} ($''$)	σ_0 (km s^{-1})	
1	0.1955	0.6322	1.47	282 ± 11	SLACS
2	0.3317	0.5235	1.15	349 ± 24	SLACS
3	0.3223	0.5812	1.03	326 ± 16	SLACS
4	0.1642	0.3240	1.61	325 ± 12	SLACS
5	0.2405	0.4700	1.32	318 ± 17	SLACS
6	0.1260	0.5349	1.00	229 ± 13	SLACS
7	0.2318	0.7950	1.15	274 ± 15	SLACS
8	0.0808	0.7115	0.85	195 ± 10	SLACS
9	0.2046	0.4814	1.39	290 ± 16	SLACS
10	0.0629	0.5352	1.04	206 ± 5	SLACS
11	0.2076	0.5241	1.21	295 ± 13	SLACS
12	0.2479	0.7933	1.81	279 ± 17	SLACS
13	0.2285	0.4635	1.25	305 ± 19	SLACS
14	0.1553	0.5170	1.64	271 ± 16	SLACS
15	0.0819	0.5324	1.57	245 ± 7	SLACS
16	0.485	3.595	1.34	229 ± 15	LSD
17	0.938	2.941	1.24	251 ± 19	LSD
18	0.810	3.399	1.41	224 ± 15	LSD
19	0.497	2.092	0.36	116 ± 10	LSD
20	1.004	3.263	1.56	328 ± 32	LSD

References – Treu et al. (2002), (2003), (2004), (2006); Koopmans et al. (2002), (2003a), (2006).



The concordance value of Ω_Λ is included in the 99% CL regions

Precise measurements of the cosmological parameters will be available from forthcoming deep and wide Surveys