Tracking quintessence by cosmic shear

constraints by VIRMOS-Descart and CFHTLS and prospects for DUNE

Carlo Schimd

DAPNIA / CEA Saclay @ DUNE Team

In collaboration with: I.Tereno (U.Bonn&IAP), J.-P.Uzan, Y.Mellier (IAP), L.vanWaerbeke (British Columbia U.), E.Semboloni (U.Bonn&IAP), H.Hoekstra (U.Victoria), Liping Fu, A.Riazuelo(IAP)

Based on: **astro-ph/0603158 A&A in press**

Dark energy: parametrization .vs. "physics" inspired

Copernican principle + {baryons,γ,ν} + DM + GR alone cannot account for the cosmological dynamics seen by CMB + LSS + SNe + ...

Dark energy $\equiv$ $H(z) - H_{r+m+GR}(z)$

Candidates:

- **Other "matter" fields?**
  → cosmological constant, quintessence, *K*-essence, etc.: $p < -\frac{1}{3}\rho$
- **GR : not valid anymore?**
  → scalar-tensor theories, braneworld, etc.
- **Validity of Copernican principle?**
  → effect of inhomogeneities?

Strategies:

1/0 approach: parameterization of w(z) → *departures from ΛCDM*

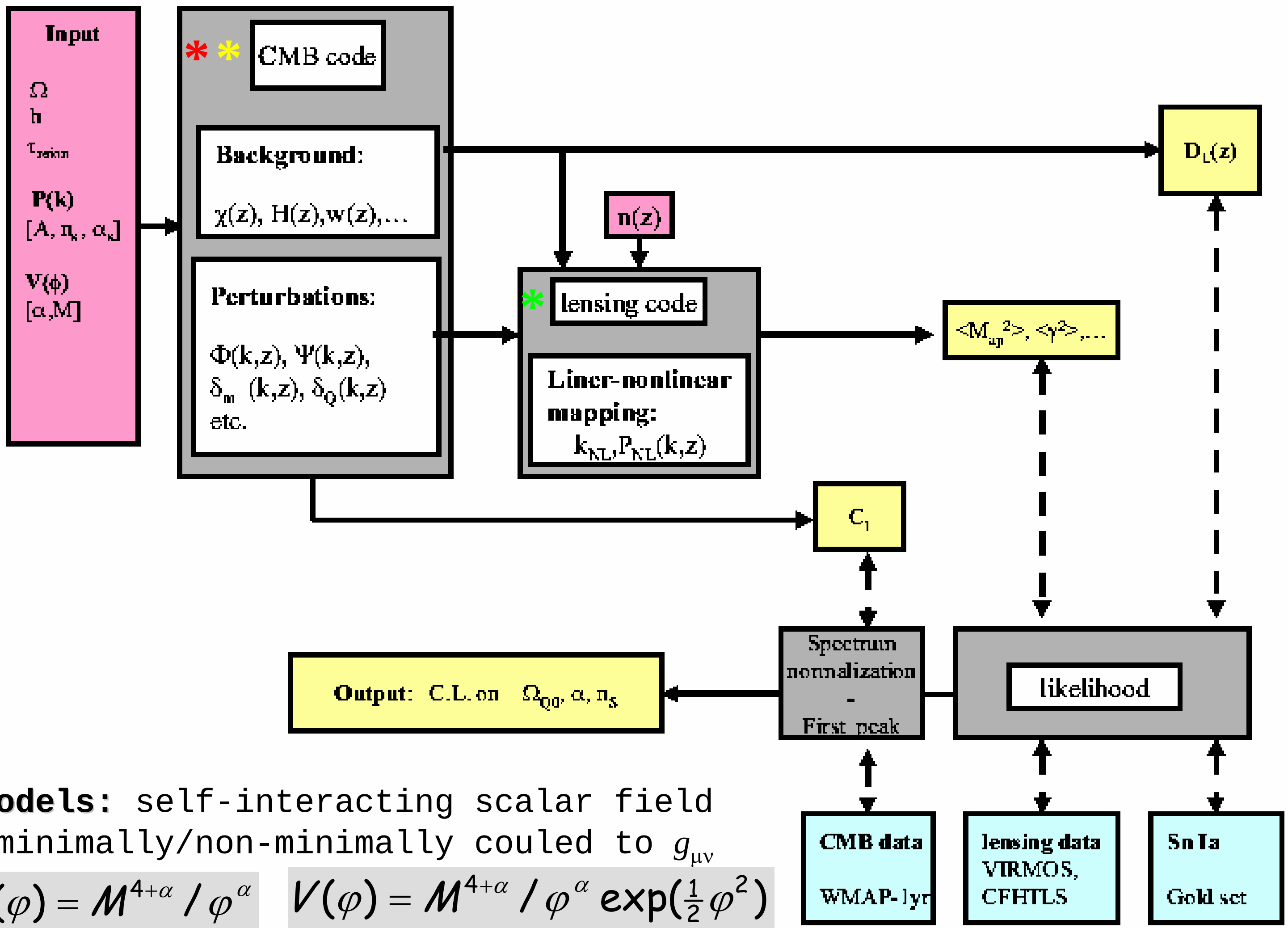
Physics-inspired approach: classes ↔ experimental/observational tests

Uzan, astro-ph/0605313

- *w* : full redshift range
- perturbations: consistently accounted for
- ↔ high-energy physics ?!
- smaller # p.

Aim: Dark energy beyond ΛCDM by cosmic shear: CFHT data analysis & DUNE

pipeline



* Riazuelo & Uzan (2002) * C.S., Uzan & Riazuelo (2004)

- **Q models:** self-interacting scalar field minimally/non-minimally couled to $g_{\mu\nu}$

$V(\varphi) = M^{4+\alpha} / \varphi^{\alpha}$ $\quad V(\varphi) = M^{4+\alpha} / \varphi^{\alpha} \exp(\tfrac{1}{2}\varphi^2)$

- **(restricted) parameter space:** $\{\Omega_Q,\ \alpha,\ n_s,\ z_{source}\}$; marginalization over z_{source}

C.S. et al (2006)

* ***CMB*** can be taken into account at ***no cost***

(ordinary) quintessence by cosmic shear

with respect to Λ, quintessence modifies:

Linear regime

☞ **angular distance** ⇒ lensing window function;3D→2D projection
growth factor ⇒ amplitude of 3D power spectrum
☞ ⇒ amplitude + shape of 2D spectra

Non-linear regime

↳ **N-body:** ...
↳ **mappings:** stable clustering, halo model, etc.:

e.g. Peacock & Dodds (1996)
Smith *et al.* (2003)
Huterer & Takada (2005

$${}^{NL}P_m(k,z) = f[{}^{L}P_m(k,z)]$$

calibrated with ΛCDM *N*-body sim, 5-10% agreement

☞ **Ansatz:** δ_c, bias, *c*, etc. not so much dependent on cosmology → at every *z* we can use them, provided we use the correct linear growth factor (defining the onset of the NL regime)...

↳ **...normalization to high-z (CMB):**

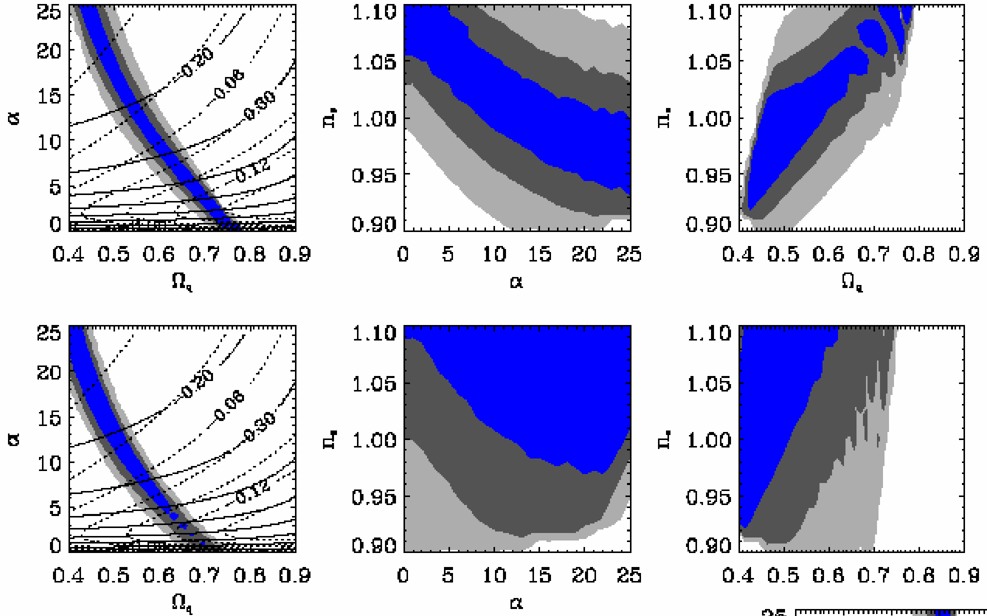
$$P_m^{LIN}(k,z) = \frac{D_+^2(z)}{D_+^2(z_{lss})} P_m^{LIN}(k,z_{lss})$$

⇒ the modes k enter in non-linear regime (σ(k)≈1) at different time ⇒ 3D non-linear power spectrum is modified ⇒ 2D shear power spectrum is modified by $k = \;/S_K(z)$ ℓ

cosmic shear data*: effects of L-NL mapping

Top-hat shear variance

Ratra-Peebles



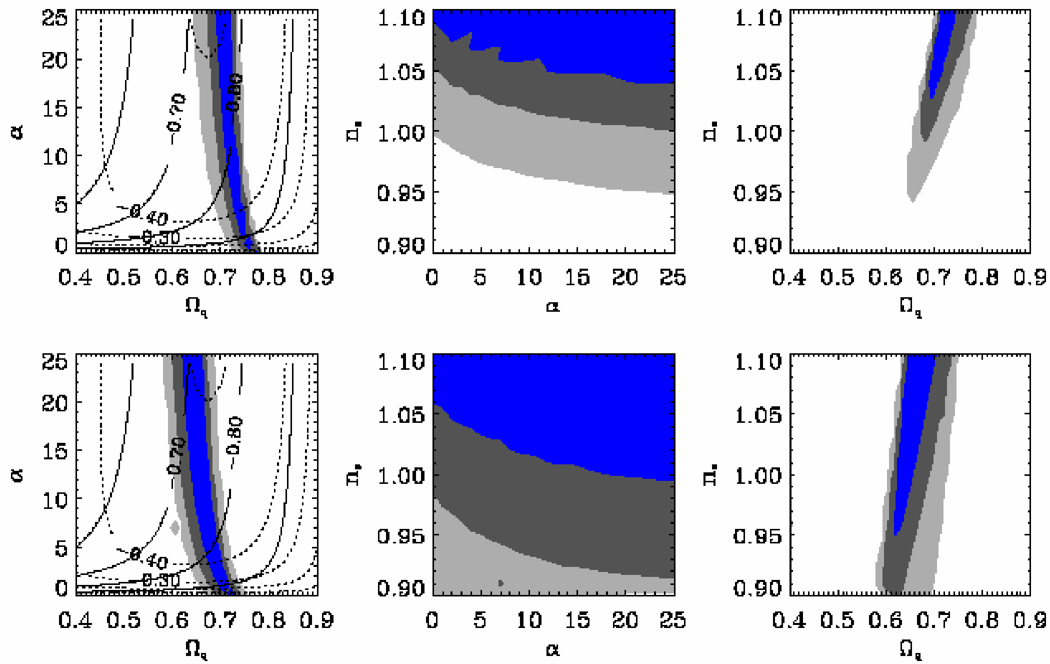
➤ Peacock & Dodds (1996)

➤ Smith *et al.* (2003)

SUGRA

Peacock & Dodds ➤

Smith *et al.* ➤

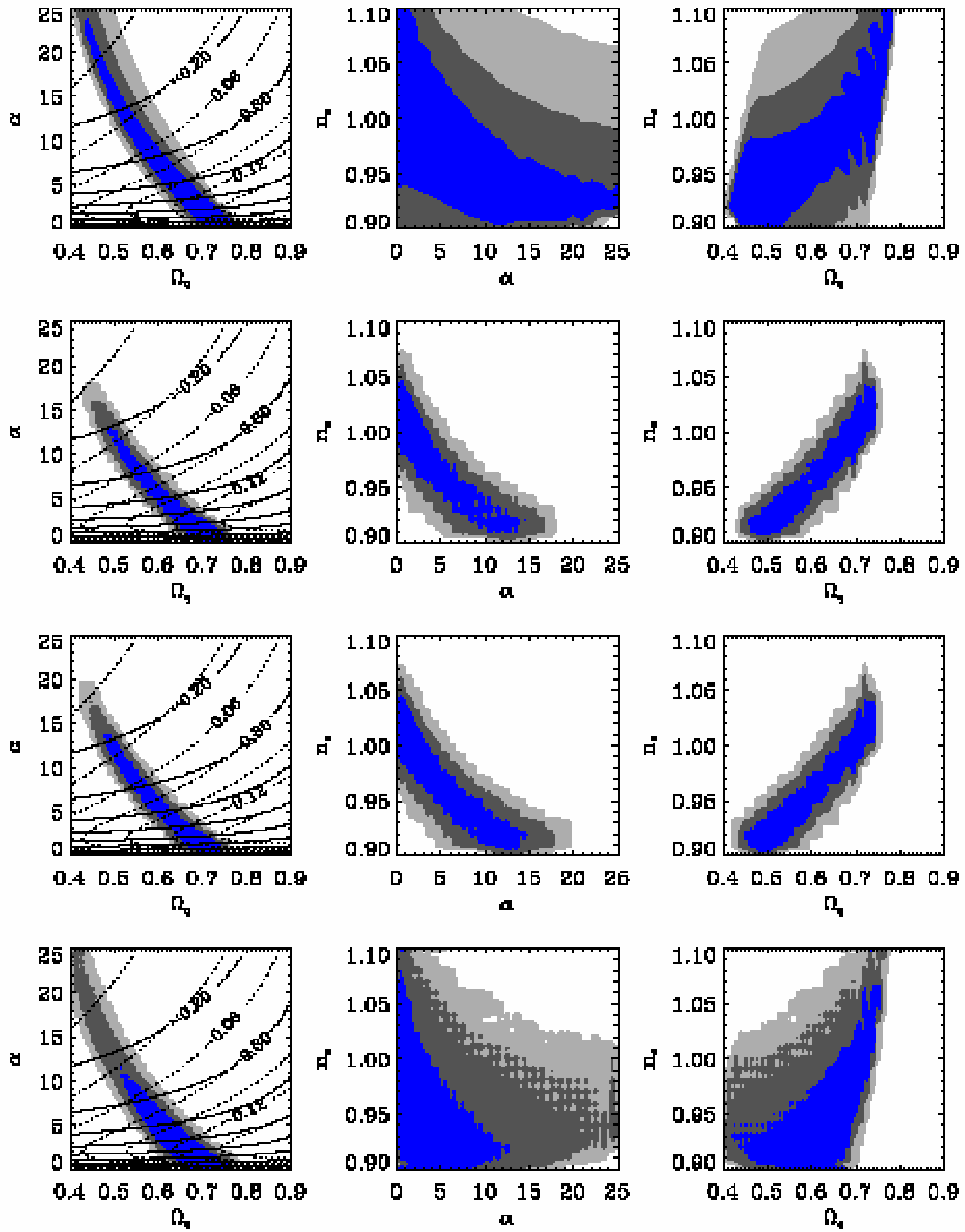


* Joint VIRMOS-Descart + CFHTLS deep + CFHTLS wide/22deg2 analysis

wide survey : Q - geometrical effects (IPL)

using Peacock & Dodds (1996)

inverse power law



- CFHTLS wide/22deg2 (**real data**)
  top-hat variance

- CFHTLS wide/170deg2 (**synth**)
  top-hat variance

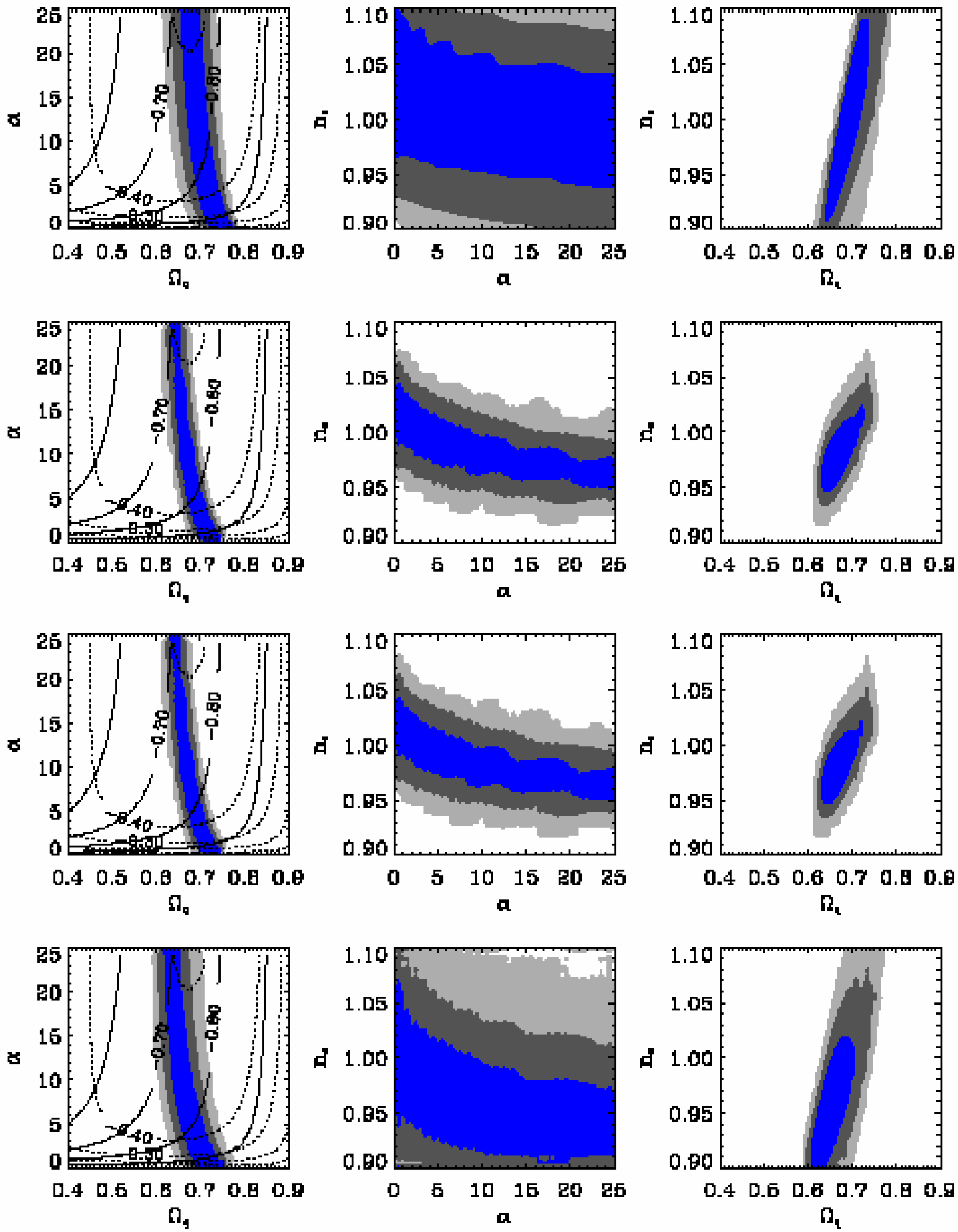
- CFHTLS wide/170deg2 (**synth**)
  aperture mass variance

- CFHTLS wide/170deg2 (**synth**)
  top-hat variance
  ☞ only scales **> 20 arcmin**

wide survey : Q - geometrical effects (SUGRA)

using Peacock & Dodds (1996)

SUGRA



- CFHTLS wide/22deg2 (**real data**)
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- CFHTLS wide/170deg2 (**synth**)
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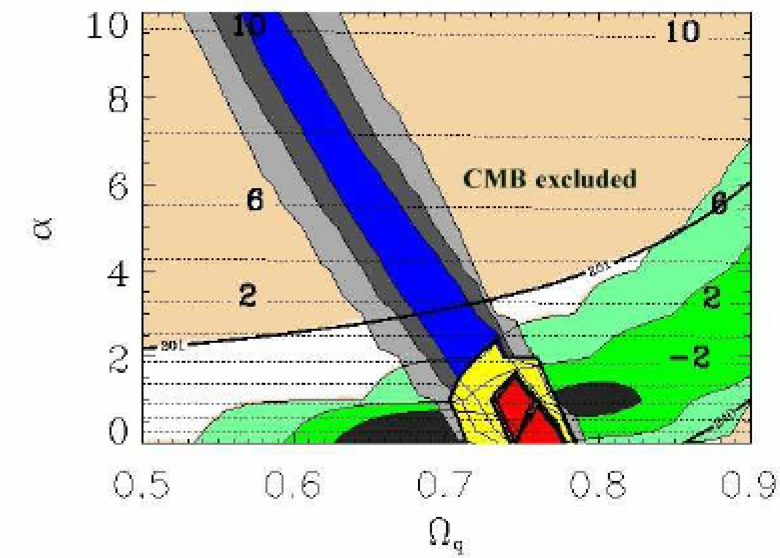
  aperture mass variance
- CFHTLS wide/170deg2 (**synth**)
  top-hat variance
  ☞ only scales **> 20 arcmin**

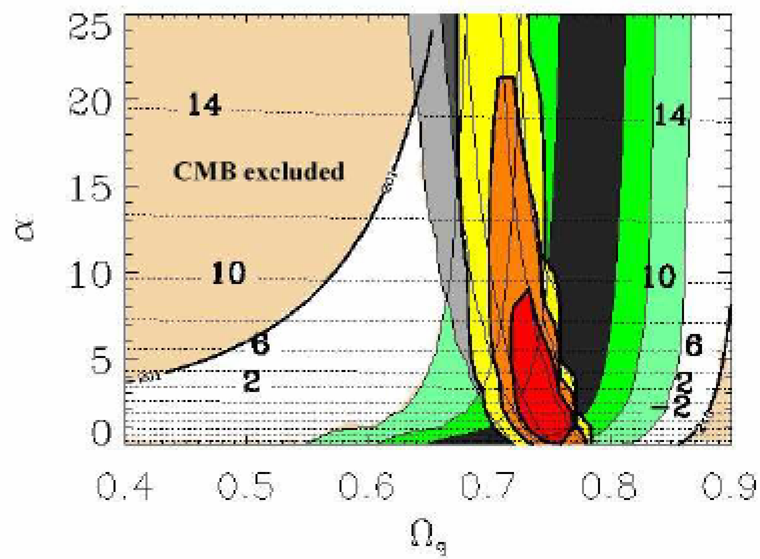
cosmic shear + SNe + CMB : Q equation of state

VIRMOS-Descart + CFHTLS deep + CFHTLS wide/22deg2 + “goldset”@SNe

Ratra-Peebles



SUGRA



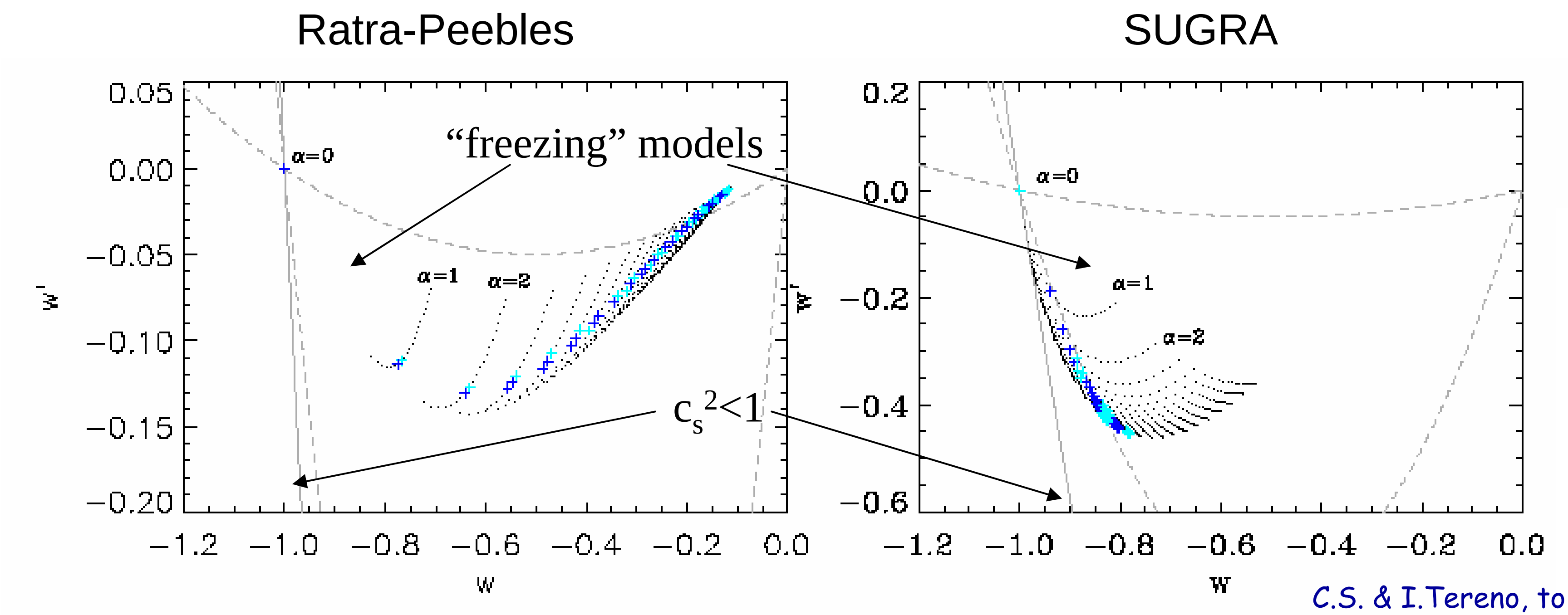
- (n_s, z_s): marginalized ; all other parameters: fixed
- Mass scale M (GeV) – dotted lines
  - SNe: confirmed literature
  - TT-CMB: rejection from first peak (analytical (Doran et al. 2000) & numerical)
    - **Cosmic shear** (real data only):
      - RP: strong degeneracy with SNe
      - SUGRA:
        1) beware of systematics! (wl: calibration when combining datasets)
        2) limit case: prefectly known/excluded Q model (weakly α-dependece)

$$\alpha < 1, \quad \Omega_Q = 0.75^{+0.03}_{-0.04}$$

$$\alpha = 2^{+18}_{-2}, \quad \Omega_Q = 0.74^{+0.03}_{-0.05}$$

95% C.L.

cosmic shear : transposed likelihood analysis of Q parameter space to Q equation of state



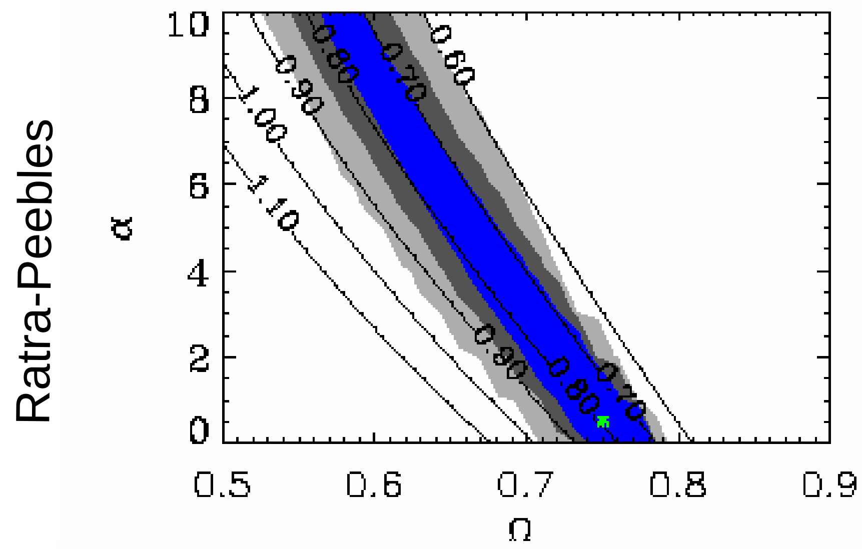
C.S. & I.Tereno, to appear

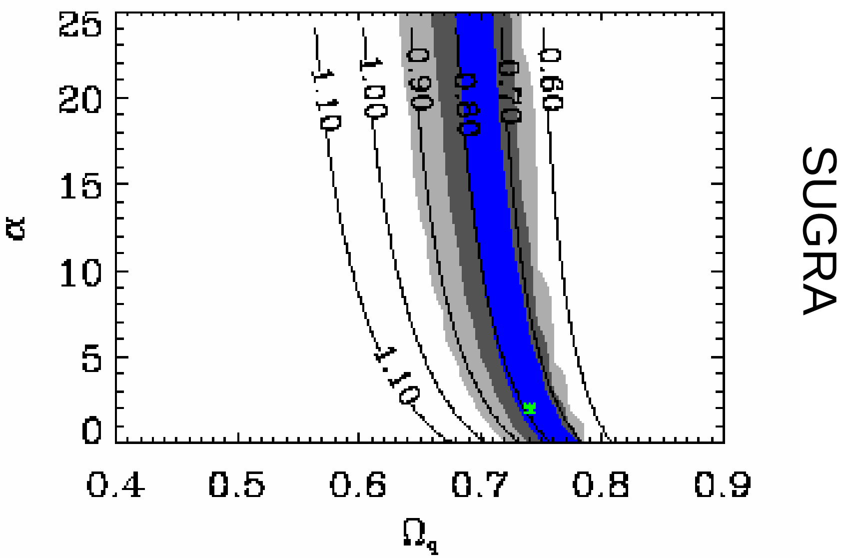
- \+ = 68% confidence level
- \+ = 95% confidence level
- • = other points of the (α,Ω_Q) grid

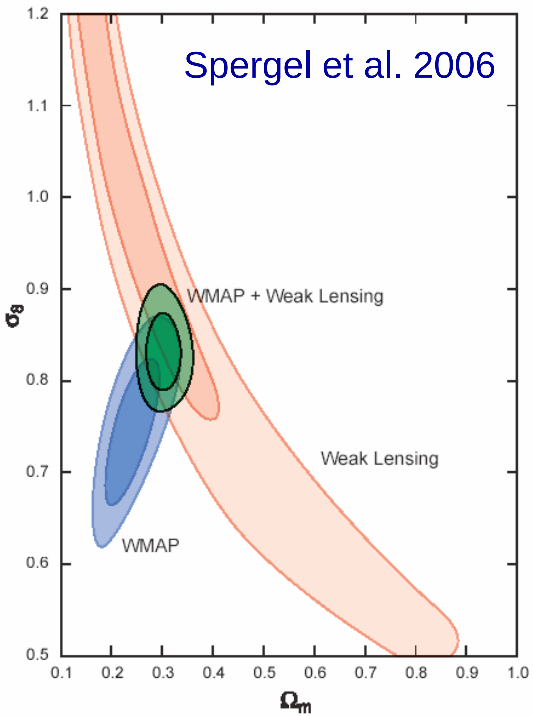
VIRMOS-Descart + CFHTLS deep + CFHTLS wide/22deg2

cosmic shear & CMB: variance on $8h^{-1}$ Mpc (σ_8)

a posteriori check







(α,Ω_Q) contours follow σ_8 degeneracy

WMAP3 – weak lensing: stress $\{h, \tau_{reion}, \text{normalization}, \Omega_q\}$

- Check normalization procedure
- Check calibration of datasets

  → **Liping Fu's talk**
- Deviations from ΛCDM ?

Fisher matrix analysis

PI: A.Réfrégier (CEA Saclay)
Scientific board: Y.Mellier (IAP), R.Pain (LPNHE), O.Boulade (CEA Saclay), B.Millard (LAM)

Space-based wide field imager for weak-lensing and SNe studies

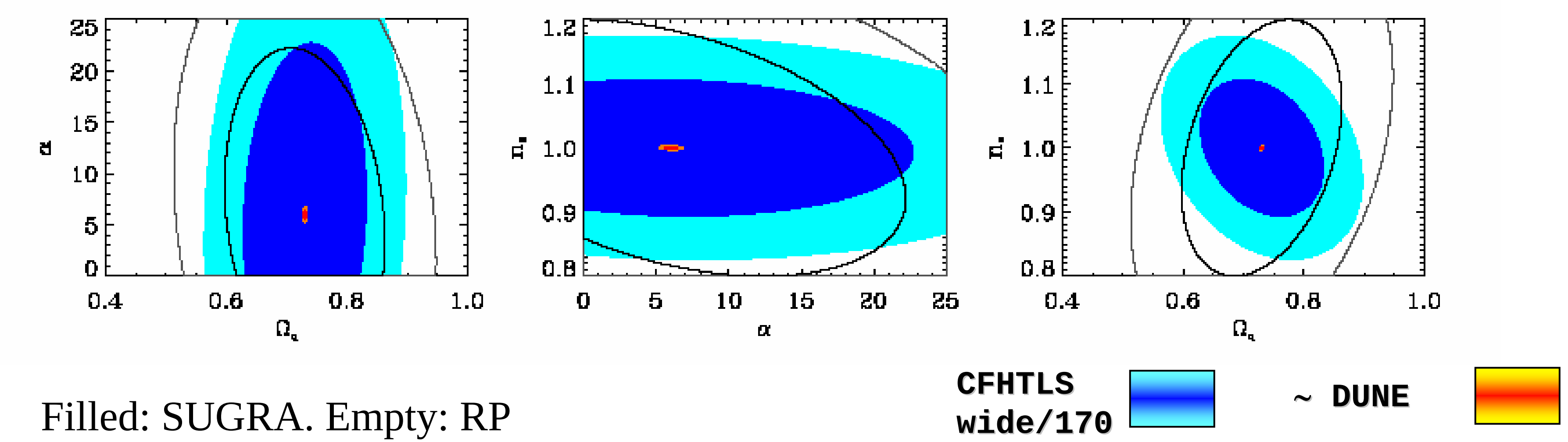
present setup:

- A = 20000 deg^2
- n_{gal} = 35/$arcmin^2$
- <z> = 1

assumptions/caveat:

- Approximate n(z) → Yannick's 2nd talk
- It assumes perfect correction PSF
- Small # cosmological parameters

➤ **= real data analysis + τ_{reion} :** all but (α, Ω_q, n_s) fixed, (τ_{reion}, z_s) marginalized



Filled: SUGRA. Empty: RP

conclusions

- **pipeline:** Boltzmann code + lensing code + data analysis by grid method:
  - **geometric approach to weak-lensing / cosmic shear** allows to deal with generic metric theories of gravity (e.g. GR, scalar-tensor)
  - dynamical models of DE (*not parameterization*): **ϕCDM**
  - consistent joint analysis of high-z (CMB) and low-z (cosmic shear, Sne,...) observables → no stress between datasets; no pivot redshift
  - **NL regime:** (two) L-NL mappings (**caveat**)
  - **redshift/shear calibrations, PSF correction: to be improved**

- **quintessence at low-z** by SNe + cosmic shear, using high-z informations (TT-CMB/Cl normalization)
  - for the first time **cosmic shear data** to this task
  - Q parameters (seem to) feel only geometry
    → **wide, shallow cosmic shear surveys** seems suitable → DUNE

astro-ph/0603158

- **Next steps:**
  - more param.→ MCMC, better ctrl n(z)/shear calibration, better ctrl LNL, 3pts/tomography/cross-correlations for source clustering, ISW, BAO, ...

in collaboration with:
J.-P. Uzan, F. Bernardeau, I.Tereno, Y.Mellier, R. Lehoucq, A. Réfrégier & DUNE team