Dark Energy Trajectories and Cosmic Observables

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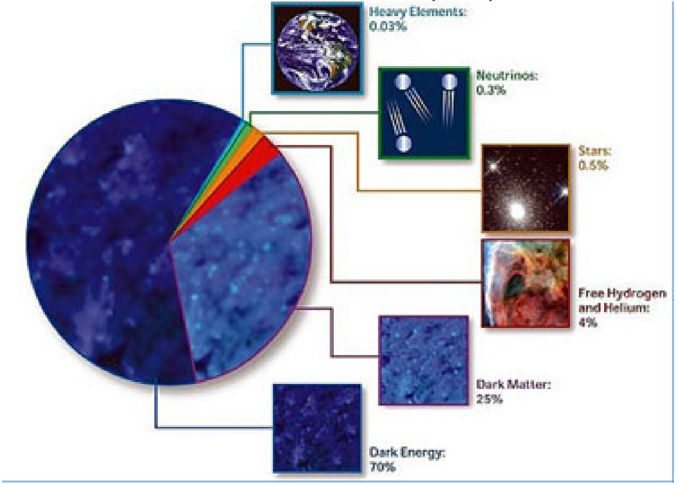
One-slide Summary

The standard logic of dark energy:
nothing $\Rightarrow w = w_0 + w_a(1-a) \Rightarrow$ confront with the data/forecasts $\Rightarrow$compare the Figure of Merit (how well w_0 and w_a are measured) $\Rightarrow$ decide which DE project should be funded

Our philosophy:
physical models (quintessence, etc.) $\Rightarrow w = w(a;$ physical parameters) $\Rightarrow$ confront with the data/forecasts$\Rightarrow$ compare how well the physical parameters are measured$\Rightarrow$ marginalize over models $\Rightarrow$ decide where the $$$ should go

Outline

Cosmic Pie and Dark Energy (DE)



NASA, http://en.wikipedia.org/wiki/File:Cosmological_composition.jpg

The equation of state w

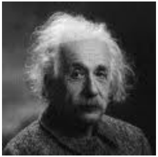
$$w \equiv \frac{\text{pressure } p}{\text{density } \rho}$$

cold dark matter and baryons: $w \approx 0$;
radiation: $w = 1/3$;
dark energy: w=?

And you know, $w_{\mathrm{DE}} < -1/3$

Options

Option #1: Cosmological constant Λ.



$$w = -1.$$

$$\rho_{DE} = \mathbf{\Lambda} = const.$$

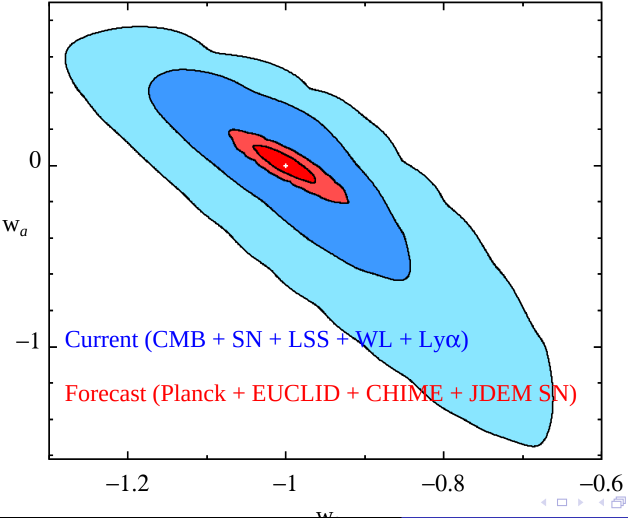
Option #2, #3 ...

$$w = w_0$$

$$w = w_0 + w_a(1 - a)$$

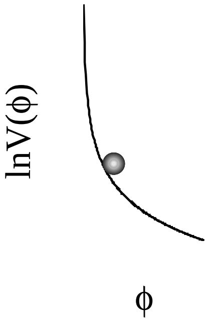
...

$w = w_0 + w_a(1 - a)$, Figure of Merit - Now and the Future



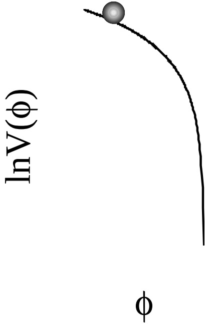
The Quintessence Models ($\mathcal{L} = 1/2\partial^\mu\phi\partial_\mu\phi - V(\phi)$)

tracking:



early-universe: fast-roll
late-universe: slow-roll

thawing:



early-universe: frozen
late-universe: slow-roll

Our w recipe

$$w_\phi = F\left(a; \Omega_m, \epsilon_s, \alpha_t, \zeta_s\right)$$

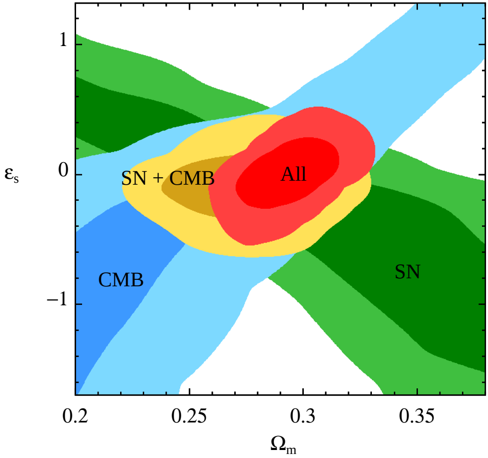
The tracking parameter $\alpha_t \sim |1 + w_\phi|$ at high redshift
The slope parameter $\epsilon_s \sim \pm(\frac{d \ln V}{d\phi})^2$ at low redshift ('+' for quintessence, '-' for phantom)
The running parameter ζ_s is related to $|d\phi/dt|$ and $\frac{d^2 \ln V}{d\phi^2}$ at low redshift (for thawing models $\zeta_s \propto \frac{d^2 \ln V}{d\phi^2}$).

More details see *Huang, Bond, Kofman*, 20xx (xx$\geq$ 10)

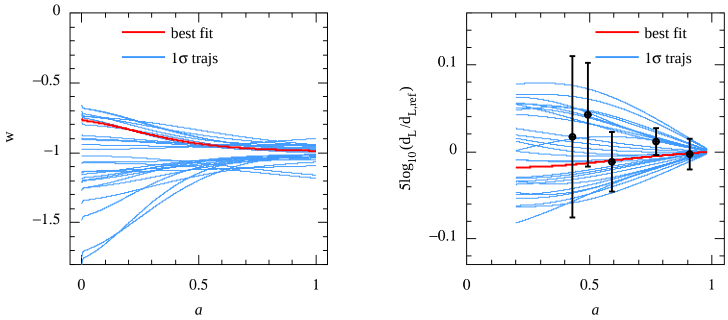
Cosmological Data Sets

- Cosmic Microwave Background (**CMB**): WMAP7(2010), ACT(2010), Acbar (2009), QUAD (2009), BICEP (2009), CBI (2008), Boomerang (2006), VSA (2004), MAXIMA (2000)
- Type Ia Supernova (**SN**): LOWZ + SDSS + ESSENCE + SNLS1yr + HST (Kessler et al 09) (soon will + SNLS3yr)
- Weak Lensing (**WL**): COSMOS + CFHTLS-wide + RCS + VIRMOS + GaBoDS
- Large Scale Structure (**LSS**): SDSS-DR7 LRG (2009)
- Lya Forest (**Ly**α): SDSS (P. McDonal 2005, 2006)

The Slope Parameter ϵ_s



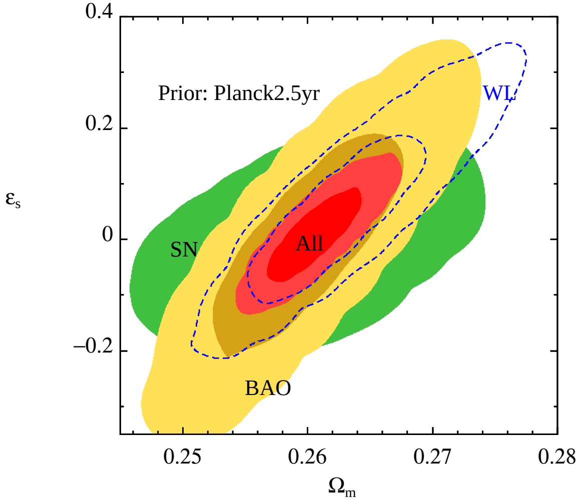
Reconstructed w Trajectories



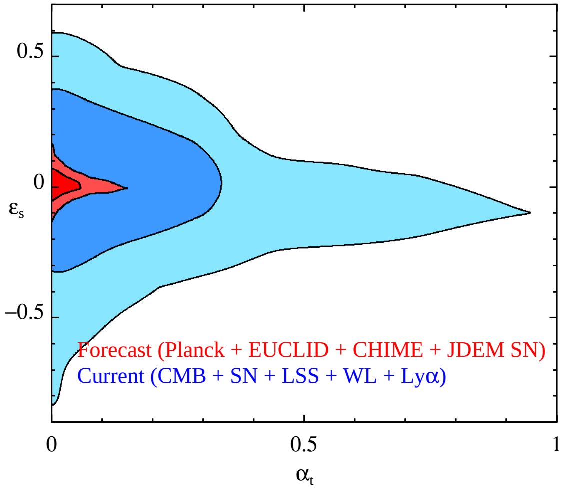
Forecasts Mock Data

- **CMB**: **Planck2.5yr**, using 3 channels (70GHz, 100GHz, 143GHz), assuming 5% foreground residual (synchrotron + dust), $f_{\rm sky} = 3/4$, $l_{\rm max} = 2500$.
- **WL**: **EUCLID** weak lensing tomography, 20000 degree^2, depth $z \sim 0.8$, 40 galaxies/arcmin^2, 4 redshift bins, $l_{\rm max} = 2500$.
- **SN**: **JDEM**, 500 LOWZ ($z < 0.03$) + 2500 HIGHZ ($0.03 < z < 1.7$)
- **BAO**: low redshift galaxy surveys (**BOSS** etc.): $z < 0.8$, 20000 deg^2, $\bar{n} = 0.003$; 21-cm survey **CHIME** 200m$\times$200m cylinder radio telescope, 4000 receivers integrated 4 yrs.

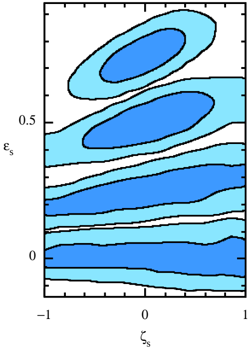
In the future: SN v.s. BAO v.s. WL



The HBK version Figure of Merit



The running parameter



A slowly rolling field does not “feel” the curvature of the potential.

Conclusion

- Both quintessence and phantom models are consistent with current observations. Tracking is slightly disfavored. The best-fit model is in the proximity of Λ.
- The constraints on the slope parameter ϵ_s and tracking parameter α_t can be improved by a factor of about 5 by the future observations.
- The running parameter (in thawing case, the second derivative of $\ln V$ at low redshift) is not measured today, and will not be measurable in the near-future observations, unless the true model significantly deviates from Λ.