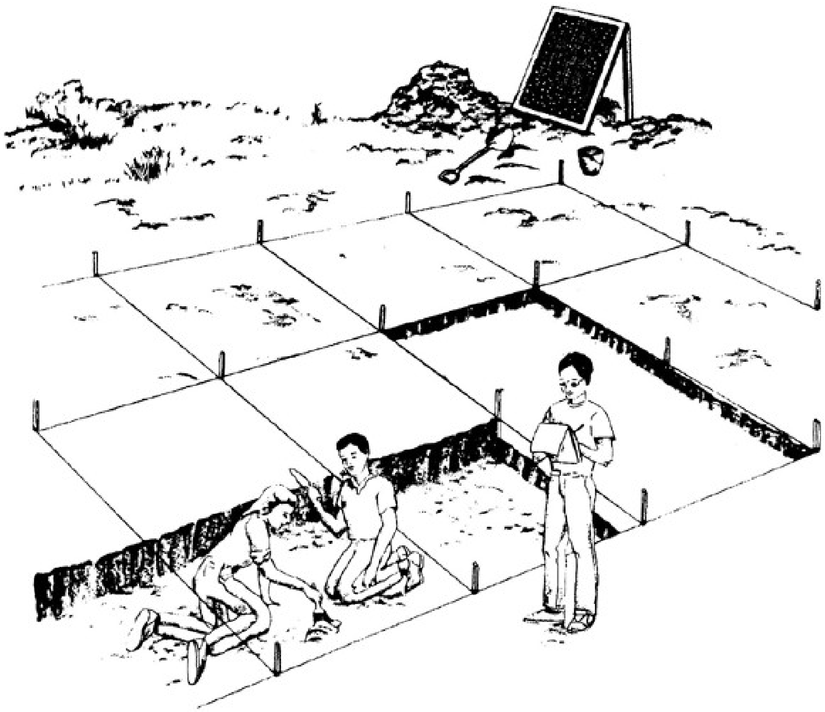
Constraining scalar field Dark Energy models & future prospects



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Collaborators: K.Ichiki, J.Ooba, N.Sugiyama, H.Tashiro, S.Tsujikawa

KEK Workshop, 9 March 2017

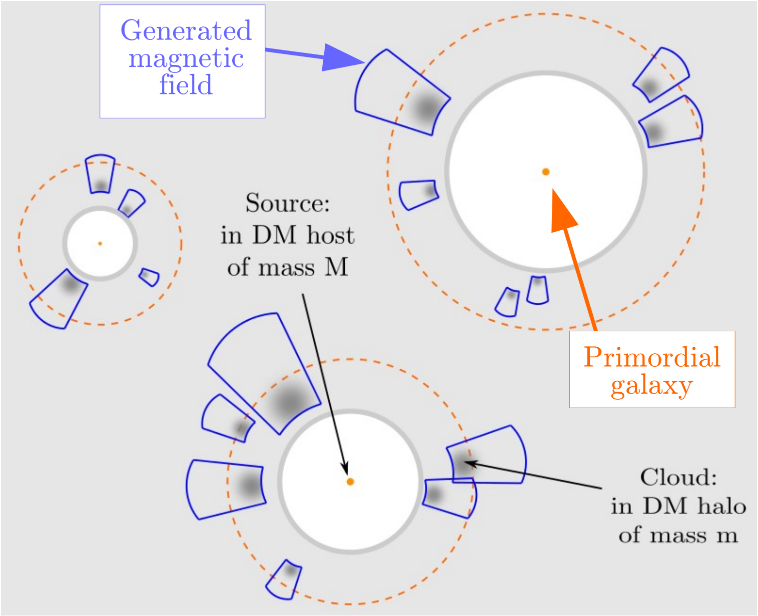
My Background

I) Origin of cosmological magnetic fields

Magnetic fields generation
by photoionization by the first galaxies
all along the Epoch of Reionization ($30 < z < 6$)

→ early magnetization of the whole
Intergalactic medium

Collaborators:
M. Langer, H. Tashiro, D.Aubert and N. Sugiyama

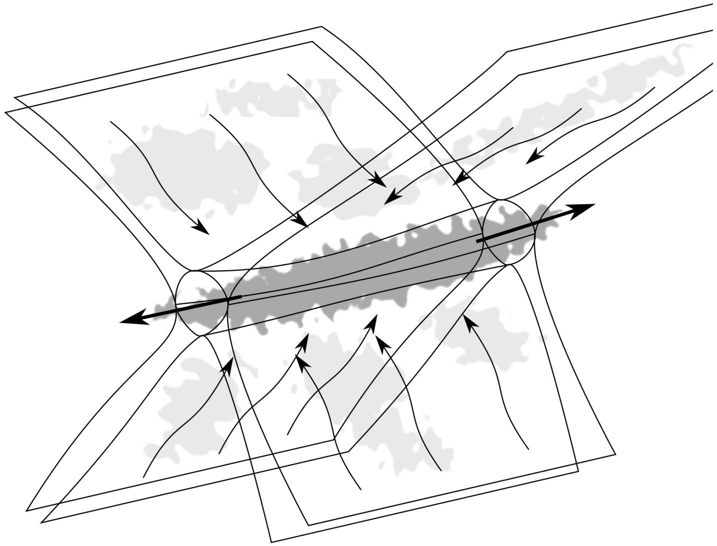


II) Gravitational fragmentation in the Cosmic Web

May baryons fragment in the Cosmic Web?

→ Gravitational instability in stratified media
using the 'spectral theory approach'
developed in the tokamak literature

Collaborator: M. Langer



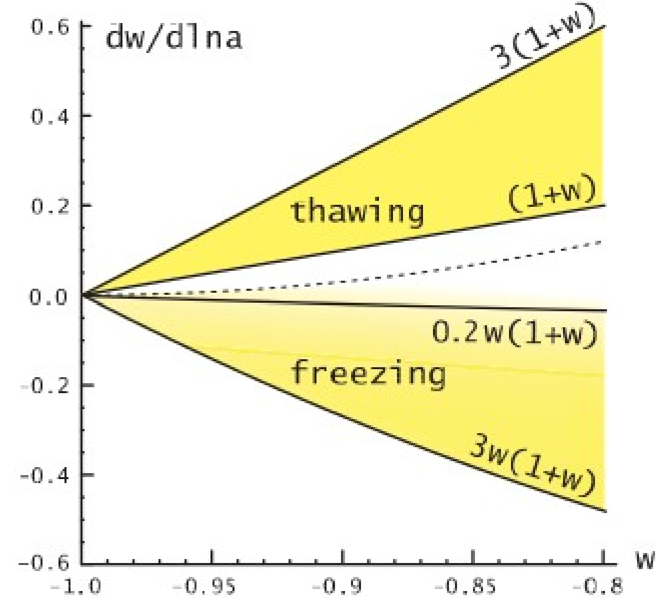
Cosmological Filament as intersection of Walls

Constraining Quintessence Models

- Minimally coupled scalar field $S = \int d^4x\sqrt{-g}\left[\frac{M_{\rm pl}^2}{2}R - \frac{1}{2}g^{\mu\nu}\partial_\mu\phi\partial_\nu\phi - V(\phi)\right] + S_m$

Quintessence models can be classified depending on evolution of $w \equiv \frac{P_\phi}{\rho_\phi} = \frac{\frac{1}{2}\dot\phi^2 - V(\phi)}{\frac{1}{2}\dot\phi^2 + V(\phi)}$

(Caldwell & Linder 2005)



- **T.Chiba, A.De Felice, S.Tsujikawa (2013)**

consider approximate analytic w(a) for

Models: 1) Thawing

2) Tracking Freezing

3) Scaling Freezing

(analysis covers most quintessence potentials)

and put observational constraints on the parameters in w(a) using:

- SN Ia from Union 2.1
- CMB shift parameters from WMAP7
- BAO from SDSS7 and BOSS

➡ Need to update these constraints with the latest data

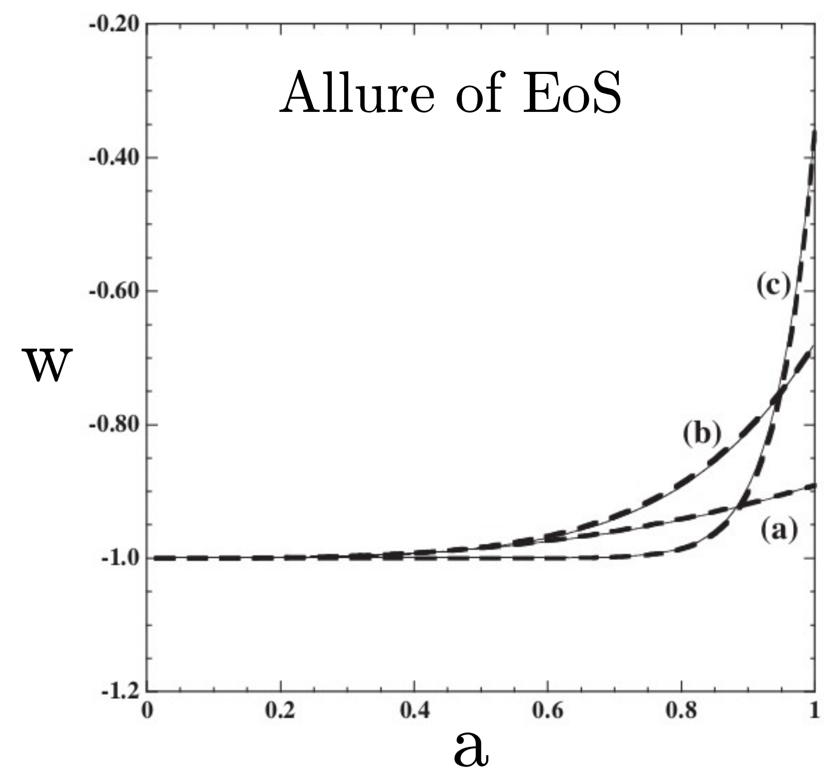
Chiba et al 2013

1) Thawing models

- Hilltop potential: $V(\phi) = \Lambda^4[1 + \cos(\phi/f)]$ (e.g. pseudo-Nambu-Goldstone boson or axions)
- EoS:

$$w(a) = -1 + (1 + w_0)a^{3(K-1)}\left[\frac{(K - F(a))(F(a) + 1)^K + (K + F(a))(F(a) - 1)^K}{(K - \Omega_{\phi 0}^{-1/2})(\Omega_{\phi 0}^{-1/2} + 1)^K + (K + \Omega_{\phi 0}^{-1/2})(\Omega_{\phi 0}^{-1/2} - 1)^K}\right]^2$$

→ Three parameters: w_0, $\Omega_{\phi 0}$ and K



- Constraints: (prior $0.1 < K < 10$)

After marginalization over K

$$-2.18 < w_0 < -0.893 \quad (95\% \text{ C.L.})$$

and $0.70265 < \Omega_{\phi 0} < 0.73515$ (95% C.L.)

with quintessence prior $w_0 > -1$

$$w_0 < -0.849 \ (68\% \text{ C.L.})$$
$$w_0 < -0.695 \ (95\% \text{ C.L.})$$

Note: BOSS data improve constraints, allowed region shifted towards $w < -1$

2) Tracking Freezing models

Chiba et al 2013

- Inverse power-law potential $V(\phi) = M^{4+p}\phi^{-p} \quad (p > 0)$

- EoS: $$w(a) = w_{(0)} + \sum_{n=1}^{\infty} \frac{(-1)^{n-1} w_{(0)}(1 - w_{(0)}^2)}{1 - (n+1)w_{(0)} + 2n(n+1)w_{(0)}^2} \left(\frac{\Omega_\phi(a)}{1 - \Omega_\phi(a)} \right)^n$$

where $$\Omega_\phi(a) = \frac{\Omega_{\phi 0} a^{-3w_{(0)}}}{\Omega_{\phi 0} a^{-3w_{(0)}} + 1 - \Omega_{\phi 0}}$$

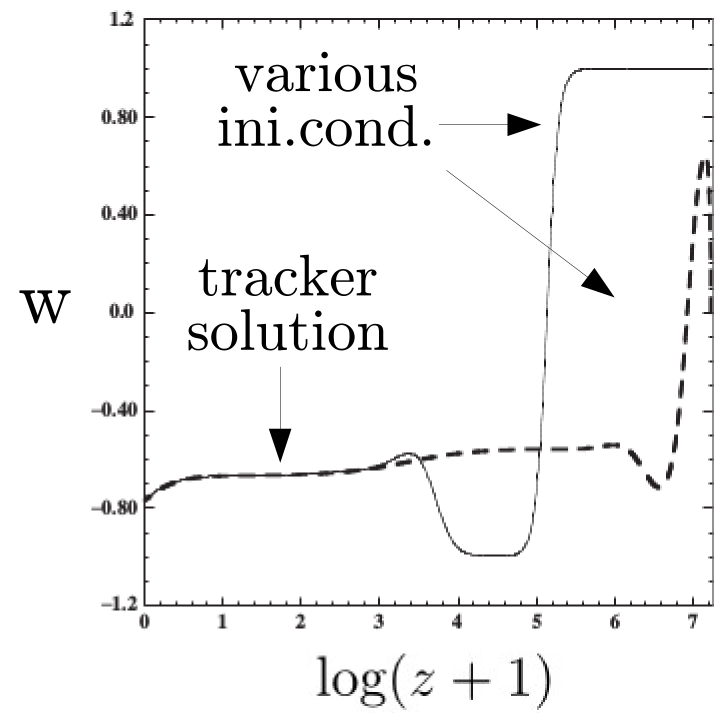
→ Two parameters: $w_{(0)}$ and $\Omega_{\phi 0}$

- Constraints:

$$-1.211 < w_{(0)} < -0.998 \quad (95\% \text{ C.L.})$$

and $$0.701 < \Omega_{\phi 0} < 0.733 \quad (95\% \text{ C.L.})$$

Example with p=1



Amendola & Tsujikawa (2010)

Tracker models with w away from -1
are severely disfavored (even without BOSS data)

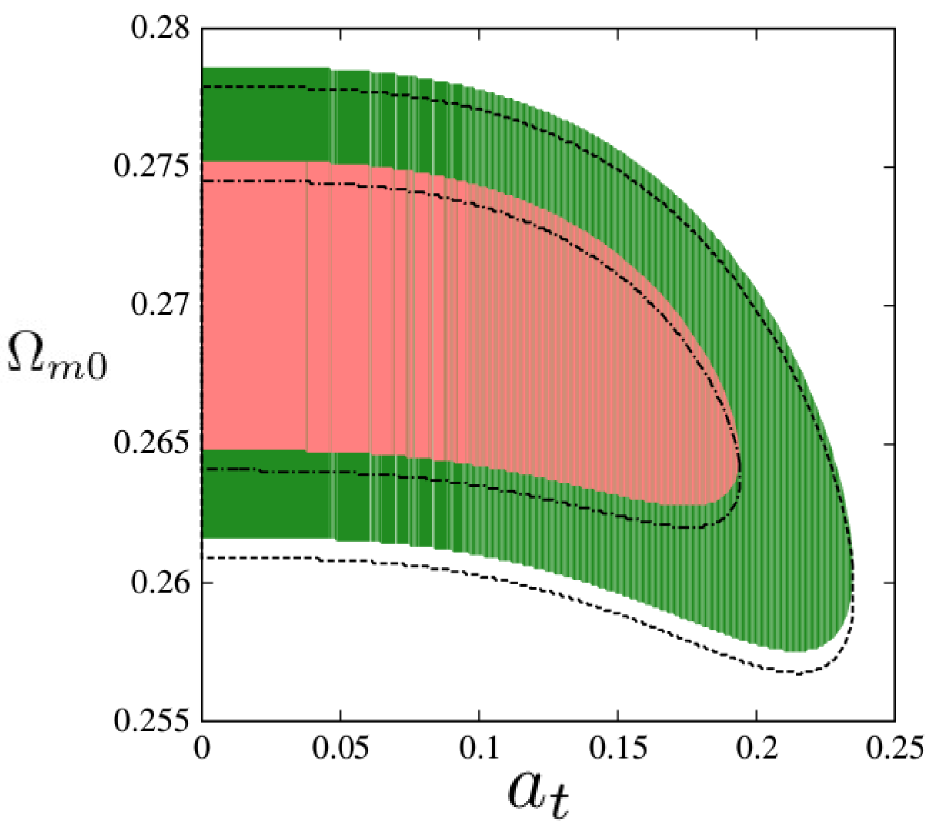
3) Scaling Freezing models

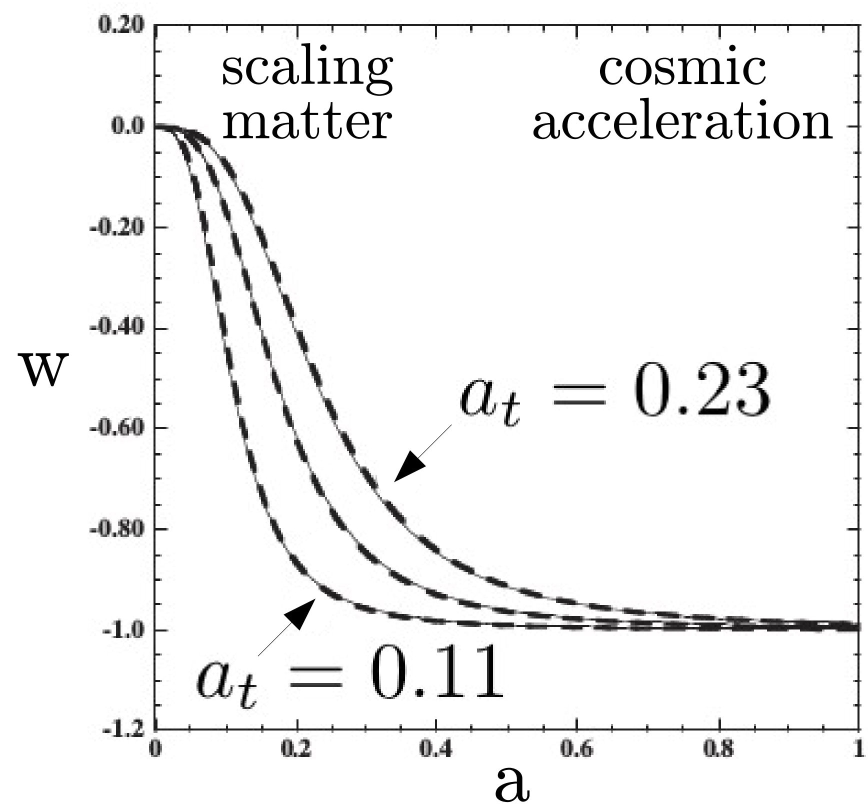
Chiba et al 2013

- Double exponential potential: $V(\phi) = V_1 e^{-\lambda_1 \phi / M_{\rm pl}} + V_2 e^{-\lambda_2 \phi / M_{\rm pl}}$
- with $\lambda_1 \gg 1$ and $\lambda_2 \ll 1$

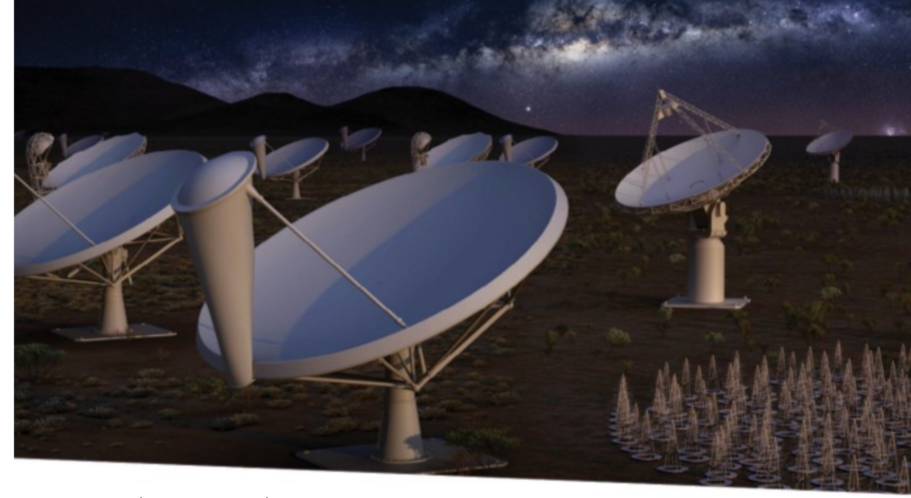
  EoS: $w(a) = -1 + \frac{1}{1+(a/a_t)^{1/\tau}}$ with $\begin{cases} a_t & \text{scale factor at transition} \\ \tau \simeq 0.33 & \text{thickness of transition} \end{cases}$

  → Two parameters: a_t and Ω_{m0}
- Constraints: $a_t < 0.23$ (95% C.L.) i.e. $z_t > 3.4$





Forecasts: 21cm Observations



Probe other redshifts ranges
than other methods

K.Kohri, Y.Oyama, T.Sekiguchi & T.Takahashi (2016)

parametrizations of DE:

- I) Linear with a $\quad \mathrm{w} = w_0 + (1-a)w_1$
- II) Sudden change of w $\quad \mathrm{w} = w_0 w_1 \dfrac{a^p + a_s^p}{w_1 a^p + w_0 a_s^p}$
- III) Early DE $\quad \mathrm{w} = \dfrac{w_0}{[1 + b\log(1+z)]^2}$

with SKA and Omniscope in combination with CMB, BAO, SNe and H0.

They conclude that

future 21 cm observations will be powerful in constraining models of dark energy, especially when its EoS varies at high redshifts.

→ Constraints on thawing and freezing models?

Thank you for your attention