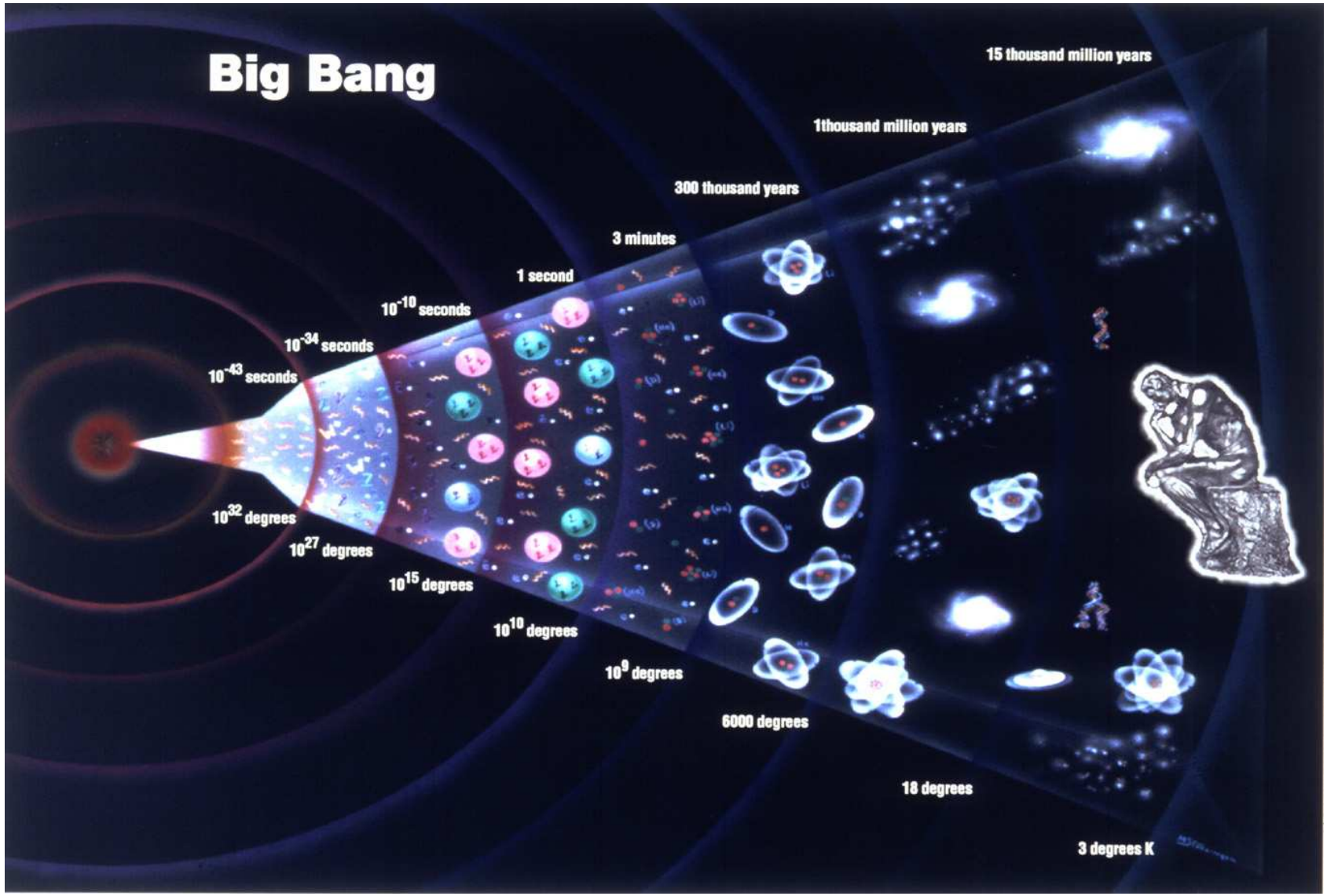
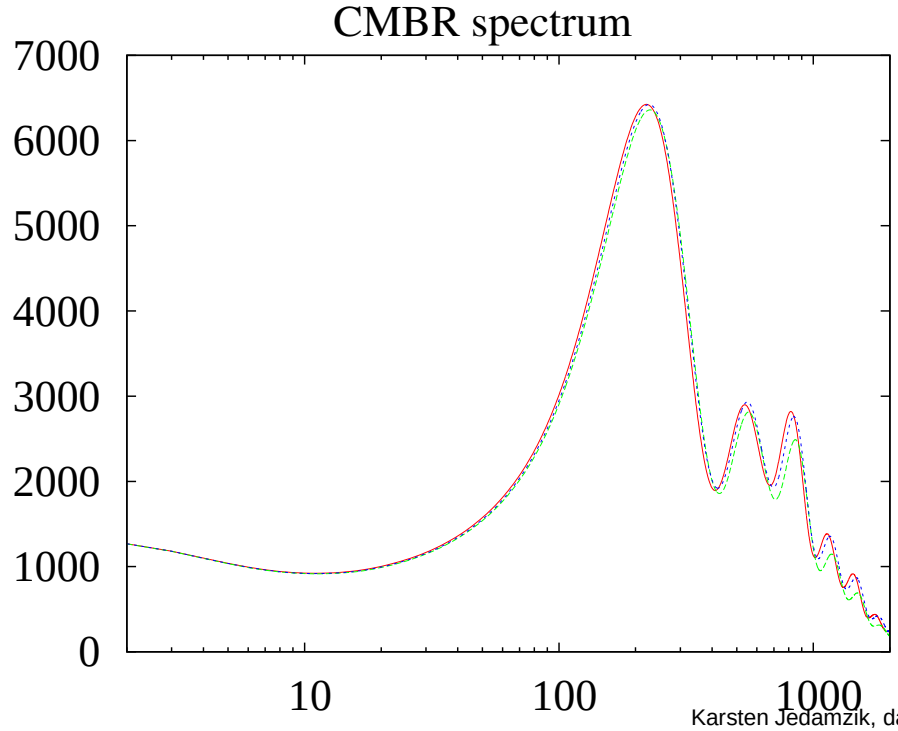
La cosmologie primordiale

Karsten JEDAMZIK


Big Bang
15 thousand million years
1thousand million years
300 thousand years
3 minutes
1 second
10^{-10} seconds
10^{-34} seconds
10^{-43} seconds
10^{32} degrees
10^{27} degrees
10^{15} degrees
10^{10} degrees
10^{9} degrees
6000 degrees
18 degrees
3 degrees K

Anisotropies dans le brut diffus de micro-onde

- a $T \approx 3000\,\mathrm{K}$ l'Universe est presque homogene
- petites perturbations pre-existantes d'amplitude $\sim 10^{-5}$ cree des vagues sonics dans le baryon-photon plasma
- ces vagues sont visible comme des perturbations de temperature du brut diffus de micro-onde
- leur comportement au fonction d'echelle angulaire nous donne des informations importantes sur l'abondance de baryon, de la matiere noire, des neutrinos, l'expansion a cet epoque, ...



Champs magnetiques dans le brut diffus de micro-onde ?

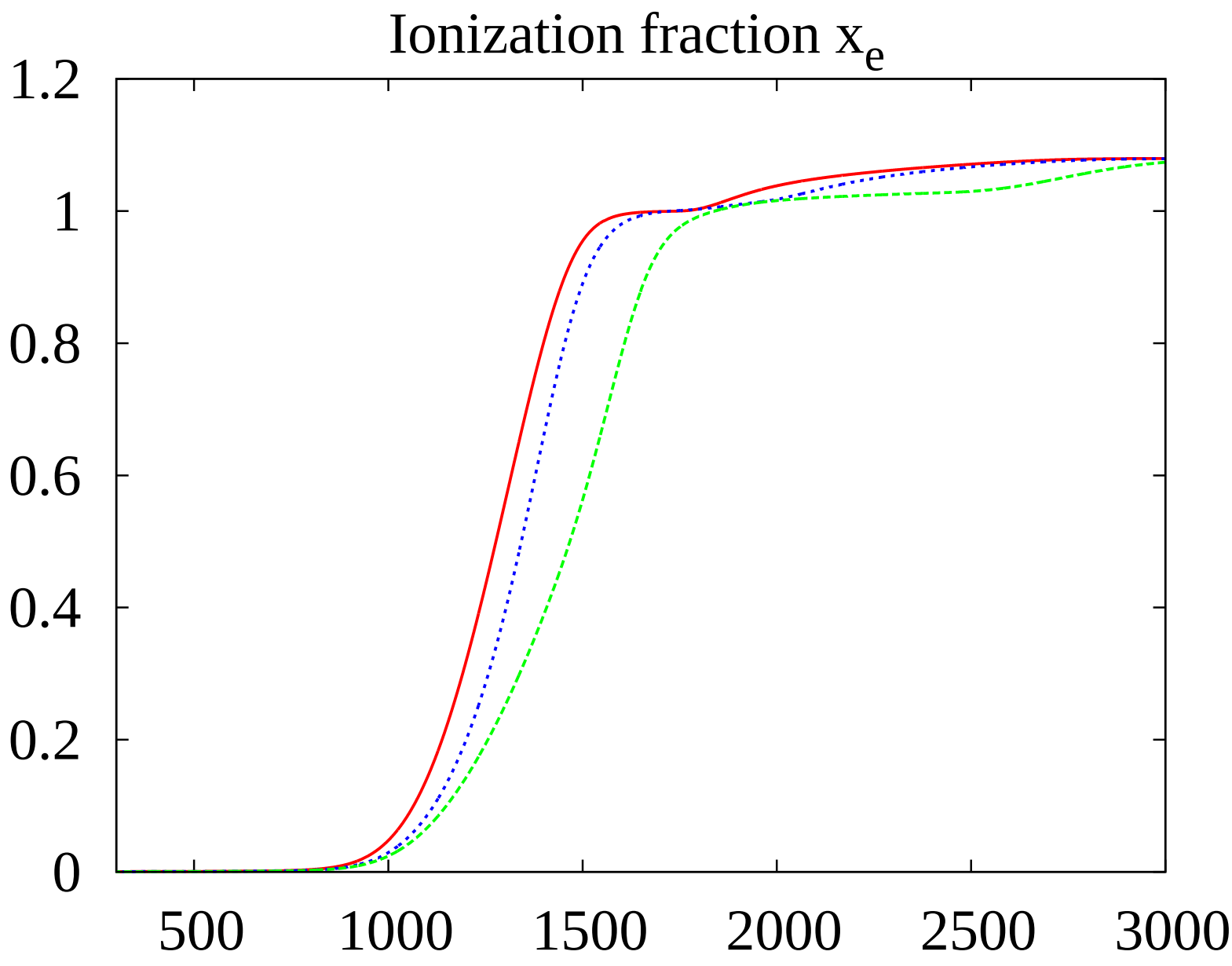
magnetic fields on scales $\lambda < l_\gamma$ produce density fluctuations before recombination i.e. $v_A \sim v_s$ for $B \sim 10^{-11}$Gauss

recombination in inhomogeneous environment

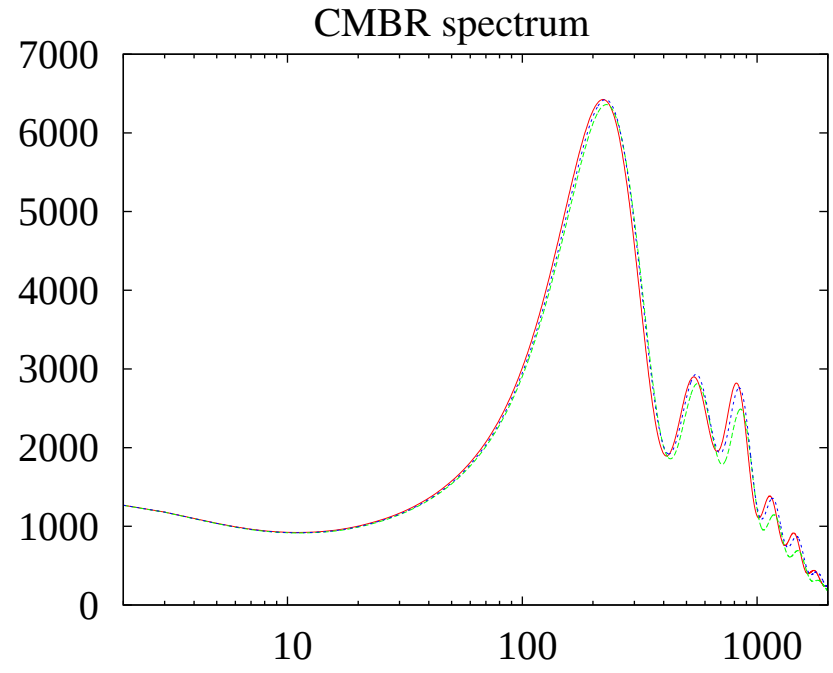
$$\frac{d\langle n_{H^0}\rangle}{dt}|_{inhomo} = \alpha_e \langle n_e n_p\rangle - \beta_e \langle n_{1s}\rangle \exp\left(\frac{-E_{\nu_\alpha}}{kT}\right) \neq \frac{d\langle n_{H^0}\rangle}{dt}|_{homo}$$

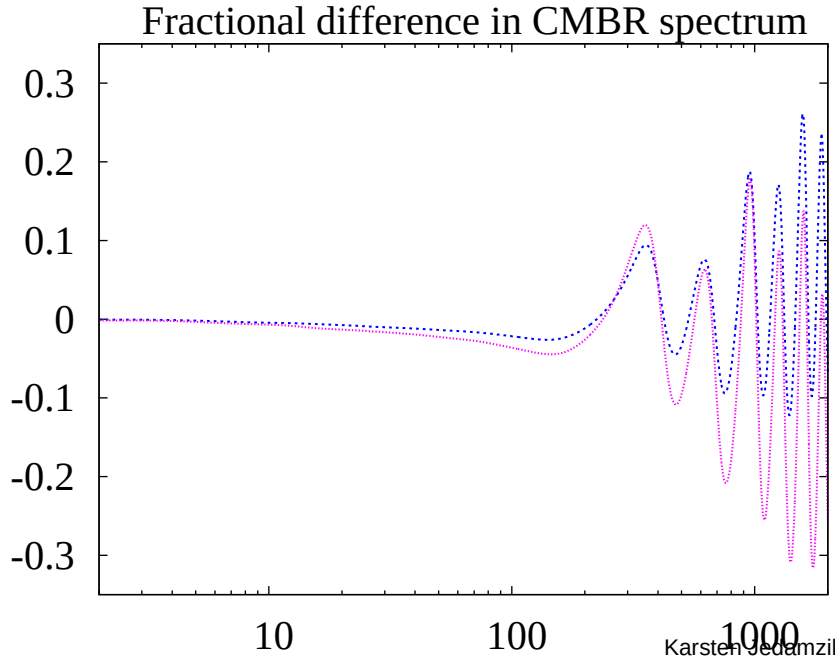
since $\langle n_e n_p\rangle \neq \langle n_e\rangle\langle n_p\rangle$

Nombre des electrons pendant la recombinaison



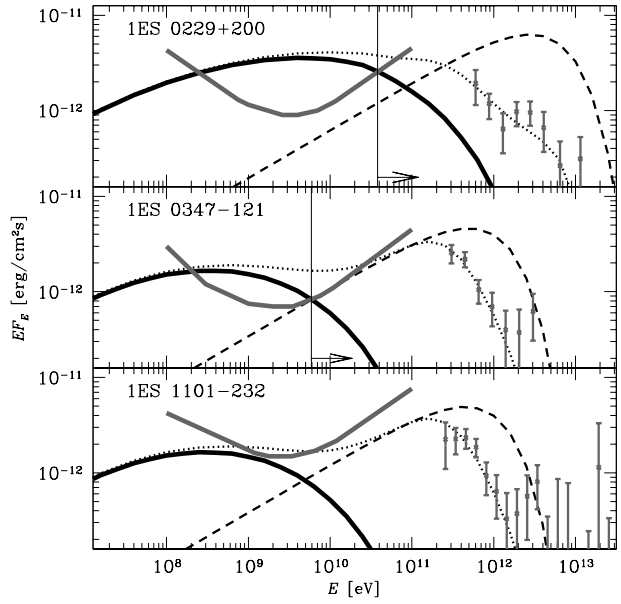
Le spectre des anisotropies avec champs magnetiques





"Observations" de champs magnetiques avec des telescopes du γ-ray

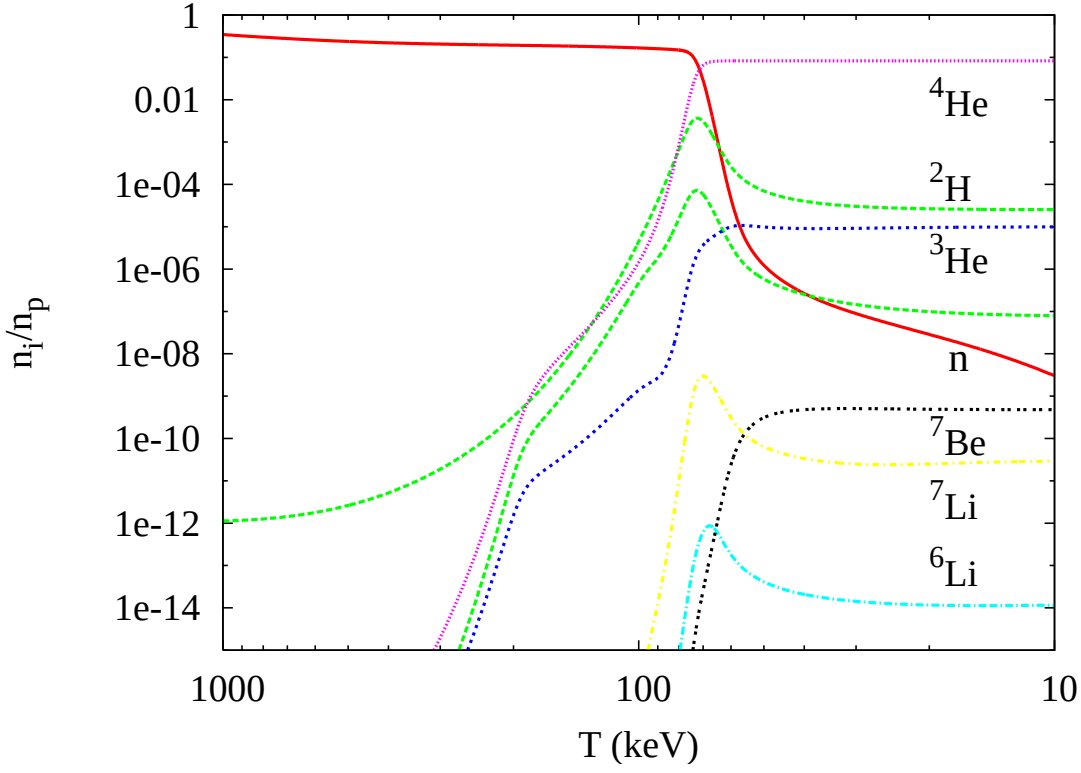
- TeV-blazars: $\gamma_{\rm TeV} + \gamma_{\rm EBL} \rightarrow e^+ + e^-$
- $e^\pm + \gamma_{\rm CMBR} \rightarrow e^\pm + \gamma_{\rm GeV}$



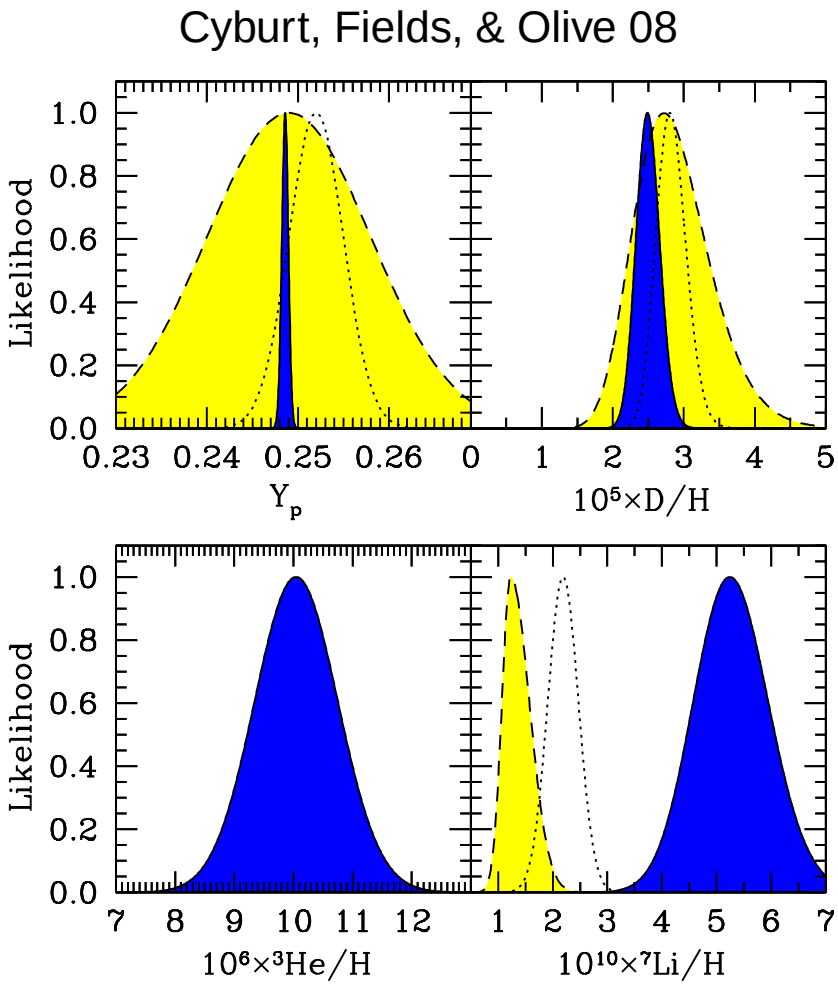
- predicted GeV γ's not observed $\rightarrow e^\pm$ deflection by magnetic fields
- cosmic (?) magnetic field $B \gtrsim 3 \times 10^{-16}$Gauss $\neq 0$

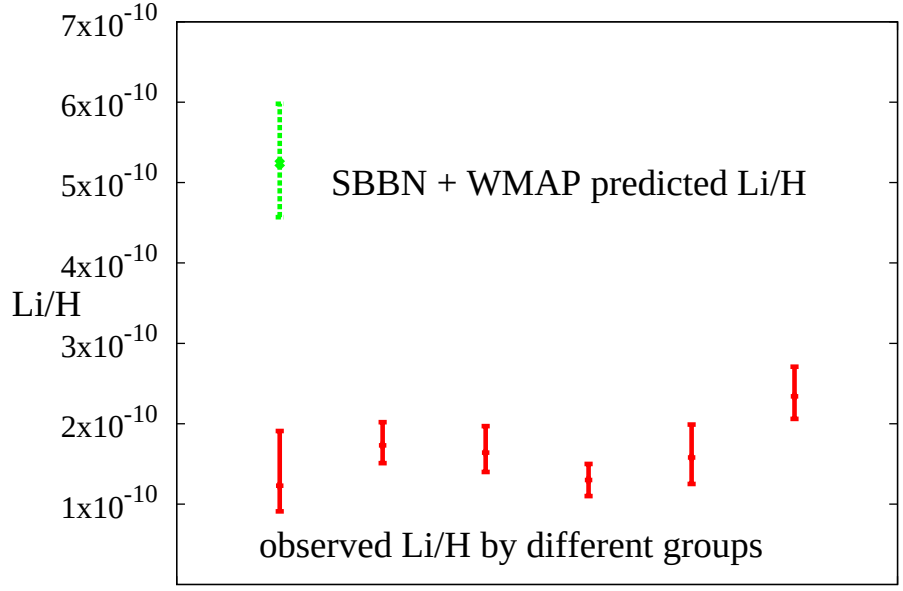
La nucleosynthèse primordiale

$$p + n \rightarrow \mathrm{D} + \gamma$$
$$\mathrm{D} + p \rightarrow {}^3\mathrm{He} + \gamma$$
$${}^3\mathrm{He} + \mathrm{D} \rightarrow {}^4\mathrm{He} + p$$
$${}^4\mathrm{He} + {}^3\mathrm{He} \rightarrow {}^7\mathrm{Be} + \gamma$$



Predictions contre Observations





^{7}Li discrepancy $4.2 - 5.3\sigma$

Destruction du lithium dans les etoiles PopII ?

$^7\mathrm{Li}$ is observed in the atmospheres of PopII stars
it may be destroyed via $^7\mathrm{Li}+p \rightarrow {}^4\mathrm{He}$ + $^4\mathrm{He}$ in the interieur of the star

atmospheric material transported into the star and $^7\mathrm{Li}$-depleted gas returned to the atmosphere

Spite plateau not primordial ?

Destruction du $^7\mathrm{Li}$ pendant la nucleosynthese primordiale

$^7\mathrm{Li}$ destruction: $^7\mathrm{Be}$ +$n \rightarrow$ $^7\mathrm{Li}$ +p; $^7\mathrm{Li}$ + $p \rightarrow ^4\mathrm{He}$ + $^4\mathrm{He}$

at $T \approx 30\,$keV

need only 10^{-5} extra neutrons per baryon

$\rightarrow$ decay or annihilation of relic particles

Production of $^6\mathrm{Li}$ in cascade nucleosynthesis

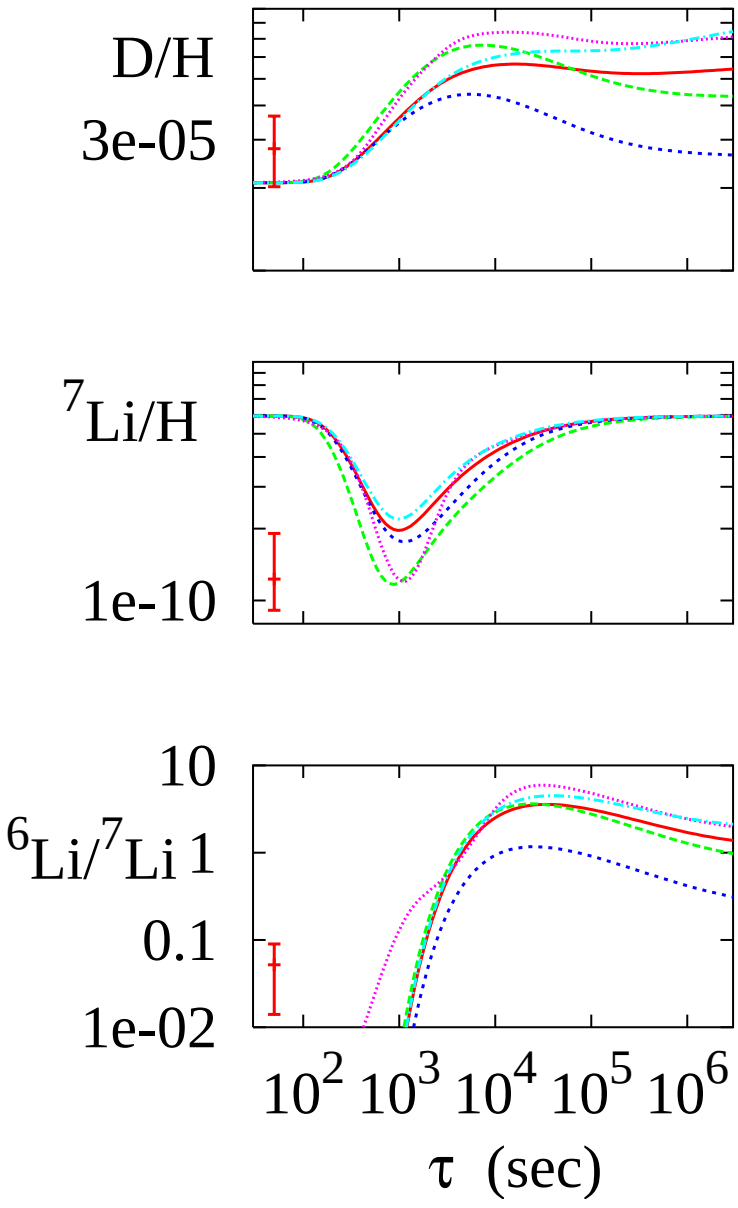
$^6\mathrm{Li}$ is very easily produced by small "perturbations" of the standard model

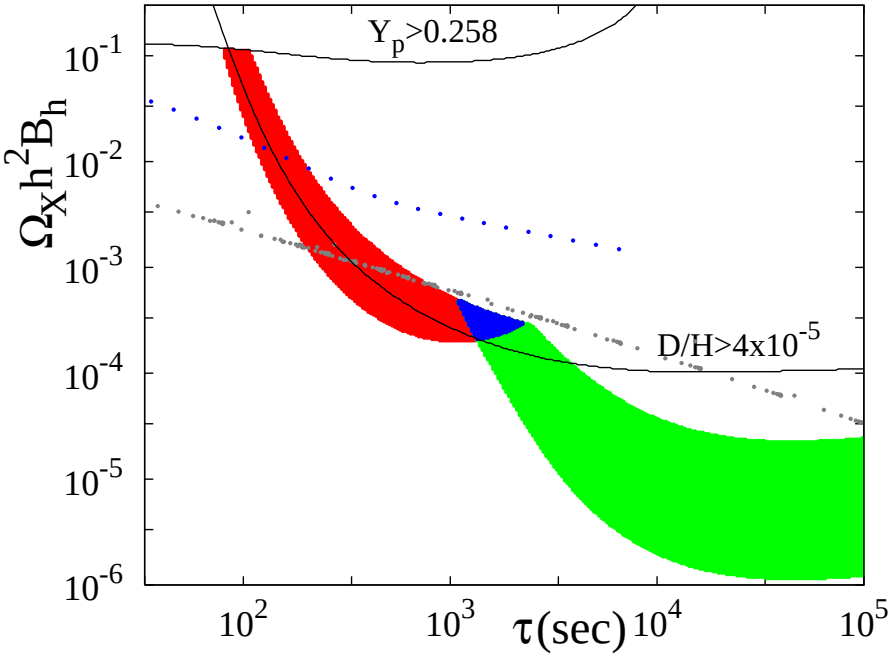
$$n + {}^4\mathrm{He} \rightarrow {}^3\mathrm{H} + p + n$$

$$^3\mathrm{H} + {}^4\mathrm{He} \rightarrow {}^6\mathrm{Li} + n$$

at $T \lesssim 10\,\mathrm{keV}$

The lithium friendly parameter space





Signatures at the LHC !

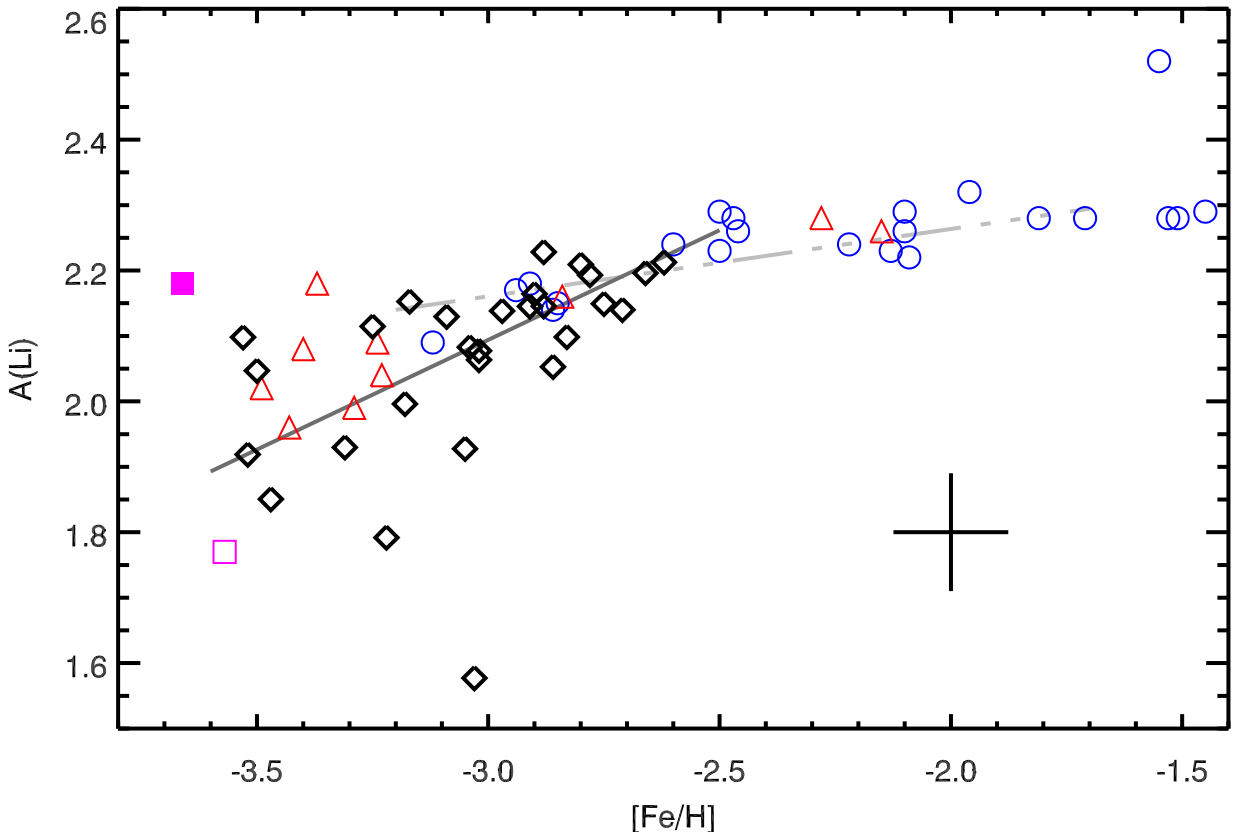
A metastable particle X with life time between $100 - 1000$ sec, **if** not too massive, could be potentially produced at the LHC (since having at least some hadronic interactions), and ...., **if** electromagnetically or strongly interacting stopped in the detector $\rightarrow$ smoking gun for non-standard BBN $\rightarrow$ possible connection to the dark matter

Examples:

Gluino in split supersymmetry

supersymmetric stau Next-to-LSP with gravitino LSP

The ^{7}Li Spite plateau in 2010 - ?



Sbordone *et al.* 10, Asplund *et al.*, Aoki *et al.*

- well defined upper envelope - plateau
- no measurable star-to-star scatter at metallicities $[Z] \gtrsim -2.7$
- absence of stars with ^{7}Li/H above plateau

^{6}Li/H observations

Asplund, Lambert, Nissen, Primas, & Smith

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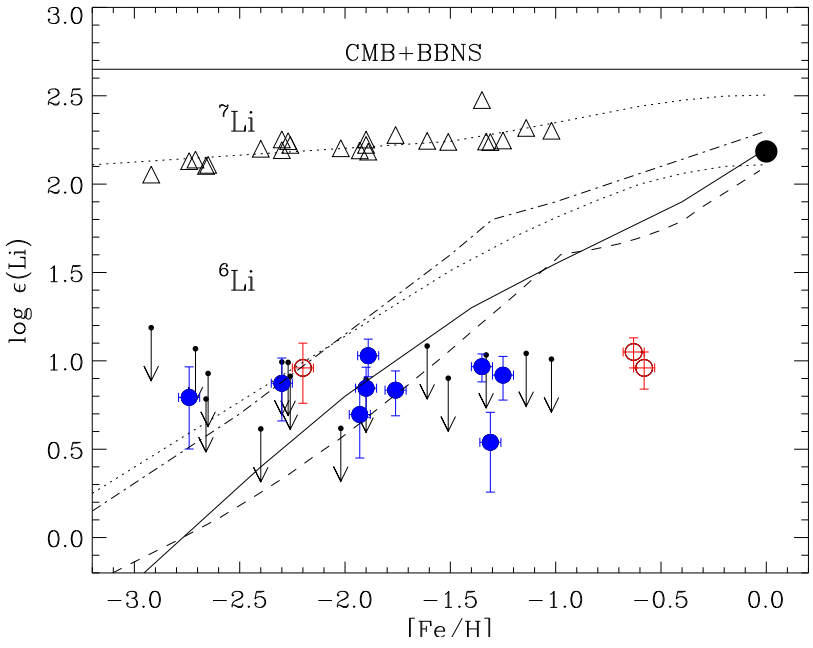
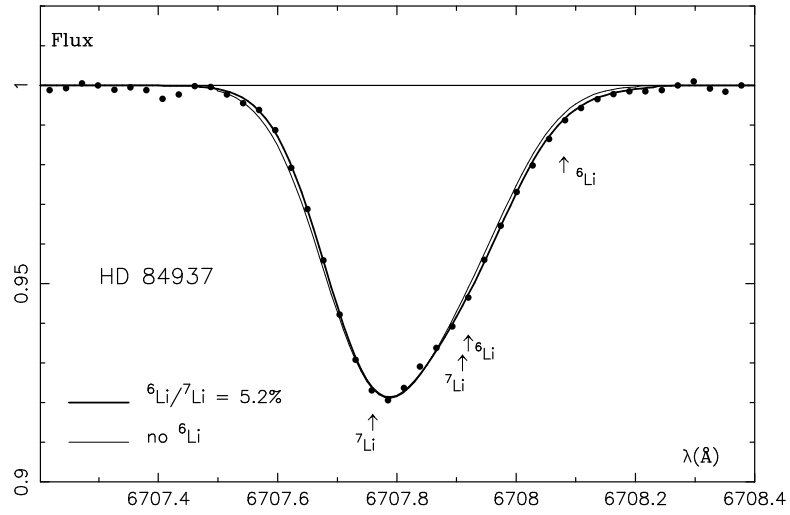


A second Lithium plateau ?

$^6\mathrm{Li/H} \approx 6 \times 10^{-12}$ compare to standard BBN $^6\mathrm{Li/H} \sim 10^{-14}$



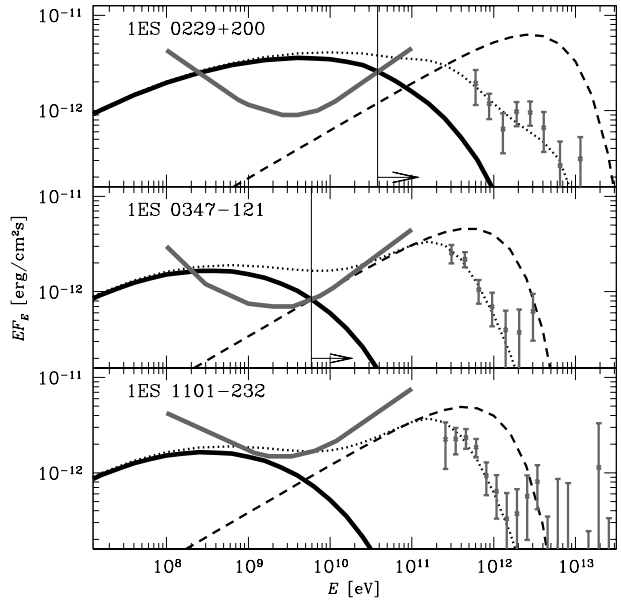
- ^{6}Li and ^{7}Li absorption features blend together
- ^{6}Li from asymmetry of lines
- asymmetry of lines from convective Doppler shifts ?
- non-LTE hydrodynamic simulations of two groups reach opposite conclusions

Cosmic Magnetic Fields

- μ-Gauss magnetic fields exist in galaxies and clusters of galaxies
- their origin is unknown !
- until 2010 only upper limits on magnetic fields in intragalactic medium

Magnetic field "Observations" by γ-ray telescopes

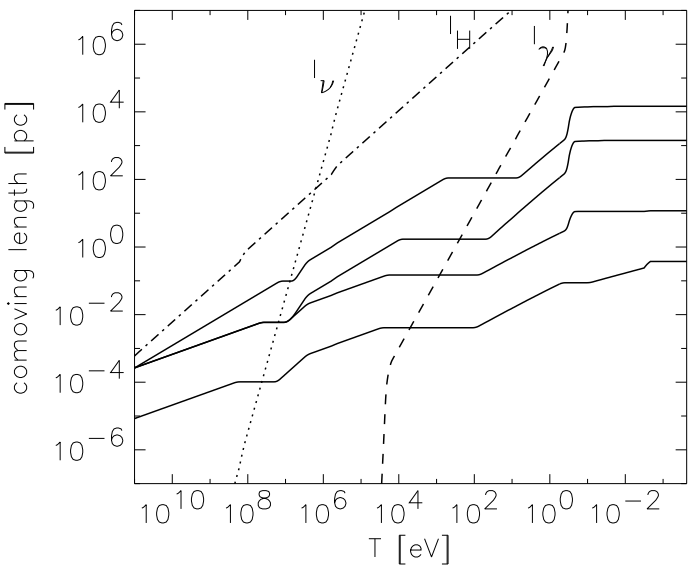
- TeV-blazars: $\gamma_{\rm TeV} + \gamma_{\rm EBL} \rightarrow e^+ + e^-$
- $e^\pm + \gamma_{\rm CMBR} \rightarrow e^\pm + \gamma_{\rm GeV}$

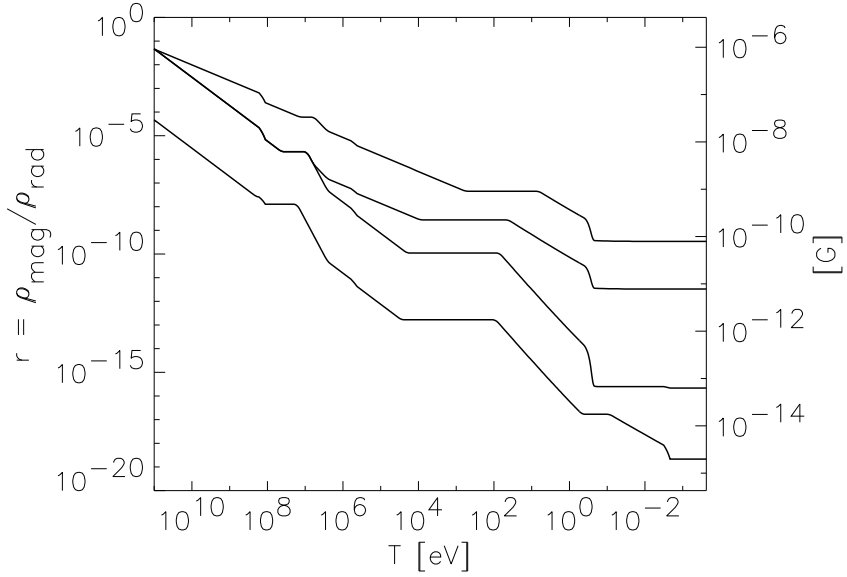


- predicted GeV γ's not observed $\rightarrow$ $e^\pm$ deflection by magnetic fields
- $B \gtrsim 3 \times 10^{-16}$Gauss $\neq 0$!

- many scenarios of early Universe $t \lesssim 1$ sec cosmic magnetogenesis proposed
- evolution afterwards had not been known

Evolution: The Global Picture





from top to bottom: (a) $h_g = 1$, $r_g = 0.01$, (b) $h_g = 10^{-3}$, $n = 3$, $r_g = 0.01$, (c) $h_g = 0$, $n = 3$, $r_g = 0.01$, (d) $h_g = 0$, $n = 3$, $r_g = 10^{-5}$

magnetic fields on scales $\lambda < l_\gamma$ produce density fluctuations before recombination i.e. $v_A \sim v_s$ for $B \sim 10^{-11}$Gauss

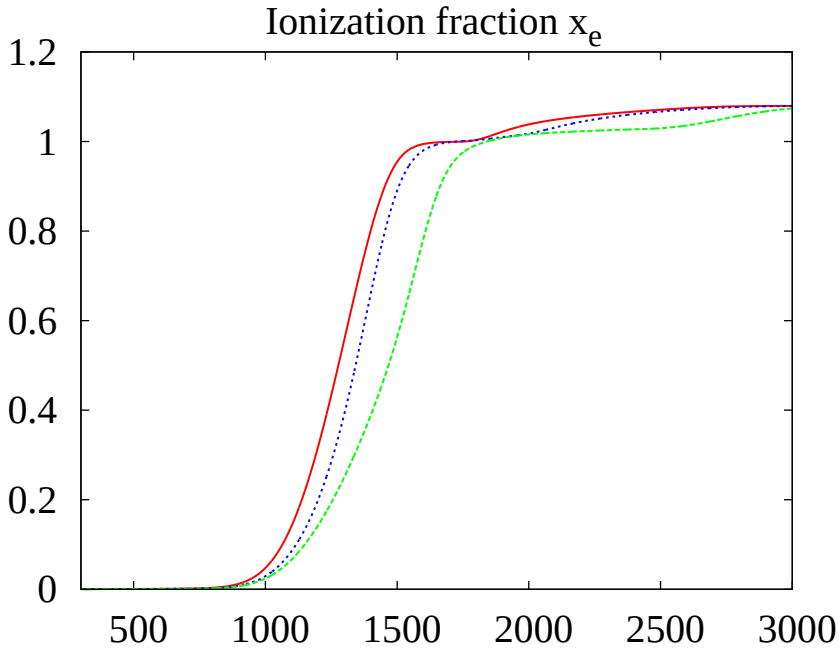
recombination in inhomogeneous environment

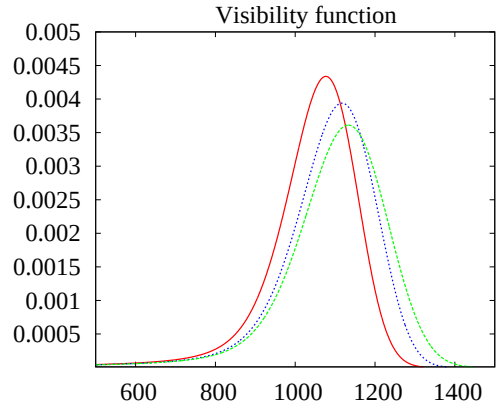
$$\frac{d\langle n_{H^0}\rangle}{dt}|_{inhomo} = \alpha_e\langle n_e n_p\rangle - \beta_e\langle n_{1s}\rangle \exp\Big(\frac{-E_{\nu_\alpha}}{kT}\Big) \neq \frac{d\langle n_{H^0}\rangle}{dt}|_{homo}$$

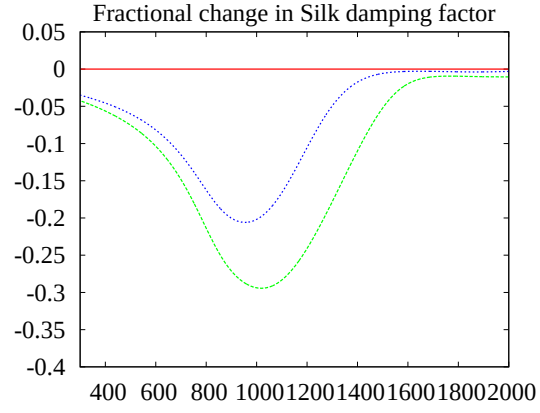
since $\langle n_e n_p\rangle \neq \langle n_e\rangle\langle n_p\rangle$

Weak Magnetic Fields and the CMBR

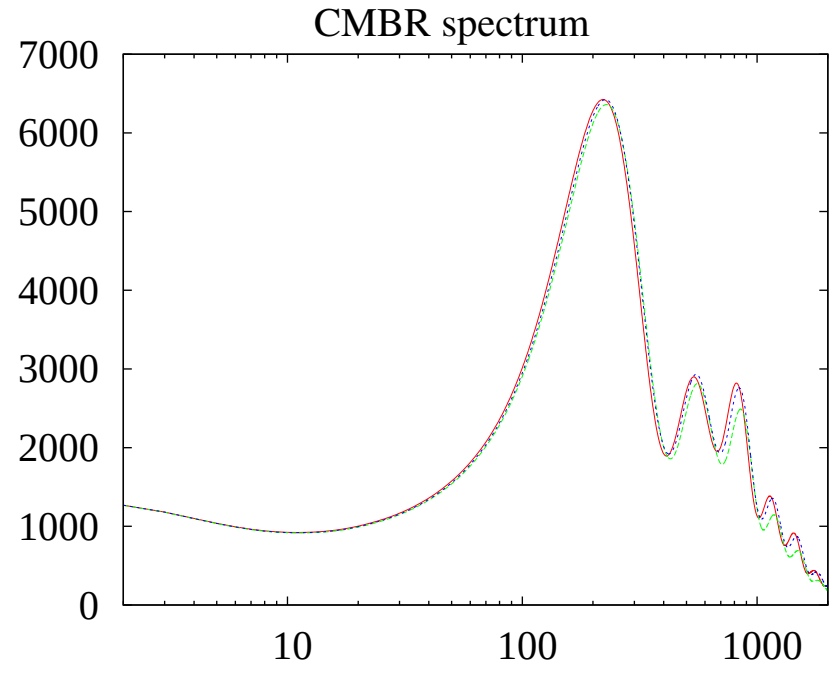
$$\left(\frac{\delta\rho}{\rho}\right)_{rms} = 0,\ \sqrt{3},\ 10$$

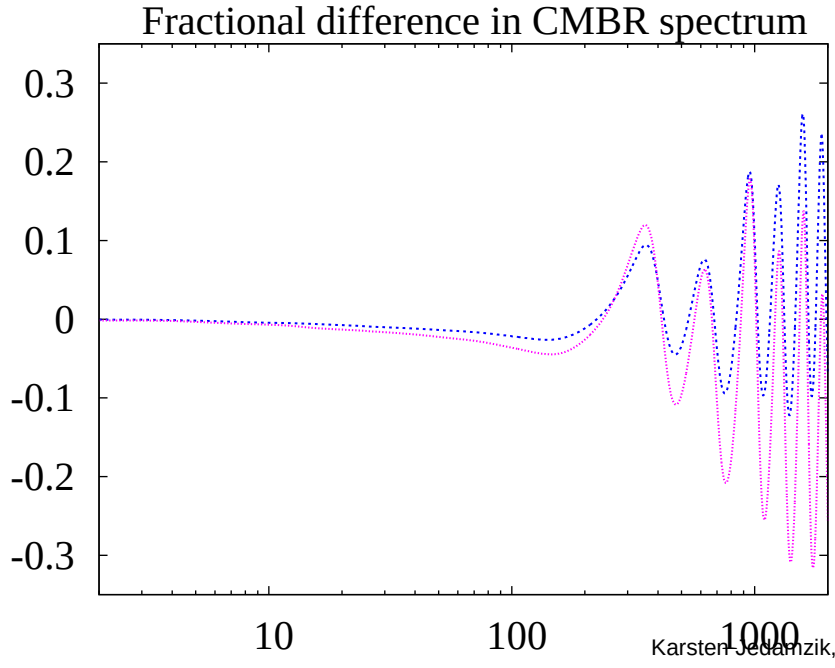






Weak Magnetic Fields and the CMBR





in case such density inhomogeneities may be excluded or detected by Planck (?)

$\rightarrow$

stringent limits/sensitive indirect detection of

- $B_{\rm today} \lesssim 5 \times 10^{-12}$ Gauss for $n = 3$ causual white noise spectrum or
- $B_{\rm today} \lesssim 5 \times 10^{-11}$ Gauss for scale-invariant spectrum

may be obtained.

Sujets de Recherches

I. La Nucleosynthèse Primordiale

II. Champs Magnetiques Cosmologiques

III. La Matière Noire

IV. Les Trous Noir Primordiaux

III. (Transistion de Phases Cosmologiques)

IV. (Formation de Structures Cosmiques)