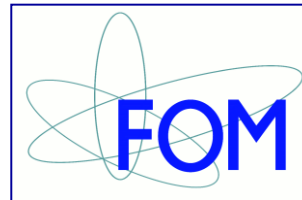


CONSTRAINT ON A DRIFTING PROTON-TO-ELECTRON MASS RATIO THROUGH ANALYSIS OF MOLECULAR ABSORPTION LINES

Mario Daprà

LaserLaB, Department of Physics and Astronomy, VU University Amsterdam

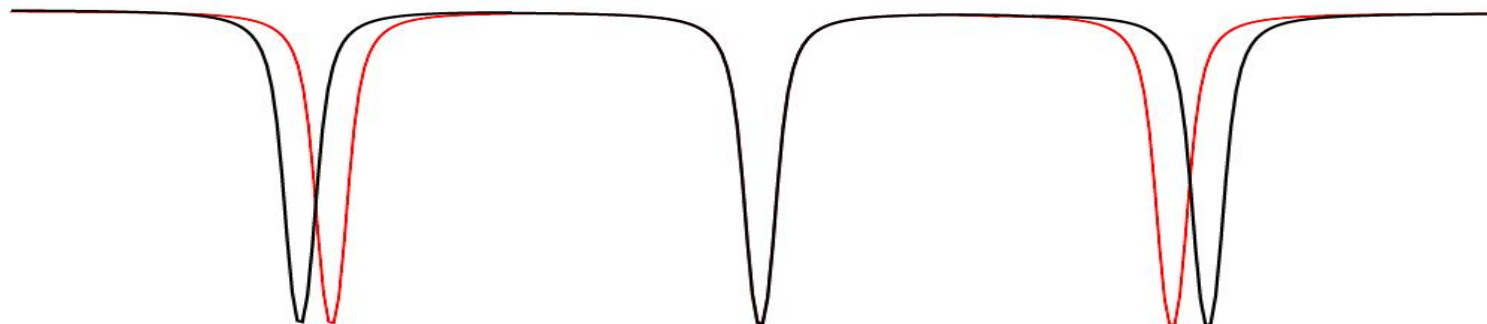


Azores 2014 – 03/06/2014

VARYING CONSTANTS

Dimensionless quantities: $\alpha = \frac{e^2}{4\pi\epsilon_0\hbar c} = \frac{1}{137}$

$$\mu = \frac{M_p}{m_e} = 1836.15267245(75)$$



$$\frac{\Delta\nu}{\nu} = K_\mu \frac{\Delta\mu}{\mu}$$

ν

K_μ

μ

Calculate

Measure

Determine

The shifting power is expressed via sensitivity coefficients K_μ .

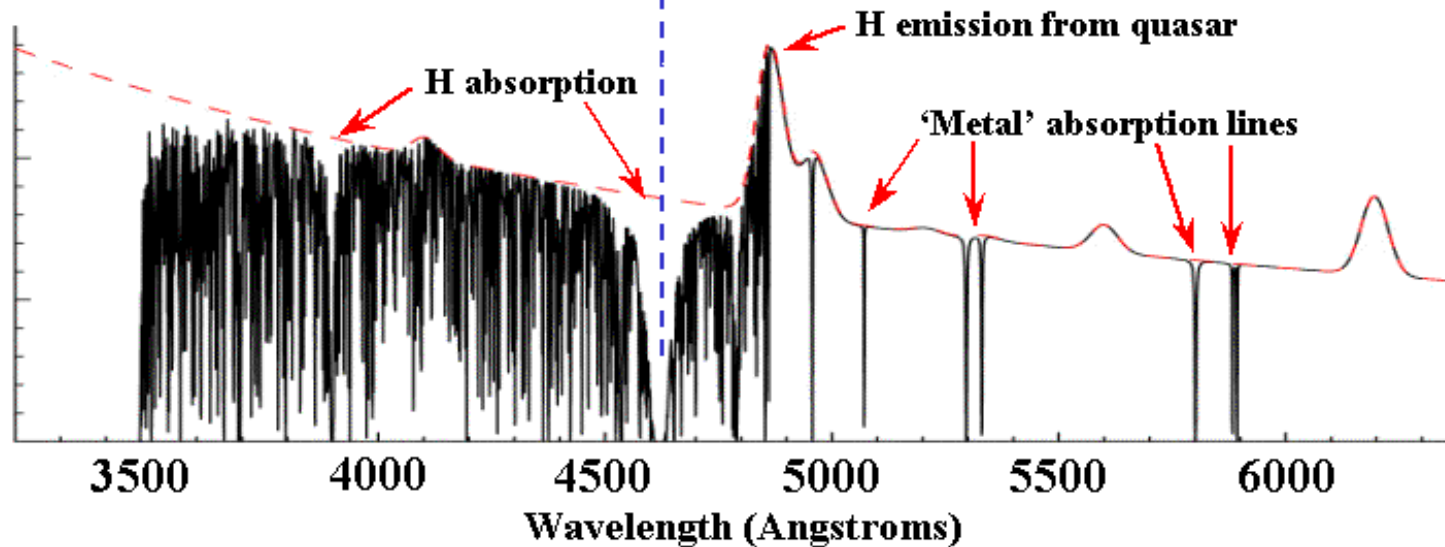
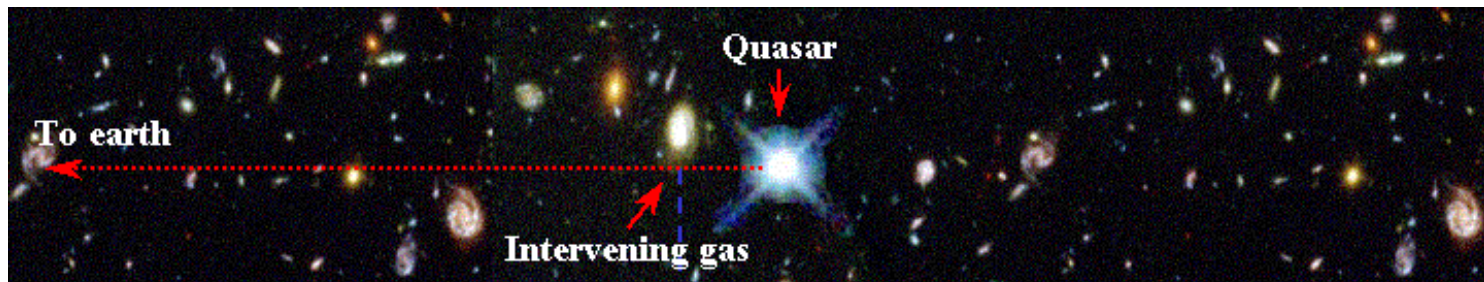
At least two lines with different sensitivities are necessary to constrain $\Delta\mu/\mu$.

Suitable molecules are H_2 , CH_3OH , CO , NH_3 .

MOLECULES

Two basic requirements:

1. sensitive transitions $\Leftrightarrow K_{\mu} \neq 0$
2. Detectable at intermediate – high redshift



Molecular hydrogen - H_2

$K_{\mu} = -0.05$ to $+0.02$ - weak sensitivity

High redshift $z > 2$

Methanol – CH_3OH

$K_{\mu} = -42$ to $+53$ – high sensitivity

Intermediate redshift $z = 0.89$

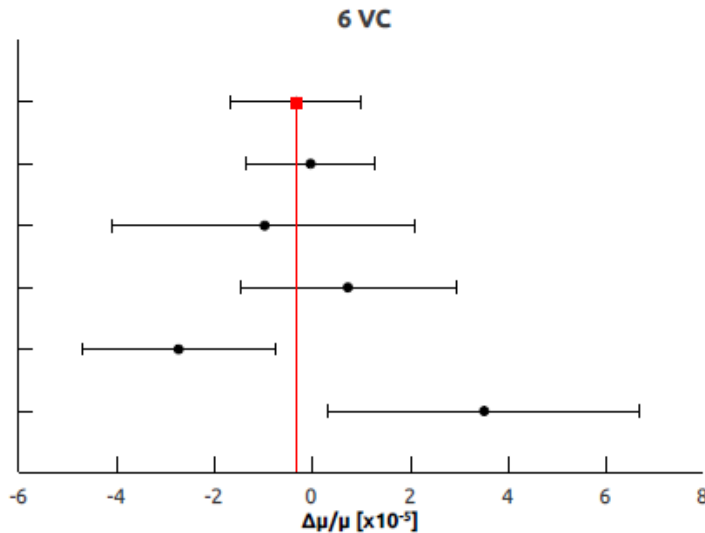
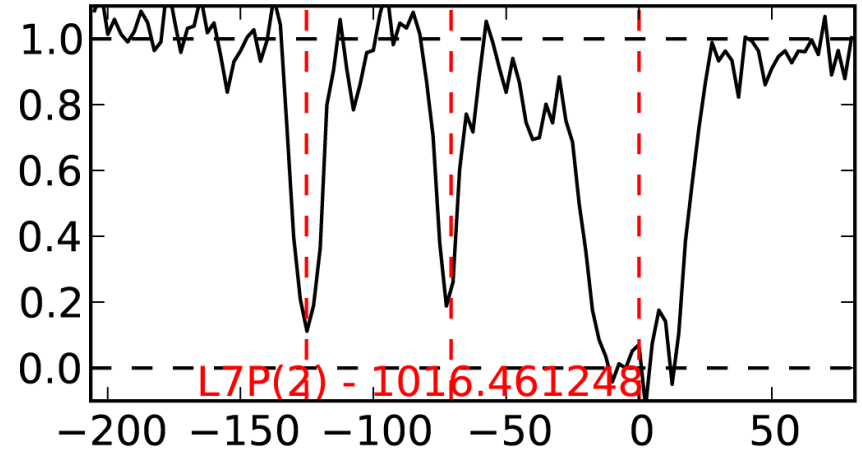
MOLECULAR HYDROGEN

118 H₂ lines are detected in three absorbers towards QSO J1237+0647 at redshift:

$$z_{\text{abs1}} = 2.68801$$

$$z_{\text{abs2}} = 2.68868$$

$$z_{\text{abs3}} = 2.68955$$



$$\text{GENERIC} - \Delta\mu/\mu = (-0.35 \pm 1.33) \cdot 10^{-5}$$

$$\text{WARM STATES} - \Delta\mu/\mu = (-0.03 \pm 1.32) \cdot 10^{-5}$$

$$\text{COLD STATES} - \Delta\mu/\mu = (-0.99 \pm 3.10) \cdot 10^{-5}$$

$$\text{1ST ABSORBER} - \Delta\mu/\mu = (0.73 \pm 2.21) \cdot 10^{-5}$$

$$\text{2ND ABSORBER} - \Delta\mu/\mu = (-2.73 \pm 1.97) \cdot 10^{-5}$$

$$\text{3RD ABSORBER} - \Delta\mu/\mu = (3.50 \pm 3.18) \cdot 10^{-5}$$

METHANOL

Methanol is only detected in the lensing galaxy towards QSO **PKS1830-211** at redshift $z_{\text{abs}} = 0.89$



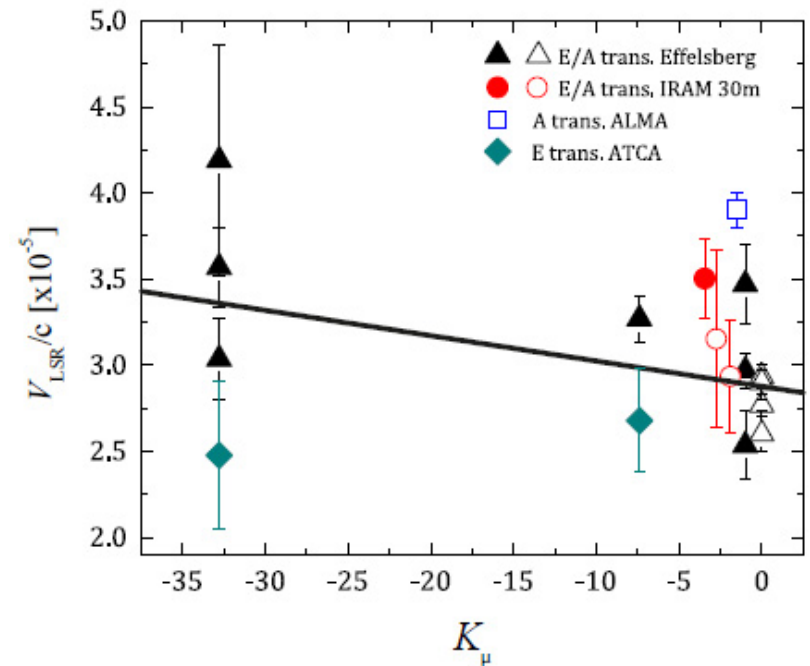
| Transition | ν [GHz] | K_{μ} | Obs. date |
|---|-------------|-----------|-----------|
| 3 ₋₁ -2 ₀ E | 6.46 | -32.8 | Feb. 2012 |
| | | | Nov. 2012 |
| | | | May 2013 |
| 0 ₀ -1 ₀ A ⁺ | 25.65 | -1.0 | Dec. 2011 |
| | | | Apr. 2012 |
| | | | Mar. 2013 |
| 0 ₀ -1 ₀ E | 25.65 | -1.0 | Dec. 2011 |
| | | | Apr. 2012 |
| | | | Mar. 2013 |
| 2 ₋₁ -1 ₀ E | 32.10 | -7.4 | Apr. 2013 |
| | | | Apr. 2012 |
| | | | Mar. 2012 |



| Transition | ν [GHz] | K_{μ} | Obs. date |
|---|-------------|-----------|-----------|
| 3 ₀ -2 ₁ A ⁺ | 83.04 | -2.7 | Aug. 2012 |
| 1 ₋₁ -1 ₀ E | 83.40 | -3.5 | Aug. 2012 |
| 2 ₋₁ -2 ₀ E | 83.40 | -3.5 | Aug. 2012 |
| 3 ₋₁ -3 ₀ E | 83.40 | -3.5 | Aug. 2012 |
| 1 ₀ -1 ₁ A ^{+/-} | 160.87 | -1.9 | Aug. 2012 |



| Transition | ν [GHz] | K_{μ} | Obs. date |
|---|-------------|-----------|-----------|
| 3 ₀ -4 ₁ A ⁺ | 261.04 | -1.6 | Jun. 2012 |



$$\frac{\Delta\mu}{\mu} = (-1.0 \pm 0.8_{\text{stat}} \pm 1.0_{\text{syst}}) \cdot 10^{-7}$$

HIGHLIGHTS

- J1237+0647

Constraint on $\Delta\mu/\mu$ from 118 H₂ lines molecular hydrogen of:

$$\Delta\mu/\mu = (-0.35 \pm 1.33_{\text{stat}}) \cdot 10^{-5}$$

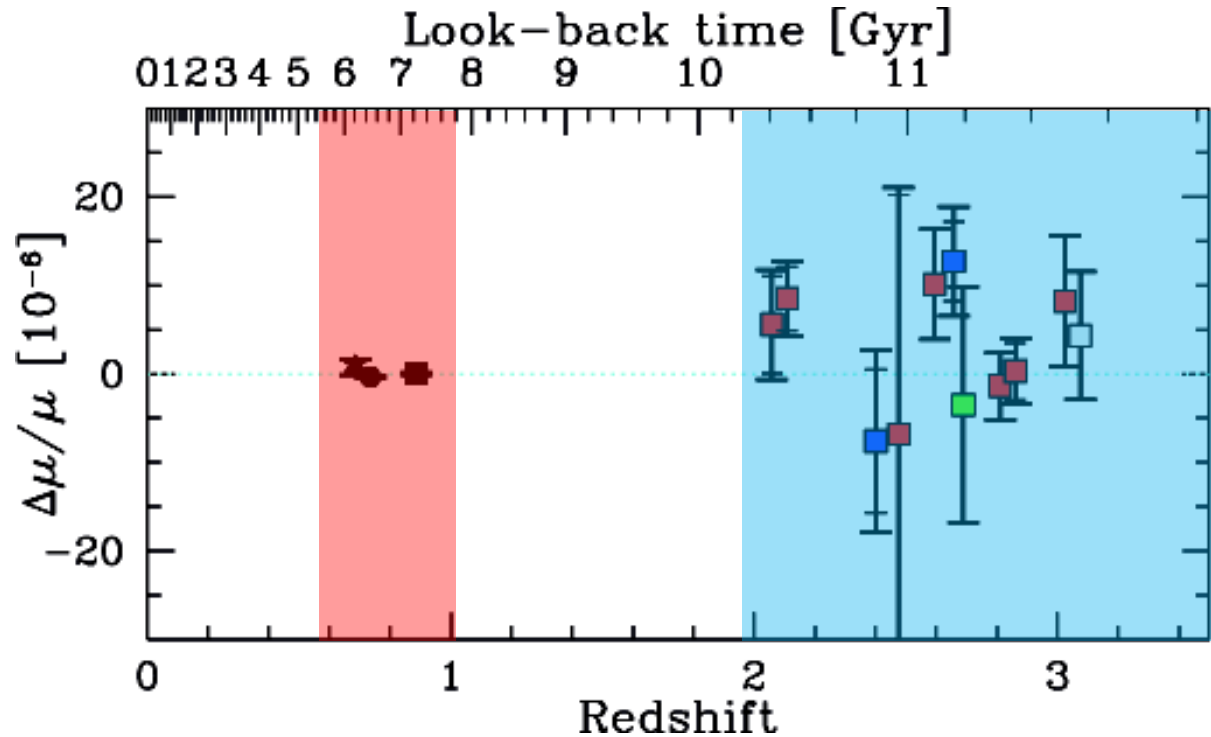
- J1237+0647

Use CO lines to derive another constraint on $\Delta\mu/\mu$

- PKS1830-211

Constraint on $\Delta\mu/\mu$ from 17 methanol lines of:

$$\Delta\mu/\mu = (-1.0 \pm 0.8_{\text{stat}} \pm 1.0_{\text{syst}}) \cdot 10^{-7}$$



The varying constants team:

- Julija Bagdonaite
- Paul Jansen
- Lex Kaper
- Michael Murphy
- Rick Bethlem
- Christian Henkel
- Karl Menten
- Wim Ubachs