Combined heliospheric modulation of galactic protons and helium nuclei from solar minimum to maximum activity related to observations by PAMELA and AMS-02

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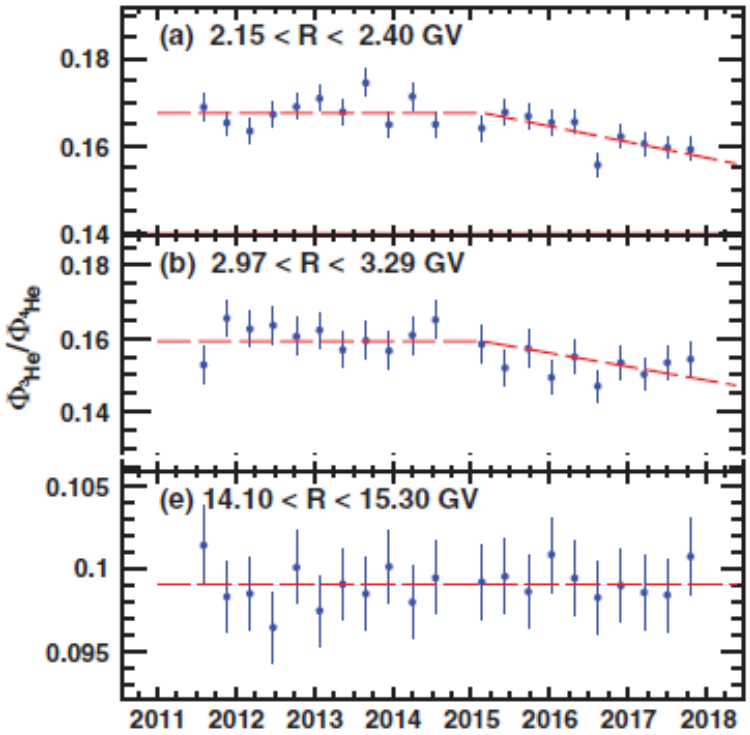
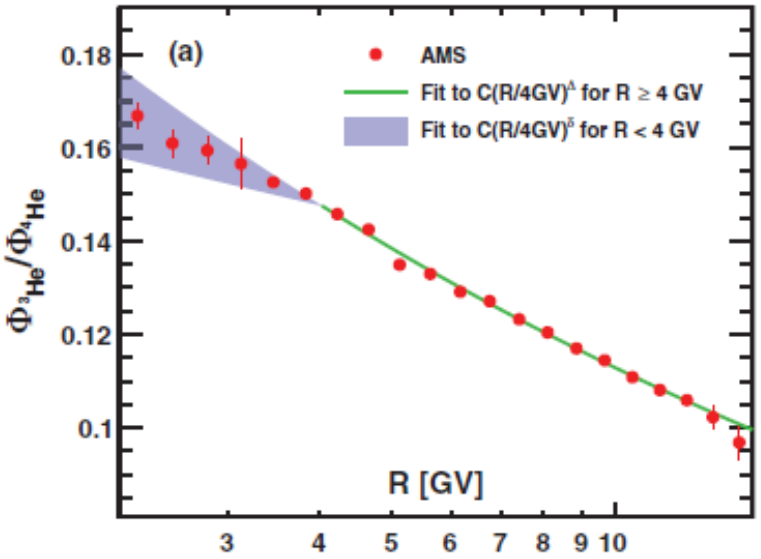
1. Introduction

Some observed ratios of $^3He_2$ to $^4He_2$ from Aguilar et al.(2019)





2. Transport equation and diffusion coefficients

Modulation processes in the Parker's (1965) transport equation:

$$\frac{\partial f}{\partial t} = -(\vec{V} + \langle \vec{v}_D \rangle) \cdot \nabla f + \nabla \cdot (\mathbf{K} \cdot \nabla f) + \frac{1}{3}(\nabla \cdot \tilde{V}) \frac{\partial f}{\partial lnp} \qquad (1.1)$$

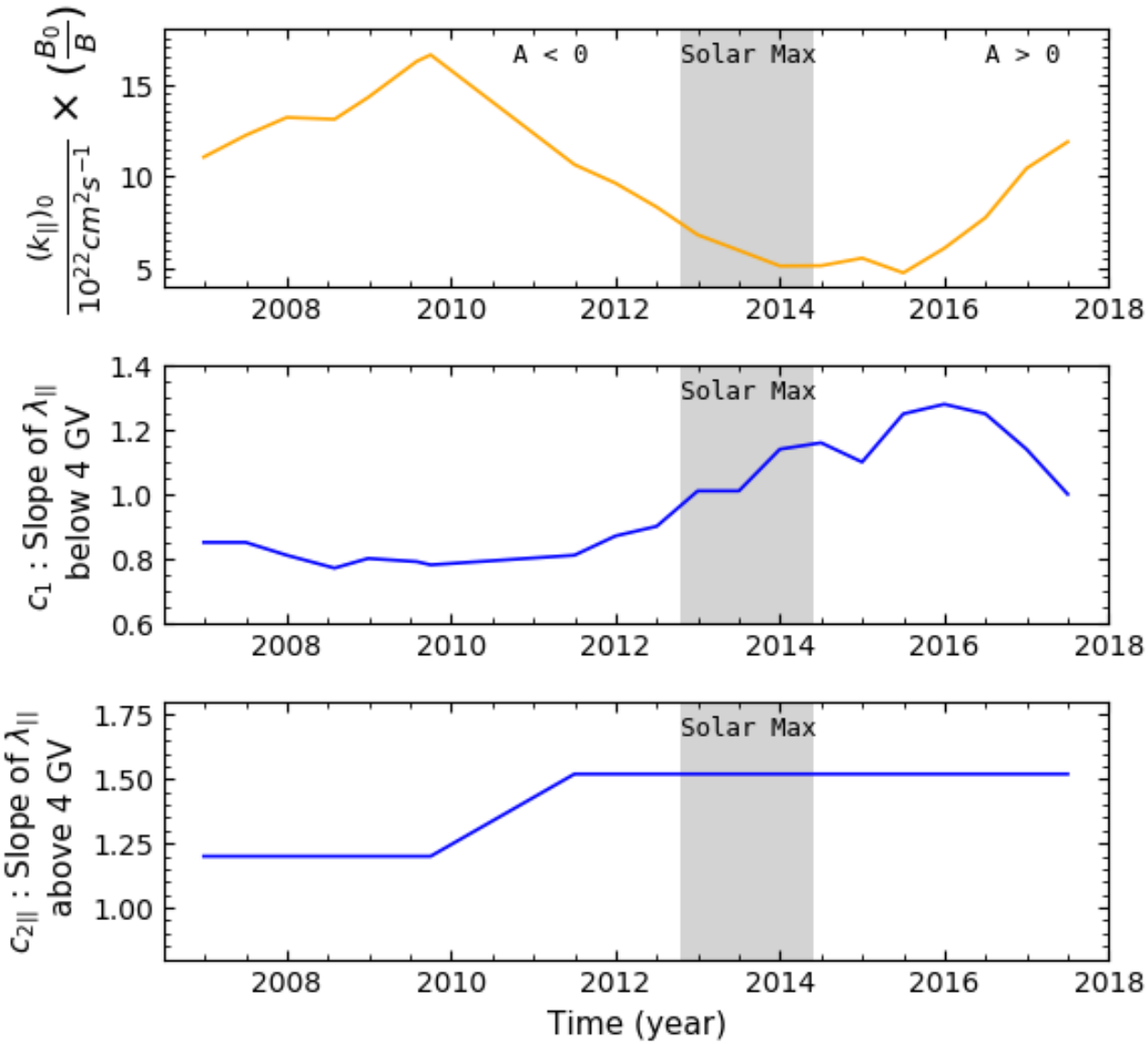
where $f(\vec{r}, p, t)$ is the CR distribution function, $\mathbf{K}$ the diffusion tensor, $\vec{V}(r, \theta)$ the solar wind vector and $\vec{v}_D$ the drift velocity.

Diffusion coefficients of interest:

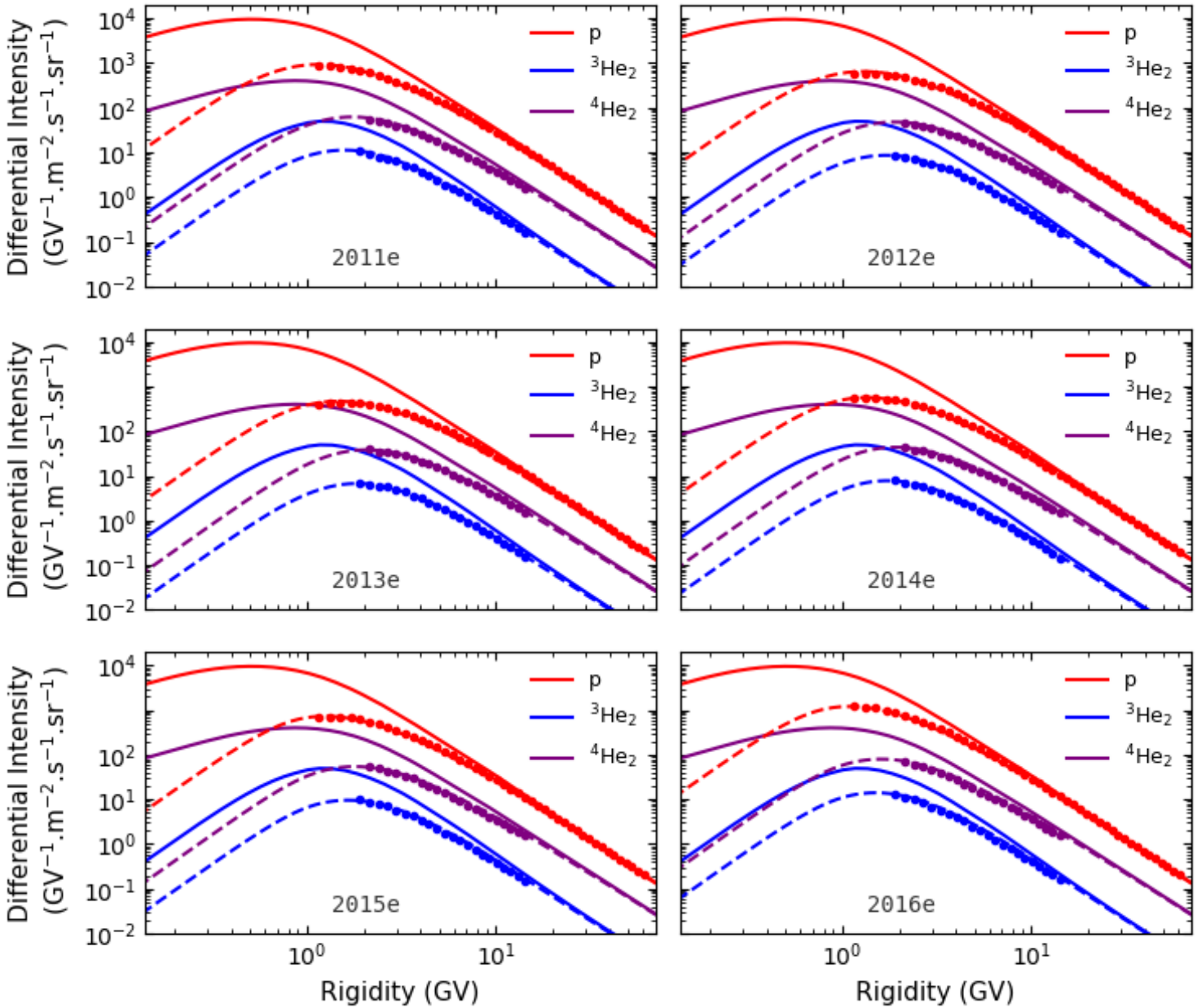
$$k_{||} = (k_{||})_0 \beta \left(\frac{B_0}{B}\right) \left(\frac{P}{P_0}\right)^{c_1} \left(\frac{\left(\frac{P}{P_0}\right)^{c_3} + \left(\frac{P_k}{P_0}\right)^{c_3}}{1 + \left(\frac{P_k}{P_0}\right)^{c_3}} \right)^{\frac{c_{2||} - c_1}{c_3}} \qquad (1.2)$$

where $(k_{||})_0$ is the scaling constant of the DCs, B the strength of the magnetic field, c_1 the slope of the DCs below and $c_{2||}$ above 4 GV, respectively.

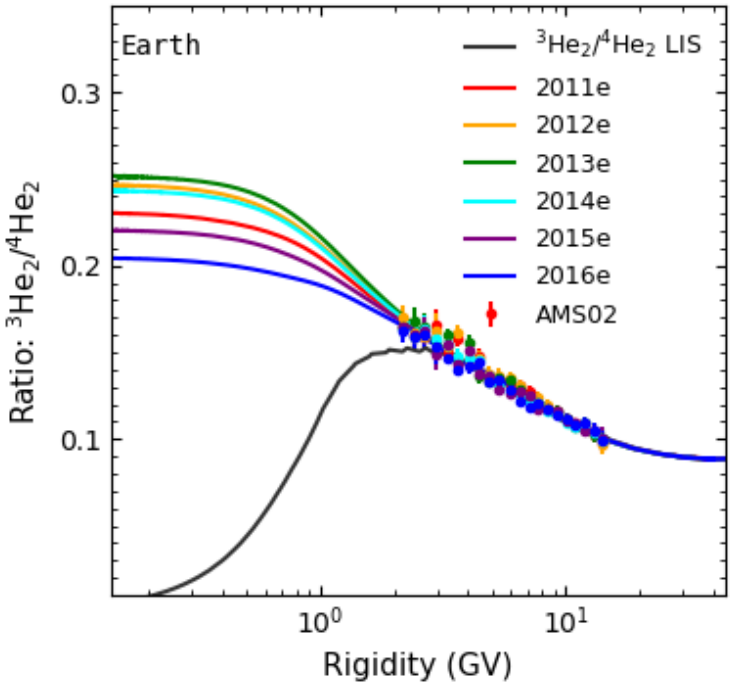
2.1 Assumed time dependence of the DCs and their slopes



3. Combined modulation of proton, $^3He_2$ and $^4He_2$



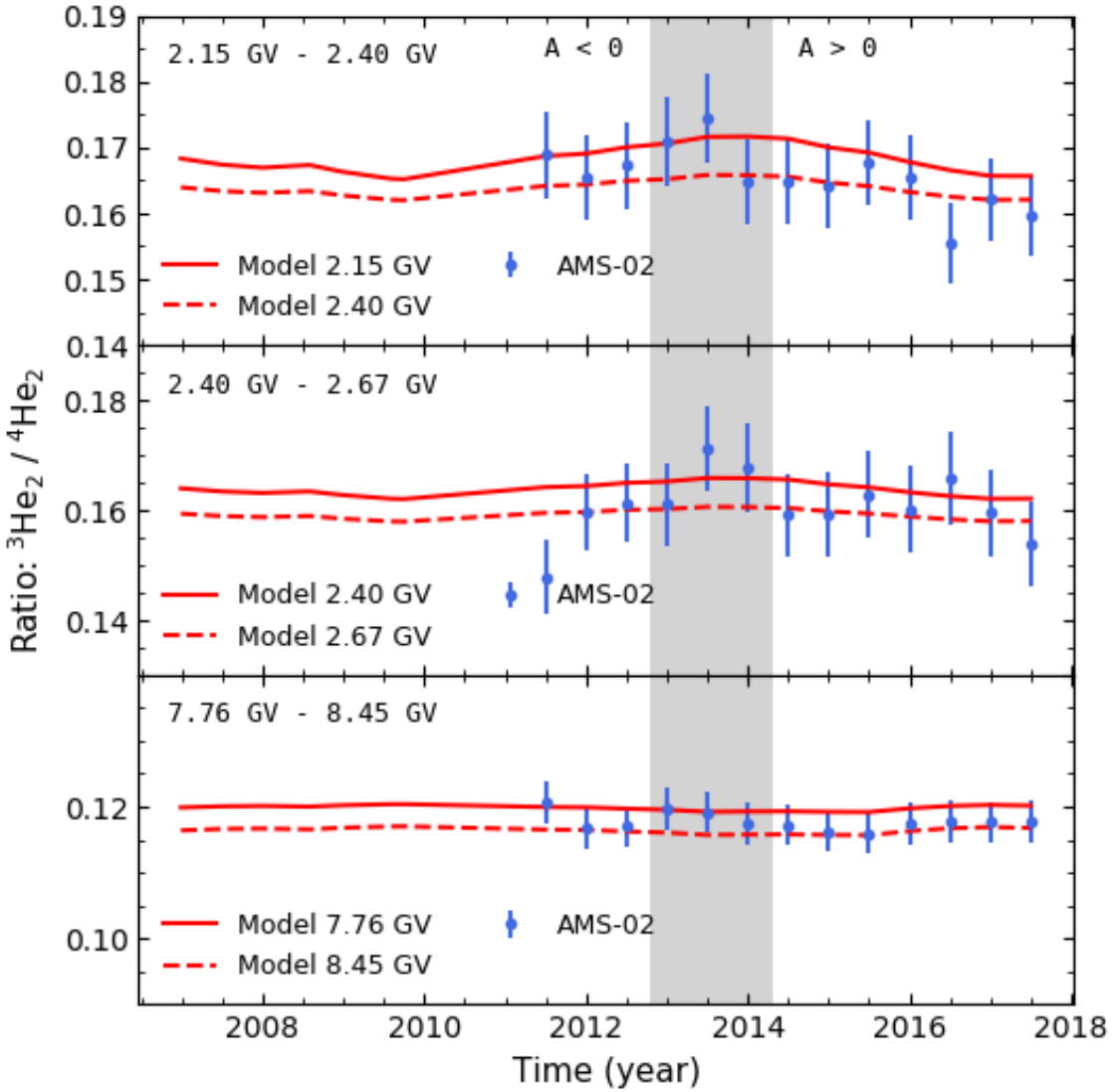
3.1 Rigiditiy dependence of $^3He_2$ to $^4He_2$ ratios



The numerical model can reproduce the:

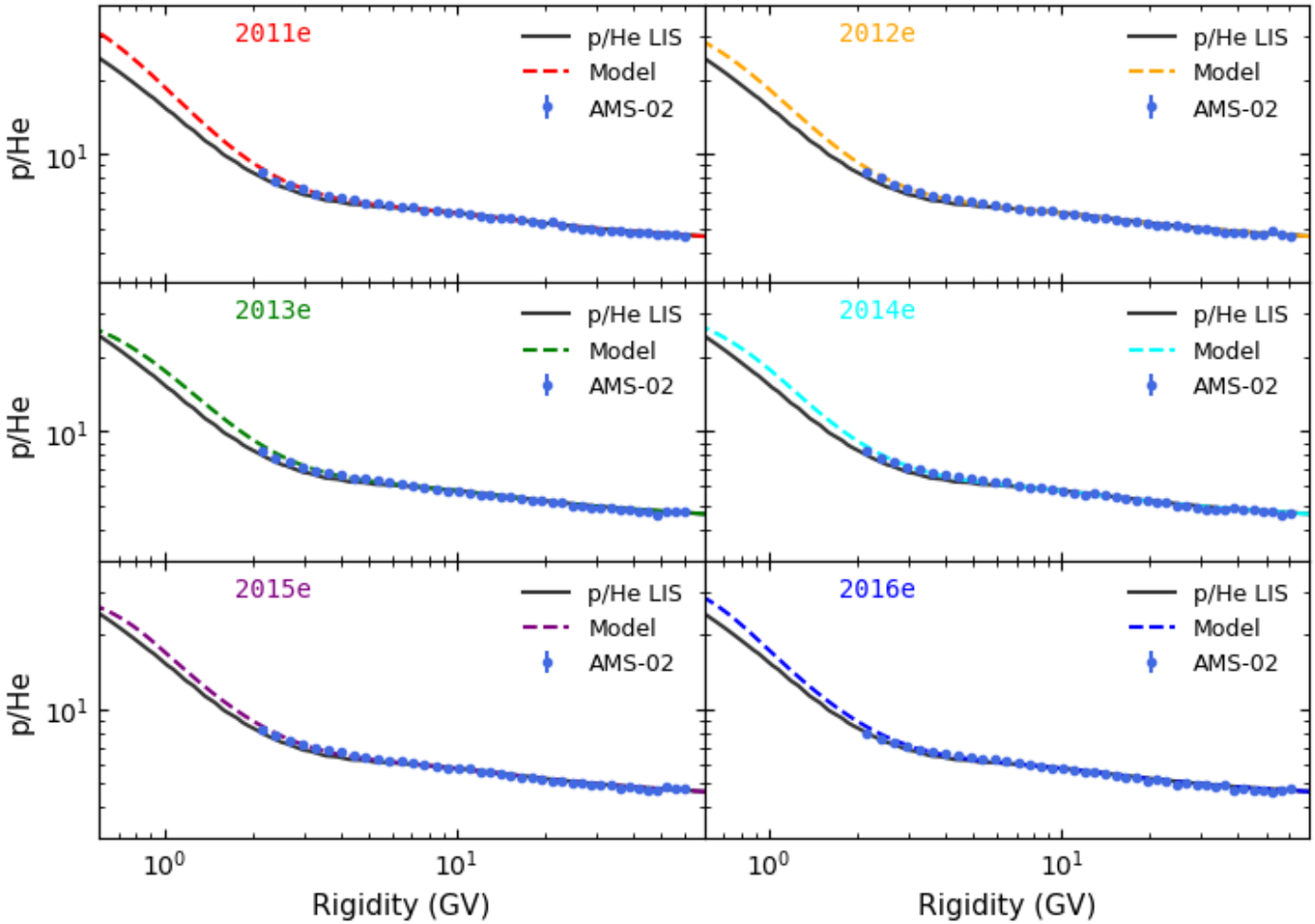
- Single rigidity power law dependence; and
- Time independence of this ratio above 4 GV.

3.2 Time variation in $^3He_2$ to $^4He_2$ ratios



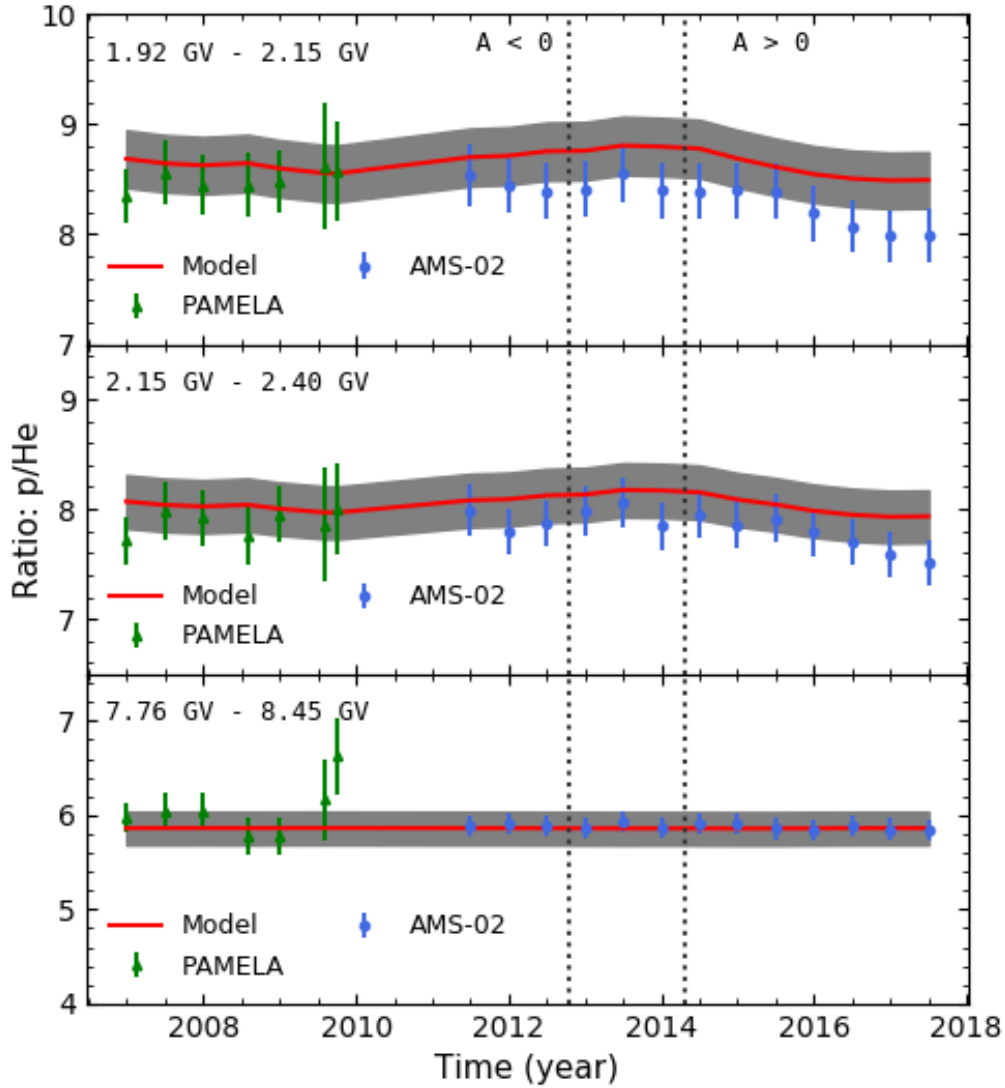
More on $^3He_2$ and $^4He_2$ during the poster session

3.3 rigiditiy dependence of p/He ratios



- AMS02 measurement of p/He above 5 GV precisely reveals the difference in the rigidity slopes of their VLIS's at these rigidities.

3.4 Time dependence of p/He ratios



- Possible deuteron isotopic mixing of $\sim 3\%$.

Summary and conclusions

- To reproduce the observed p/He ratios, a time dependence in the rigidity slopes of the DCs below 4 GV is required.
- At rigidity below about ~ 3 GV the decreasing (increasing) values of the computed p/He coincide with the increasing (decreasing) intensities of both species.
- The AMS02 measurement of p/He ratio above ~ 5 GV reveals the shapes of their VLIS's.
- More numerical studies and observations are required to study the contribution of deuteron to p/He ratio, moreso below 5 GV.

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