AARHUS
UNIVERSITY
Stellar Astrophysics Centre

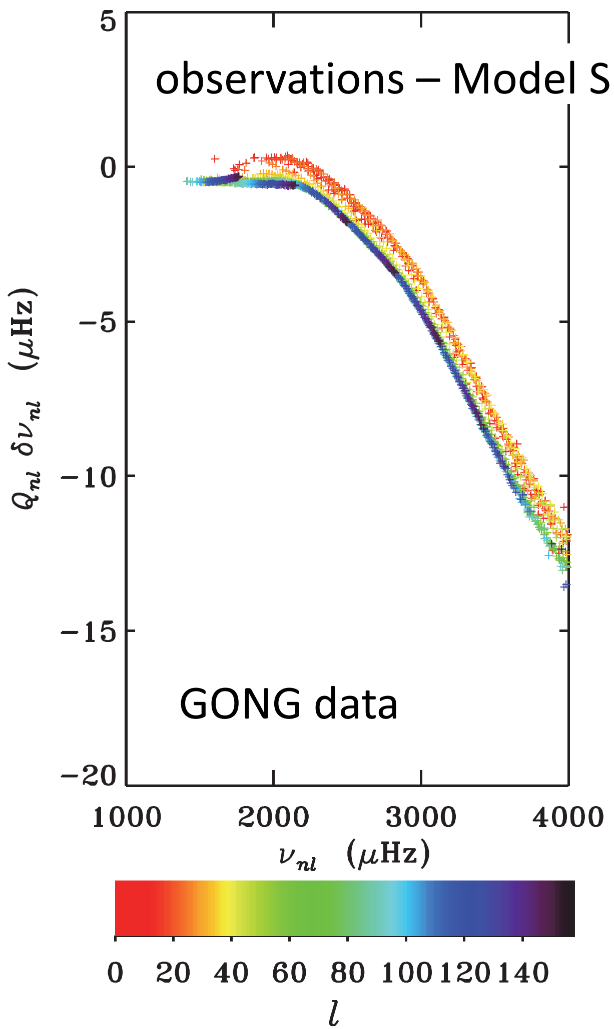
Surface effects: convection dynamics & nonadiabaticity

Günter Houdek
Magnus Aarslev
Regner Trampedach
Jørgen Christensen-Dalsgaard

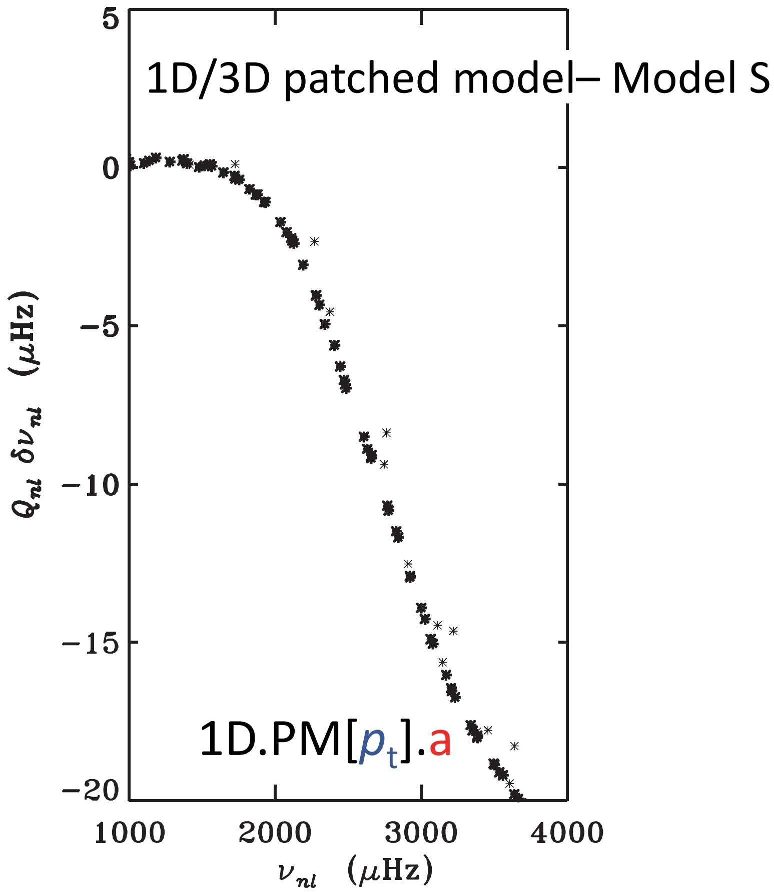
Surface effects: current models for adiabatic frequency corrections

Solar observations – **adiabatic** calculations

Christensen-Dalsgaard et al. (1996)



Rosenthal et al. (1995)



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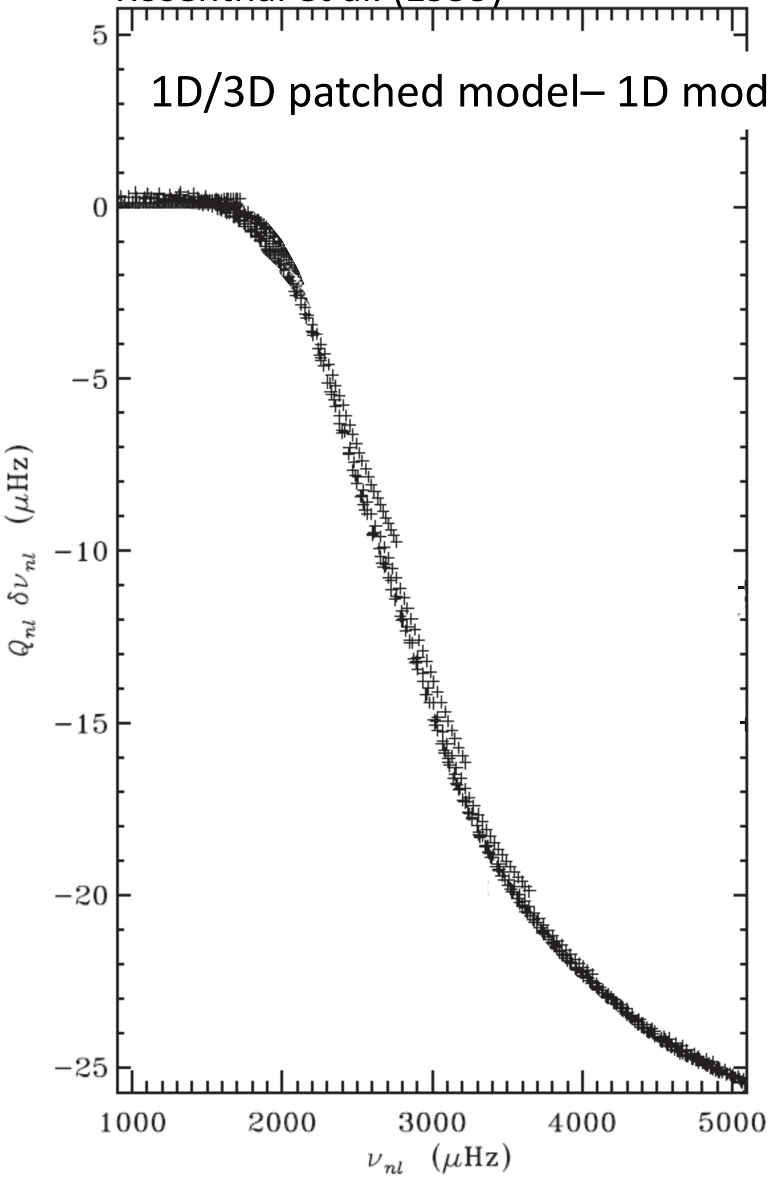

$$p = p_{\mathrm{g}} + p_{\mathrm{t}}$$

$$\frac{\partial r}{\partial m} = \frac{1}{4\pi r^2 \rho} \quad ; \quad \frac{\partial p}{\partial m} = -\frac{1}{4\pi r^2}\left(g + \frac{\partial r^2}{\partial t^2}\right)$$

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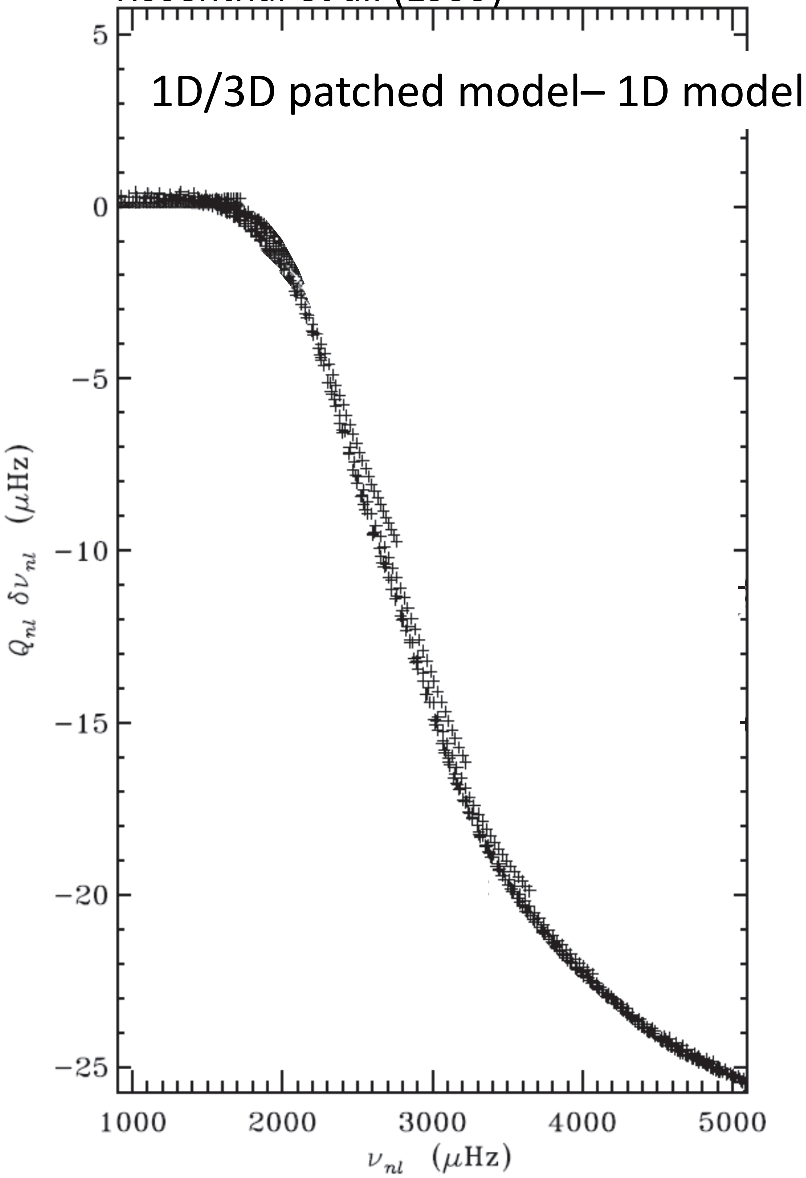

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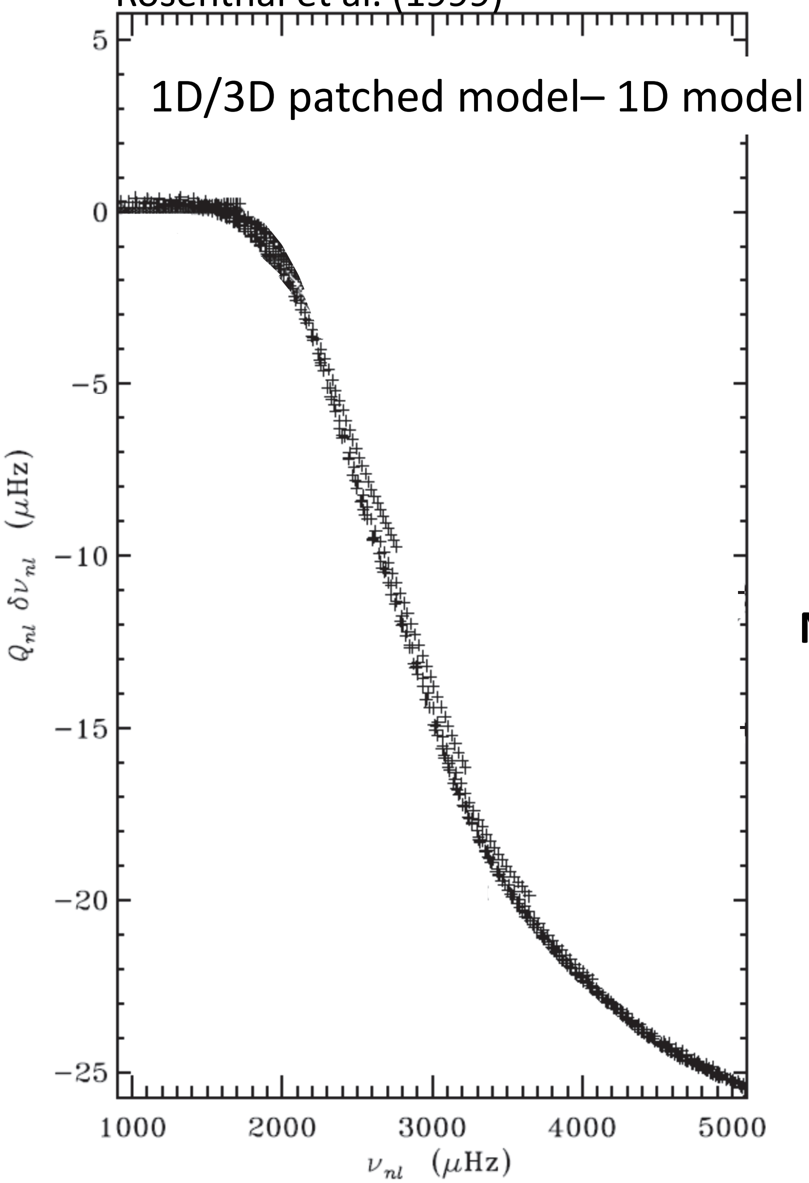

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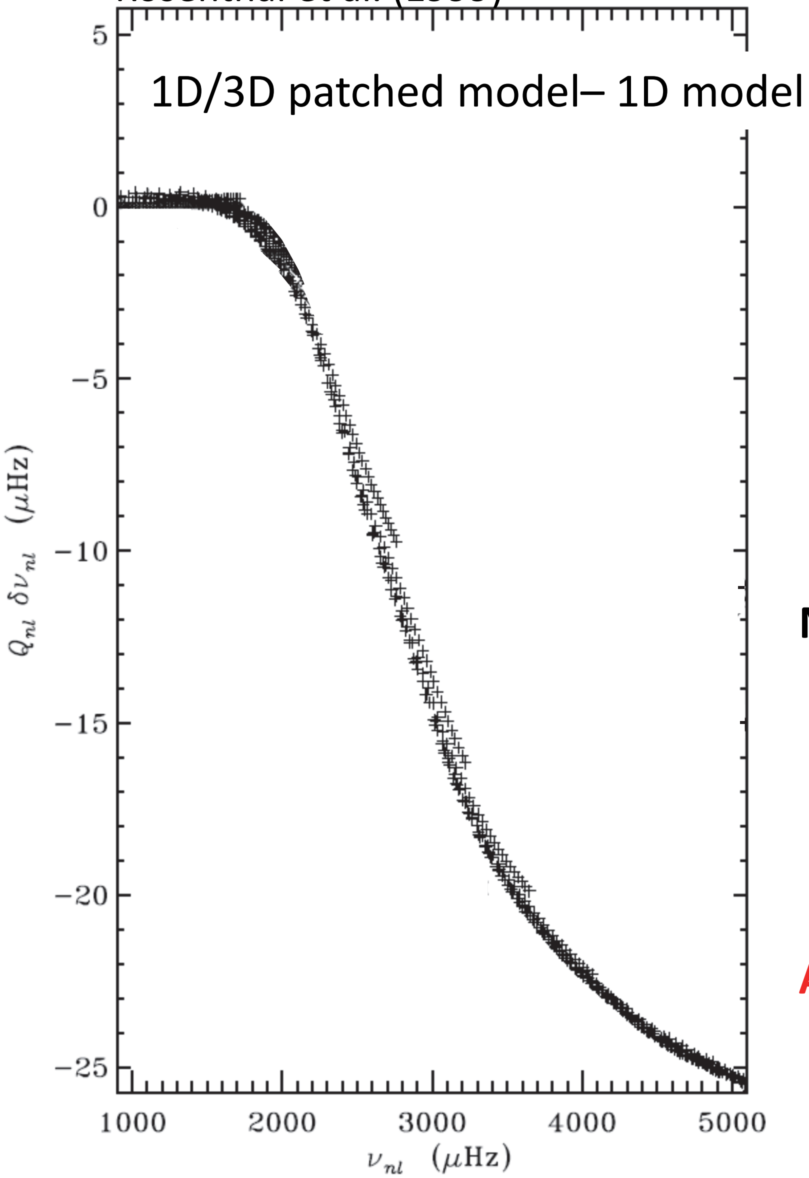

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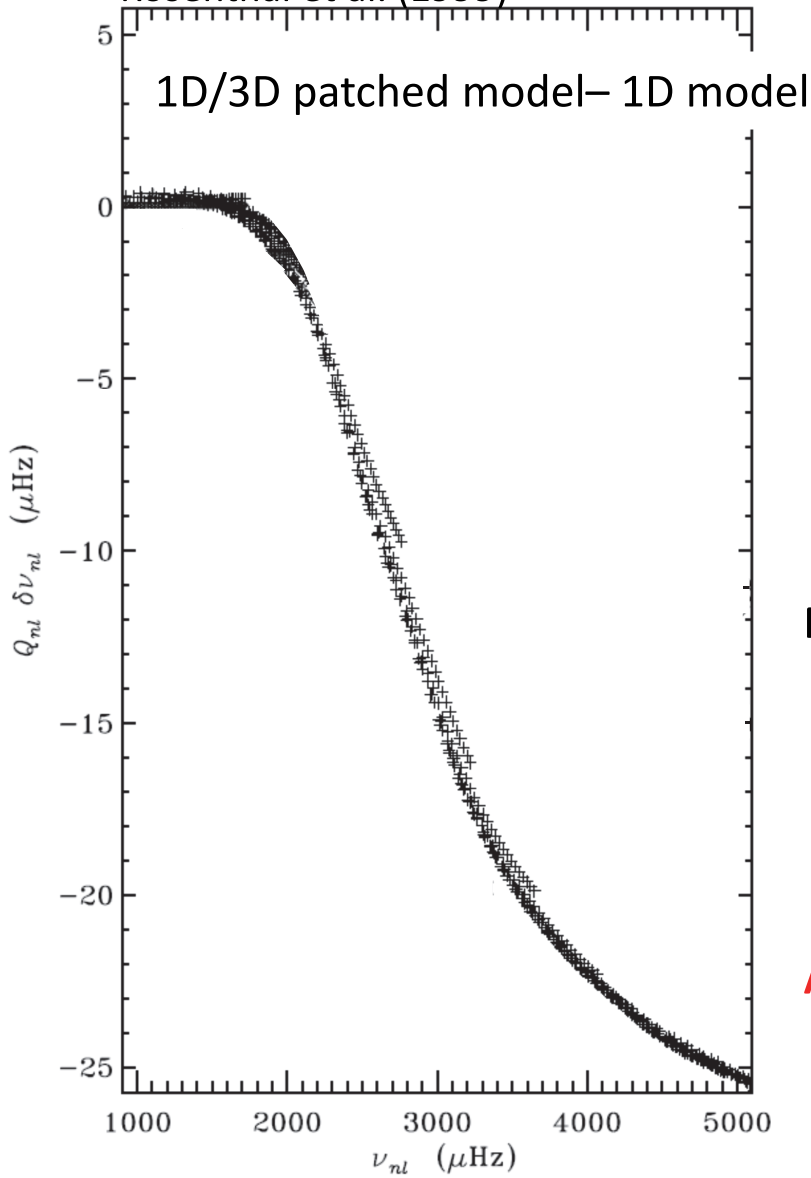

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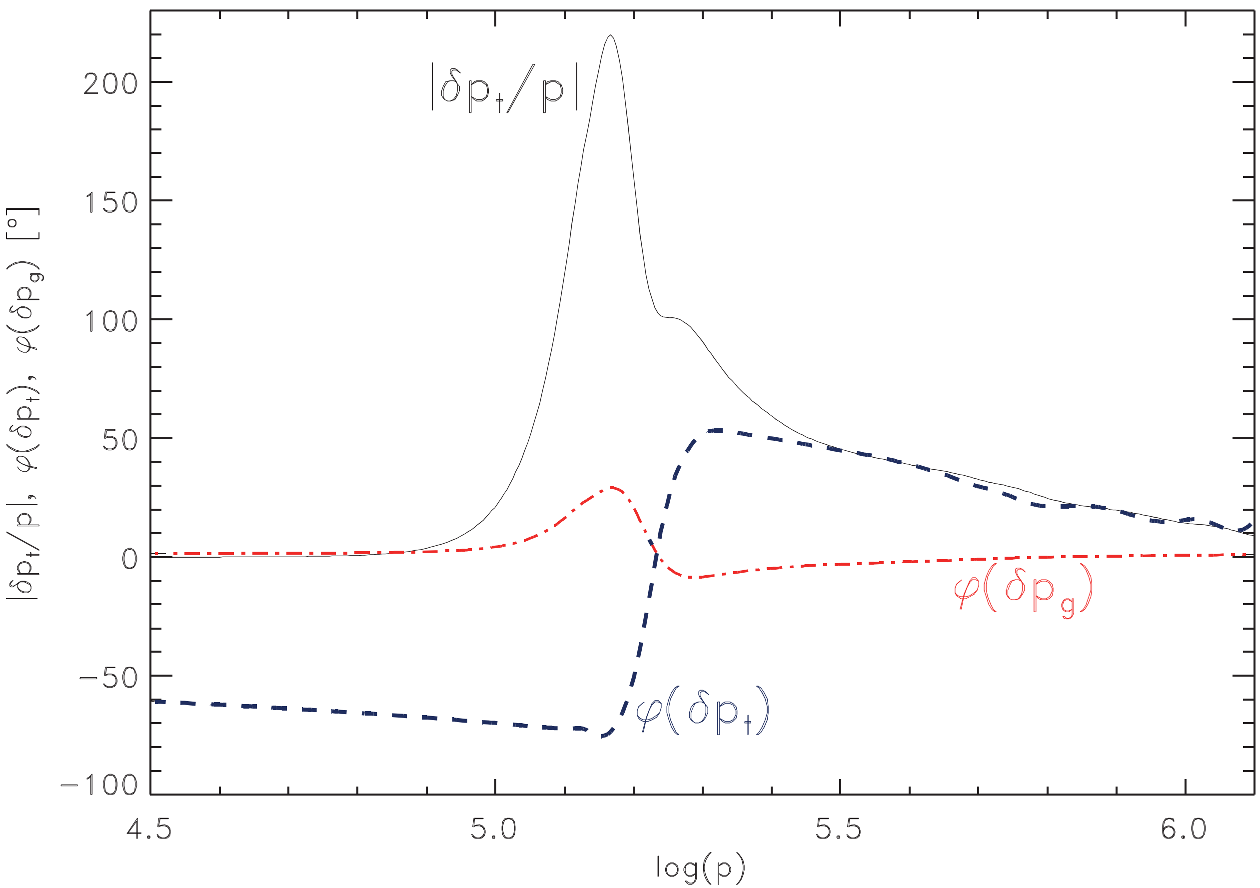
GH (1997)



→ δp_t contributes predominantly to imaginary part of the (complex) pulsation frequency

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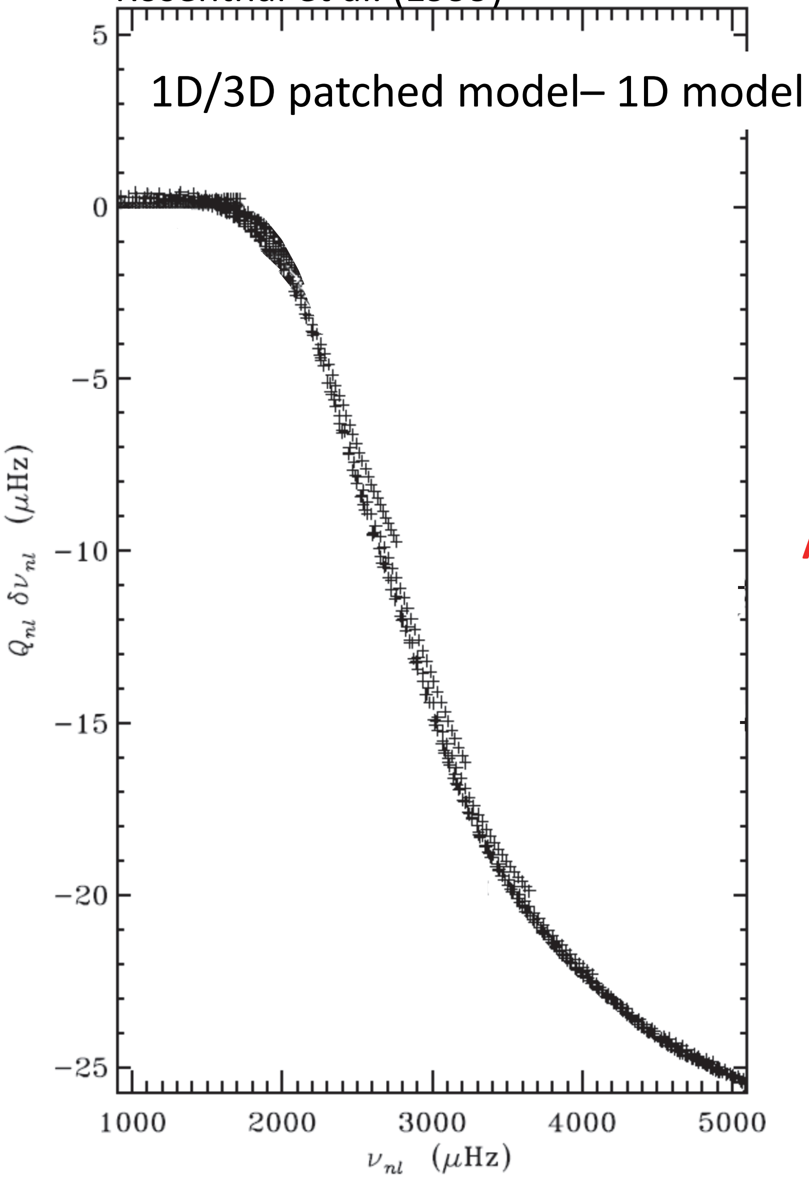

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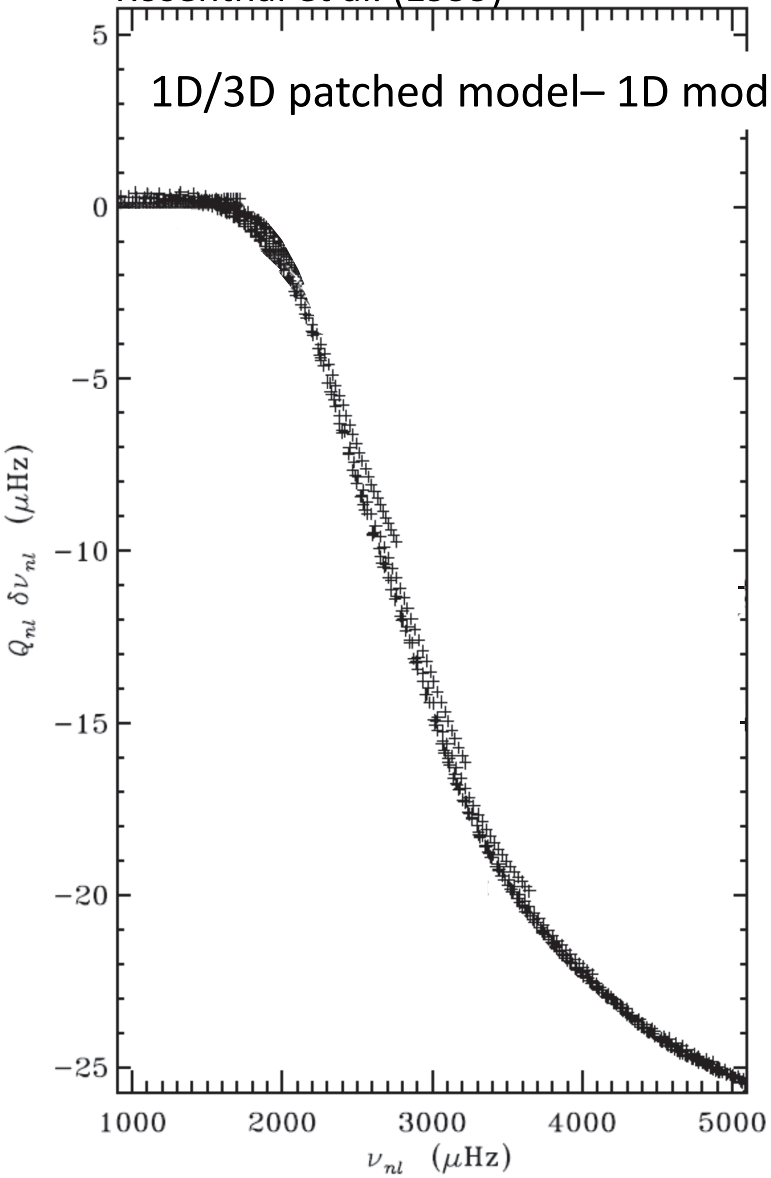

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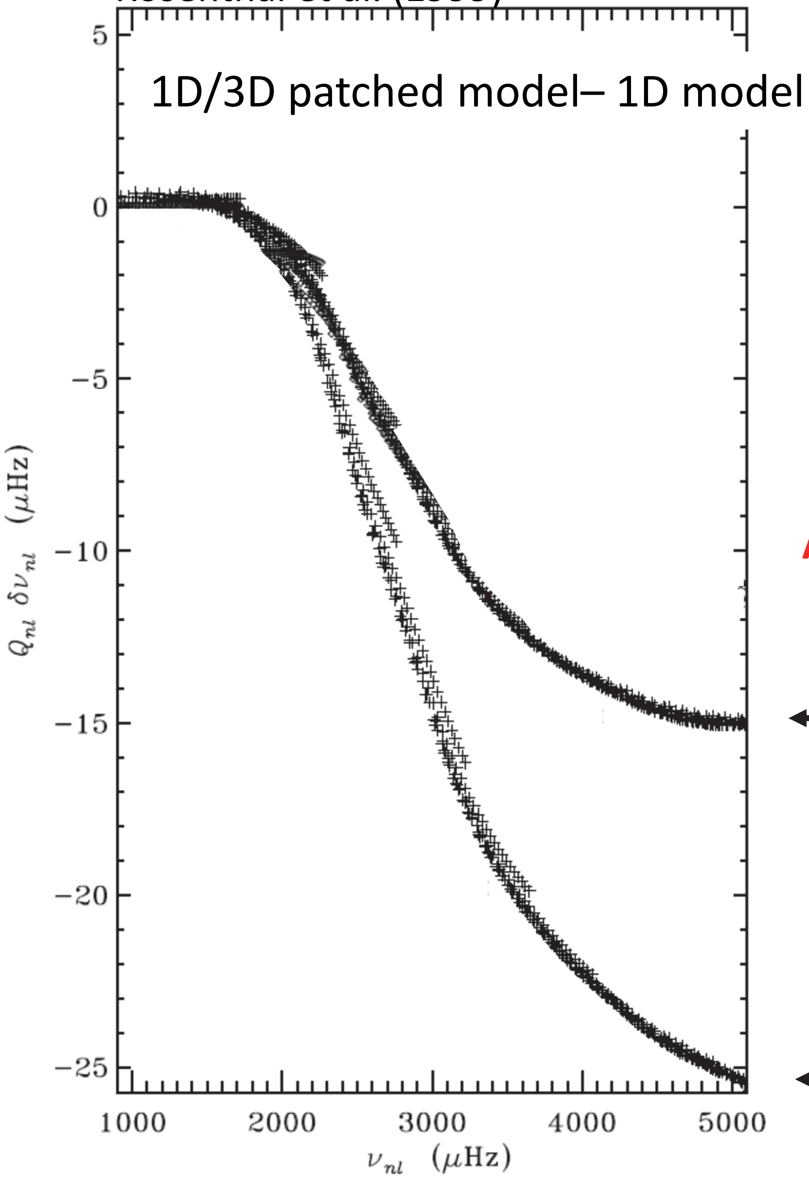

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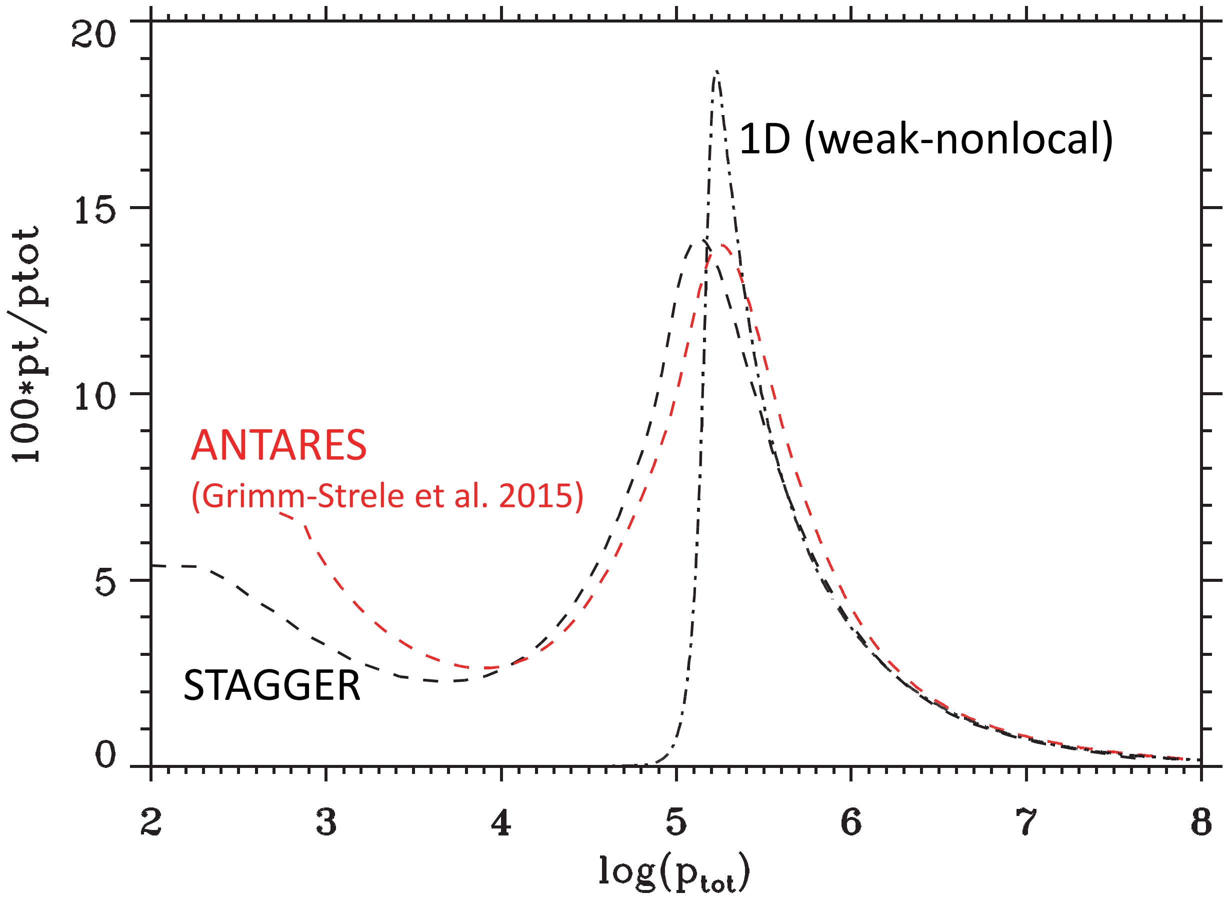
$\frac{1}{\gamma_1}\frac{p}{p_{\rm g}}$

1D models including turbulent pressure p_t

$$\frac{\partial}{\partial m}(p_g + p_t) = -\frac{1}{4\pi r^2}\left(\frac{Gm}{r^2} + \frac{\partial^2 r}{\partial t^2}\right)$$



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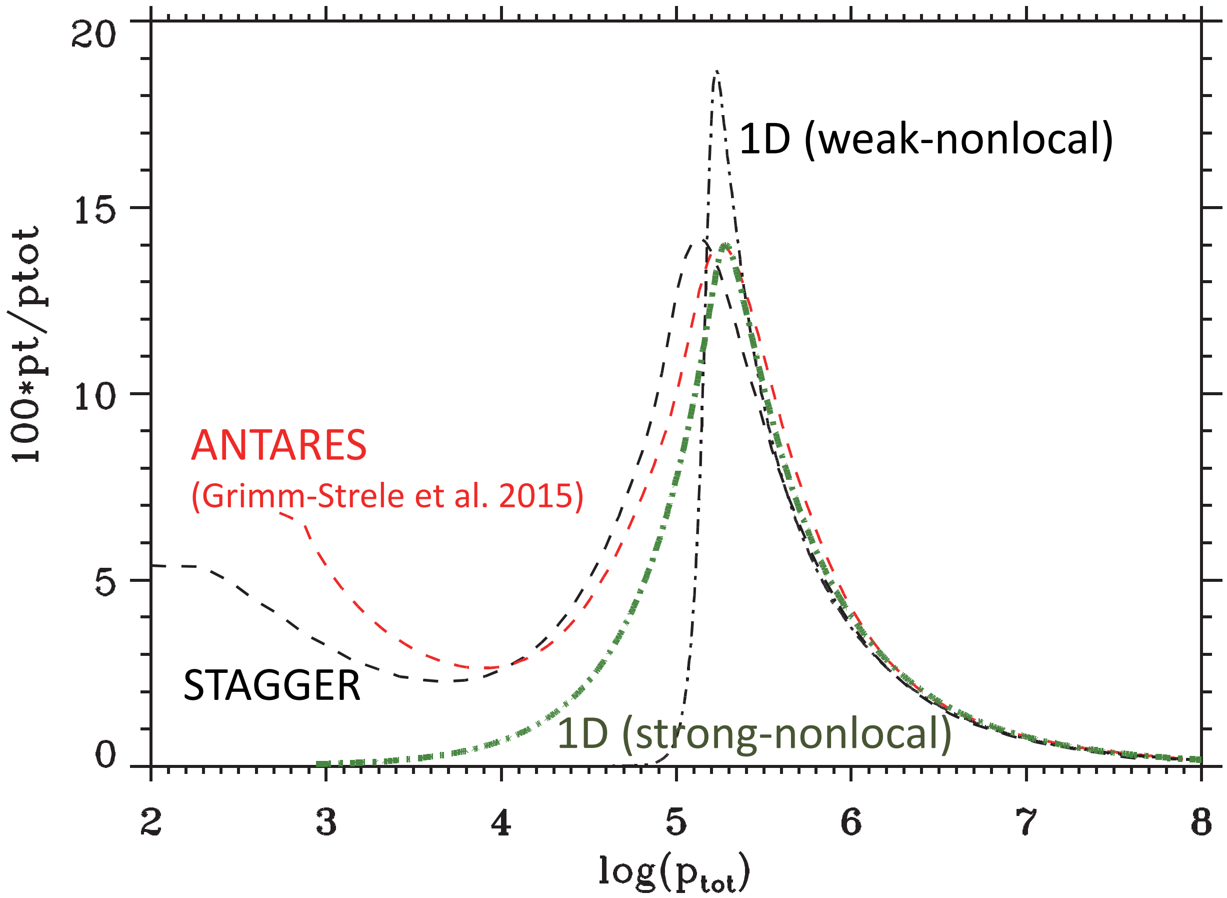
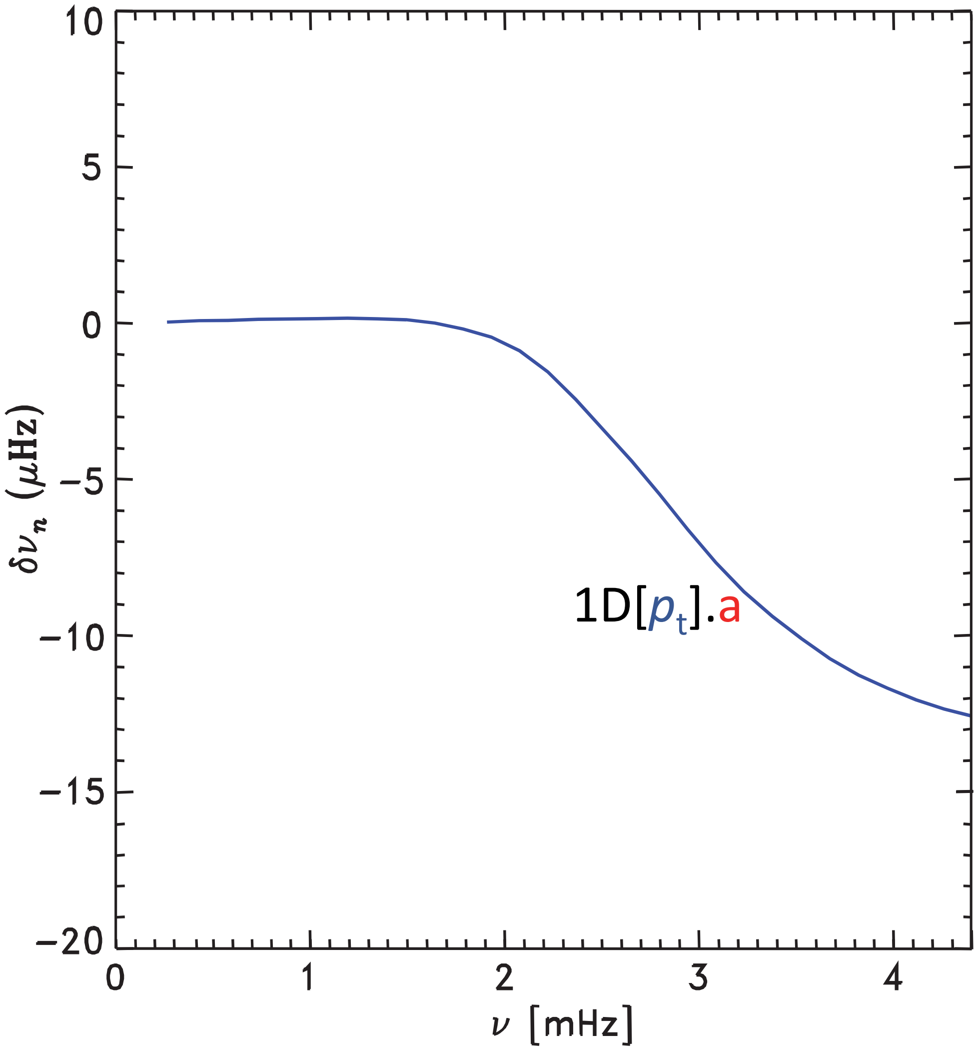
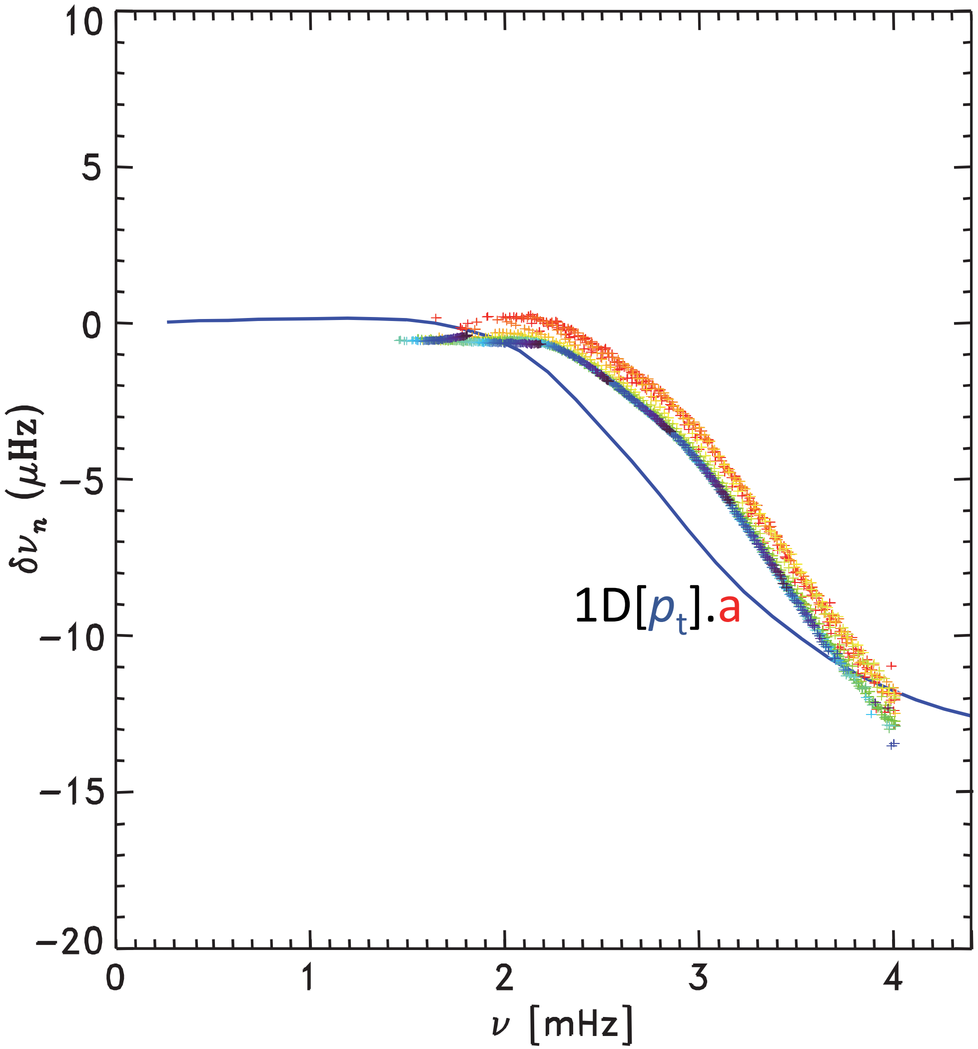


1D models with turbulent pressure p_{t} , δp_{t} , $\delta(L_{\mathrm{r}} + L_{\mathrm{c}})$



weak nonlocality (GH 1997)

1D models with turbulent pressure $p_{\rm t}$, $\delta p_{\rm t}$, $\delta(L_{\rm r} + L_{\rm c})$



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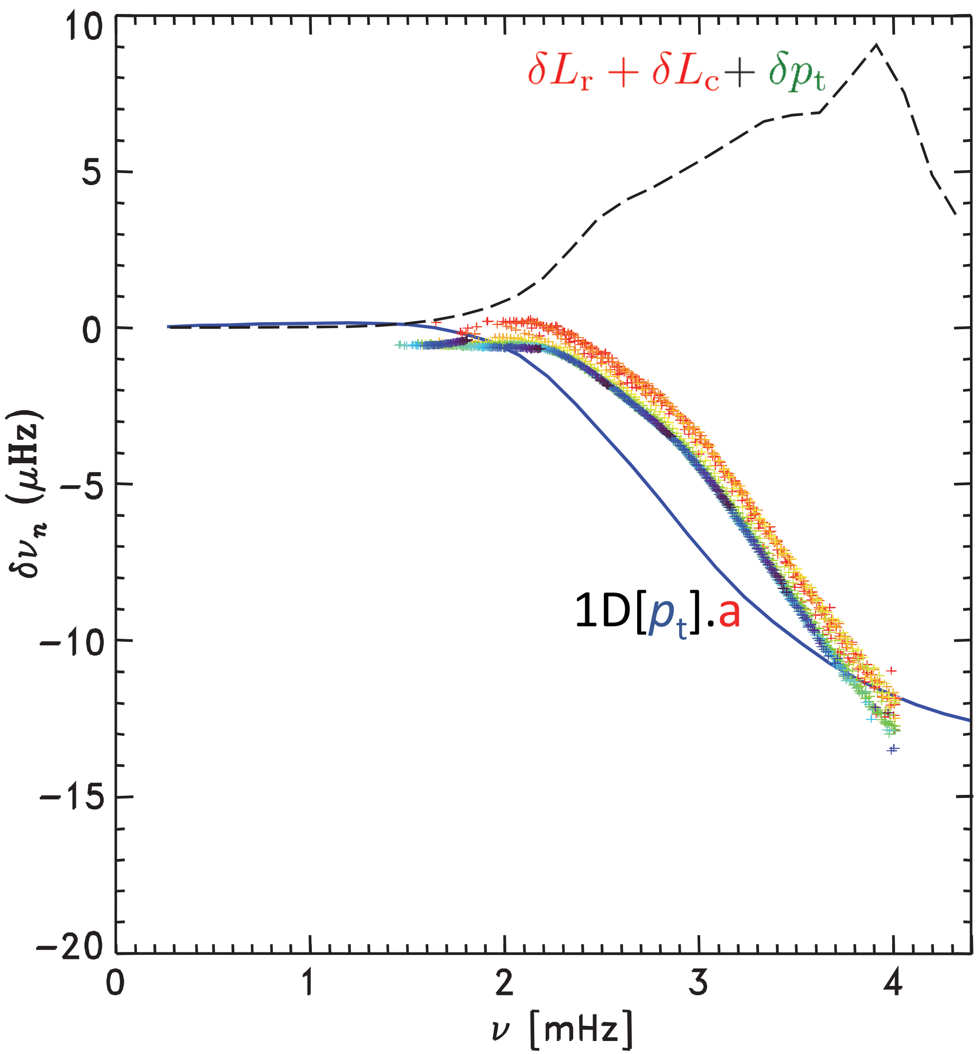
1D models with turbulent pressure $p_{\rm t}$, $\delta p_{\rm t}$, $\delta(L_{\rm r}+L_{\rm c})$

Nonadiabaticity: $\delta(L_{\rm r}+L_{\rm c})$

Convection dynamics: $\delta p_{\rm t}$



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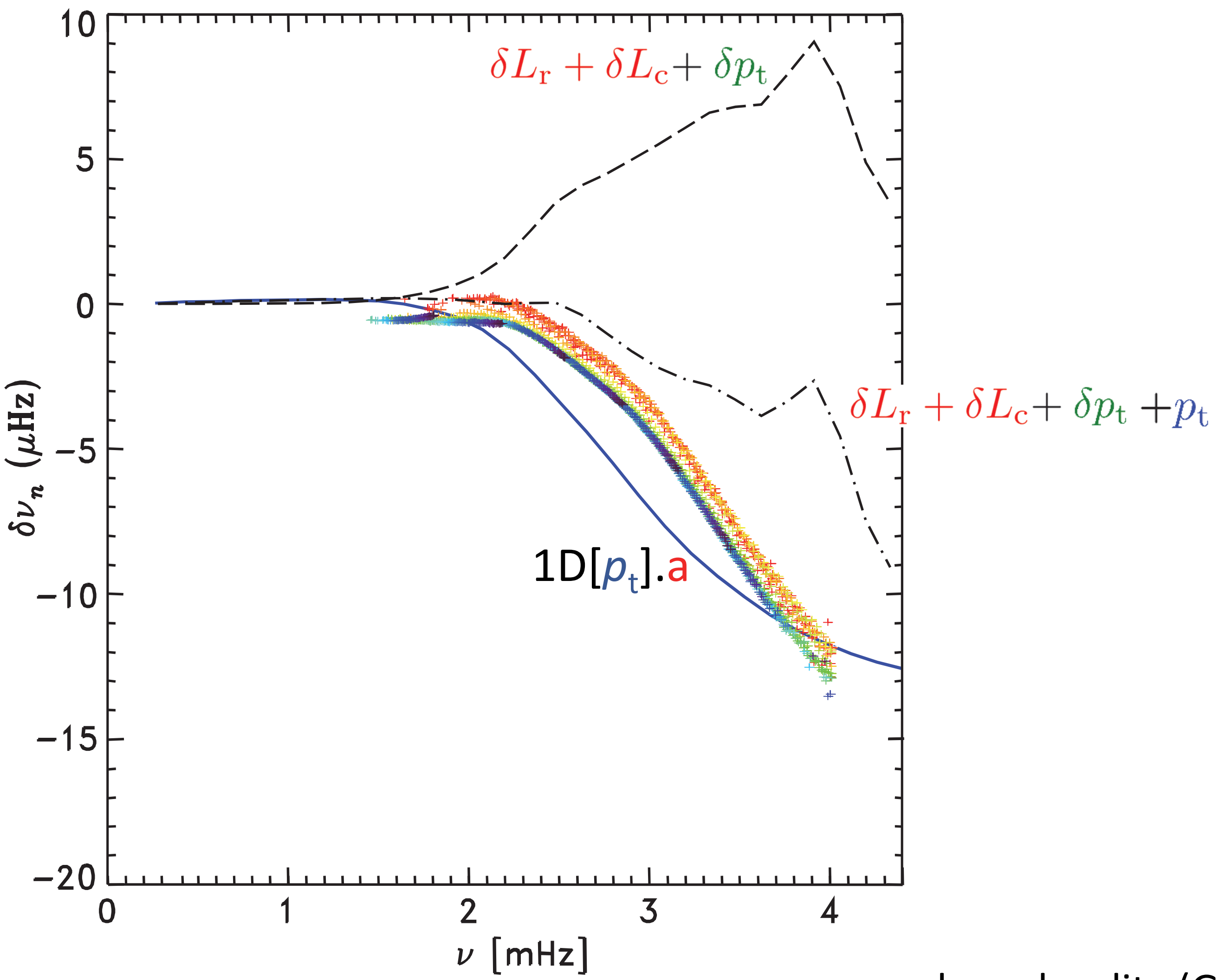

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1D models with turbulent pressure p_t, δp_t, $\delta(L_\mathrm{r} + L_\mathrm{c})$

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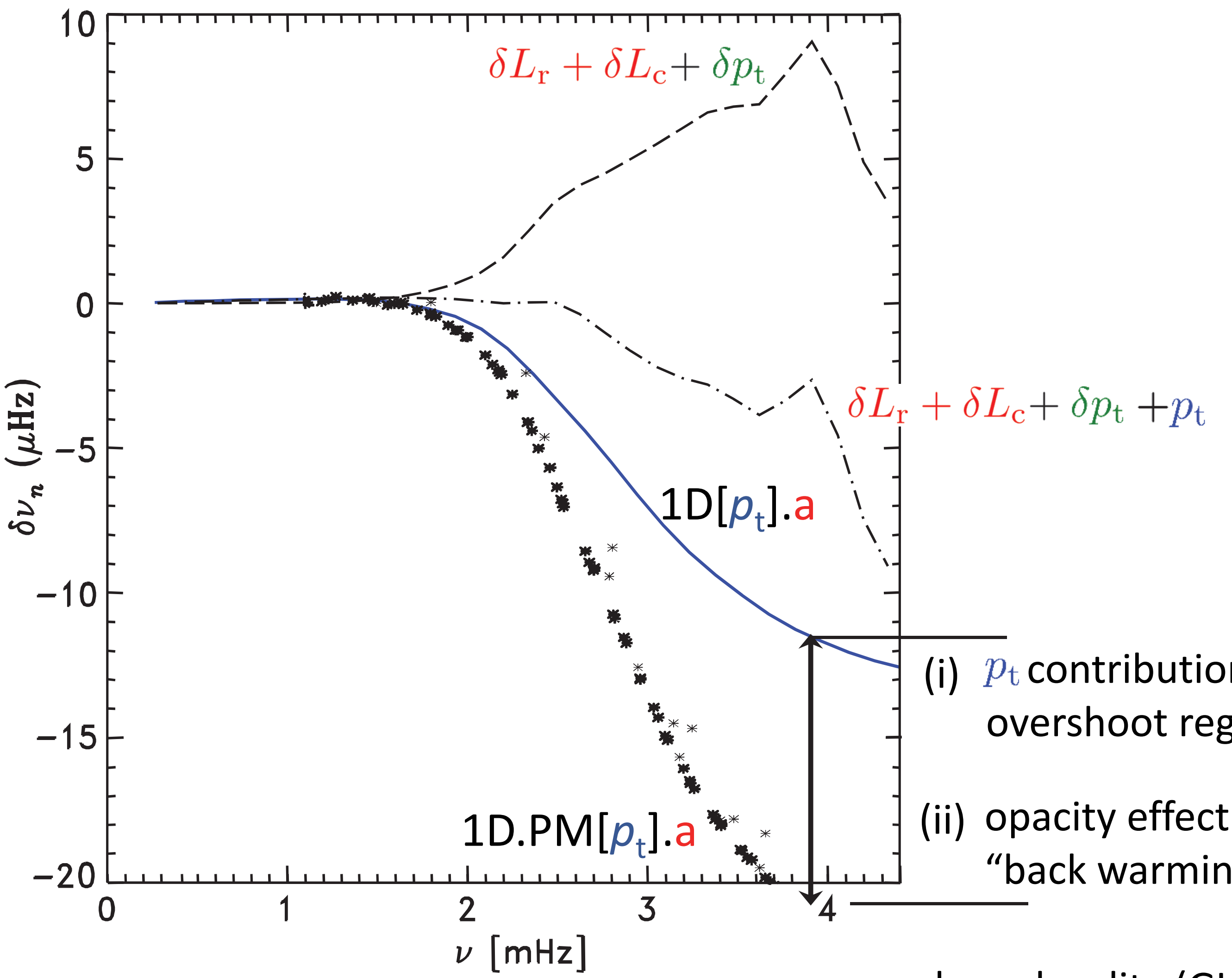
Convection dynamics: δp_t



(i) p_t contribution in the overshoot region

(ii) opacity effect: "back warming"

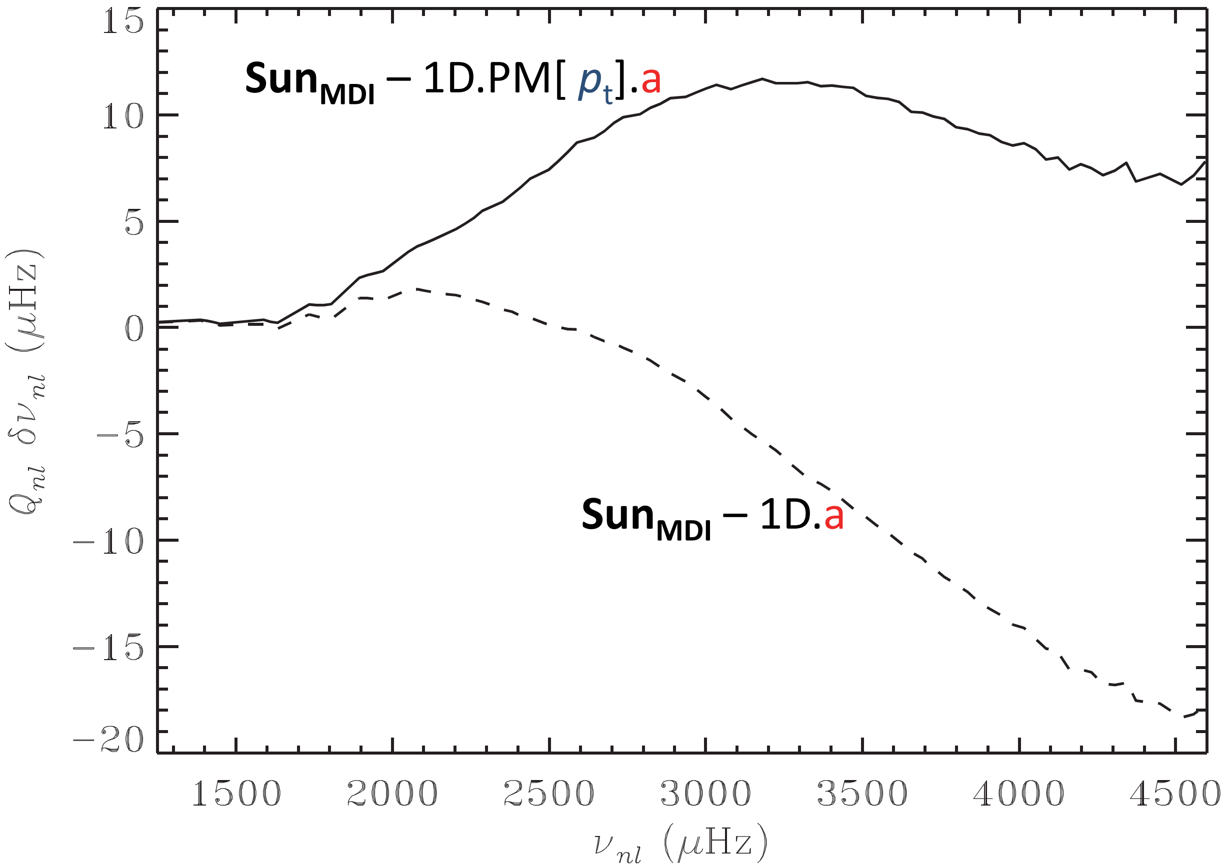
weak nonlocality (GH 1997)

Patched 1D models with turbulent pressure p_{t} , δp_{t} , $\delta(L_{\mathrm{r}} + L_{\mathrm{c}})$

"Patched Model"

MDI observations − 1D.PM[p_{t}].adiabatic

M. Aarslev (2016)



Patched 1D models with turbulent pressure p_{t} , δp_{t} , $\delta(L_{\mathrm{r}} + L_{\mathrm{c}})$

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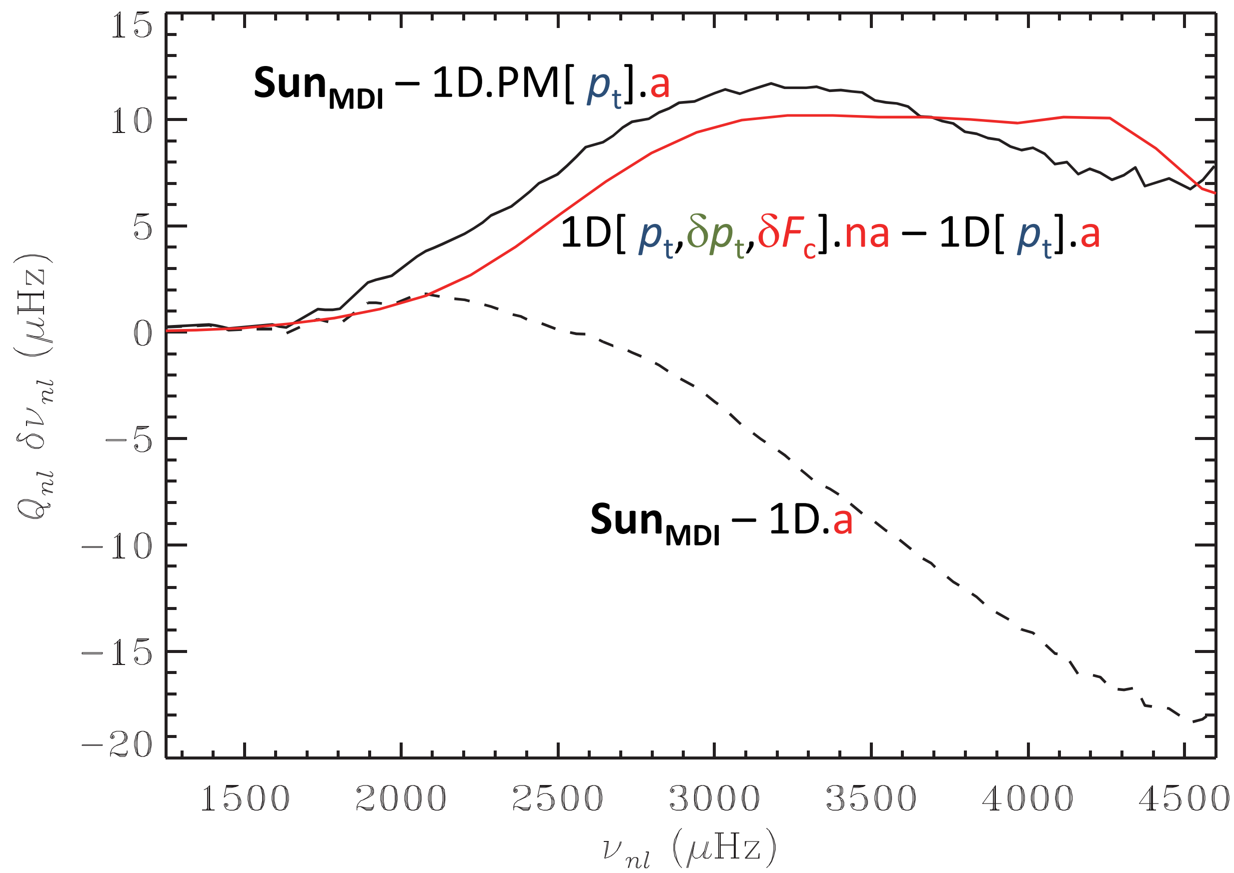
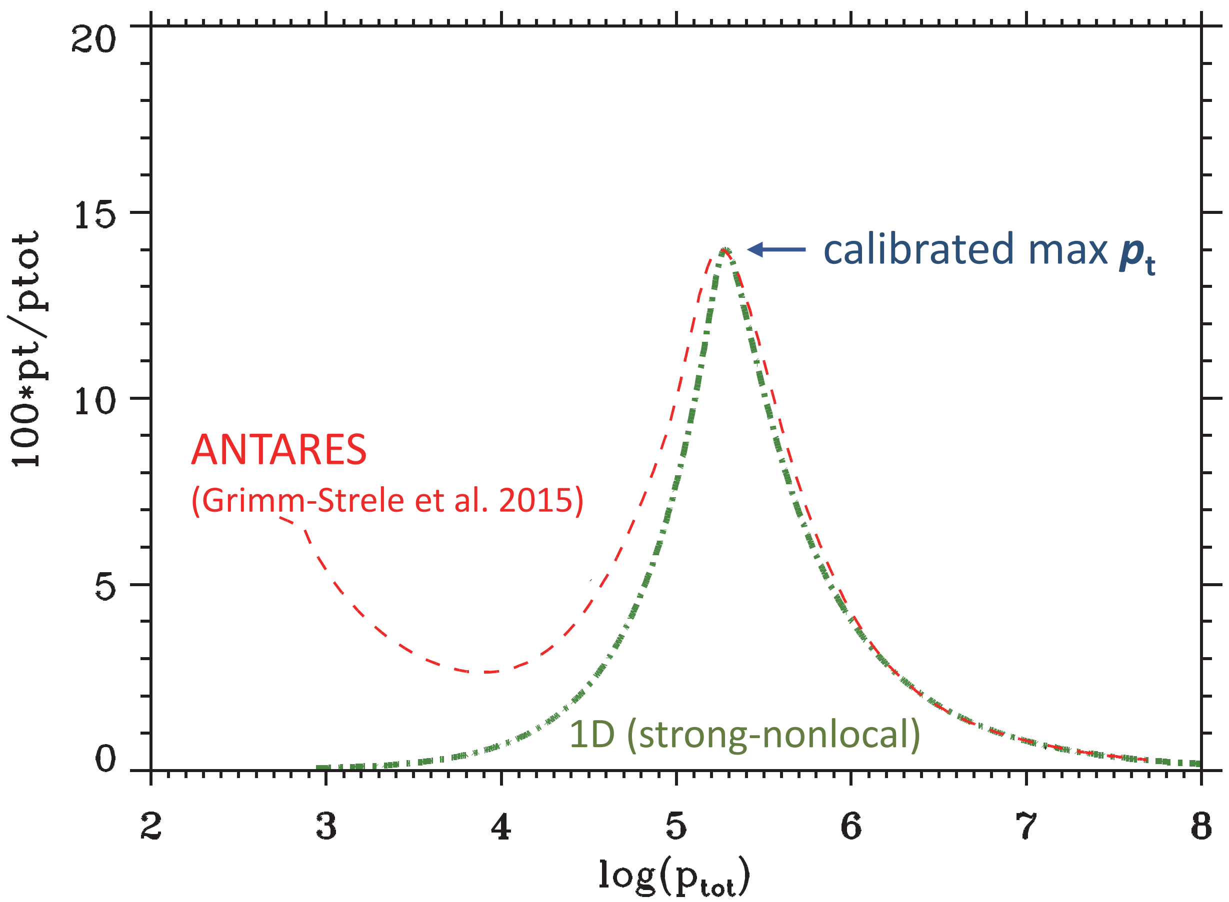


calibrated max $\boldsymbol{p_t}$ (strong nonlocality)

1D models including turbulent pressure p_t



Patched 1D models with turbulent pressure p_{t} , δp_{t} , $\delta(L_{\mathrm{r}} + L_{\mathrm{c}})$

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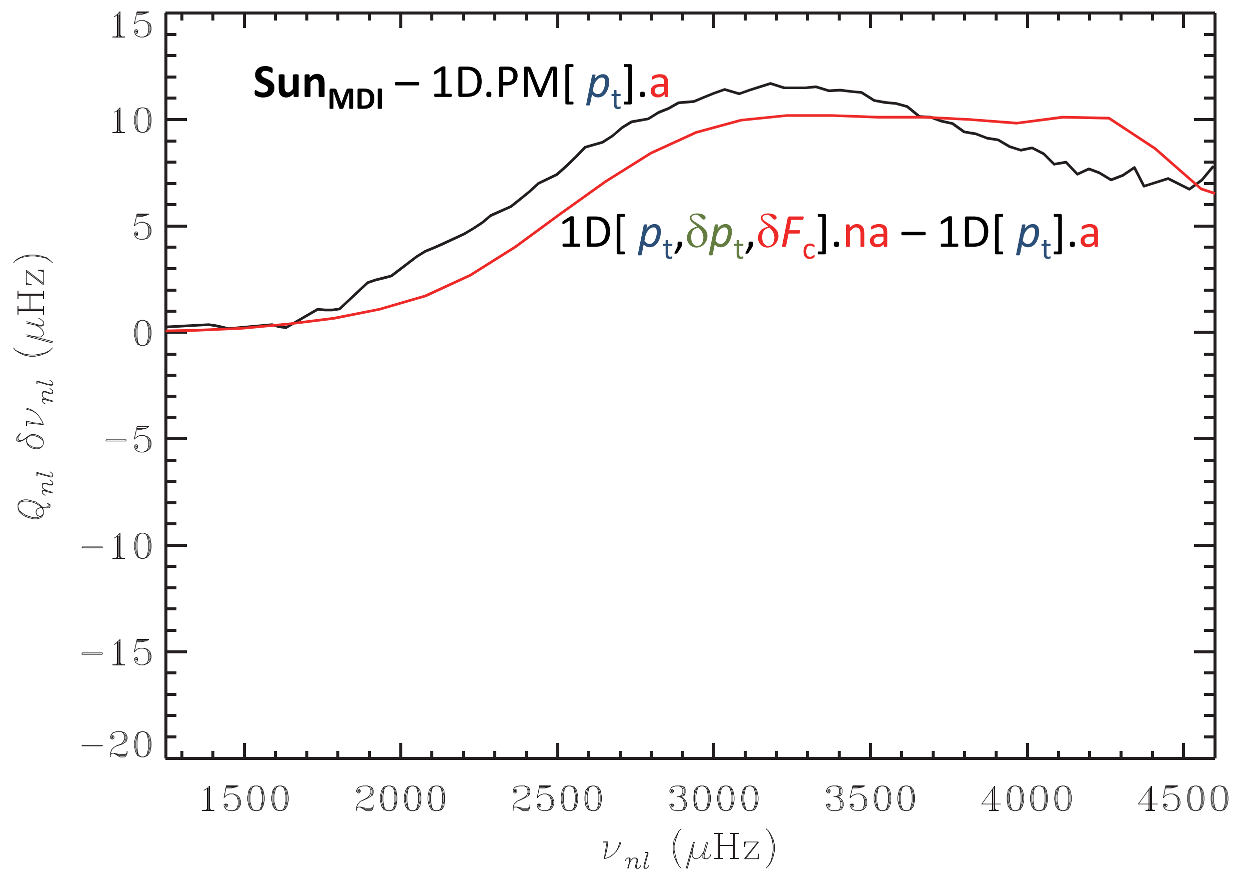

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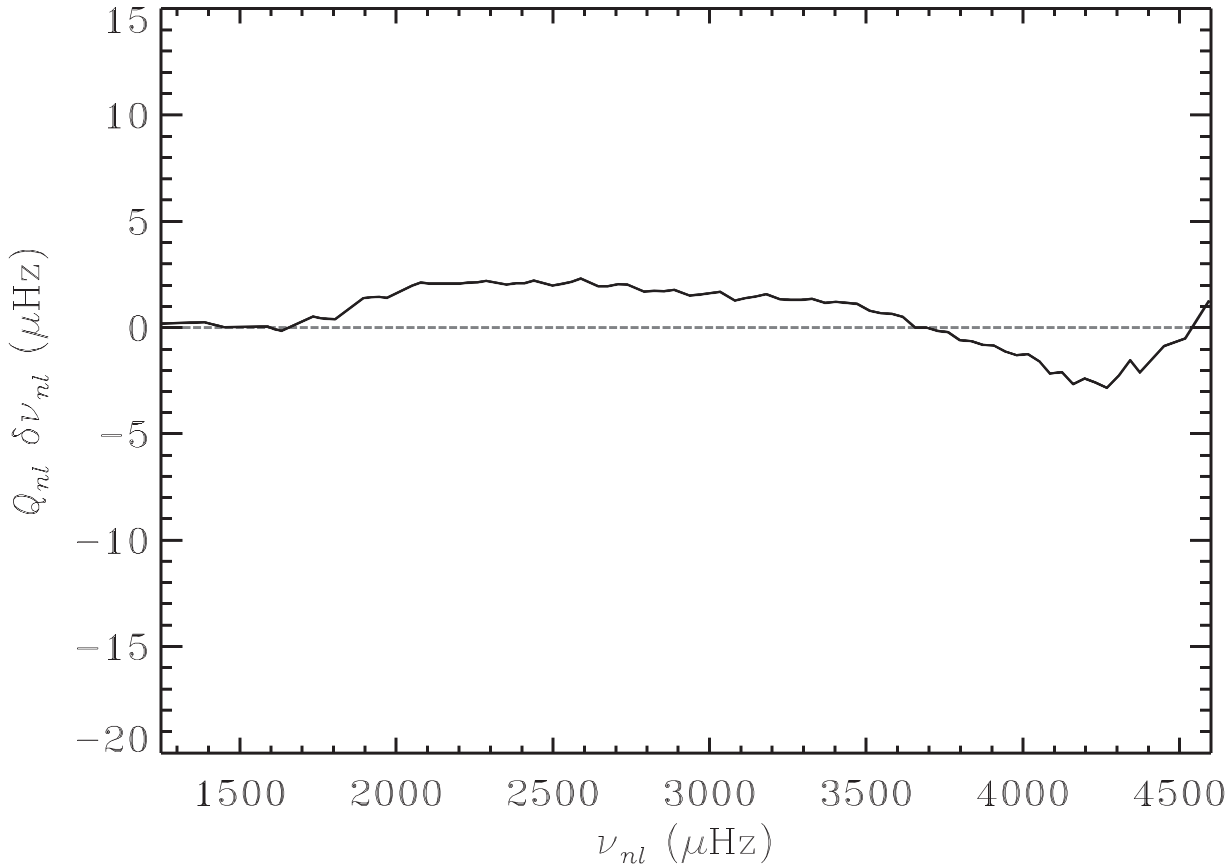
1D model with turbulent pressure p_{t}, δp_{t}, $\delta(L_{\mathrm{r}} + L_{\mathrm{c}})$

MDI observations − 1D[p_t,δp_t,δF_c].na



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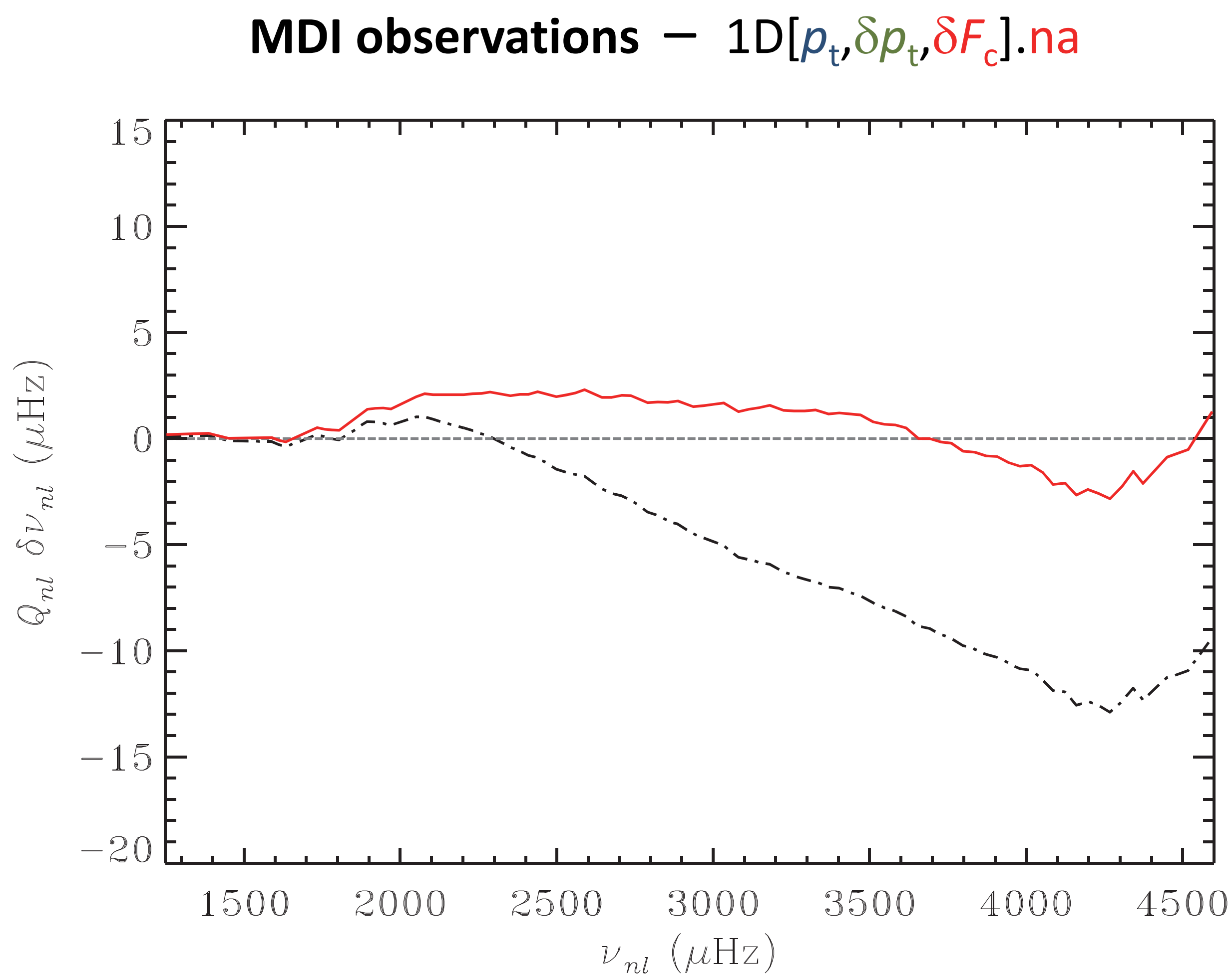

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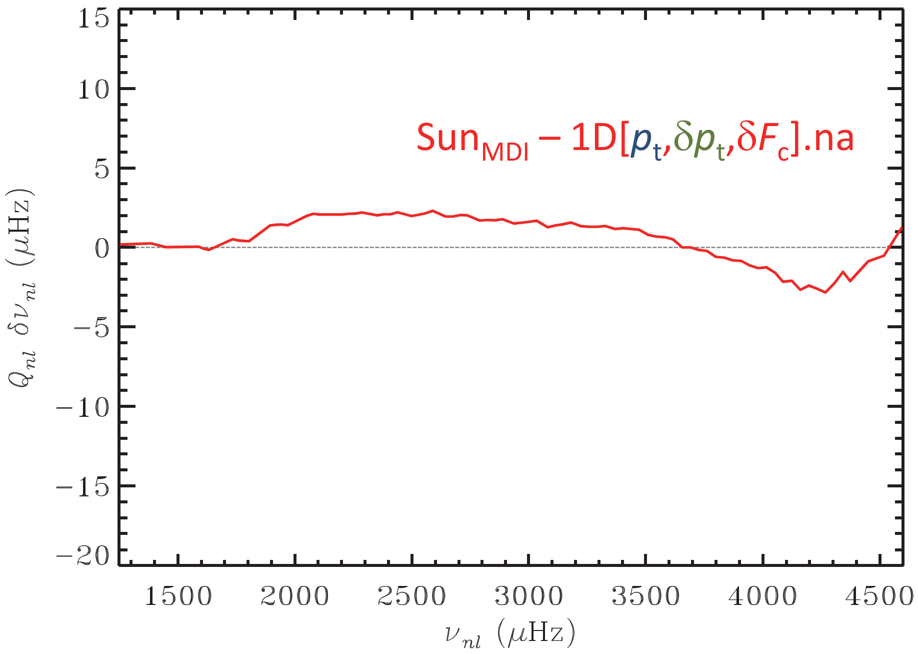

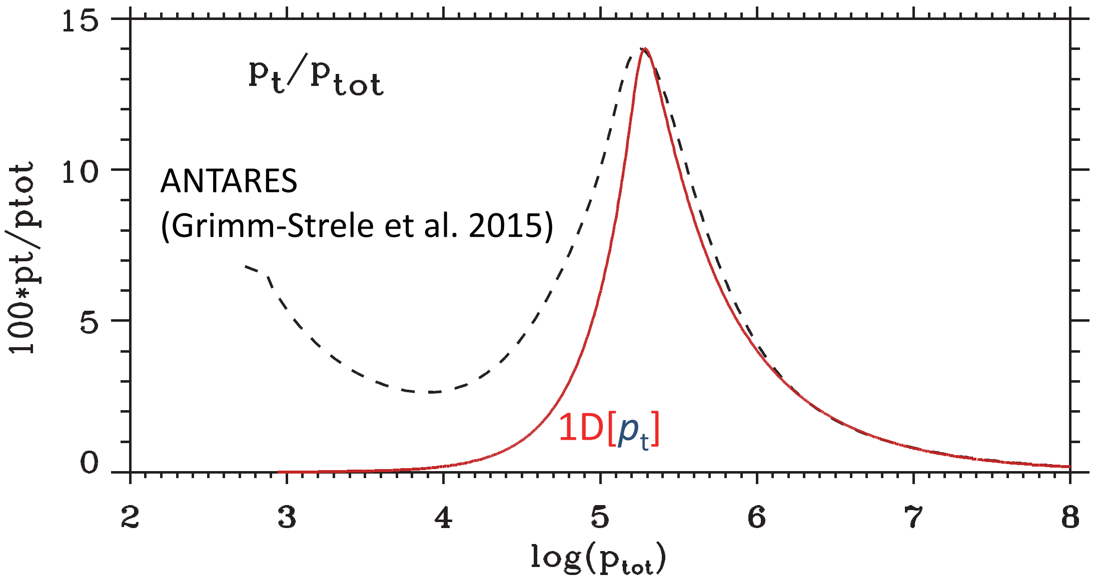

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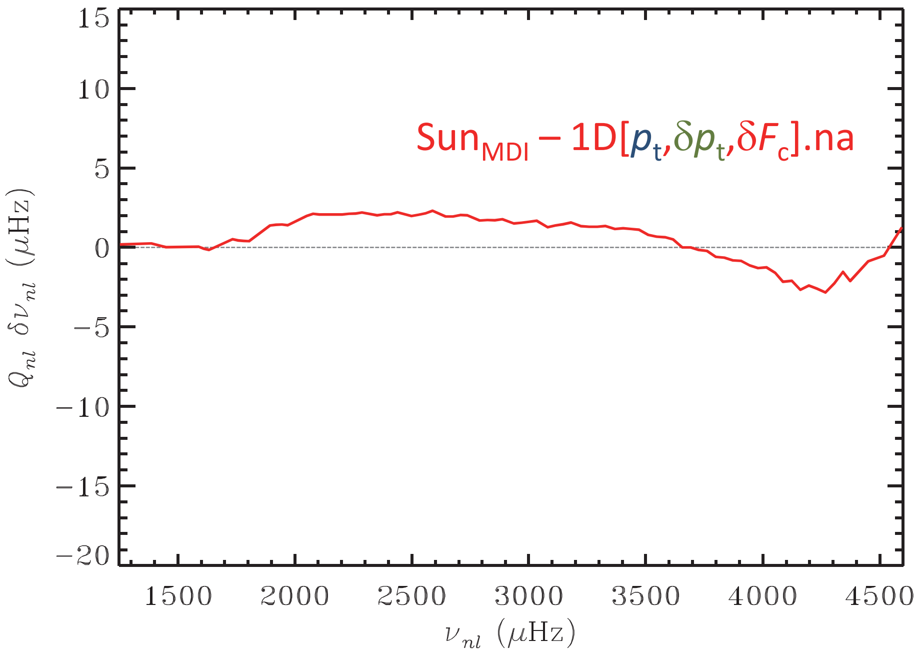

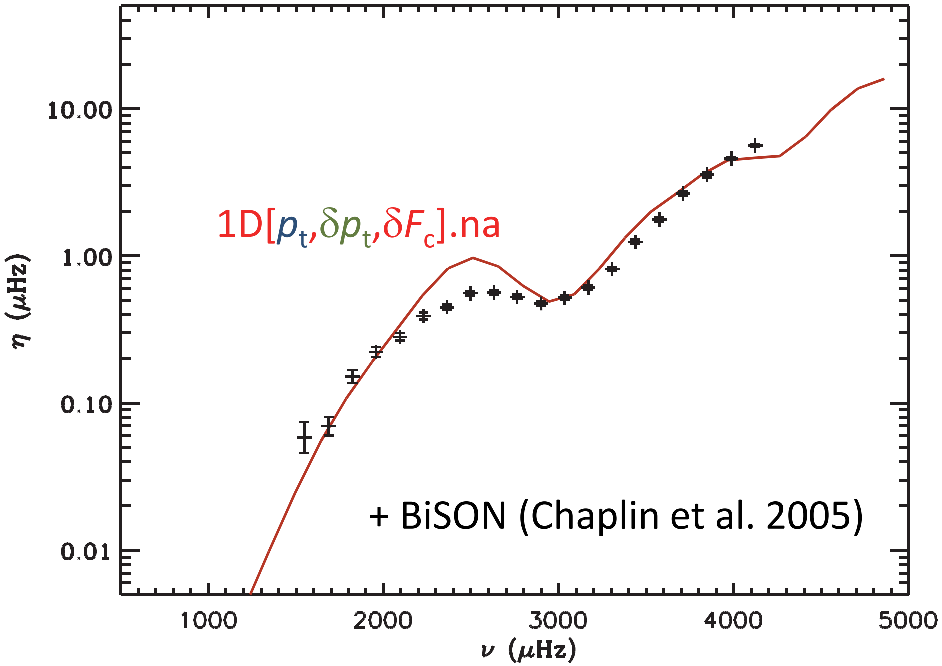

Points still to consider

- effect of turbulent **velocity anisotropy**

- modal effects due to **advection** of the oscillations by **spatially varying** radial **flows**
  Zhugzhda & Stix (1994, A&A)
  Bhattacharya, Hanasoge, Antia (2015, ApJ)

- Calculate “full” nonadiabatic (with convection dynamics) directly from the patched 1D/<3D> models

- effects we haven’t thought about

Surface effect: convection dynamics and nonadiabaticity

Anisotropy factor:

$$\Phi = \frac{\langle u^2\rangle + \langle v^2\rangle + \langle w^2\rangle}{\langle w^2\rangle}$$

$\boldsymbol{u} = (u, v, w)$ ... turbulent velocity field