XIX. Ulusal Astronomi Kongresi

Işınımsal Olarak Etkin Olmayan Toplanma Akışlarında Gyroviskoz Manyetik Dönme Kararsızlığı

Hazırlayan: Melis Yardımcı

Danışman: Yrd. Doç. Dr. Ebru Devlen

Işınımsal Olarak Etkin Olmayan Toplanma Akışlarında Gyroviskoz MRI

- Bazı sistemler: Düşük ışıtmalı AGN'ler, sakin X-ışın çiftleri vb. ($L \ll L_{Edd}$)

- Radiation Inefficient Accretion Flows = RIAFs

- Süper kütleli karadeliklerin toplanmasına ilişkin RIAF gözlemleri: Sagittarius A* $\left(L_{Edd} \sim 10^5 L_{obs}\right)$

- Chandra gözlemleri: Çarpışmasız veya çok düşük çarpışmalı seyreltik (dilute) plazma

Kararsızlık → Çalkantı → Açısal Momentum Taşınımı Maxwell Stresleri > Reynold Stresleri → Toplanma → Işıtma

RIAFs → Isı Taşınımı

- GvMRI: Gyroviskoz Manyetik Dönme Kararsızlığı (Devlen, E., 2011, ApJ, 731, 104; Devlen, E. and Pekünlü E. R. 2010, 404, 830-836.)
- Toplanmayı tanımlamak için;

  1. Viskozite
  2. Gyroviskozite

  → Basınç ve sıcaklık değişimleri

Işınımsal Olarak Etkin Olmayan Toplanma Akışlarında Gyroviskoz MRI

MHD Denklemleri:

$$\frac{d\rho}{dt} + \rho\nabla\cdot\mathbf{v} = 0$$

$$\rho\frac{d\mathbf{v}}{dt} = -\nabla P - \nabla\cdot\mathbf{\Pi} + \frac{(\nabla\times\mathbf{B})\times\mathbf{B}}{c} + \rho\mathbf{g}$$

$$\frac{\partial\mathbf{B}}{\partial t} = \nabla\times(\mathbf{v}\times\mathbf{B})$$

$$\frac{dP}{dt} + \frac{5}{3}P(\nabla\cdot\mathbf{v}) = -\frac{2}{3}\nabla\cdot\mathbf{Q}$$

Stres Tensörleri:

$$\Pi^{\nu} = 0.96\frac{P_i}{2\nu_i}\left(I - 3\hat{b}\hat{b}\right)\left(\hat{b}\cdot\overleftrightarrow{W}\cdot\hat{b}\right)$$

$$\Pi^{g\nu} = \frac{P_i}{4\omega_{ci}}\left[\hat{b}\times\overleftrightarrow{W}\cdot\left(I + 3\hat{b}\hat{b}\right) + \left[\hat{b}\times\overleftrightarrow{W}\cdot\left(I + 3\hat{b}\hat{b}\right)\right]^T\right]$$

Uzay-Zaman İlişkisi:

$$\exp(ik_z z + \omega\, t)$$

$$\mathbf{B} = \left(0,\ B_0\cos\theta,\ B_0\sin\theta\right) \qquad v_\phi = R\ \Omega(R)$$

Devlen, E., The Astrophysical Journal, 731:104(16pp), 2011 April 20.

$$a_5\gamma^5+\gamma^4\left(a_4+ib_4\right)+\gamma^3\left(a_3+ib_3\right)+.....+\left(a_0+ib_0\right)=0$$

$$a_5=\left(1-\frac{1}{4\tilde{\omega}_{ci}}\frac{d\ln\Omega^2}{d\ln R}H\right)$$

$$\begin{aligned}a_4=&\left[\left(\frac{1}{M_{th}^2}\tilde{k}_z^2\sin^2\theta+\frac{1}{M_{vis}^2}\tilde{k}_z^2 2D\cos\theta\right)\left(1-\frac{1}{4\tilde{\omega}_{ci}}\frac{d\ln\Omega^2}{d\ln R}H\right)+\frac{1}{M_{vis}^2}\tilde{k}_z^2\frac{1}{4\tilde{\omega}_{ci}}\frac{d\ln\Omega^2}{d\ln R}\frac{1}{2}FI\right]\\&+\mathbf{i}\left[\frac{1}{M_D^2}\frac{1}{2}\frac{\partial\ln P}{\partial\ln R}\tilde{k}_z 6c^3\left(1-\frac{1}{4\tilde{\omega}_{ci}}\frac{d\ln\Omega^2}{d\ln R}H\right)-\frac{1}{M_D^2}\frac{\partial\ln P}{\partial\ln R}\tilde{k}_z\frac{1}{4\tilde{\omega}_{ci}}\frac{d\ln\Omega^2}{d\ln R}\frac{1}{4}AI\right]\end{aligned}$$

$$\begin{aligned}a_3=&\left\{\left[\begin{aligned}&2\tilde{k}_z^2\frac{1}{M_{Az}^2}+\tilde{k}_z^2\frac{1}{M_D^2}\frac{1}{2}\frac{d\ln\Omega^2}{d\ln R}(G+H)+\tilde{N}^2+\tilde{\kappa}^2-\left(\frac{1}{M_D^2}\frac{\partial\ln P}{\partial\ln R}\tilde{k}_z\right)^2\frac{1}{2}\cos\theta I\\&+\frac{1}{M_{vis}^2}\frac{1}{M_{th}^2}\tilde{k}_z^4\sin^2\theta 2D\cos\theta-2\left(\tilde{k}_z^2\frac{1}{M_D^2}A\right)+\frac{1}{4}\left(\tilde{k}_z^2\frac{1}{M_D^2}A\right)^2\end{aligned}\right]\left(1-\frac{1}{4\tilde{\omega}_{ci}}\frac{1}{2}\frac{d\ln\Omega^2}{d\ln R}H\right)\right.\\&\left.+\left[-\tilde{k}_z^2\frac{1}{M_{Az}M_{A\phi}}+\tilde{k}_z^2\frac{1}{M_D^2}\frac{d\ln\Omega^2}{d\ln R}D+\left(\frac{1}{M_D^2}\frac{\partial\ln P}{\partial\ln R}\tilde{k}_z\right)^2\frac{1}{2}\cos\theta A+\frac{1}{M_{vis}^2}\frac{1}{M_{th}^2}\tilde{k}_z^4F\sin^2\theta+\left(\tilde{k}_z^2\frac{1}{M_D^2}\right)E-\left(\tilde{k}_z^2\frac{1}{M_D^2}\right)^2\frac{1}{4}EA\right]\frac{1}{4\tilde{\omega}_{ci}}\frac{1}{2}\frac{d\ln\Omega^2}{d\ln R}I\right\}\\&+\mathbf{i}\left\{\left[+\frac{1}{M_D^2}\frac{\partial\ln P}{\partial\ln R}\frac{1}{M_{vis}^2}\tilde{k}_z^3 4\sin^2\theta\cos\theta+\frac{1}{M_{th}^2}\frac{1}{M_D^2}\frac{\partial\ln P}{\partial\ln R}\tilde{k}_z^3\sin^2\theta 3c^3-\left(\frac{1}{M_{vis}^2}\frac{\partial\ln P}{\partial\ln R}\tilde{k}_z 2\sin 2\theta\right)\right]\left(1-\frac{1}{4\tilde{\omega}_{ci}}\frac{1}{2}\frac{d\ln\Omega^2}{d\ln R}H\right)\right.\\&\left.+\left[-\left(\frac{1}{M_D^2}\frac{\partial\ln P}{\partial\ln R}\frac{1}{M_{vis}^2}\tilde{k}_z^3\right)4\sin\theta\cos^2\theta-\left(\frac{1}{M_{th}^2}\tilde{k}_z^2\sin^2\theta\right)\frac{1}{M_D^2}\frac{1}{2}\frac{\partial\ln P}{\partial\ln R}\tilde{k}_z A\right]\frac{1}{4\tilde{\omega}_{ci}}\frac{1}{2}\frac{d\ln\Omega^2}{d\ln R}I\right\}\end{aligned}$$

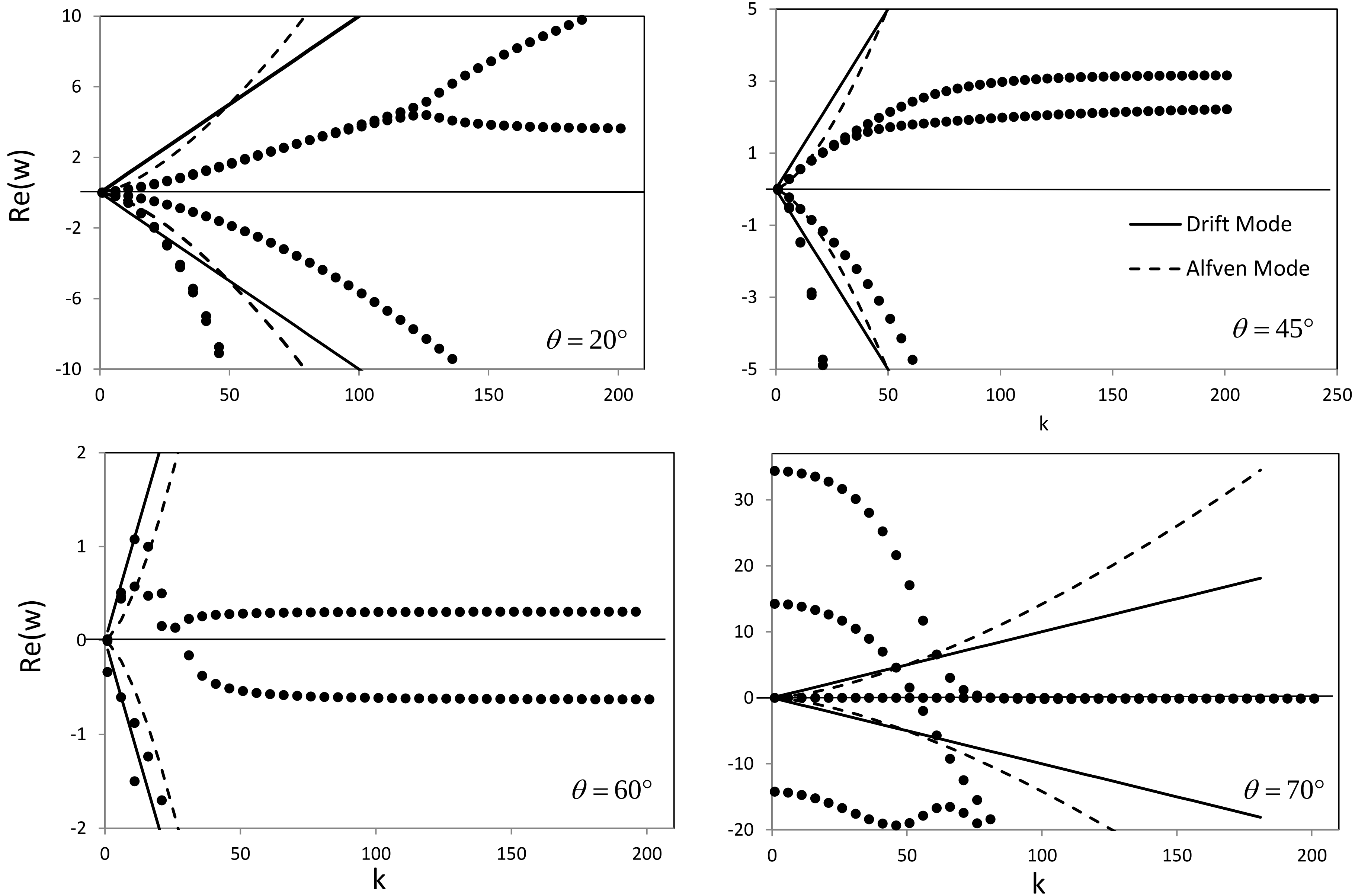
$$
\begin{aligned}
a_2 = \Bigg\{ & \Bigg[+\frac{1}{M_{th}^2}\tilde{k}_z^2 \sin^2\theta \left(\begin{aligned} & 2\tilde{k} \text{[redacted]} \\ & +\tilde{\kappa}^2 - \tilde{k}_z^2 \frac{1}{M_D^2} 2A + \frac{1}{4}\tilde{k}_z^4 \frac{1}{M_D^4} A^2 \end{aligned} \right) \\
& + \frac{1}{M_{vis}^2}\tilde{k}_z^2 2D\cos\theta \left(\tilde{k}_z^2 \frac{1}{M_{Az}^2} + \tilde{k}_z^2 \frac{1}{M_D^2} \frac{d\ln\Omega^2}{d\ln R} \frac{1}{4} G + \tilde{N}^2 + \frac{d\ln\Omega^2}{d\ln R} \right) - \frac{d\ln\Omega^2}{d\ln R} \frac{1}{M_{vis}^2} \frac{1}{M_D^2} \left(\frac{\partial\ln P}{\partial\ln R}\tilde{k}_z \right)^2 \frac{1}{4}\sin 2\theta I \Bigg] \left(1 - \frac{1}{4\tilde{\omega}_{ci}} \frac{d\ln\Omega^2}{d\ln R} H \right) \\
& + \Bigg[\begin{aligned} & \frac{1}{M_{th}^2} \text{[redacted]} \\ & + \frac{1}{M_{vis}^2} \text{[redacted]} \end{aligned} \Bigg] \frac{1}{4\tilde{\omega}_{ci}} \frac{d\ln\Omega^2}{d\ln R} \frac{1}{2} I \Bigg\} \\
+\mathrm{i} \Bigg\{ & \frac{\partial\ln P}{\partial\ln R}\tilde{k}_z \left[\begin{aligned} & +\tilde{k}_z^2 \frac{1}{M_{Az}^2} \frac{1}{M_D^2} 3c^3 + \tilde{N}^2 \frac{1}{M_D^2} \frac{1}{2} I + \tilde{k}_z^2 \frac{d\ln\Omega^2}{d\ln R} \frac{1}{M_D^4} \frac{1}{2} \cos\theta (G+H) \\ & + \frac{1}{M_{th}^2}\tilde{k}_z^2 \sin^2\theta \left(\frac{1}{M_{vis}^2} \frac{1}{M_D^2} \tilde{k}_z^2 4cs^2 - \frac{1}{M_{vis}^2} 2\sin 2\theta \right) \end{aligned} \right] \left(1 - \frac{1}{4\tilde{\omega}_{ci}} \frac{d\ln\Omega^2}{d\ln R} H \right) \\
& + \frac{\partial\ln P}{\partial\ln R}\tilde{k}_z \left[\begin{aligned} & -\tilde{k}_z^2 \frac{1}{M_{Az}M_{A\phi}} \frac{1}{M_D^2} \cos\theta + \tilde{k}_z^2 \frac{1}{M_D^4} \frac{d\ln\Omega^2}{d\ln R} D\cos\theta + \frac{1}{M_{th}^2}\tilde{k}_z^2 \sin^2\theta \frac{1}{M_{vis}^2} \frac{1}{M_D^2} \tilde{k}_z^2 4sc^2 \\ & - \left(\tilde{k}_z^2 \frac{1}{M_{Az}^2} + \tilde{N}^2 \right) A \frac{1}{M_D^2} \frac{1}{2} - \frac{1}{M_D^2} \sin\theta \frac{d\ln\Omega^2}{d\ln R} \end{aligned} \right] \frac{1}{4\tilde{\omega}_{ci}} \frac{d\ln\Omega^2}{d\ln R} \frac{1}{2} I \Bigg\}
\end{aligned}
$$

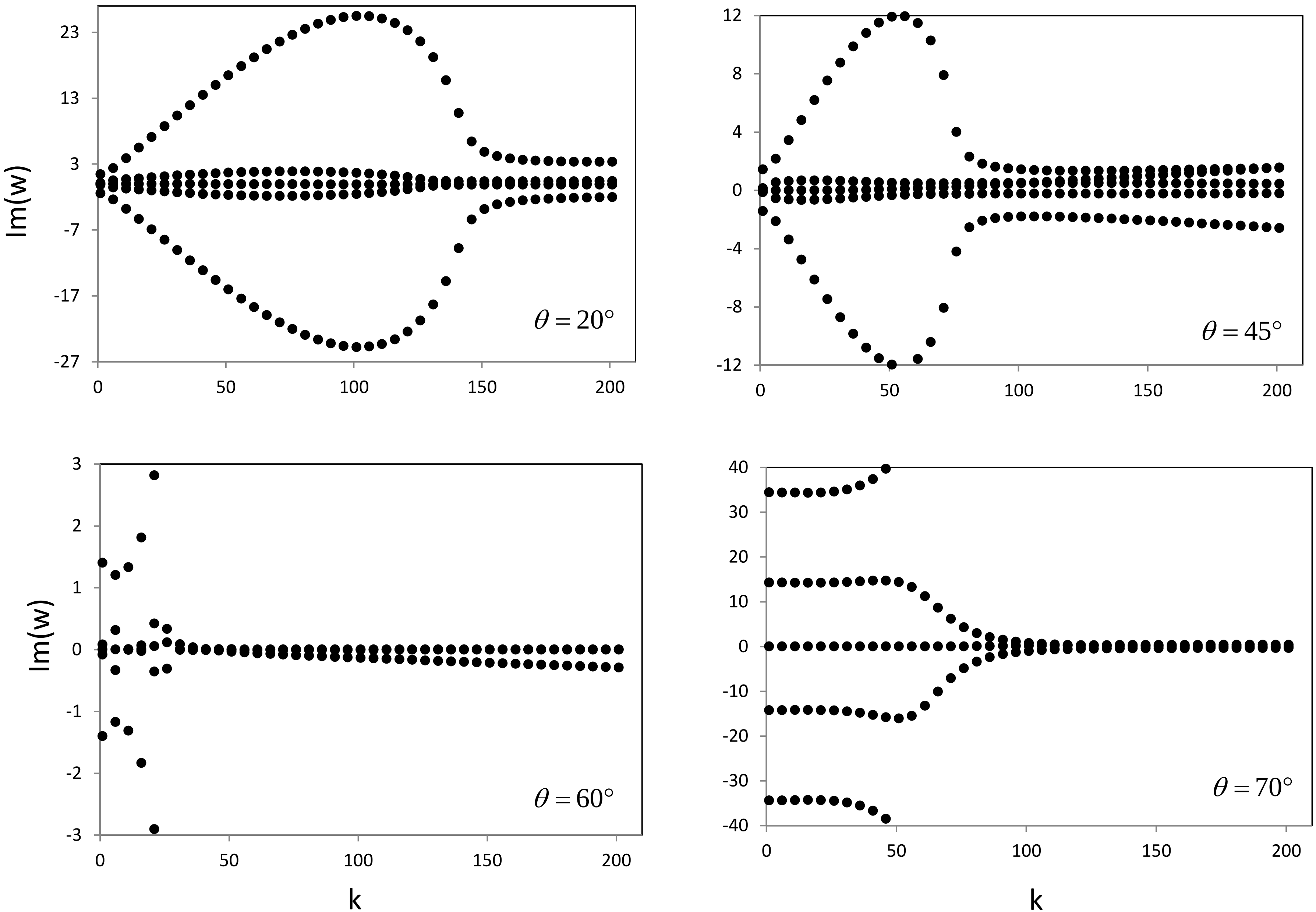
$$
\begin{aligned}
a_1 = \Bigg\{ & \Bigg[+\left(\tilde{k}_z^2 \frac{1}{M_{Az}^2} + \tilde{k}_z^2 \frac{1}{M_D^2} \frac{d\ln\Omega^2}{d\ln R} \frac{1}{4}(G+2H) \right) \left[\tilde{k}_z^2 \frac{1}{M_{Az}^2} + \tilde{k}_z^2 \frac{1}{M_D^2} \frac{d\ln\Omega^2}{d\ln R} \frac{1}{4} G + \frac{d\ln\Omega^2}{d\ln R} + \tilde{N}^2 \right] \\
& + \frac{1}{M_{th}^2} \tilde{k}_z^2 \sin^2\theta \left[\begin{aligned} & \frac{1}{M_{vis}^2} \tilde{k}_z^2 2D\cos\theta \left(\tilde{k}_z^2 \frac{1}{M_{Az}^2} + \tilde{k}_z^2 \frac{1}{M_D^2} \frac{d\ln\Omega^2}{d\ln R} \frac{1}{4} G + \frac{d\ln\Omega^2}{d\ln R} - \frac{3}{5} \frac{1}{M_s^2} \frac{\partial\ln P}{\partial\ln R} \frac{\partial\ln T}{\partial\ln R} \right) \\ & - \frac{1}{M_{vis}^2} \frac{1}{M_D^2} \left(\frac{\partial\ln P}{\partial\ln R} \tilde{k}_z \right)^2 \frac{d\ln\Omega^2}{d\ln R} \frac{1}{4} I \sin 2\theta \end{aligned} \right] \Bigg] \left(1 - \frac{1}{4\tilde{\omega}_{ci}} \frac{d\ln\Omega^2}{d\ln R} H \right) \\
& + \Bigg[+ \left[-\tilde{k}_z^2 \frac{1}{M_{Az} M_{A\phi}} + \tilde{k}_z^2 \frac{1}{M_D^2} D \frac{d\ln\Omega^2}{d\ln R} \right] \left[\tilde{k}_z^2 \frac{1}{M_{Az}^2} + \tilde{k}_z^2 \frac{1}{M_D^2} \frac{d\ln\Omega^2}{d\ln R} \frac{1}{4} G + \frac{d\ln\Omega^2}{d\ln R} + \tilde{N}^2 \right] \\
& + \frac{1}{M_{th}^2} \tilde{k}_z^2 \sin^2\theta \left[\begin{aligned} & \frac{1}{M_{vis}^2} \tilde{k}_z^2 F \left(\tilde{k}_z^2 \frac{1}{M_{Az}^2} + \tilde{k}_z^2 \frac{1}{M_D^2} \frac{d\ln\Omega^2}{d\ln R} \frac{1}{4} G + \frac{d\ln\Omega^2}{d\ln R} - \frac{3}{5} \frac{1}{M_s^2} \frac{\partial\ln P}{\partial\ln R} \frac{\partial\ln T}{\partial\ln R} \right) \\ & - \frac{1}{M_D^2} \left(\frac{\partial\ln P}{\partial\ln R} \tilde{k}_z \right)^2 \frac{1}{M_{vis}^2} \frac{d\ln\Omega^2}{d\ln R} \sin 2\theta \frac{1}{4} G \end{aligned} \right] \Bigg] \frac{1}{4\tilde{\omega}_{ci}} \frac{d\ln\Omega^2}{d\ln R} \frac{1}{2} I \Bigg\} \\
+ \mathrm{i} \Bigg\{ & \left[+ \frac{1}{M_{th}^2} \tilde{k}_z^2 \sin^2\theta \left(\frac{1}{M_D^2} \frac{1}{2} \frac{\partial\ln P}{\partial\ln R} \tilde{k}_z \right) \left[+ \tilde{k}_z^2 \frac{1}{M_{Az}^2} 6c^3 - I \frac{3}{5} \frac{1}{M_s^2} \frac{\partial\ln P}{\partial\ln R} \frac{\partial\ln T}{\partial\ln R} + \tilde{k}_z^2 \frac{1}{M_D^2} \frac{d\ln\Omega^2}{d\ln R} \cos\theta (G+H) \right] \right] \left(1 - \frac{1}{4\tilde{\omega}_{ci}} \frac{d\ln\Omega^2}{d\ln R} H \right) \\
& + \left[+ \frac{1}{M_{th}^2} \tilde{k}_z^2 \sin^2\theta \left(\frac{1}{M_D^2} \frac{1}{2} \frac{\partial\ln P}{\partial\ln R} \tilde{k}_z \right) \left[\begin{aligned} & -\tilde{k}_z^2 \frac{1}{M_{Az} M_{A\phi}} 2\cos\theta - A \left(\tilde{k}_z^2 \frac{1}{M_{Az}^2} - \frac{3}{5} \frac{1}{M_s^2} \frac{\partial\ln P}{\partial\ln R} \frac{\partial\ln T}{\partial\ln R} \right) \\ & + \tilde{k}_z^2 \frac{1}{M_D^2} \frac{d\ln\Omega^2}{d\ln R} 2\cos\theta D - 2\sin\theta \frac{d\ln\Omega^2}{d\ln R} \end{aligned} \right] \right] \frac{1}{4\tilde{\omega}_{ci}} \frac{d\ln\Omega^2}{d\ln R} \frac{1}{2} I \Bigg\}
\end{aligned}
$$

$$
\begin{aligned}
a_0 = \frac{1}{M_{th}^2} \tilde{k}_z^2 \sin^2\theta \Bigg\{ & \left(\tilde{k}_z^2 \frac{1}{M_{Az}^2} + \tilde{k}_z^2 \frac{1}{M_D^2} \frac{d\ln\Omega^2}{d\ln R} \frac{1}{4}(G+2H) \right) \left[\tilde{k}_z^2 \frac{1}{M_{Az}^2} + \tilde{k}_z^2 \frac{1}{M_D^2} \frac{d\ln\Omega^2}{d\ln R} \frac{1}{4} G + \frac{d\ln\Omega^2}{d\ln R} - \frac{3}{5} \frac{1}{M_s^2} \frac{\partial\ln P}{\partial\ln R} \frac{\partial\ln T}{\partial\ln R} \right] \left(1 - \frac{1}{4\tilde{\omega}_{ci}} \frac{d\ln\Omega^2}{d\ln R} H \right) \\
& + \left(-\tilde{k}_z^2 \frac{1}{M_{Az} M_{A\phi}} + \tilde{k}_z^2 \frac{1}{M_D^2} D \frac{d\ln\Omega^2}{d\ln R} \right) \left[\tilde{k}_z^2 \frac{1}{M_{Az}^2} + \tilde{k}_z^2 \frac{1}{M_D^2} \frac{d\ln\Omega^2}{d\ln R} \frac{1}{4} G + \frac{d\ln\Omega^2}{d\ln R} - \frac{3}{5} \frac{1}{M_s^2} \frac{\partial\ln P}{\partial\ln R} \frac{\partial\ln T}{\partial\ln R} \right] \frac{1}{4\tilde{\omega}_{ci}} \frac{d\ln\Omega^2}{d\ln R} \frac{1}{2} I \Bigg\}
\end{aligned}
$$

Sonuçlar:

$$\theta = \tan^{-1}\left(B_z / B_\phi\right)$$




Im(w)
k
θ = 20°
θ = 45°
θ = 60°
θ = 70°

Kaynaklar:

- Balbus, S. A. and Hawley J.F. 1998, Rev. Mod. Phys., 70, 1.
- Devlen, E. 2011, The Astrophysical Journal, 731, 104.
- Pessah, M. E. and Psaltis D. 2005, The Astrophysical Journal, 628, 879-901.
- Devlen, E. and Pekünlü E. R. 2010, Montly Notices of Royal Astronomical Society, 404, 830-836.
- Quataert, E. 2003, Astron. Nachr, 324, 435-443.
- Yuan, F., Quataert, E., Narayan, R. 2003. The Astrophysical Journal, 598, 301-531.

Dinlediğiniz İçin Teşekkürler…