

$$\begin{aligned}
\Sigma &= \text{cov} \begin{pmatrix} \mathbf{w}_{i,1} \\ \mathbf{v}_{i,1} \\ \mathbf{w}_{i,2} \\ \mathbf{v}_{i,2} \end{pmatrix} \\
&= \begin{pmatrix} \Sigma_{11} & \Sigma_{12} & \Sigma_{13} & \Sigma_{14} \\ & \Sigma_{22} & \Sigma_{23} & \Sigma_{24} \\ & & \Sigma_{33} & \Sigma_{34} \\ & & & \Sigma_{44} \end{pmatrix} \\
&= \begin{pmatrix} \Phi + \Omega_{11} & \Phi\beta^T + \Omega_{12} & \Phi & \Phi\beta^T \\ & \beta\Phi\beta^T + \Psi + \Omega_{22} & \beta\Phi & \beta\Phi\beta^T + \Psi \\ & & \Phi + \Omega_{33} & \Phi\beta^T + \Omega_{34} \\ & & & \beta\Phi\beta^T + \Psi + \Omega_{44} \end{pmatrix}
\end{aligned}$$