



5 极化SAR原理与应用

1 极化SAR简介

2 电磁波极化特性及其描述

3 目标极化散射特性的描述

不确定散射体

特点与应用

极化

极化椭圆

Poincare球

完全极化波

部分极化波

JONES矢量

STOKES矢量

散射坐标系

Sinclair矩阵

Mueller矩阵

相干矩阵

协方差矩阵

§ 5.1 极化SAR基本理论

§ 5.2 极化目标分解

§ 5.3 极化SAR信息提取

§ 5.4 极化SAR技术研究进展



5.2 极化目标分解

- 1 典型目标的极化响应
- 2 典型散射模型
- 3 极化目标分解方法

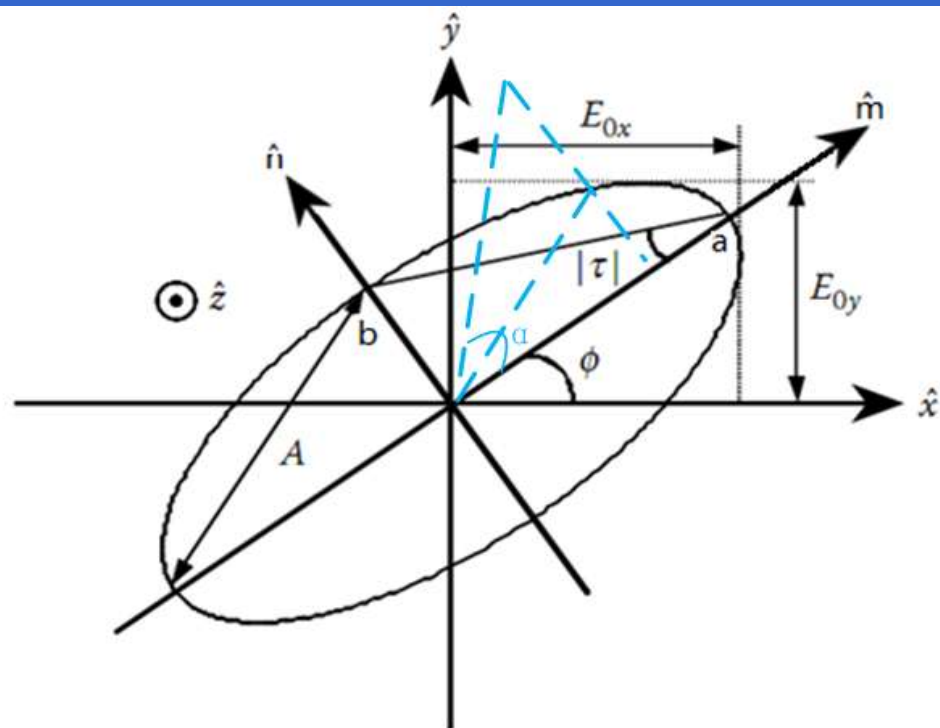
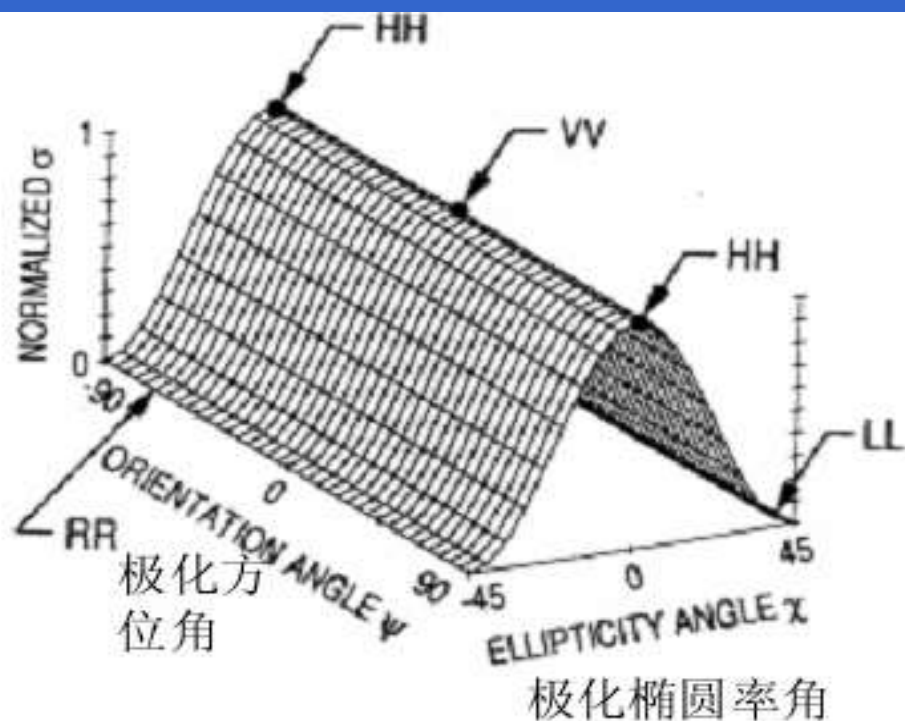
预习内容

为了理解和分析地物极化特性，
常用的极化目标分解的方法有那些？

极化信号图

- ◆ 极化响应又称极化特征，是描述地面散射体任意极化状态下散射特性的曲面或曲线。
- ◆ 极化响应与光学遥感中的光谱响应类似，是分析地物散射的基础。
- ◆ 极化信号图是一种三维图，在一定程度上反映了目标在特定极化组合下产生的回波功率的变化情况。
- ◆ 根据收发天线之间的极化状态，通常有**共极化信号图**与**交叉极化信号图**。

极化信号图



$\chi=0$ 表示所有的线性极化

$\Psi = 0$ 或 π

$\Psi = \frac{\pi}{2}$

VV极化

HH极化

同极化波

$\chi = \pm \frac{\pi}{4}$ 表示所有的圆极化。

VH极化波

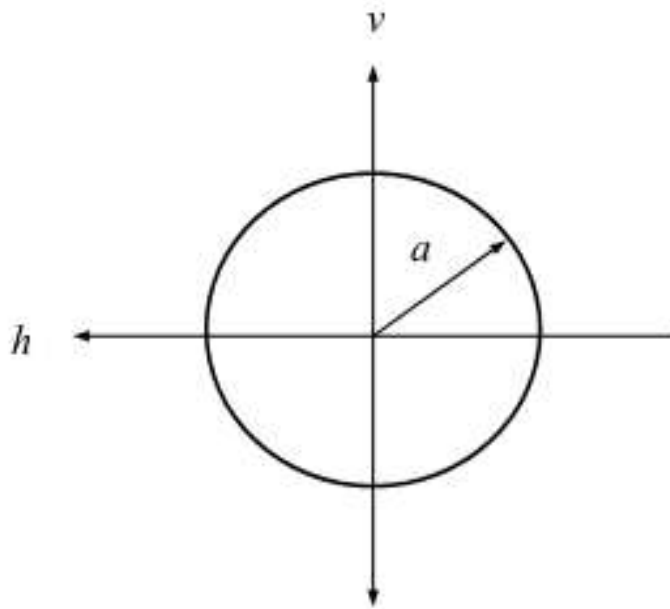
HV极化波

交叉极化波

极化响应基座即散射系数最小值点与零值平面之间的距离。极化响应基座反映极化度的大小。

理想导电体的基座高度为0，说明极化度为1；自然界地物极化响应的基座高度越高，说明极化度越小，HH与VV信号的相关性越小，交叉极化越大，也就是多重散射的成份越

导电球的极化响应

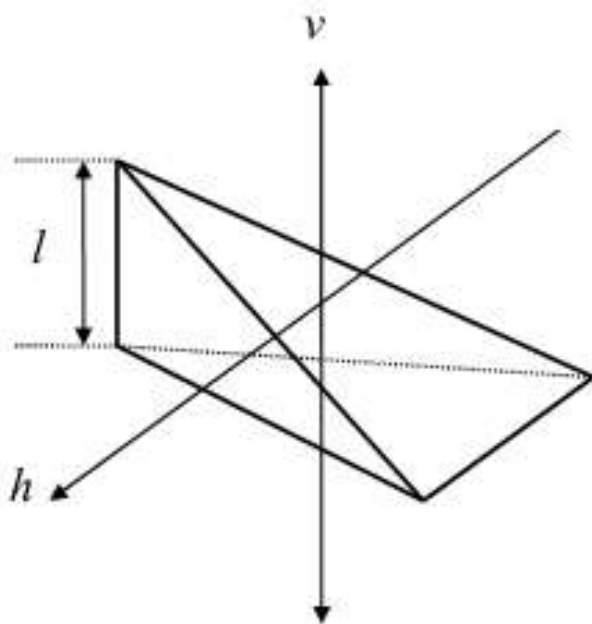


$$S = \frac{a}{2} \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}$$

$$K = \frac{a^2}{8} \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & -1 \end{bmatrix}$$

$$C = \frac{a^2}{4} \begin{bmatrix} 1 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 1 \end{bmatrix}$$

三面角反射器的极化响应



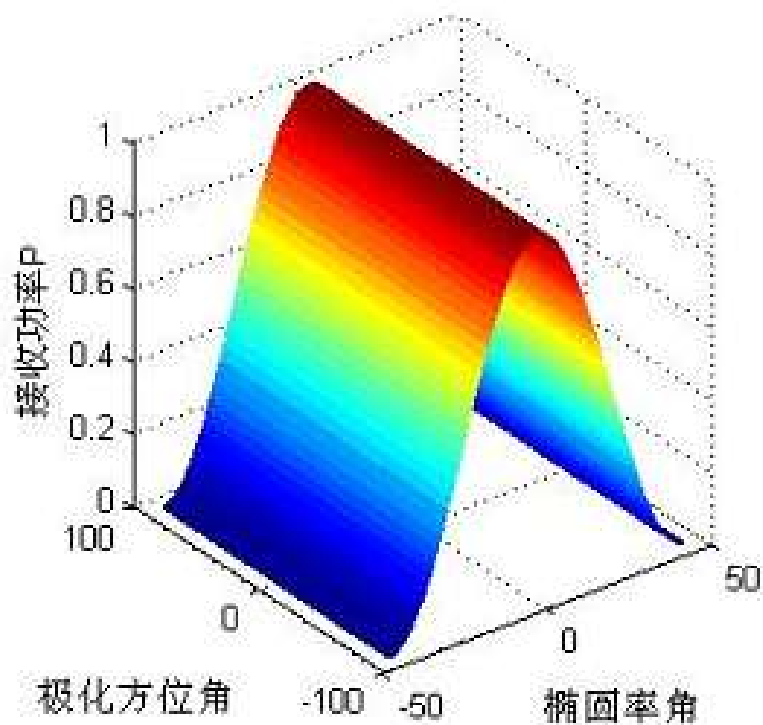
$$S = \frac{k_0 l^2}{\sqrt{12}\pi} \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}$$

$$C = \frac{k_0^2 l^4}{24\pi^2} \begin{bmatrix} 1 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 1 \end{bmatrix}$$

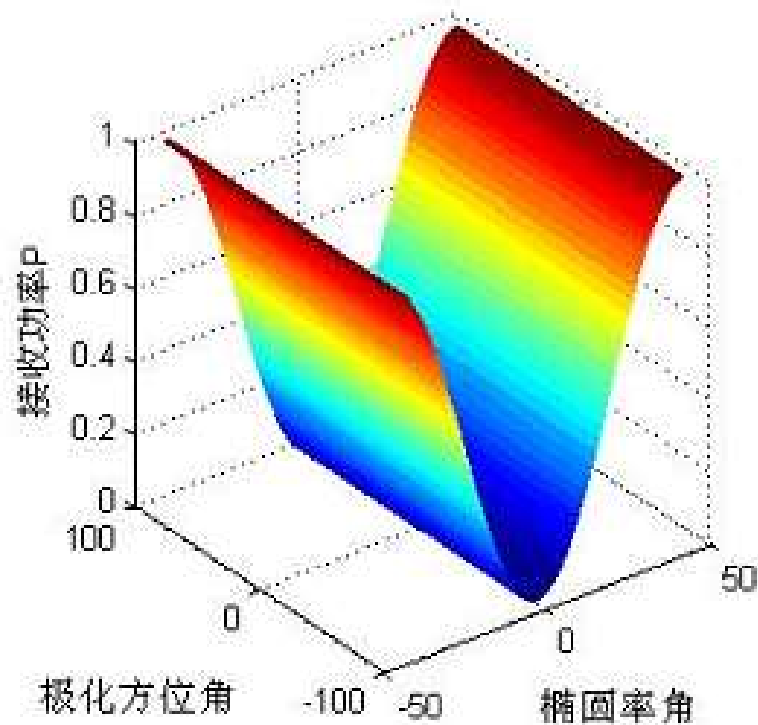
入射电磁波要在三面角反射器上反射三次才能返回雷达。三次反射使得

S_{HH} 与 S_{VV} 之间发生360度的相移。

导电球的极化响应



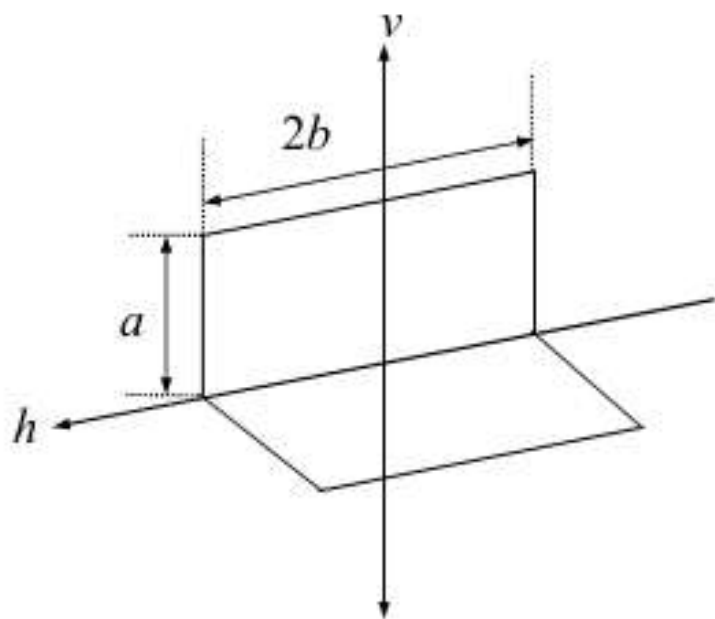
共极化响应



交叉极化响应

除了乘性系数不同之外，三面角反射器与导电球的散射矩阵具有类似的形式。

二面角反射器的极化响应



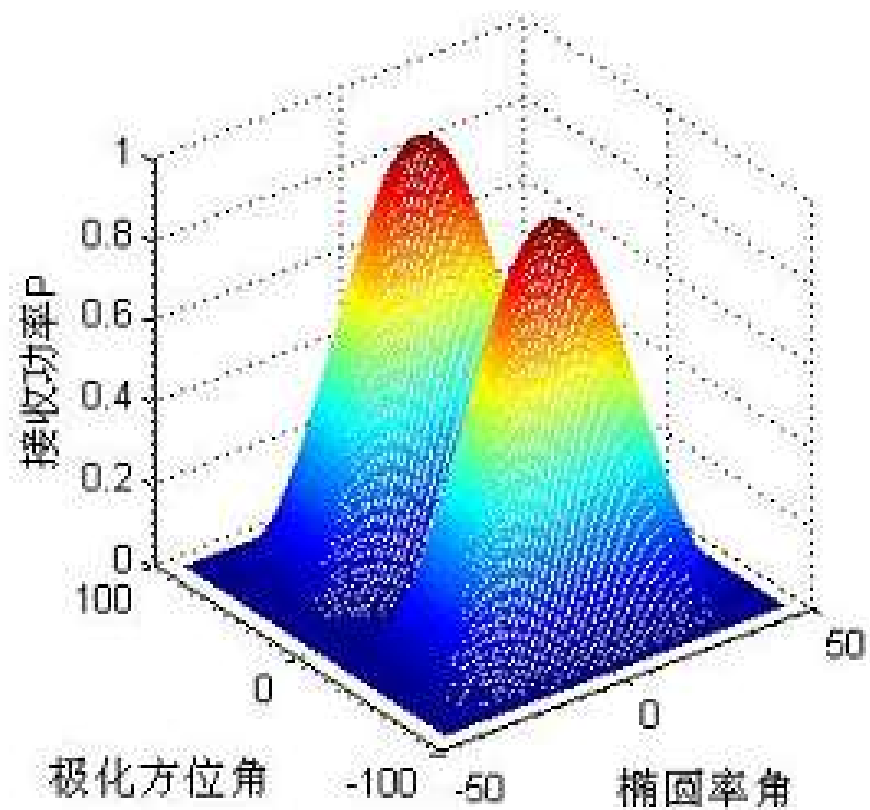
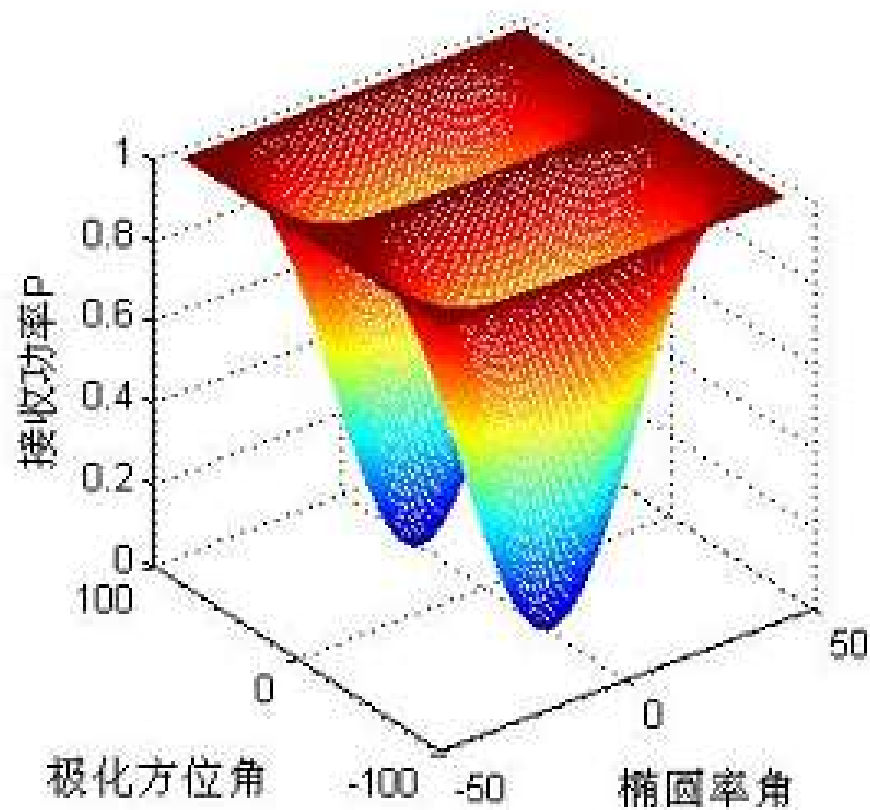
$$S = \frac{k_0 ab}{\pi} \begin{bmatrix} -\cos 2\alpha & \sin 2\alpha \\ \sin 2\alpha & \cos 2\alpha \end{bmatrix}$$

$\alpha = 0^\circ$ 为两面角反射器相对于
雷达视线的偏转角

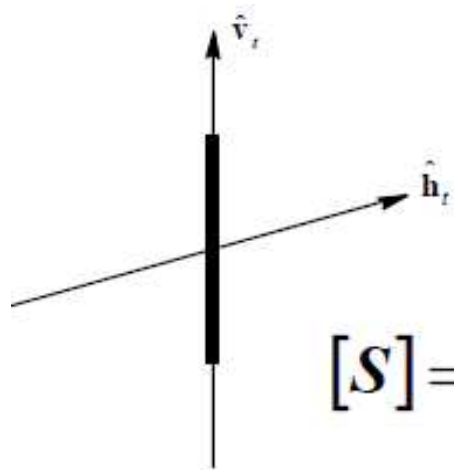
$$C = \frac{k_0^2 a^2 b^2}{2\pi^2} \begin{bmatrix} 1 & 0 & 0 & -1 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ -1 & 0 & 0 & 1 \end{bmatrix}$$

$$S = \frac{k_0 ab}{\pi} \begin{bmatrix} -1 & 0 \\ 0 & 1 \end{bmatrix}$$

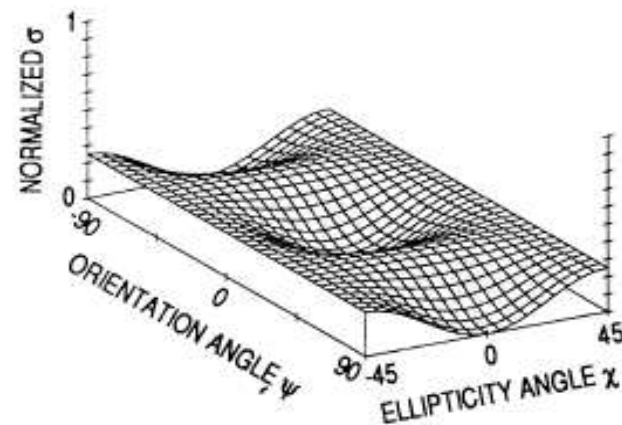
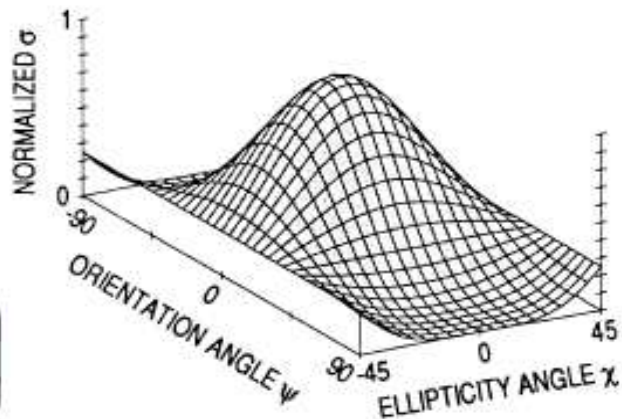
二面角反射器的极化响应



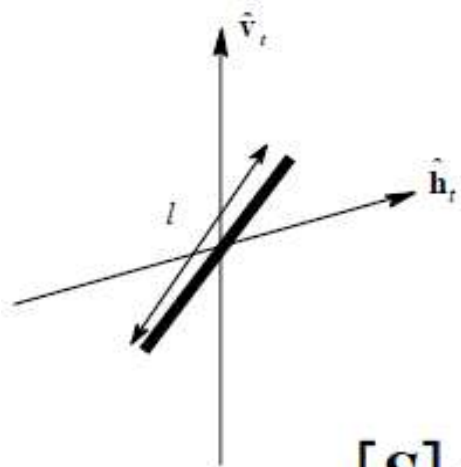
偶极子



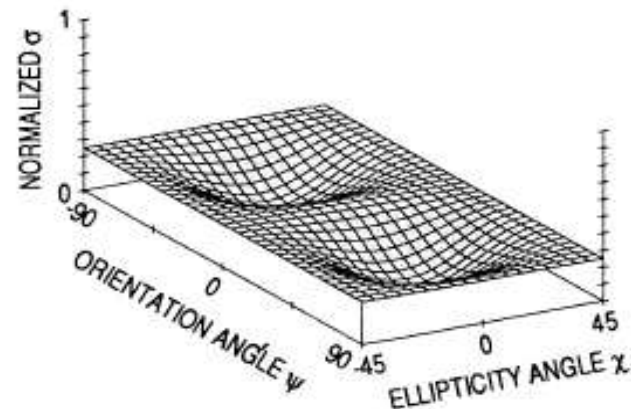
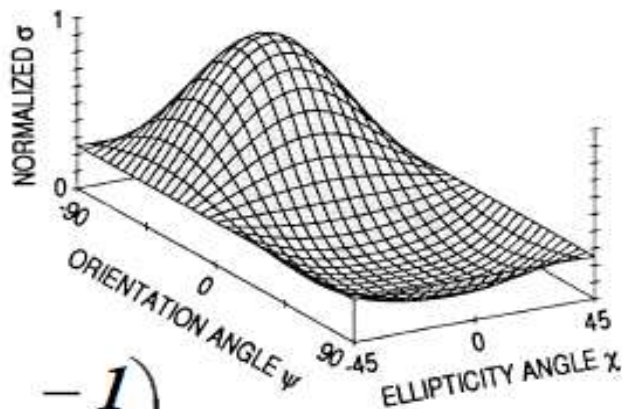
$$[S] = c \begin{pmatrix} 0 & 0 \\ 0 & 1 \end{pmatrix}$$



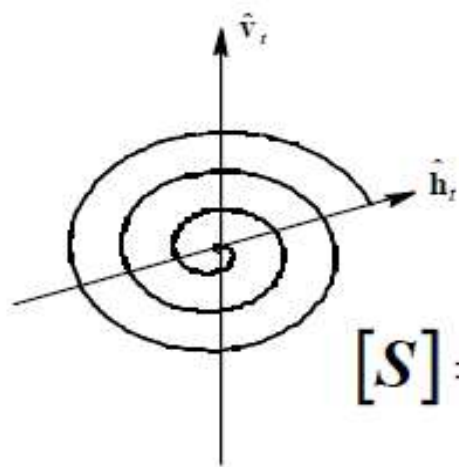
倾斜偶极子



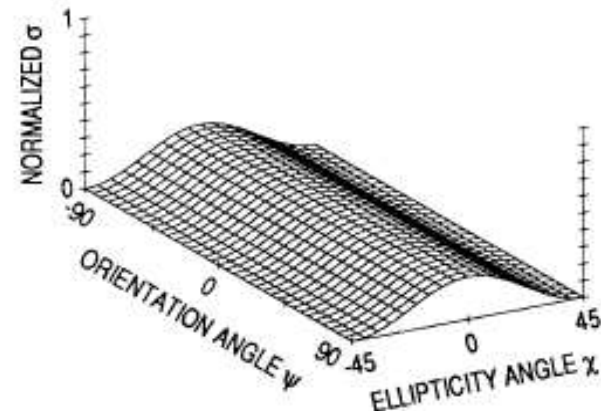
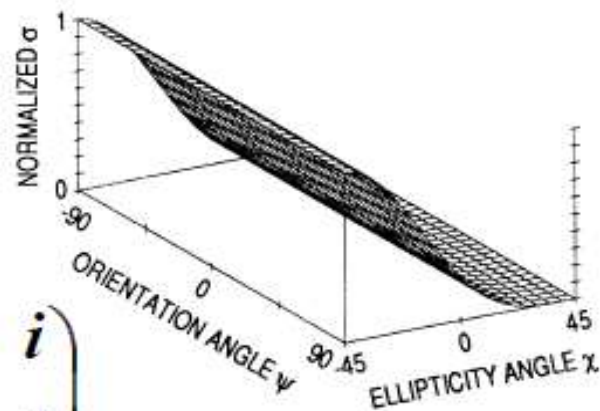
$$[S] = c \begin{pmatrix} 1 & -1 \\ -1 & 1 \end{pmatrix}$$



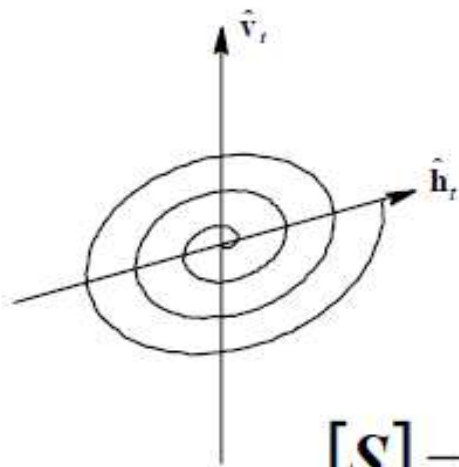
左螺旋



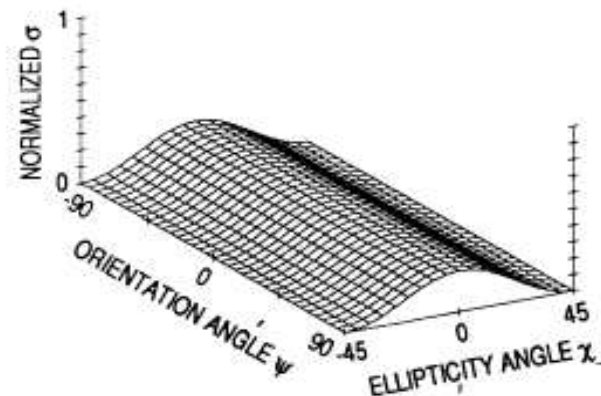
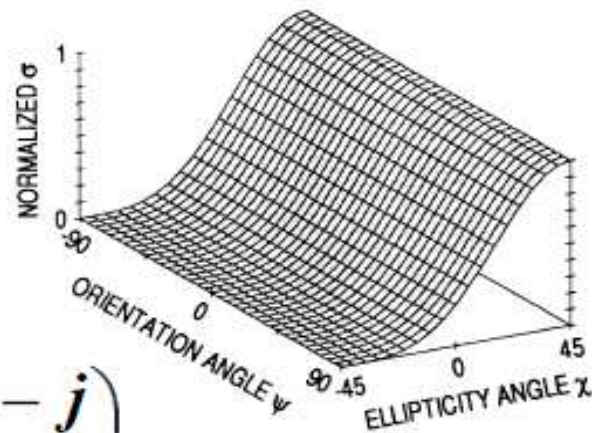
$$[S] = \frac{1}{2} \begin{pmatrix} 1 & i \\ i & -1 \end{pmatrix}$$



右螺旋



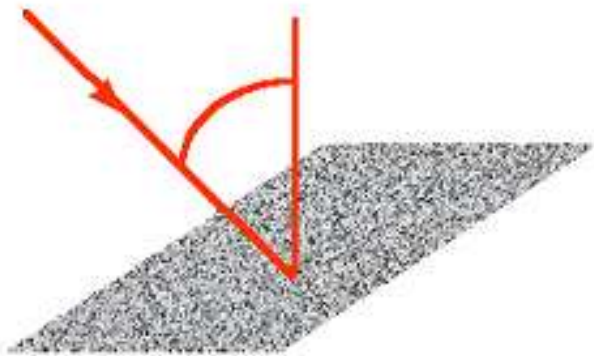
$$[S] = \frac{1}{2} \begin{pmatrix} 1 & -j \\ -j & -1 \end{pmatrix}$$



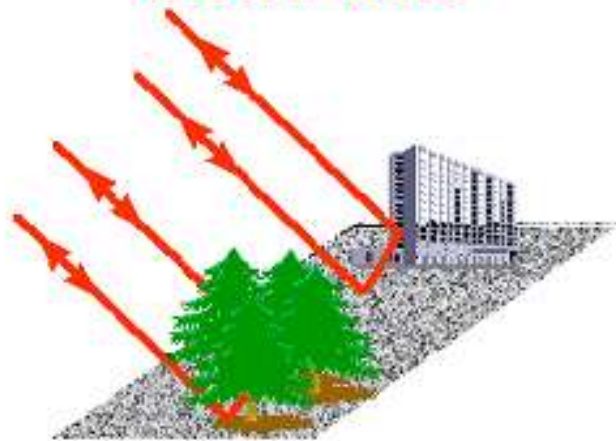
目标散射的物理解释

PHYSICAL INTERPRETATION

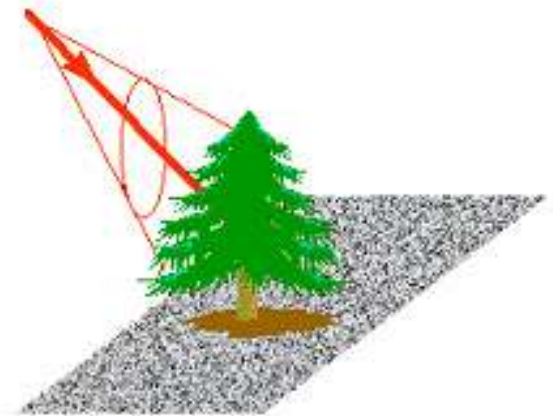
**SINGLE BOUNCE
SCATTERING
(ROUGH SURFACE)**



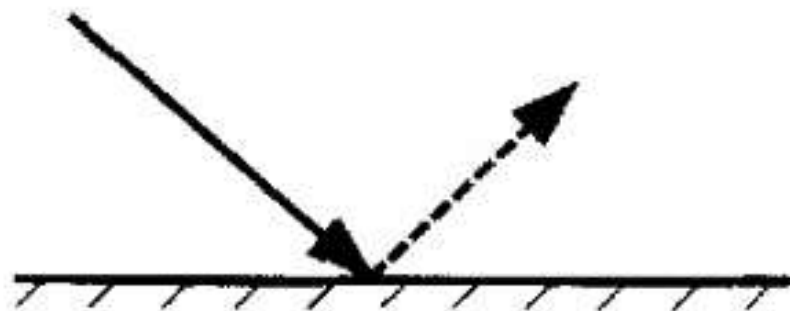
**DOUBLE BOUNCE
SCATTERING**



**VOLUME
SCATTERING**



奇次散射模型



(a) 奇次散射模型

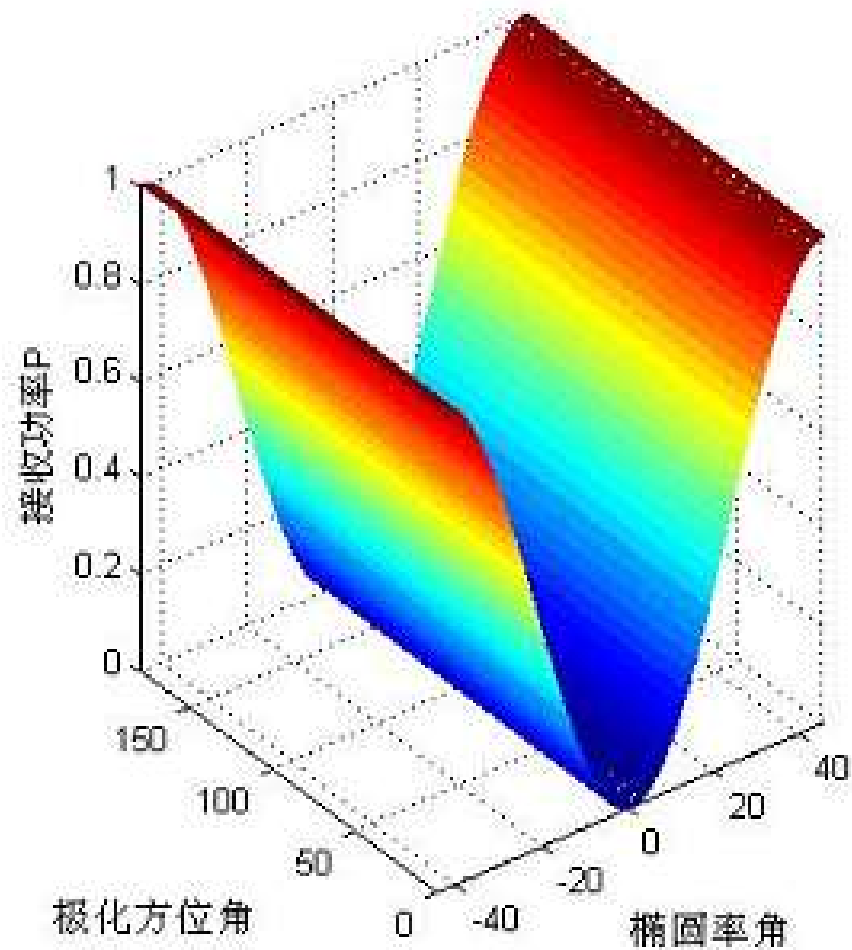
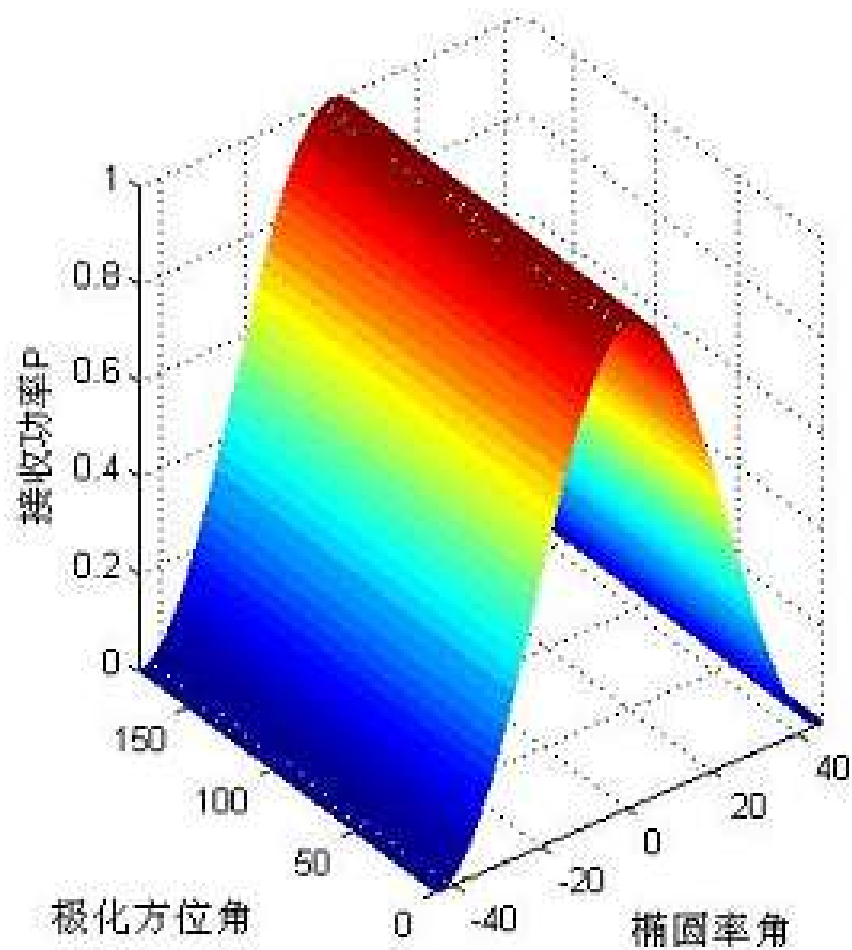
$$S_{odd} = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}$$

$$K = \begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & -1 \end{pmatrix}$$

$$C = \begin{pmatrix} 1 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 1 \end{pmatrix}$$

典型代表?

奇次散射模型



漫散射(Bragg)模型



(b) 漫散射模型

$$S_{\text{Bragg}} = \begin{bmatrix} 1 & 0 \\ 0 & \sqrt{\beta} \end{bmatrix}$$

$$K = \begin{pmatrix} 1 & (1-\beta)/(1+\beta) & 0 & 0 \\ (1-\beta)/(1+\beta) & 1 & 0 & 0 \\ 0 & 0 & 2\sqrt{\beta}/(1+\beta) & 0 \\ 0 & 0 & 0 & 2\sqrt{\beta}/(1+\beta) \end{pmatrix}$$

$$C = \begin{pmatrix} |\beta|^2 & 0 & 0 & \beta \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ \beta^* & 0 & 0 & 1 \end{pmatrix}$$

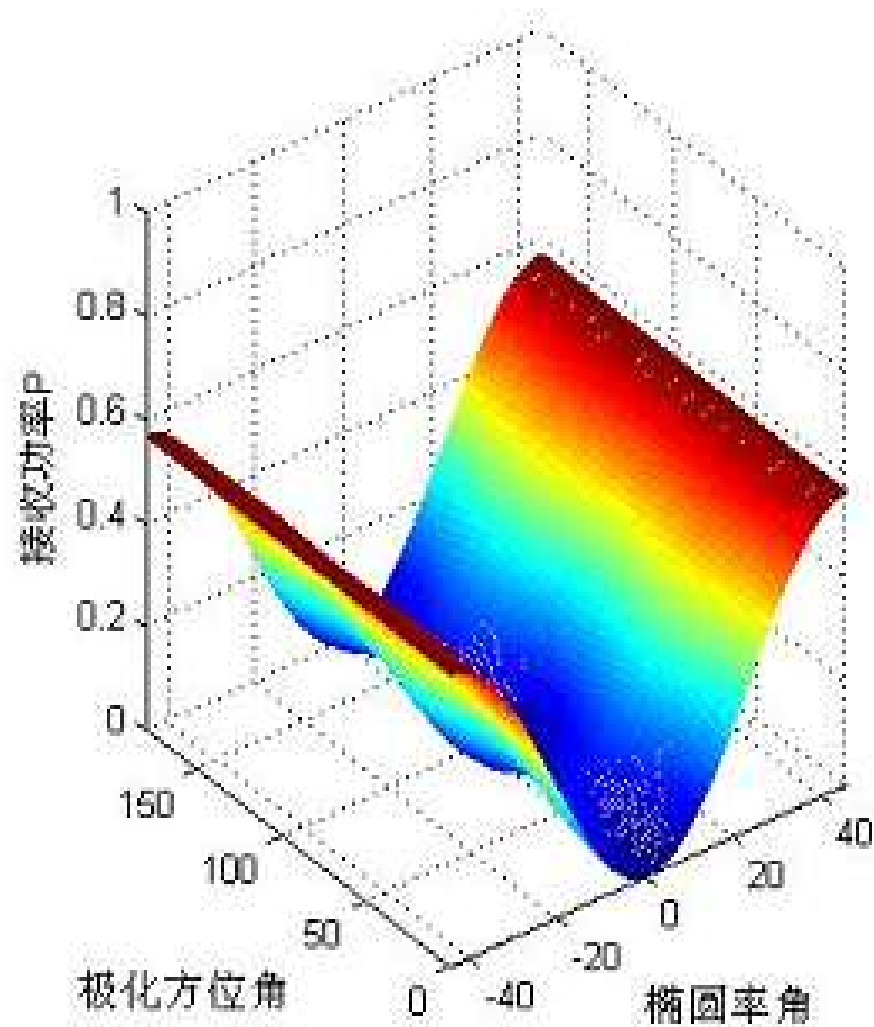
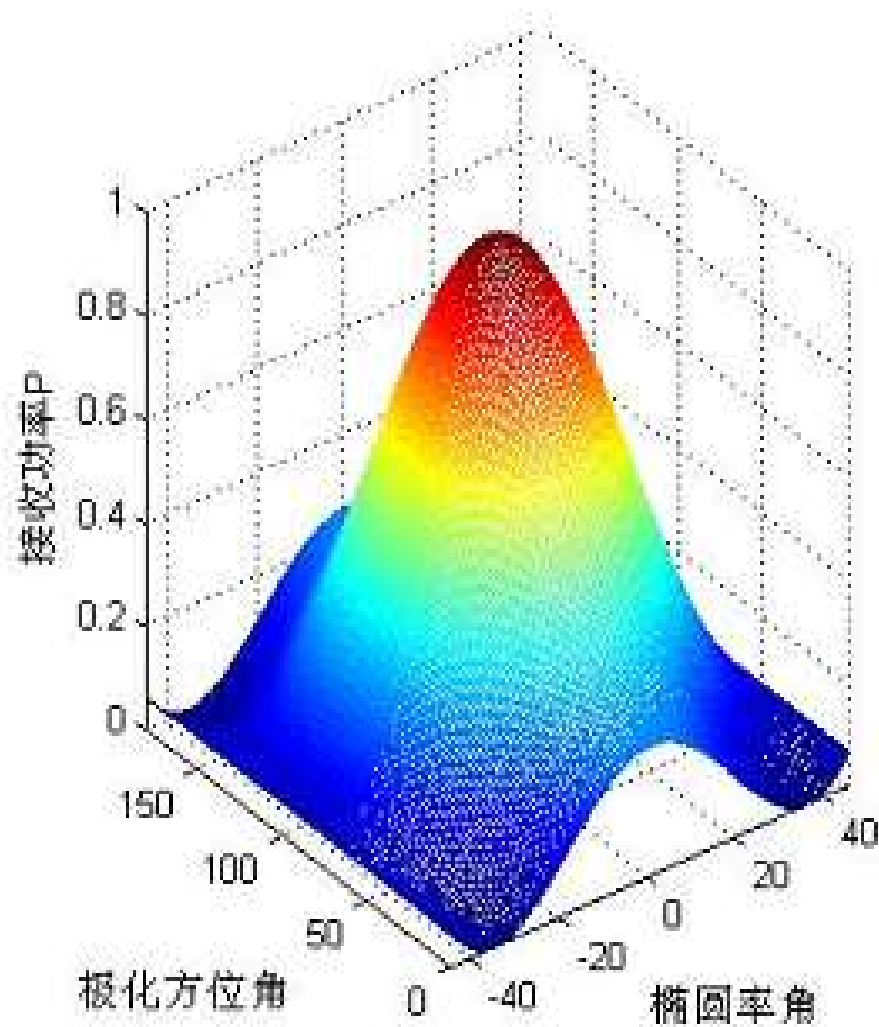
$$|S_{hh}| \geq |S_{hv}| \quad |S_{vv}| \geq |S_{hv}|$$

$$\Re(S_{hh}^* S_{vv}) \geq |S_{hv}|^2 \quad \text{Phase}(S_{hh}^* S_{vv}) \approx 0$$

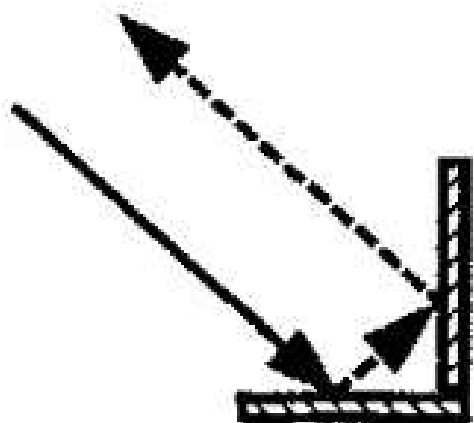
$$\text{where, } \beta = \frac{R_H}{R_V}$$

典型代表?

漫散射(Bragg)模型



偶次散射模型



(c) 偶次散射模型

$$S_{even} = \begin{bmatrix} 1 & 0 \\ 0 & \alpha \end{bmatrix}$$

$$K = \begin{pmatrix} 1 & (1-\alpha^2)/(1+\alpha^2) & 0 & 0 \\ (1-\alpha^2)/(1+\alpha^2) & 1 & 0 & 0 \\ 0 & 0 & 2\alpha \cos \delta / (1+\alpha^2) & 2\alpha \sin \delta / (1+\alpha^2) \\ 0 & 0 & -2\alpha \sin \delta / (1+\alpha^2) & 2\alpha \cos \delta / (1+\alpha^2) \end{pmatrix}$$

$$|S_{hh}| \geq |S_{hv}| \quad |S_{vv}| \geq |S_{vh}|$$

$$\Re(S_{hh}^* S_{vv}) \geq |S_{hv}|^2 \quad \text{Phase}(S_{hh}^* S_{vv}) \approx \pi$$

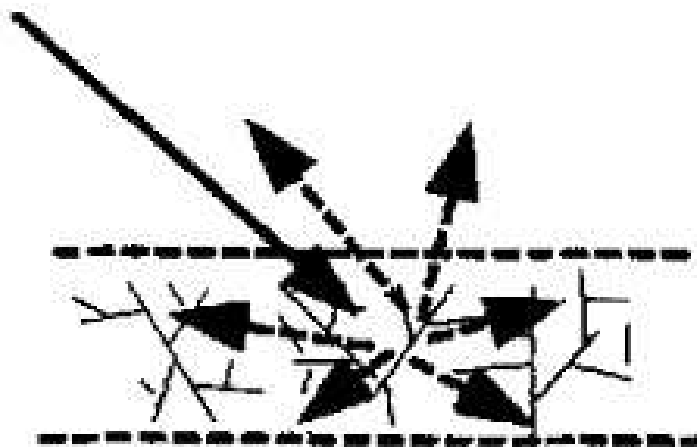
$$C = \begin{pmatrix} |\alpha|^2 & 0 & 0 & \alpha \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ \alpha^* & 0 & 0 & 1 \end{pmatrix}$$

典型代表?

其中

$$\alpha = e^{j2(\tau_h - \tau_v)} \frac{R_{\perp h} R_{\parallel h}}{R_{\perp v} R_{\parallel v}}$$

体散射模型



(d) 体散射模型

$$K = \begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & 1/2 & 0 & 0 \\ 0 & 0 & 1/2 & 0 \\ 0 & 0 & 0 & 0 \end{pmatrix}$$

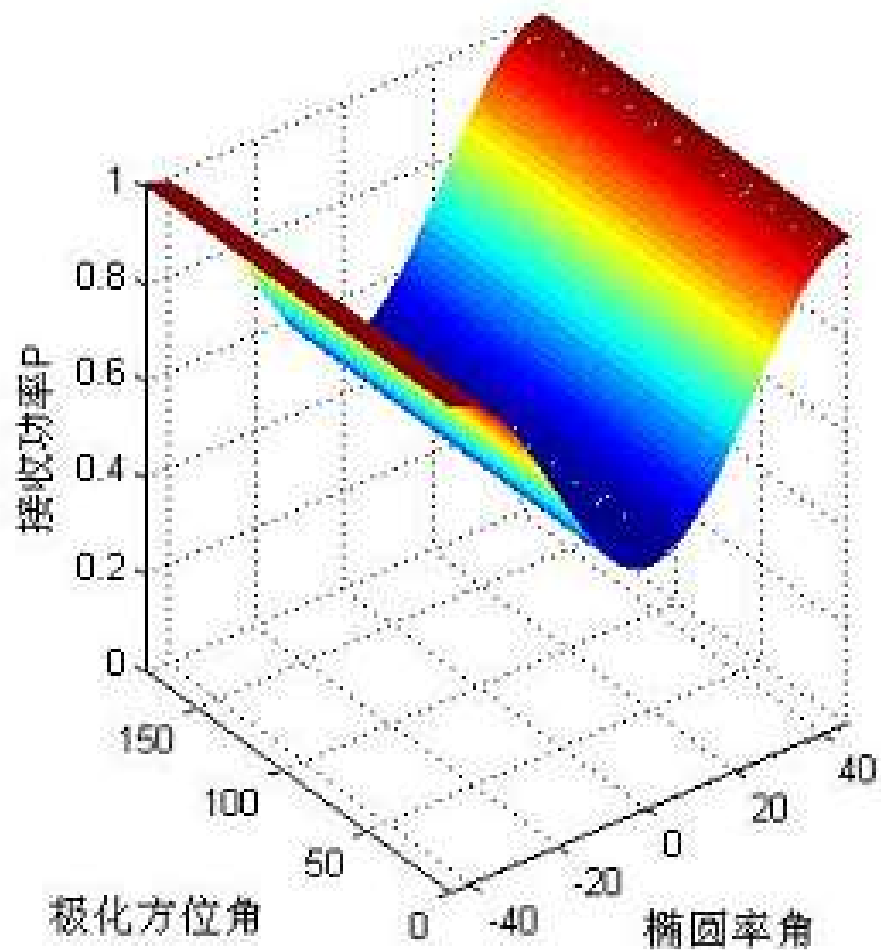
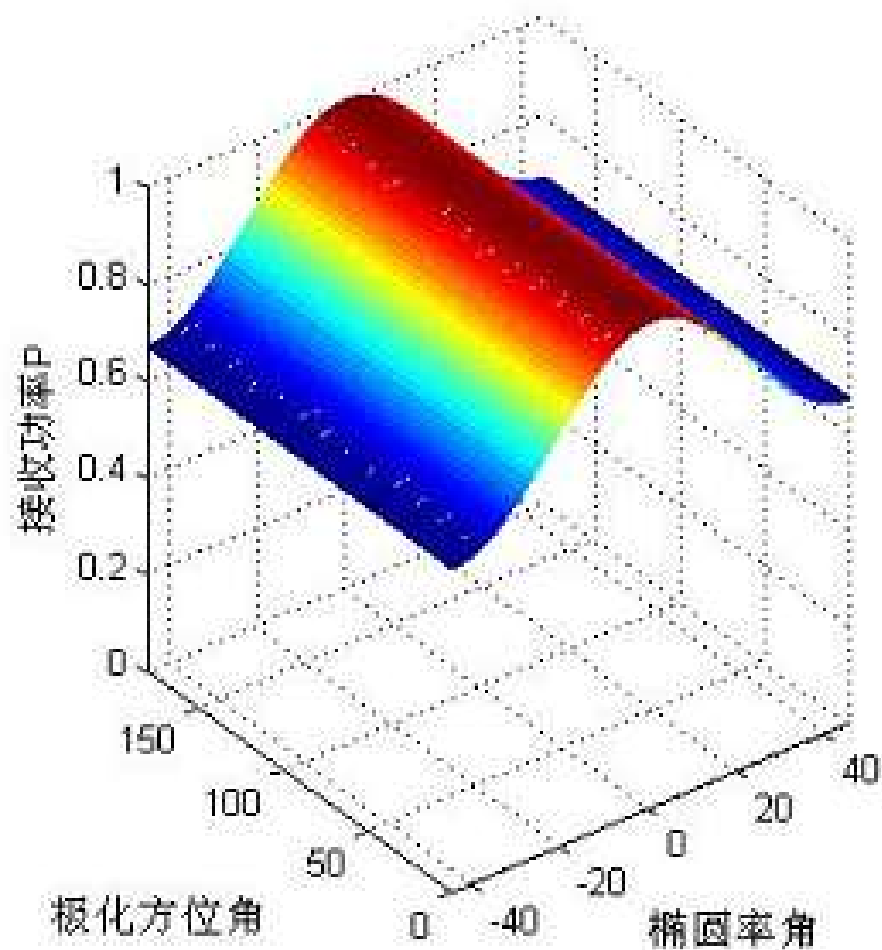
$$\langle C \rangle = \begin{bmatrix} 1 & 0 & 0 & 1/3 \\ 0 & 1/3 & 1/3 & 0 \\ 0 & 1/3 & 1/3 & 0 \\ 1/3 & 0 & 0 & 1 \end{bmatrix}$$

$$|S_{hh}| \geq |S_{hv}| \quad |S_{vv}| \geq |S_{hv}|$$

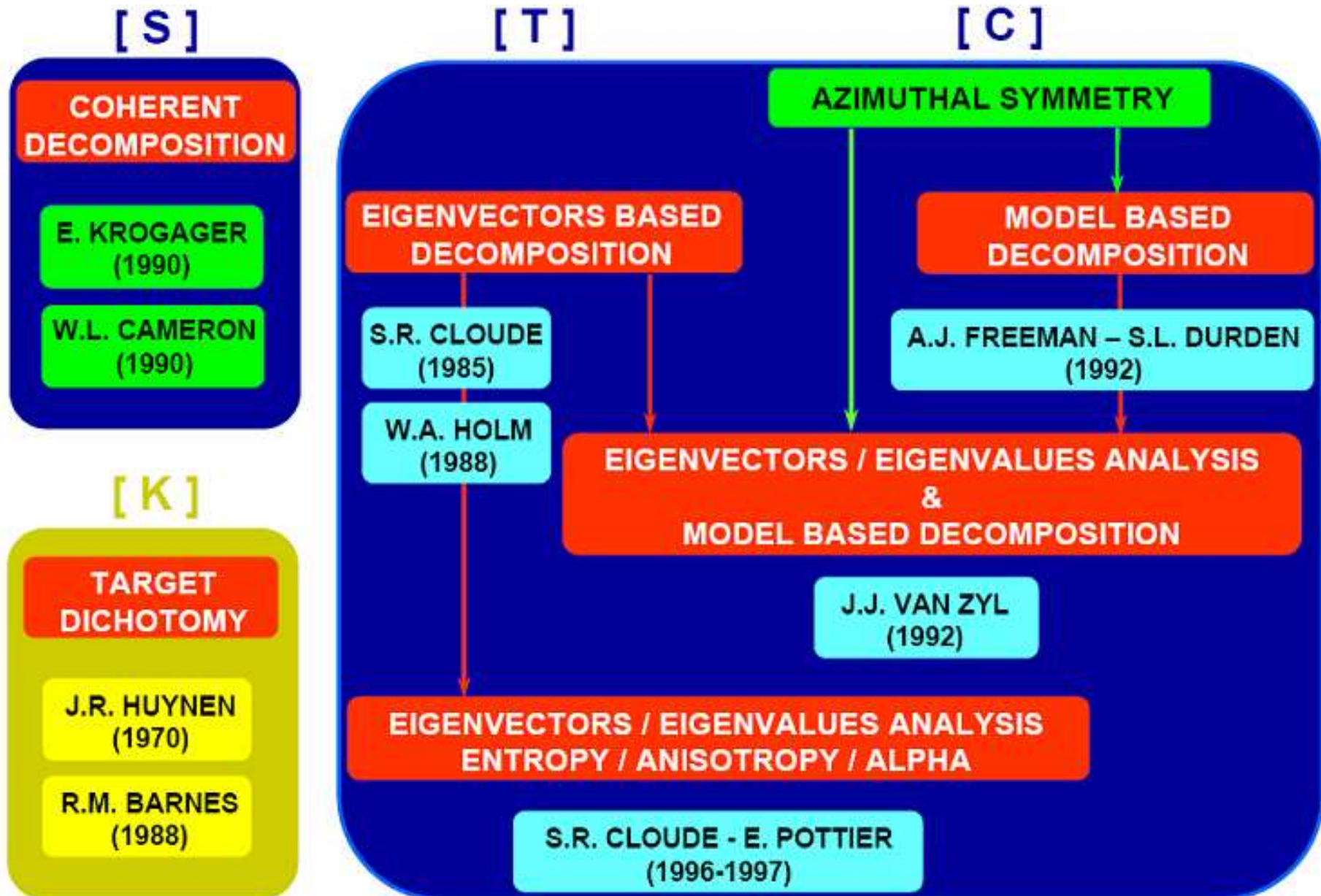
$$\Re(S_{hh}^* S_{vv}) \geq |S_{hv}|^2 \quad \text{Phase}(S_{hh}^* S_{vv}) \approx \text{uniform}[0, \pi]$$

典型代表?

体散射模型



极化目标分解方法体系



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