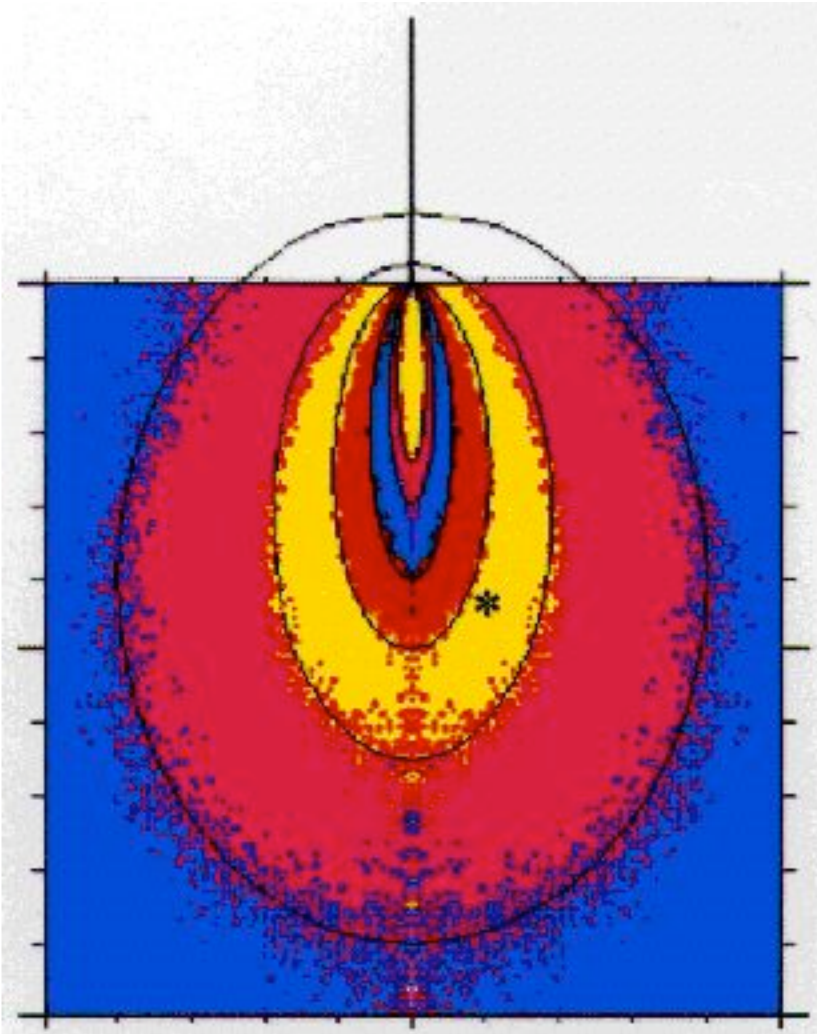

Tissue Optics

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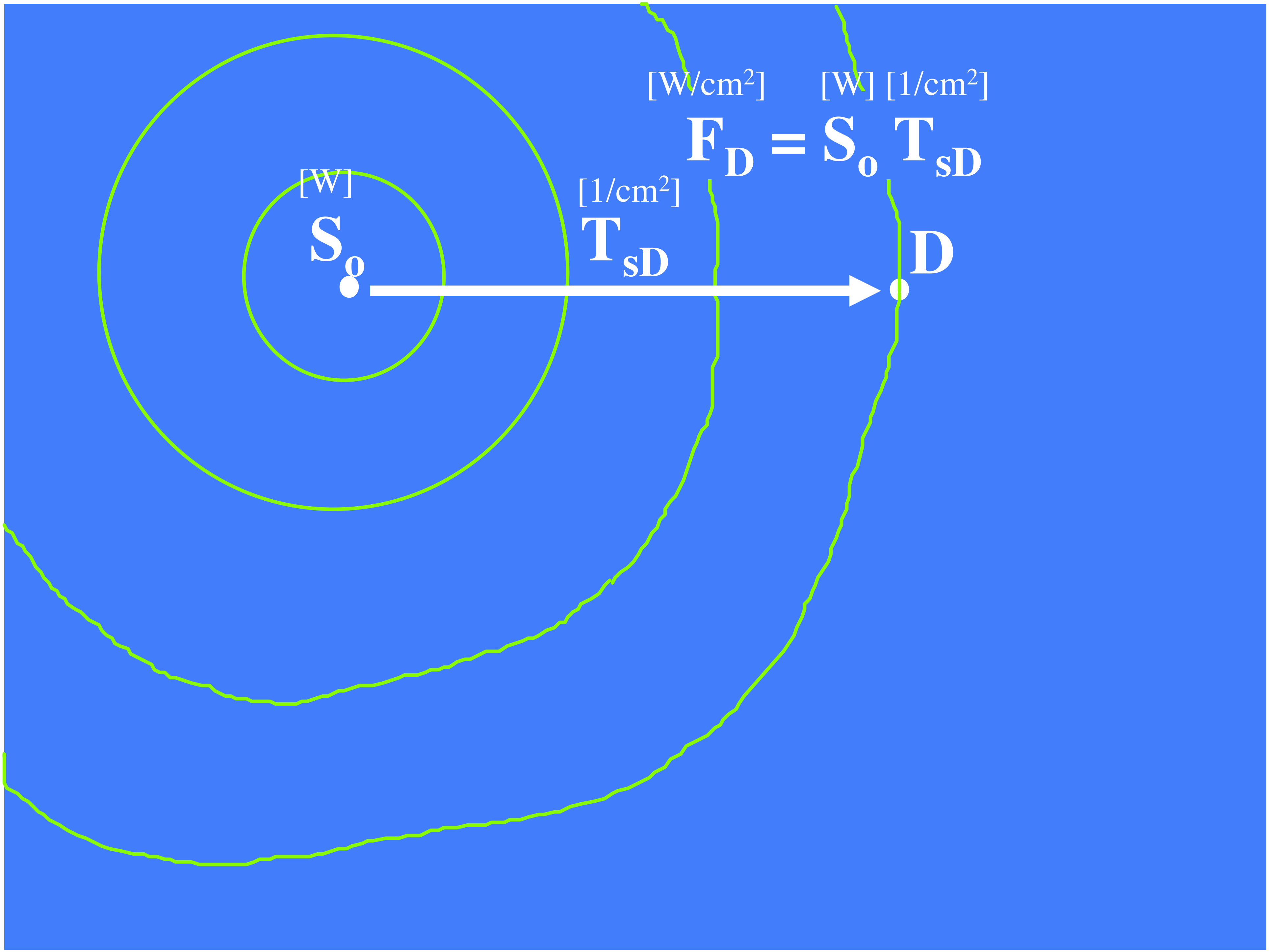
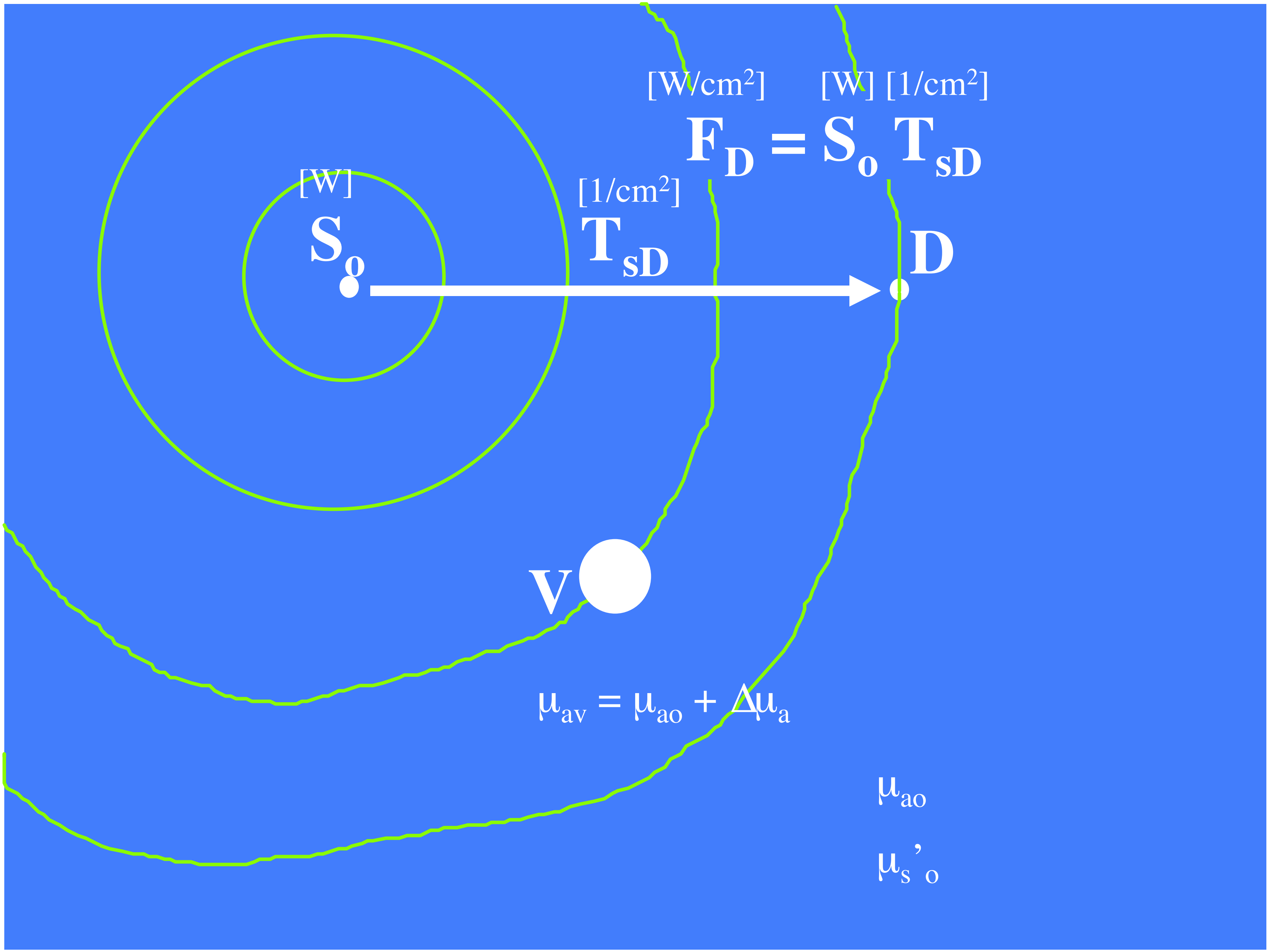
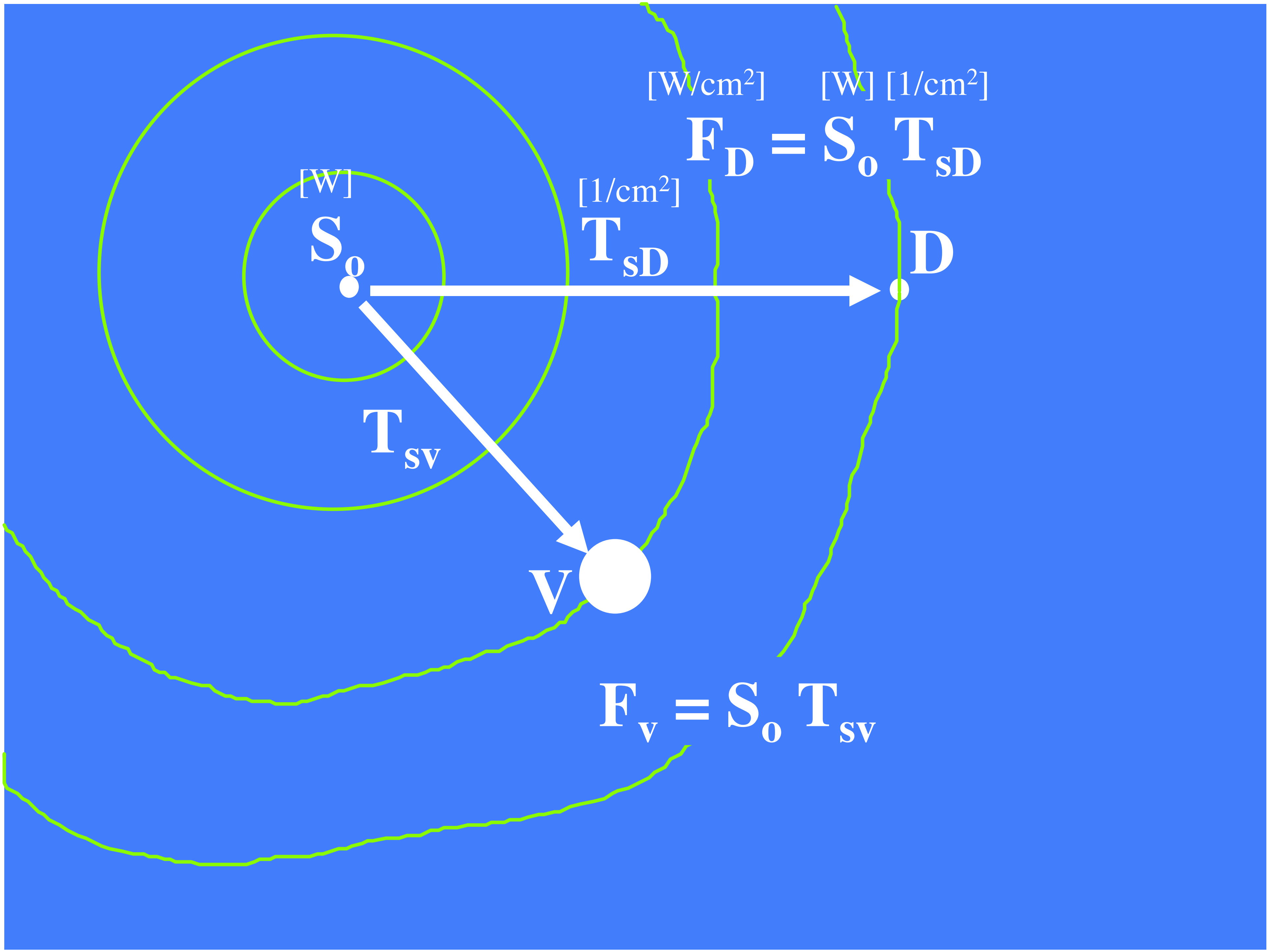
1. Optical properties
2. How to measure optical properties
3. Light transport
4. **Complex tissues**

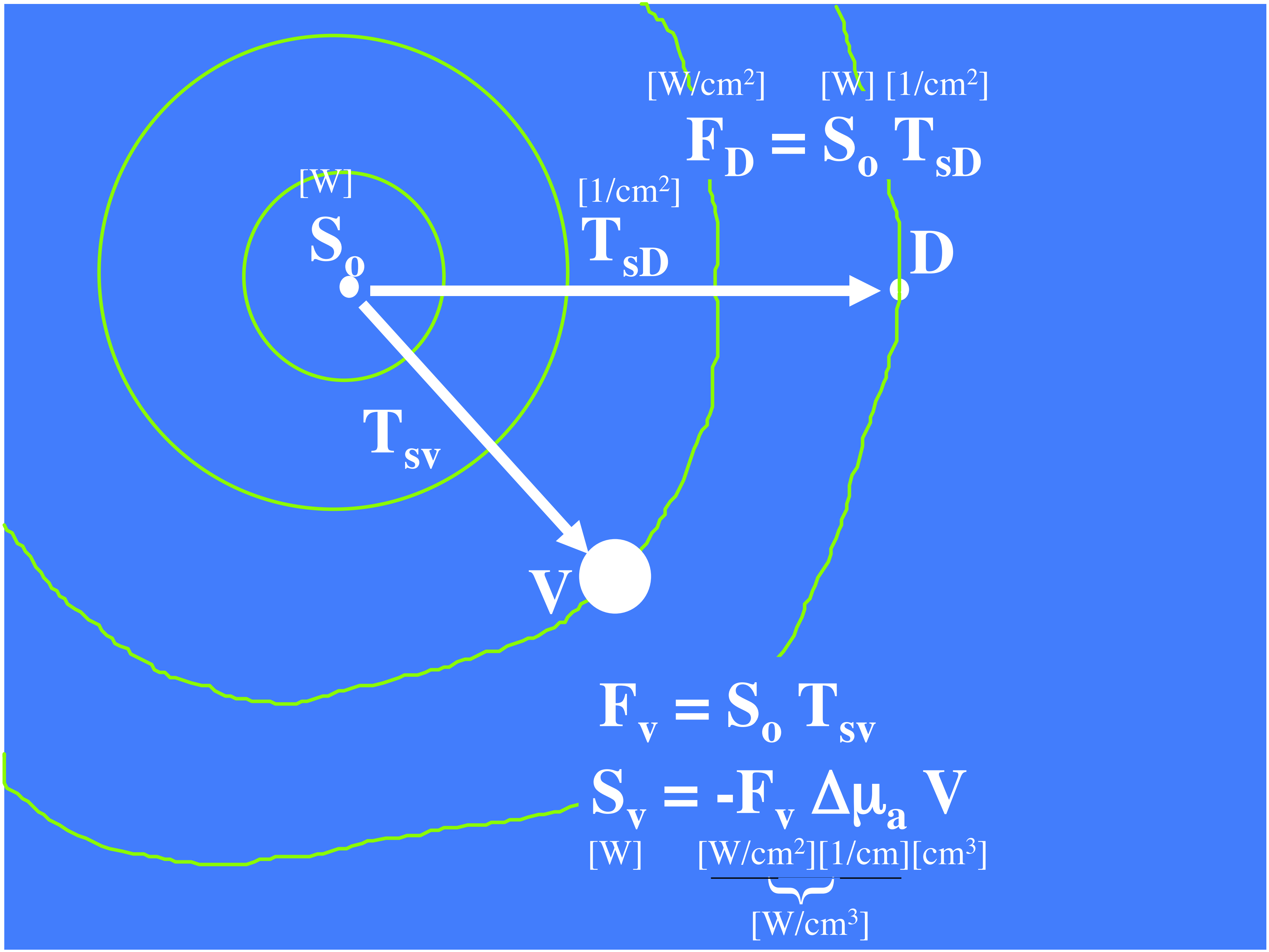
Perturbation theory

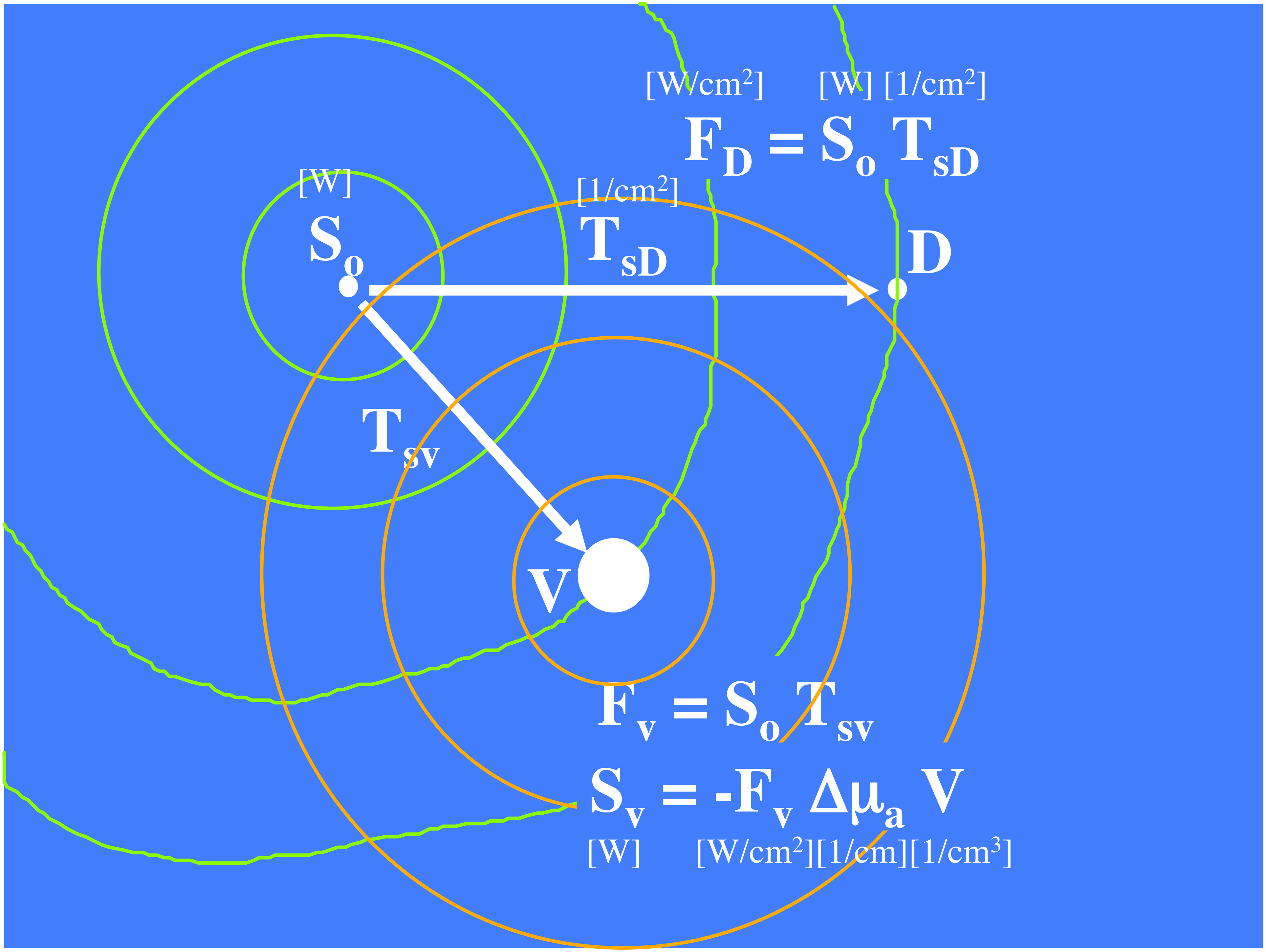

[W/cm2] [W] [1/cm2]
$F_D = S_o T_{sD}$
[W]
S_o
[1/cm2]
T_{sD}
D



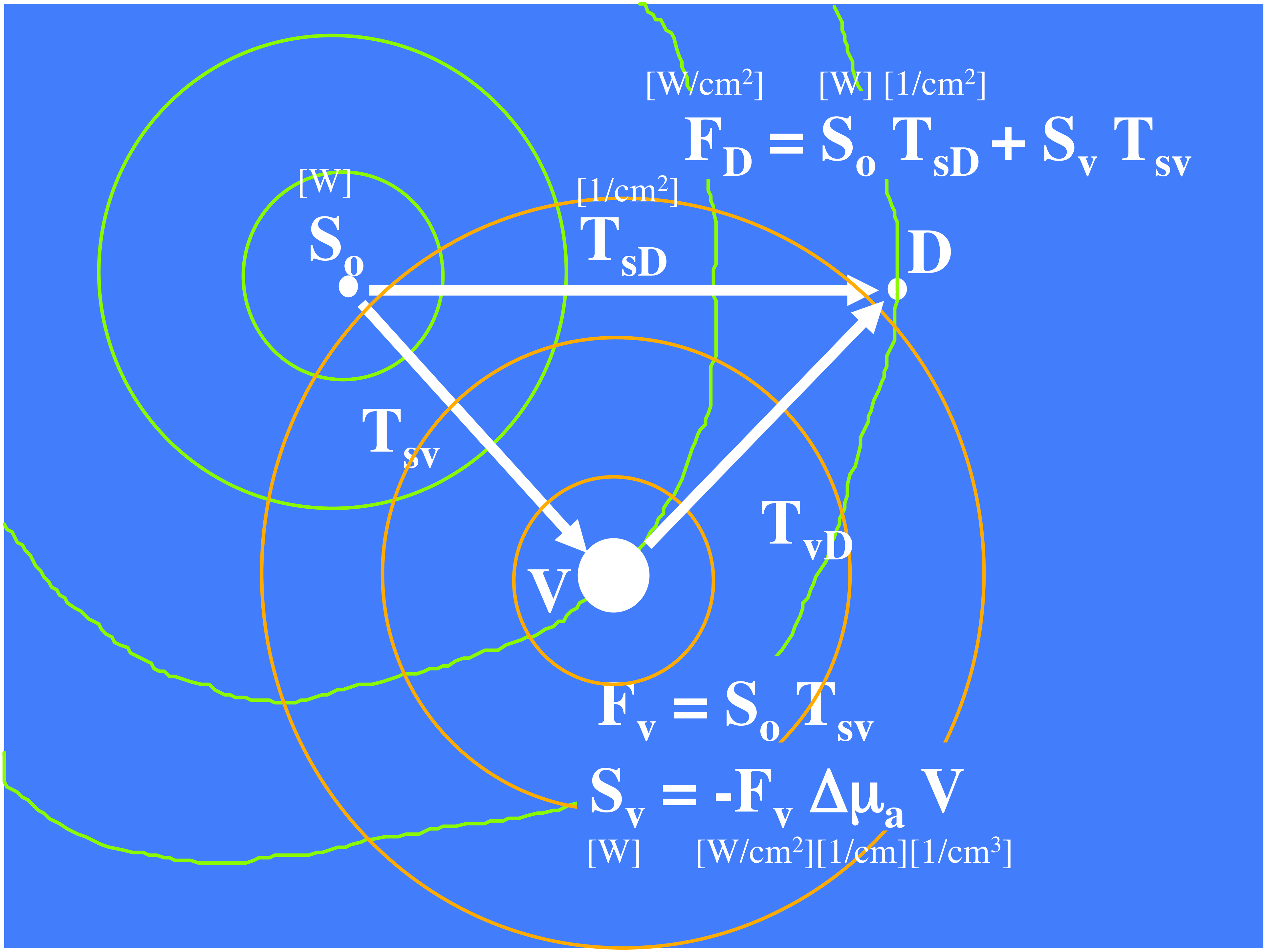
[W/cm²] [W] [1/cm²]
$F_D = S_o T_{sD}$
[W]
S_o
[1/cm²]
T_{sD}
D
V
$\mu_{av} = \mu_{ao} + \Delta\mu_a$
μ_{ao}
$\mu_s{'}_o$

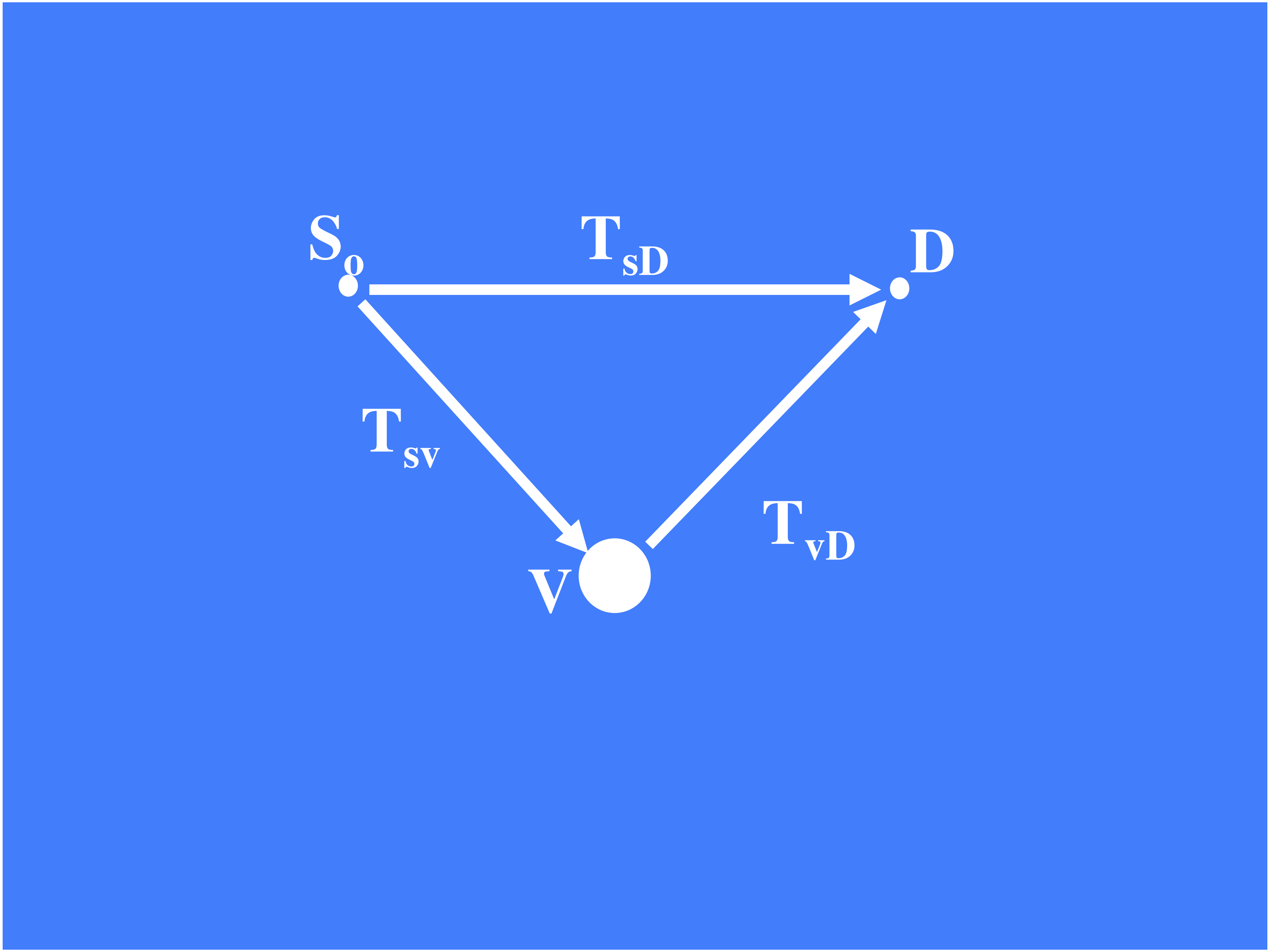

[W/cm^2]
[W] [1/cm^2]
$F_D = S_o T_{sD}$
[W]
S_o
[1/cm^2]
T_{sD}
D
T_{sv}
V
$F_v = S_o T_{sv}$


[W/cm²] [W] [1/cm²]
$F_D = S_o \, T_{sD}$
[W]
S_o
[1/cm²]
T_{sD}
D
T_{sv}
V
$F_v = S_o \, T_{sv}$
$S_v = -F_v \, \Delta\mu_a \, V$
[W] [W/cm²][1/cm][cm³]
[W/cm³]

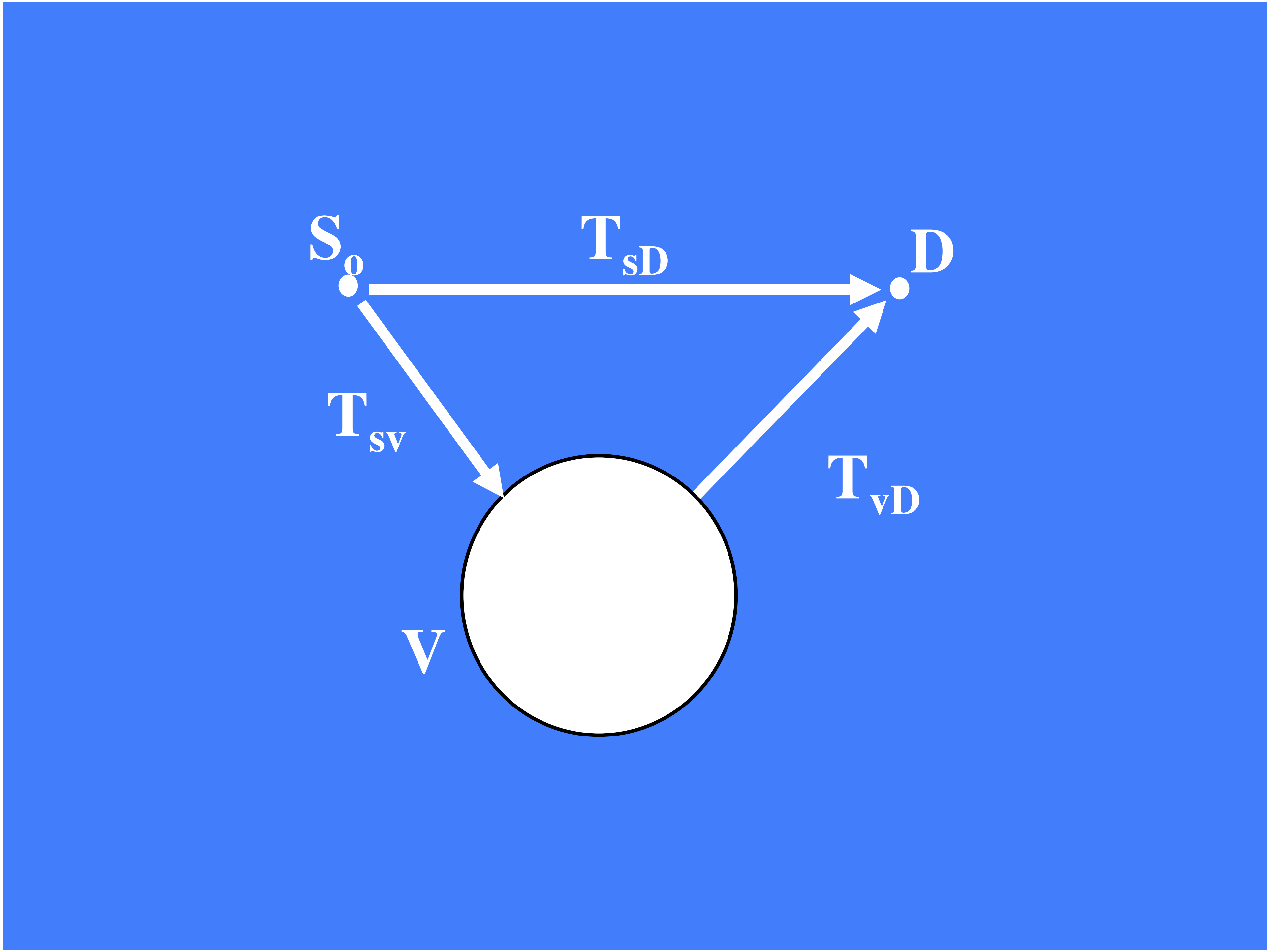


[W/cm2] [W] [1/cm2]
$F_D = S_o T_{sD}$
[W]
S_o
[1/cm2]
T_{sD}
D
T_{sv}
V
$F_v = S_o T_{sv}$
$S_v = -F_v \Delta\mu_a V$
[W] [W/cm2][1/cm][1/cm3]

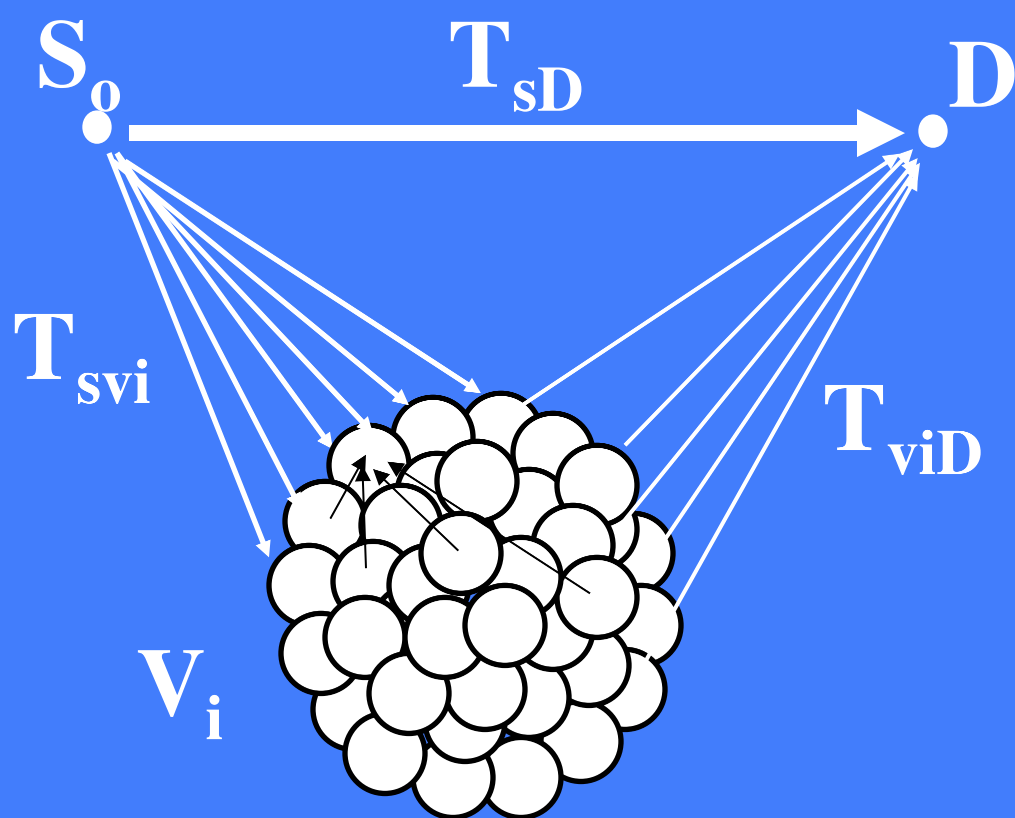

[W/cm2] [W] [1/cm2]
F_D = S_o T_sD + S_v T_sv
[W]
S_o
[1/cm2]
T_sD
D
T_sv
T_vD
V
F_v = S_o T_sv
S_v = -F_v Δμ_a V
[W] [W/cm2][1/cm][1/cm3]



S0
TsD
D
Tsv
TvD
V



So
TsD
D
Tsv
TvD
V



S o
T sD
D
T svi
T viD
V i

$$
\begin{vmatrix} F_1 \\ F_2 \\ F_3 \\ \dots \\ F_j \end{vmatrix}
=
\begin{vmatrix}
T_{01} & T_{11} & \dots & T_{j1} \\
T_{02} & T_{12} & \dots & T_{j2} \\
T_{03} & T_{13} & \dots & T_{j3} \\
\dots & \dots & & \dots \\
T_{0j} & T_{1j} & \dots & T_{jj}
\end{vmatrix}
*
\begin{vmatrix} S_0 \\ S_{v1} \\ S_{v2} \\ S_{v3} \\ \dots \\ S_{vj} \end{vmatrix}
$$

$$\begin{vmatrix} \mathbf{F_1} \\ F_2 \\ F_3 \\ \cdots \\ F_j \end{vmatrix} = \begin{vmatrix} \mathbf{T_{01}} & T_{11} & \cdots & T_{j1} \\ T_{02} & T_{12} & \cdots & T_{j2} \\ T_{03} & T_{13} & \cdots & T_{j3} \\ \cdots & \cdots & & \cdots \\ T_{0j} & T_{1j} & \cdots & T_{jj} \end{vmatrix} * \begin{vmatrix} \mathbf{S_0} \\ S_{v1} \\ S_{v2} \\ S_{v3} \\ \cdots \\ S_{vj} \end{vmatrix}$$

$$
\begin{vmatrix} F_1 \\ F_2 \\ F_3 \\ \dots \\ F_j \end{vmatrix} = \begin{vmatrix} T_{01} & T_{11} & \dots & T_{j1} \\ T_{02} & T_{12} & \dots & T_{j2} \\ T_{03} & T_{13} & \dots & T_{j3} \\ \dots & \dots & & \dots \\ T_{0j} & T_{1j} & \dots & T_{jj} \end{vmatrix} * \begin{vmatrix} S_0 \\ S_{v1} \\ S_{v2} \\ S_{v3} \\ \dots \\ S_{vj} \end{vmatrix}
$$

$$
\left|\begin{array}{c} F_1 \\ F_2 \\ F_3 \\ \dots \\ F_j \end{array}\right| = \left|\begin{array}{cccc} T_{01} & T_{11} & \dots & T_{j1} \\ T_{02} & T_{12} & \dots & T_{j2} \\ T_{03} & T_{13} & \dots & T_{j3} \\ \dots & \dots & & \dots \\ T_{0j} & T_{1j} & \dots & T_{jj} \end{array}\right| * \left|\begin{array}{c} S_0 \\ S_{v1} \\ S_{v2} \\ S_{v3} \\ \dots \\ S_{vj} \end{array}\right|
$$

$$
\begin{vmatrix} F_1 \\ F_2 \\ F_3 \\ \cdots \\ F_j \end{vmatrix} = \begin{vmatrix} T_{01} & T_{11} & \cdots & T_{j1} \\ T_{02} & T_{12} & \cdots & T_{j2} \\ T_{03} & T_{13} & \cdots & T_{j3} \\ \cdots & \cdots & & \cdots \\ T_{0j} & T_{1j} & \cdots & T_{jj} \end{vmatrix} * \begin{vmatrix} S_0 \\ S_{v1} \\ S_{v2} \\ S_{v3} \\ \cdots \\ S_{vj} \end{vmatrix}
$$

$$
\begin{vmatrix} F_1 \\ F_2 \\ F_3 \\ \ldots \\ F_j \end{vmatrix}
=
\begin{vmatrix}
T_{01} & T_{11} & \ldots & T_{j1} \\
T_{02} & T_{12} & \ldots & T_{j2} \\
T_{03} & T_{13} & \ldots & T_{j3} \\
\ldots & \ldots & & \ldots \\
T_{0j} & T_{1j} & \ldots & T_{jj}
\end{vmatrix}
*
\begin{vmatrix} S_0 \\ S_{v1} \\ S_{v2} \\ S_{v3} \\ \ldots \\ S_{vj} \end{vmatrix}
$$

$$
\begin{vmatrix} F_1 \\ F_2 \\ F_3 \\ \dots \\ F_j \end{vmatrix} = \begin{vmatrix} T_{01} & T_{11} & \dots & T_{j1} \\ T_{02} & T_{12} & \dots & T_{j2} \\ T_{03} & T_{13} & \dots & T_{j3} \\ \dots & \dots & & \dots \\ T_{0j} & T_{1j} & \dots & T_{jj} \end{vmatrix} * \begin{vmatrix} S_0 \\ S_{v1} \\ S_{v2} \\ S_{v3} \\ \dots \\ S_{vj} \end{vmatrix}
$$

$$S_{vj} = -F_i \, \Delta\mu_{ai} \, V_i$$

1st pass = "Born approximation"

$$\begin{vmatrix} F_1 \\ F_2 \\ F_3 \\ \dots \\ F_j \end{vmatrix} = \begin{vmatrix} T_{01} & T_{11} & \dots & T_{j1} \\ T_{02} & T_{12} & \dots & T_{j2} \\ T_{03} & T_{13} & \dots & T_{j3} \\ \dots & \dots & & \dots \\ T_{0j} & T_{1j} & \dots & T_{jj} \end{vmatrix} * \begin{vmatrix} S_0 \\ 0 \\ 0 \\ 0 \\ \dots \\ 0 \end{vmatrix}$$

$$S_{vj} = -F_i \, \Delta\mu_{ai} \, V_i$$

iterative passes → relaxes to solution

$$\begin{vmatrix} F_1 \\ F_2 \\ F_3 \\ \ldots \\ F_j \end{vmatrix} = \begin{vmatrix} T_{01} & T_{11} & \ldots & T_{j1} \\ T_{02} & T_{12} & \ldots & T_{j2} \\ T_{03} & T_{13} & \ldots & T_{j3} \\ \ldots & \ldots & & \ldots \\ T_{0j} & T_{1j} & \ldots & T_{jj} \end{vmatrix} * \begin{vmatrix} S_0 \\ S_{v1} \\ S_{v2} \\ S_{v3} \\ \ldots \\ S_{vj} \end{vmatrix}$$

$$S_{vj} = -F_i \, \Delta\mu_{ai} \, V_i$$

total fluence rate

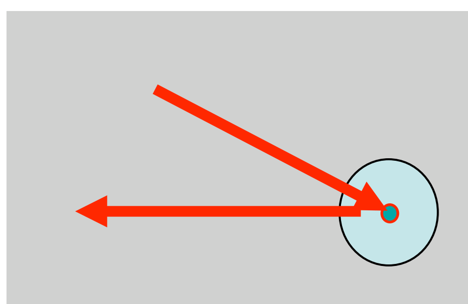
fluence rate without object

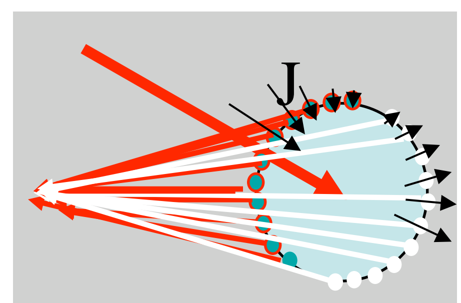
change in fluence rate because of object

$$F(r) = F_o(r) + F_{pert}(r)$$

where

$$F_{pert}(r) = \text{volume component} + \text{surface component}$$





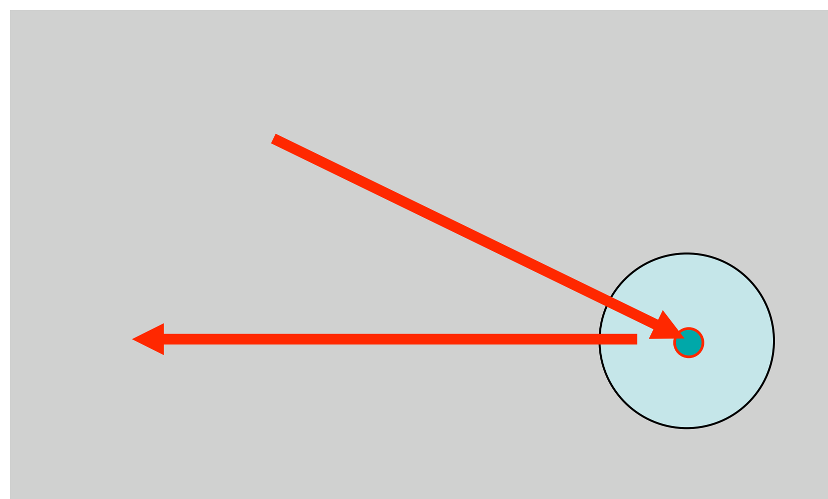
volume component =

fluence rate **P** **transport** **incremental volume**

$$-\int_{V_{object}} F(r') \left(\Delta\mu_a + \Delta\mu'_s \frac{\mu_{a0}}{\mu'_{s0}} + \frac{\Delta\mu_a \Delta\mu'_s}{\mu'_{s0}} \right) T(|r - r'|)\ dV'$$

~ 0

incremental absorption **scattering-enhanced absorption**



surface component =

incremental attenuation

P

transport

flux

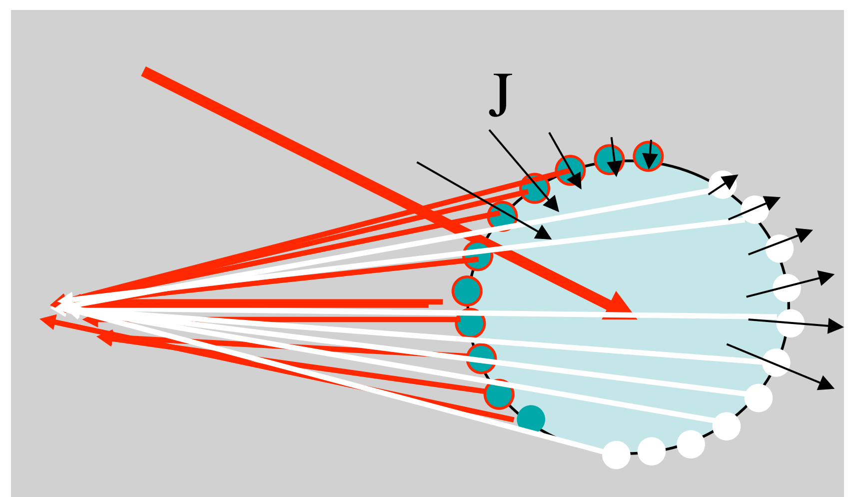
Incremental surface

$$\frac{\Delta\mu_a + \Delta\mu'_s}{\mu'_{s0}} \int_{S_{object}} T(|r - r'|)\; J \bullet dS'$$

Background attenuation

where

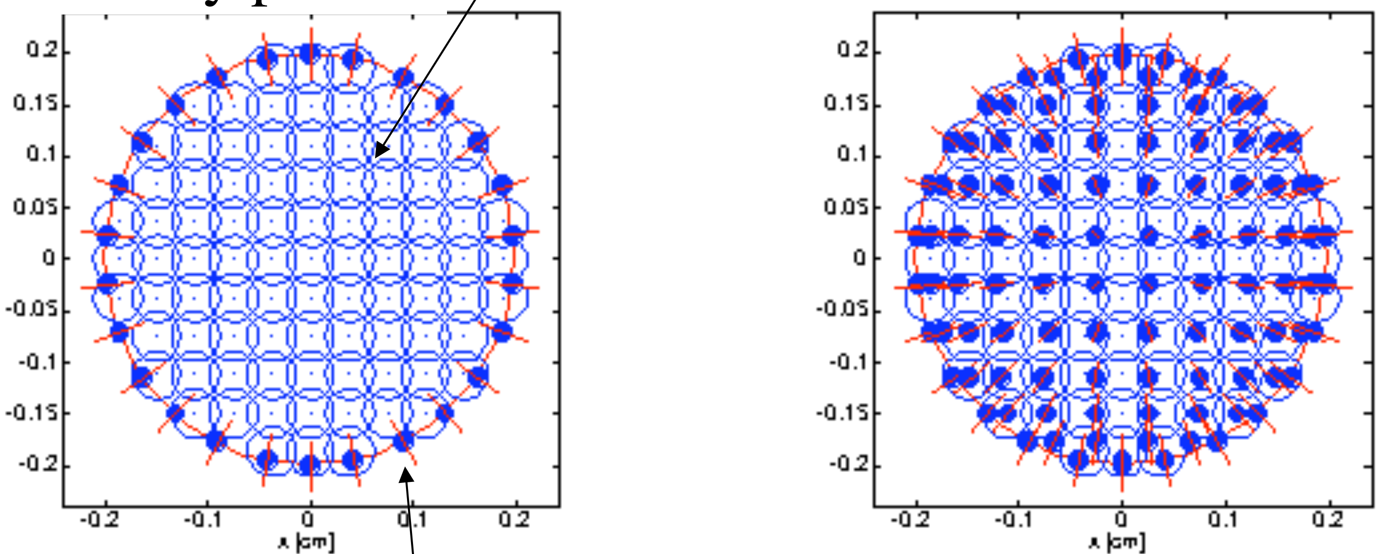
$J = -D\nabla F$, flux entering surface of object



Absorbing volumes

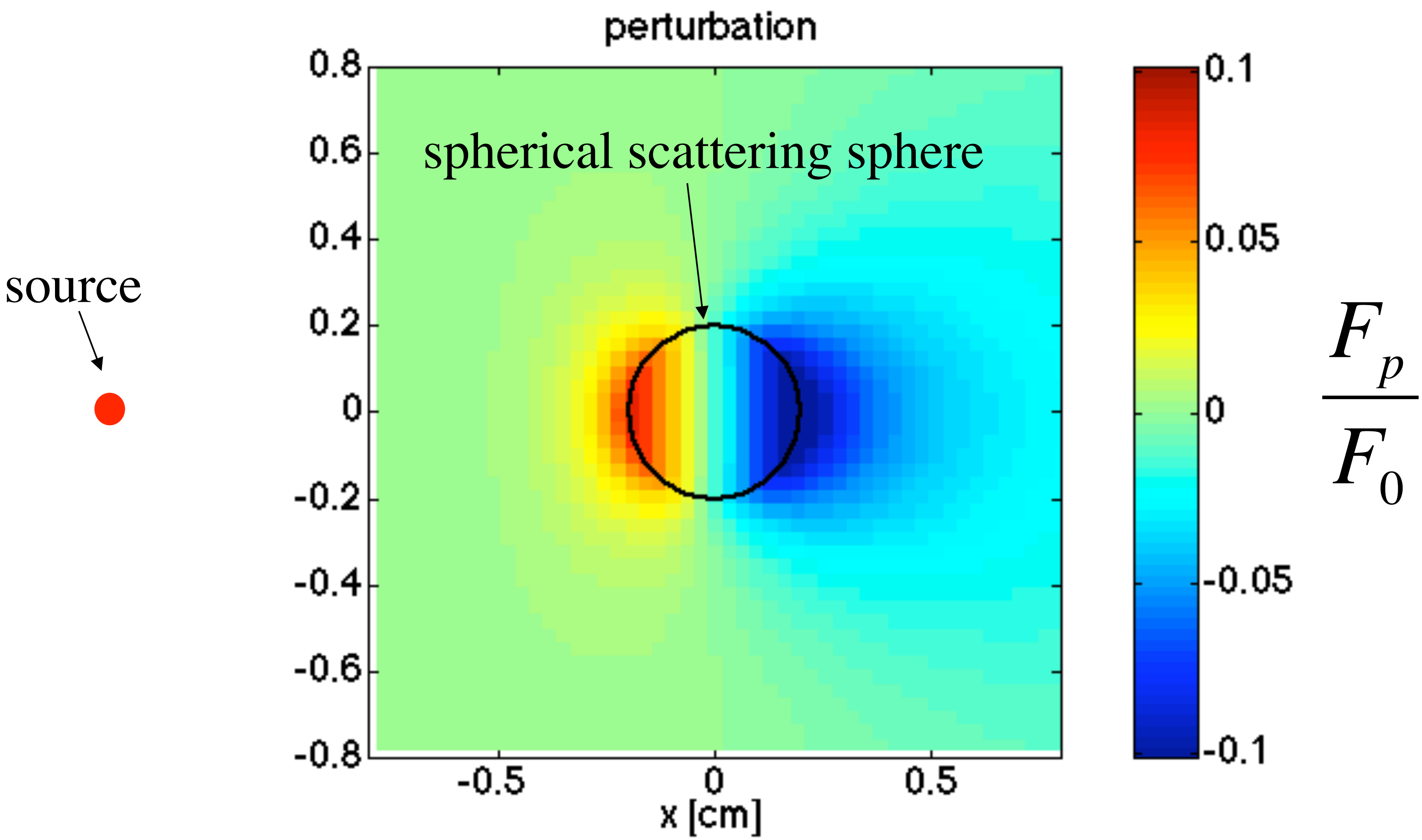
virtual sources in x-y plane

all virtual sources in 3D



Surface sources due to scattering

Perturbation by object

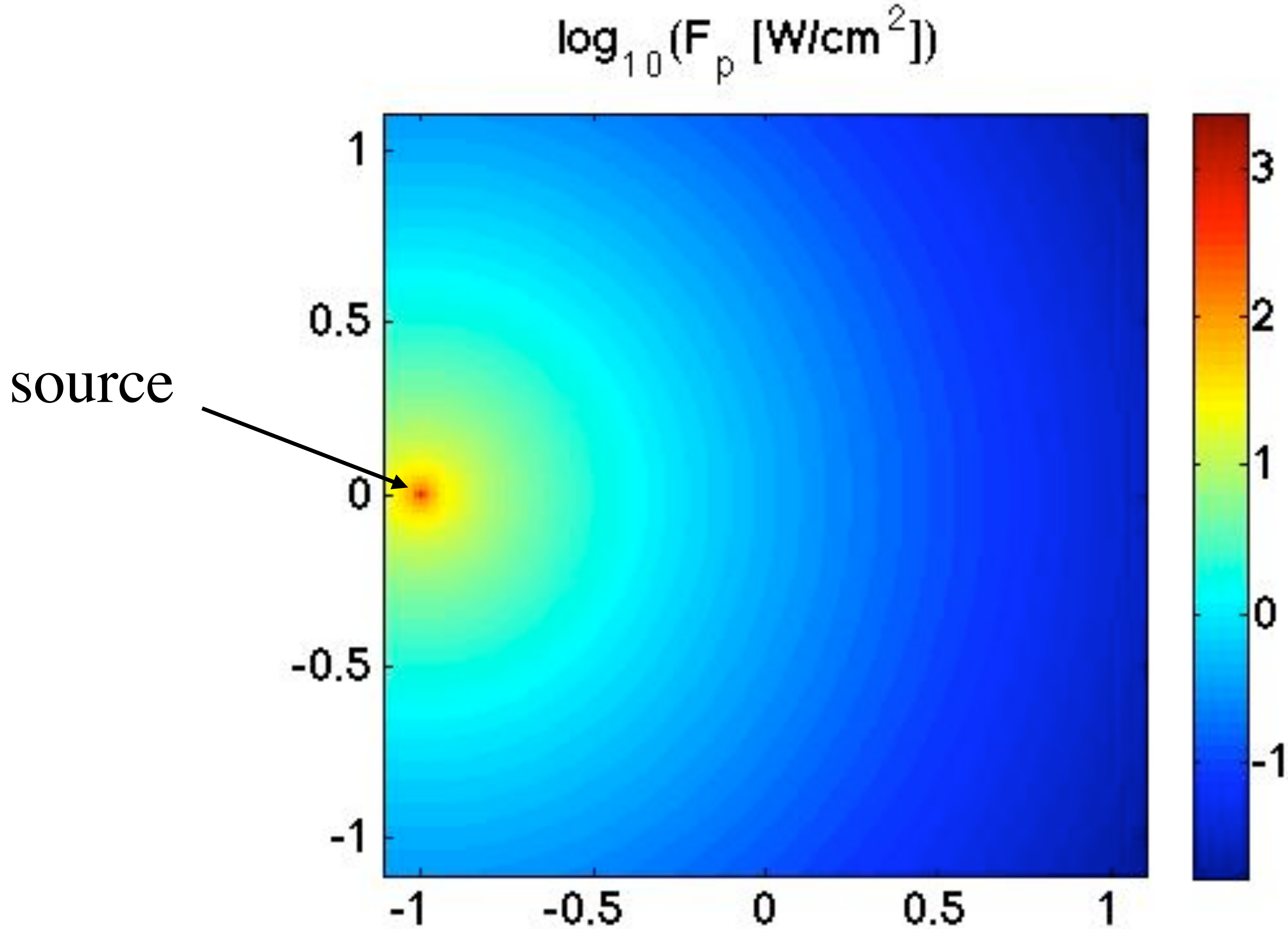


$\mu_{a\ object} = \mu_{a0} = 0.1\ cm^{-1}$

$\mu'_{s\ object} = 20\ cm^{-1},\ \mu'_{s0} = 10\ cm^{-1}$

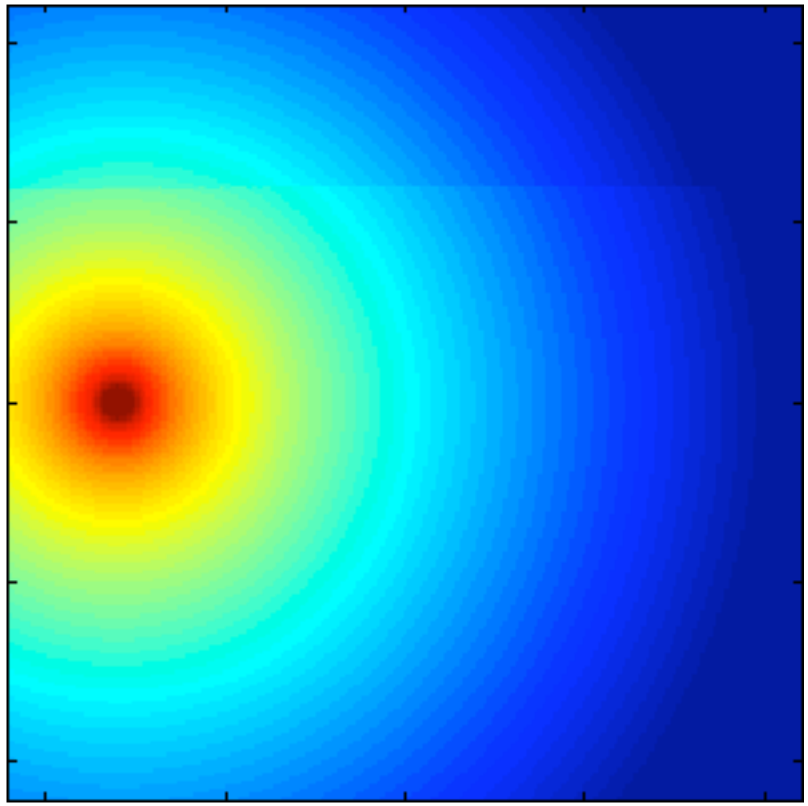
example

$$F_0 = F_{with.object}$$



example

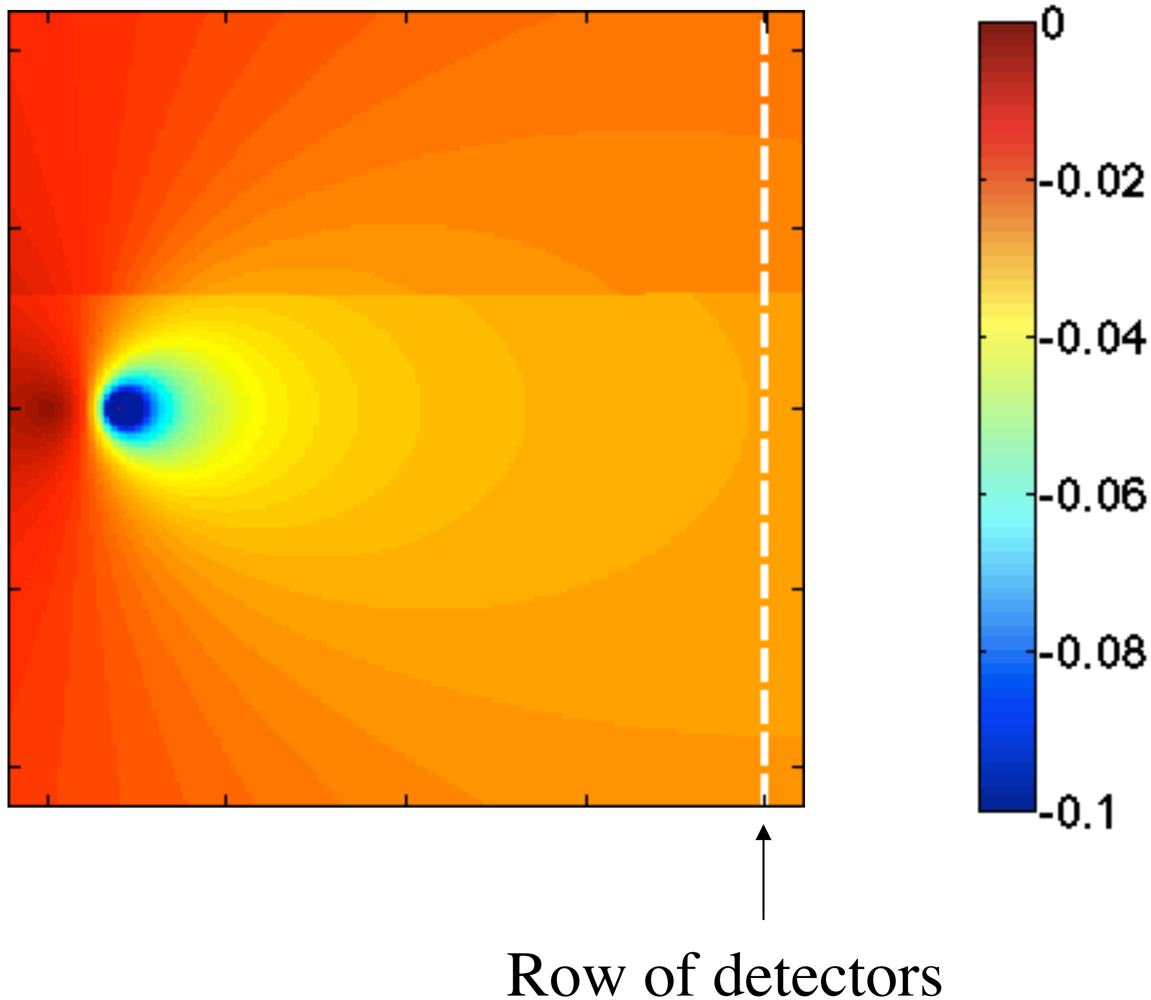
$$F_p = F_{with.object} - F_{no.object}$$



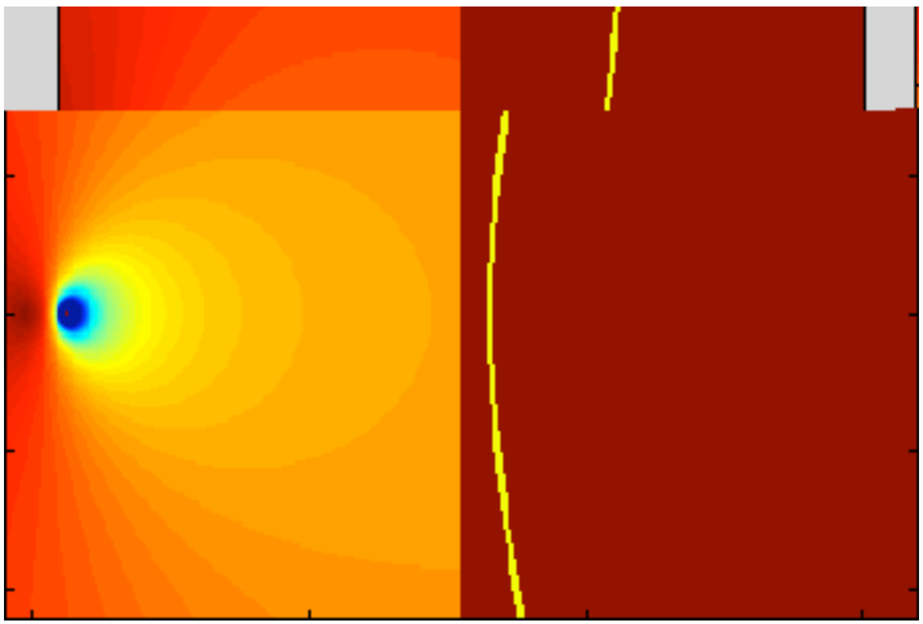
perturbing virtual source

example

$$perturbation = \frac{F_{with.object} - F_{no.object}}{F_{no.object}} = \frac{F_p}{F_0}$$



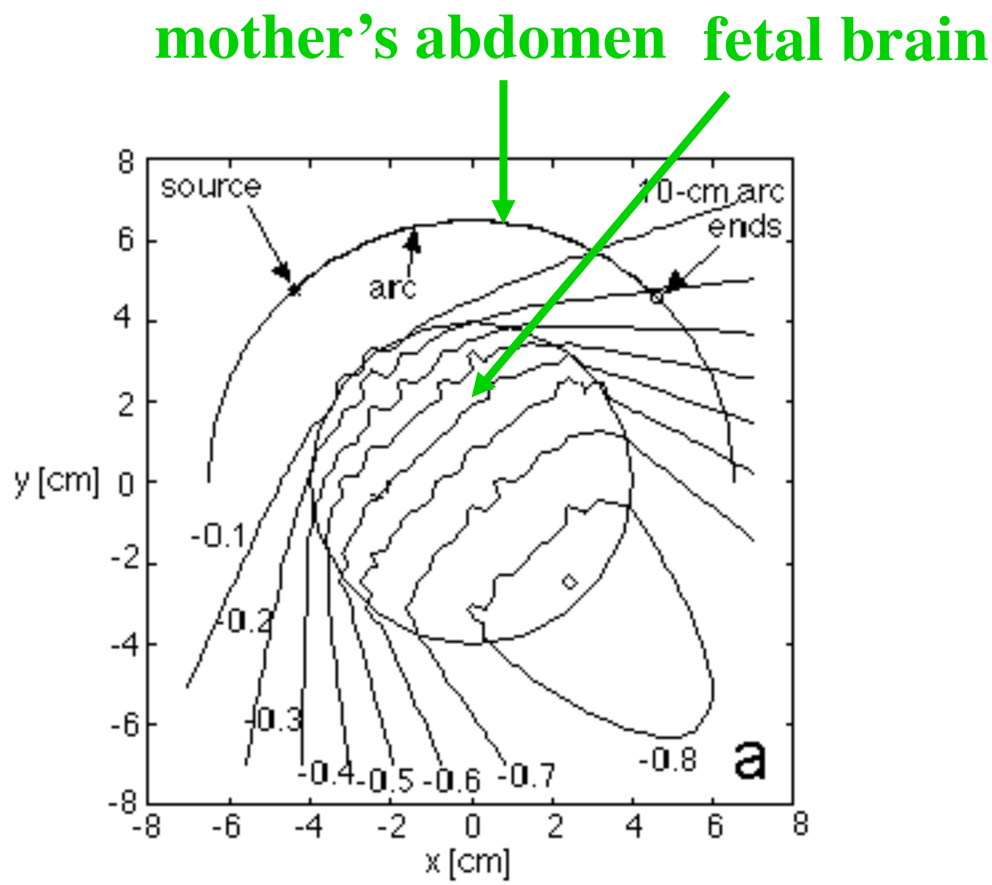
example

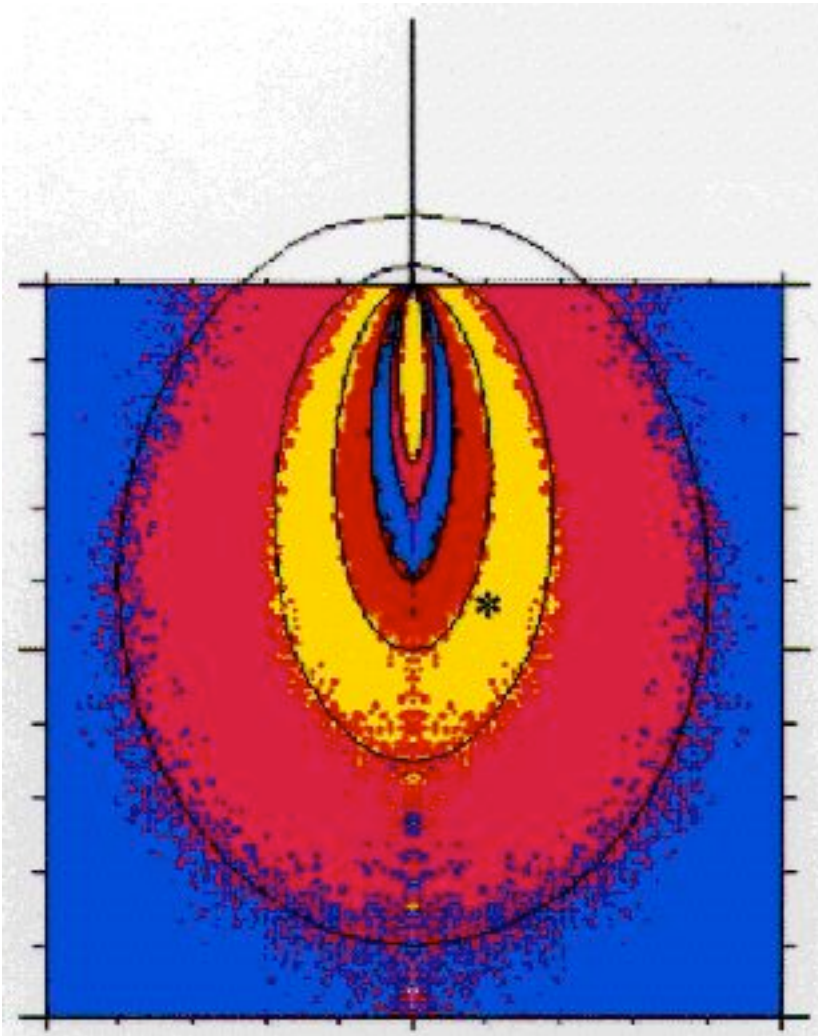


response of detectors

Perturbation by object

$$P = \frac{T_{\text{with fetus}} - T_{\text{without fetus}}}{T_{\text{without fetus}}}$$





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