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THE PREMIER CONFERENCE & EXHIBITION ON
COMPUTER GRAPHICS & INTERACTIVE TECHNIQUES

DEEP REAL-TIME VOLUMETRIC RENDERING

USING MULTI-FEATURE FUSION

Jinkai Hu,*[1] Chengzhong Yu,*[2] Hongli Liu,[3] Lingqi Yan,[4] Yiqian Wu,[1] Xiaogang Jin[1]

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面临的挑战：

体积渲染很 困难

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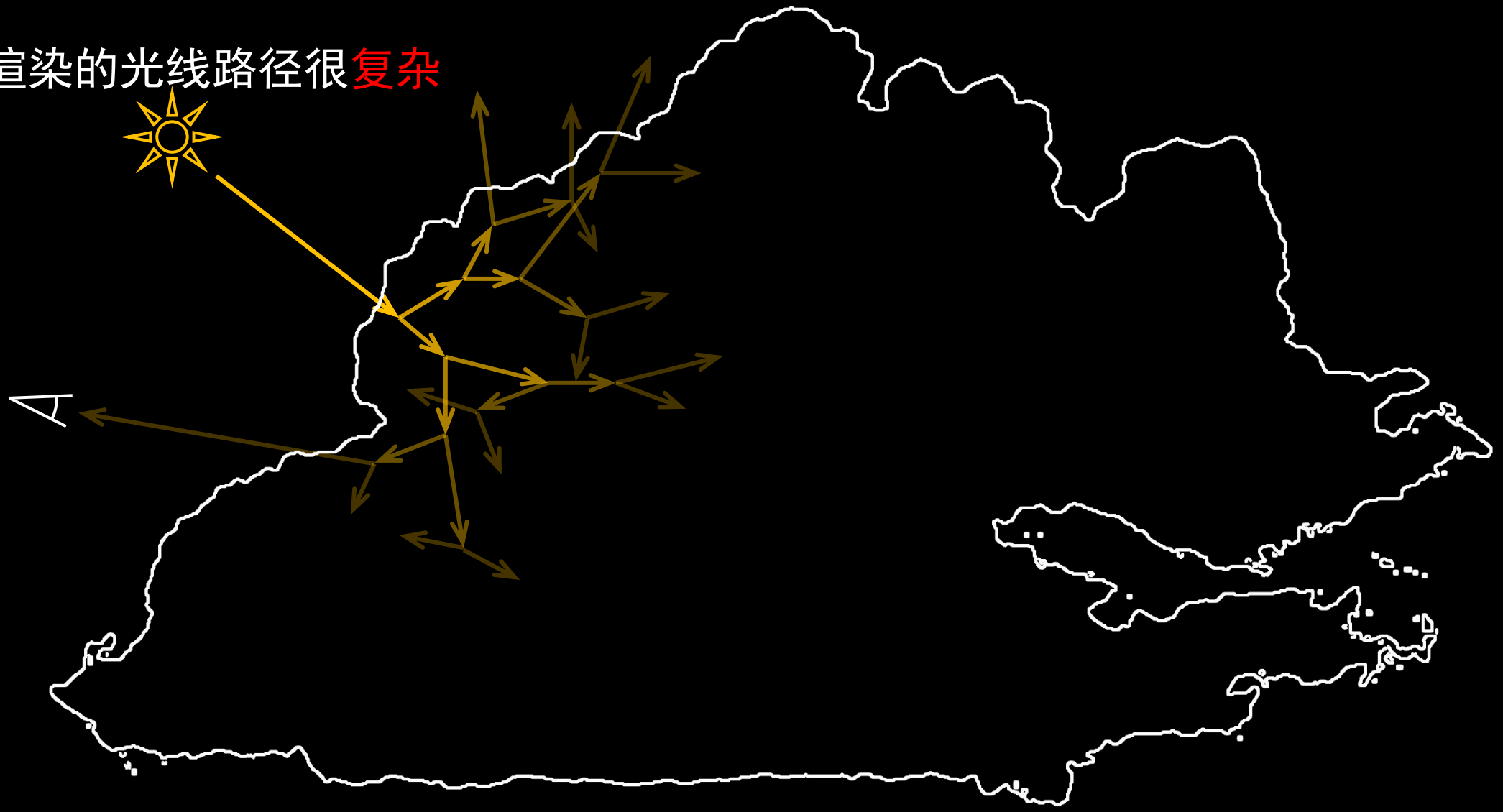
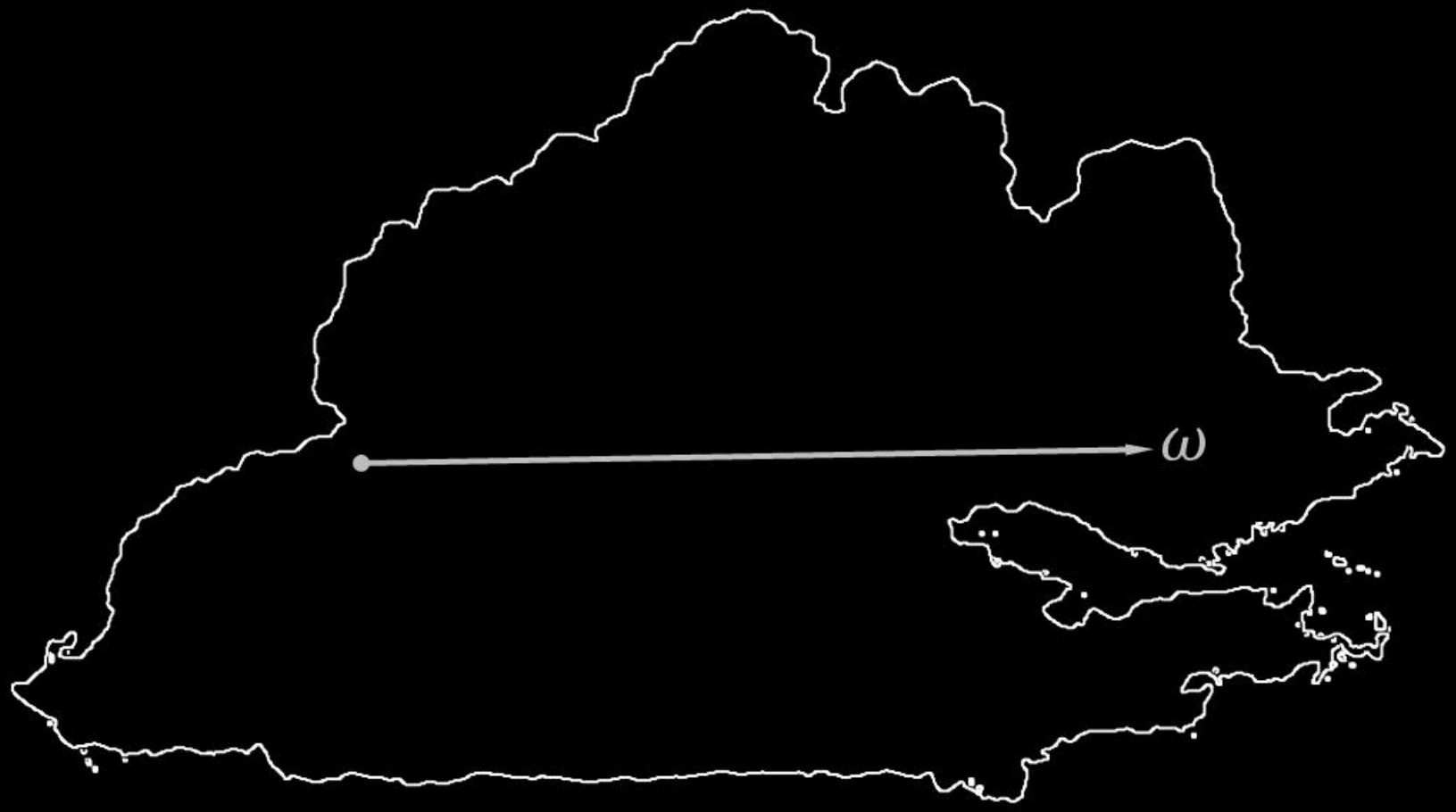
为什么体积渲染很 困难?

- 体积渲染的光线路径很复杂

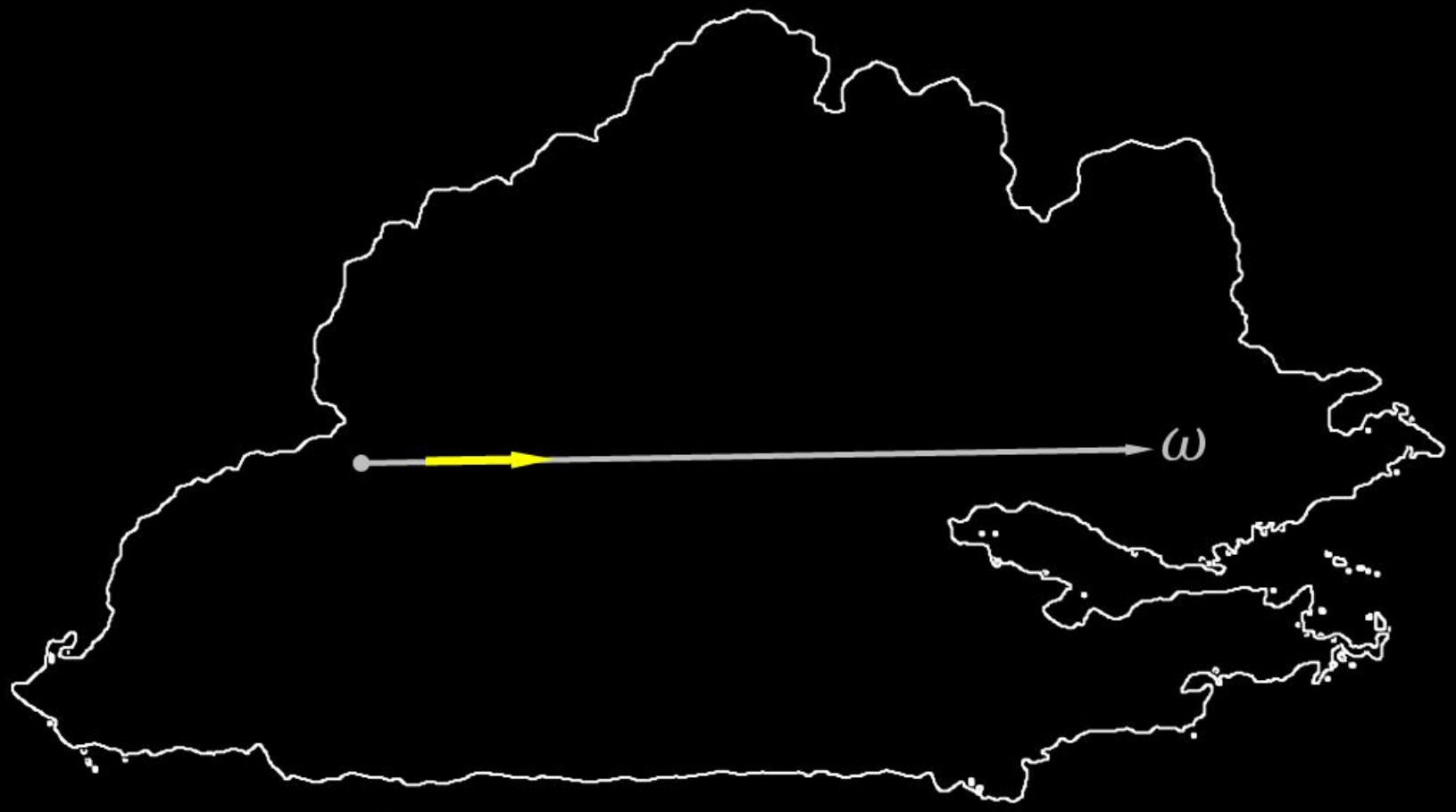


为什么体积渲染很 困难？



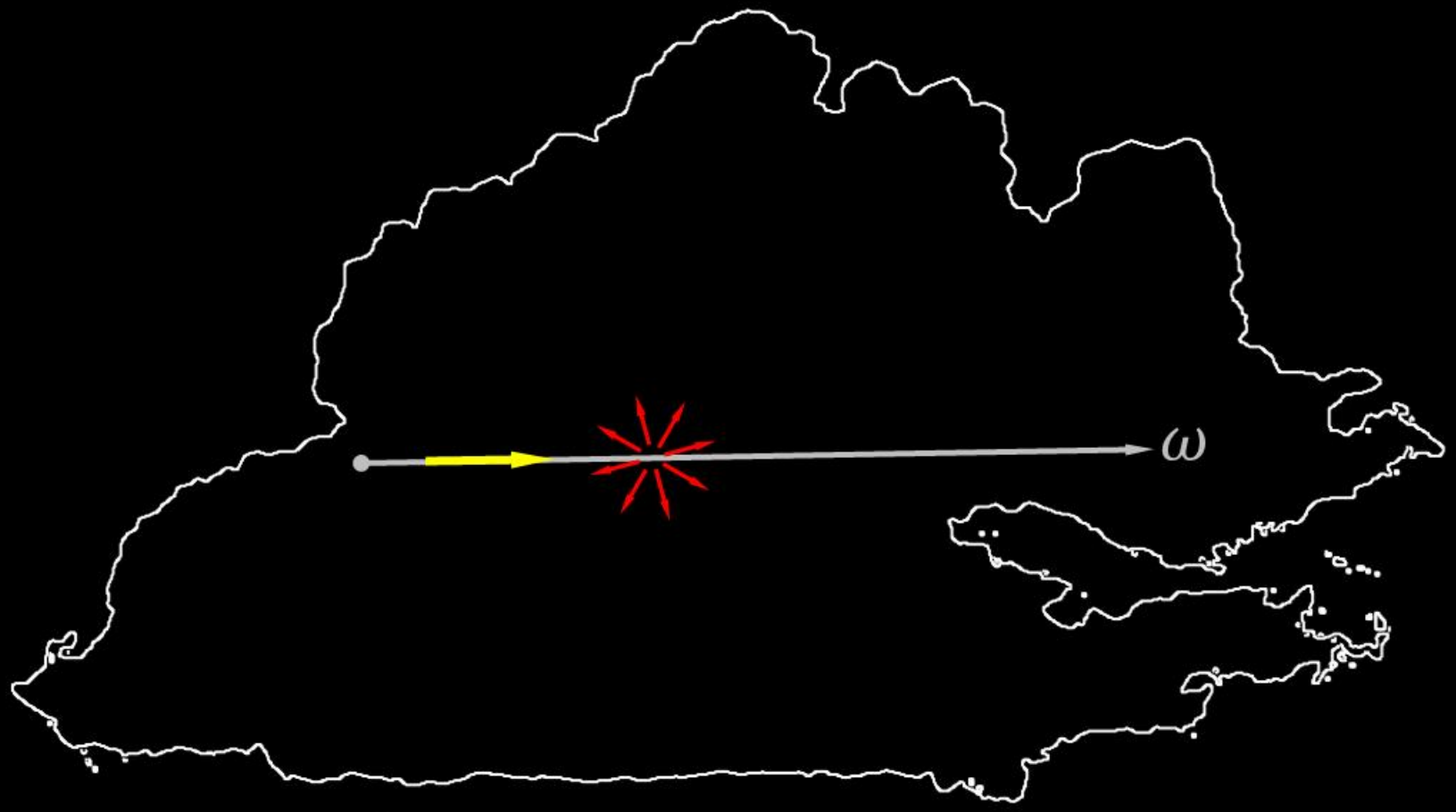
$$\frac{\partial}{\partial \omega} L(x, \omega) =$$

为什么体积渲染很 困难？



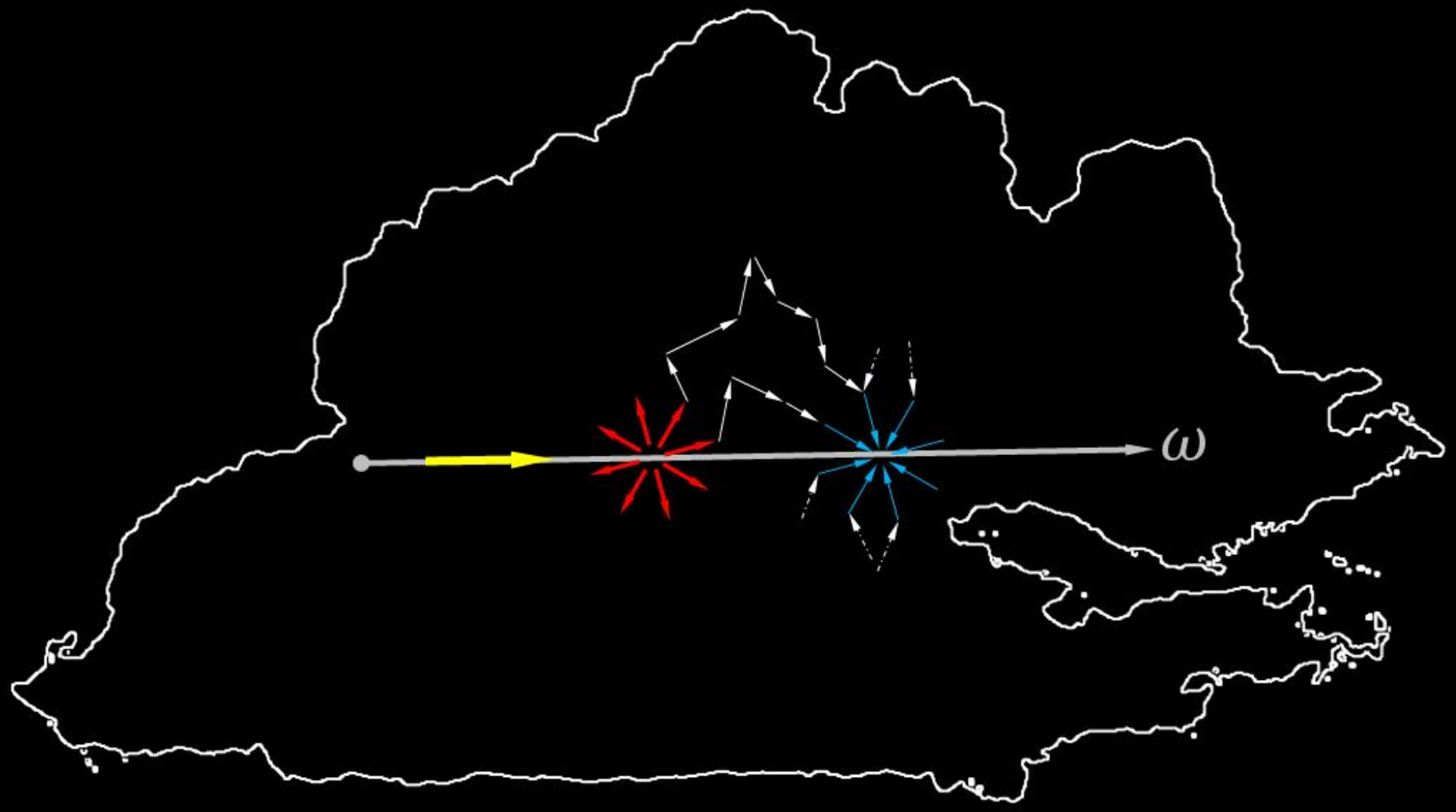
$$\frac{\partial}{\partial \omega} L(x, \omega) = L_e(x, \omega)$$

为什么体积渲染很 困难？



$$\frac{\partial}{\partial \omega} L(x,\omega) = L_e(x,\omega) - \mu_t(x) L(x,\omega)$$

为什么体积渲染很 困难？



$$\frac{\partial}{\partial \omega} L(x,\omega) = L_e(x,\omega) - \mu_t(x) L(x,\omega) + \mu_s(x) \int_{\Omega} p(\omega,\omega_i) L(x,\omega_i) d\omega_i$$

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探究

RADIANCE TRANSPORT EQUATION

$$\frac{\partial}{\partial \omega} L(x,\omega) = L_e(x,\omega) - \mu_t(x) L(x,\omega) + \mu_s(x) \int_{\Omega} p(\omega,\omega_i) L(x,\omega_i) d\omega_i$$

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探究 RTE

$$\frac{\partial}{\partial \omega} L(x,\omega) = L_e(x,\omega) - \mu_t(x) L(x,\omega) + \mu_s(x) \int_{\Omega} p(\omega,\omega_i) L(x,\omega_i) d\omega_i$$

探究 RTE

$$\frac{\partial}{\partial \omega} L(x,\omega) = \underbrace{L_e(x,\omega)}_{\text{自发光项}} - \mu_t(x) L(x,\omega) + \mu_s(x) \int_{\Omega} p(\omega,\omega_i) L(x,\omega_i) d\omega_i$$

探究 RTE

$$\frac{\partial}{\partial \omega} L(x,\omega) = \underbrace{L_e(x,\omega)} - \mu_t(x) L(x,\omega) + \mu_s(x) \int_{\Omega} p(\omega,\omega_i) L(x,\omega_i) d\omega_i$$

我们忽略自发光项

探究 RTE

$$\frac{\partial}{\partial \omega} L(x,\omega) = \underbrace{-\mu_t(x)L(x,\omega)}_{\text{Extinction}} + \mu_s(x)\int_{\Omega} p(\omega,\omega_i)L(x,\omega_i)d\omega_i$$

（衰减）

探究 RTE

$$\frac{\partial}{\partial \omega} L(x,\omega) = \underbrace{-\mu_t(x)L(x,\omega)}_{\text{Extinction（衰减）}} + \underbrace{\mu_s(x)\int_{\Omega} p(\omega,\omega_i)L(x,\omega_i)d\omega_i}_{\text{In-scattering（入射散射）}}$$

探究 RTE

$$L(x,\omega) = \int_x^z e^{-\int_x^y \mu_t(v)dv} \mu_s(x) \int_\Omega p(\omega,\omega_i) L(x,\omega_i) d\omega_i \, du$$

探究 RTE

$$L(x,\omega) = \int_x^z e^{-\int_x^y \mu_t(v)dv} \mu_s(u) \int_\Omega p(\omega,\omega_i) L(u,\omega_i) d\omega_i \, du$$

探究 RTE

$$\underbrace{L(x,\omega)}_{\text{这里需要递归积分}} = \int_x^z e^{-\int_x^y \mu_t(v)dv} \mu_s(u) \int_\Omega p(\omega,\omega_i) L(u,\omega_i) d\omega_i \, du$$

探究 RTE

$$\underbrace{L(x,\omega)}_{\text{这里需要递归积分}} = \int_x^z T(x,u)\mu_s(u)\int_\Omega p(\omega,\omega_i)L(u,\omega_i)d\omega_i\,du$$

探究 RTE

$$\underbrace{L(x,\omega)}_{\text{这里需要递归积分}} = \int_x^z T(x,u)\mu_s(u)\int_\Omega p(\omega,\omega_i)L(u,\omega_i)d\omega_i\,du$$

$$T(x,y) = e^{-\int_x^y \mu_t(v)dv}$$

探究 RTE

$$L(x,\omega) = \int_x^z T(x,u)\mu_s(u)S(u,\omega)du$$

$$T(x,y) = e^{-\int_x^y \mu_t(v)dv}$$

$$S(x,\omega) = \int_\Omega p(\omega,\omega_i)L(u,\omega_i)d\omega_i$$

探究 RTE

$$L(x,\omega) = \int_x^z T(x,u)\mu_s(u)S(u,\omega)du$$

$$T(x,y) = e^{-\int_x^y \mu_t(v)dv}$$

$$S(x,\omega) = \int_\Omega p(\omega,\omega_i)L(u,\omega_i)d\omega_i$$

探究 RTE

$$L(x,\omega) = \int_x^z T(x,u)\mu_s(u)S(u,\omega)du$$

$$T(x,y) = e^{-\int_x^y \mu_t(v)dv}$$

$$S(x,\omega) = \int_\Omega p(\omega,\omega_i)L(u,\omega_i)d\omega_i$$

如果我们可以快速求解 S …

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先行研究

RADIANCE PREDICT NEURAL NETWORKS (RPNN)

by Kallweit et al.[2017]

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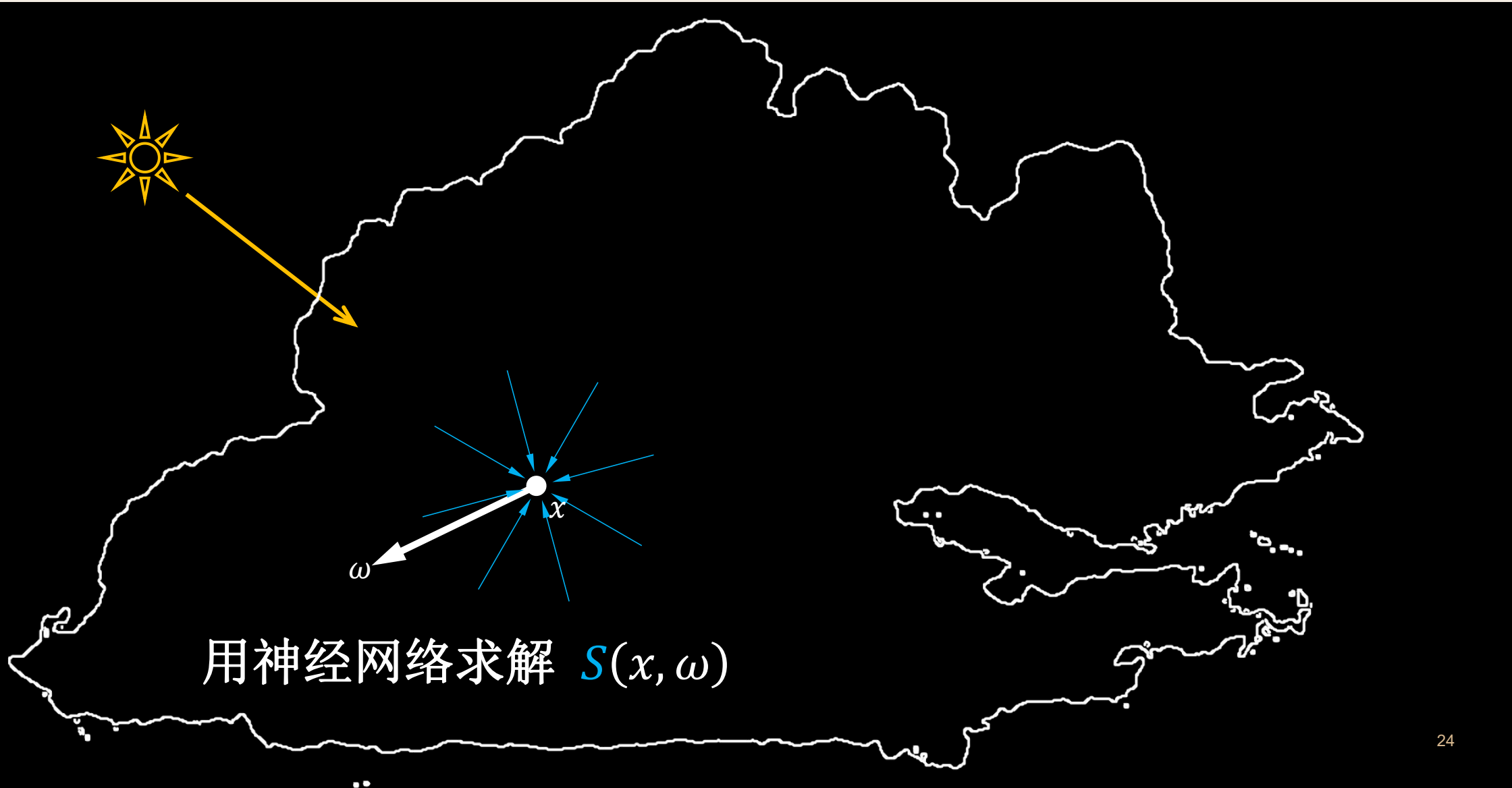
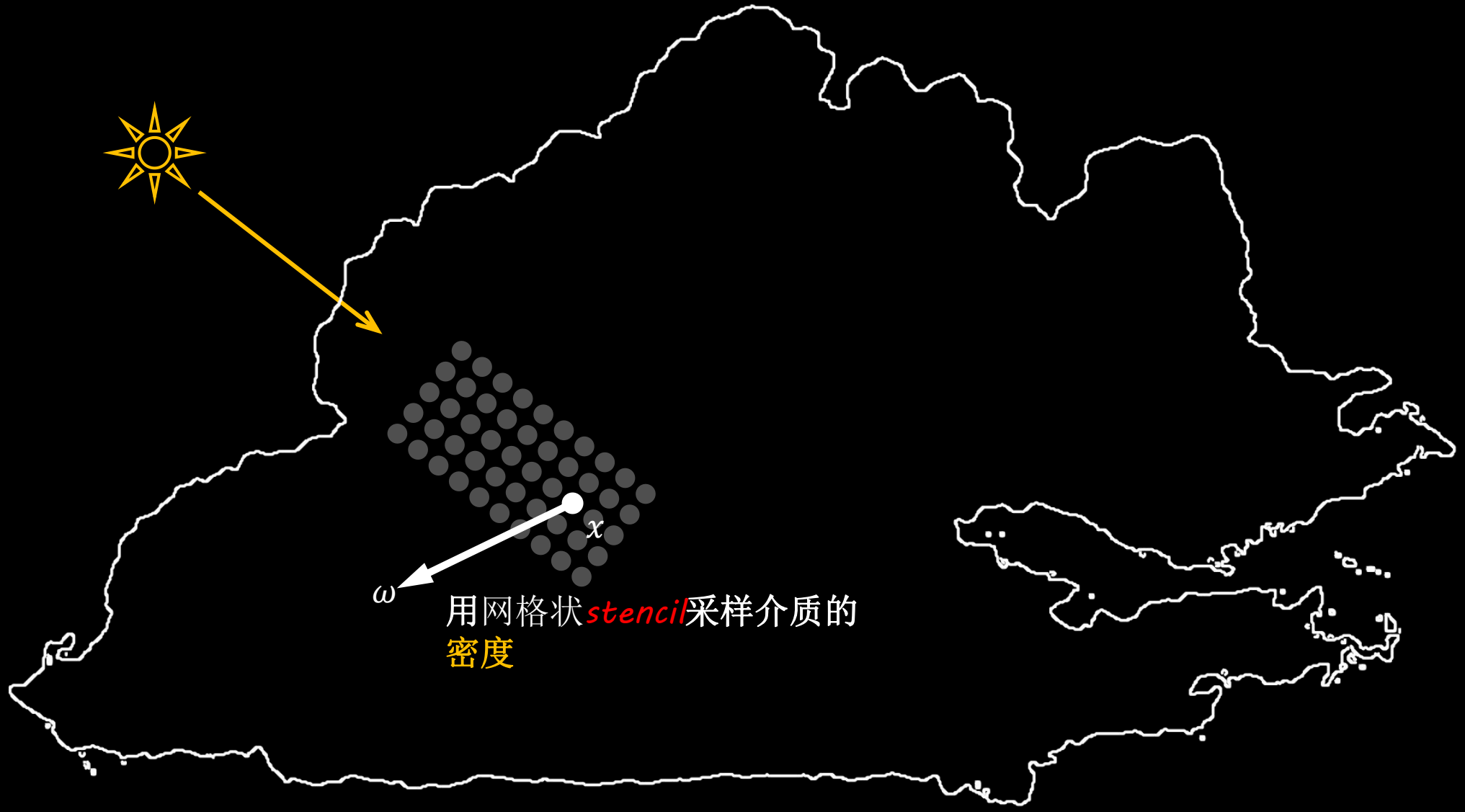
辐射度预测神经网络 (RPNN)

$$\underbrace{S(x,\omega)}_{\text{用神经网络求解 } S} = \int_{\Omega} p(\omega,\omega_i) L(u,\omega_i) d\omega_i$$

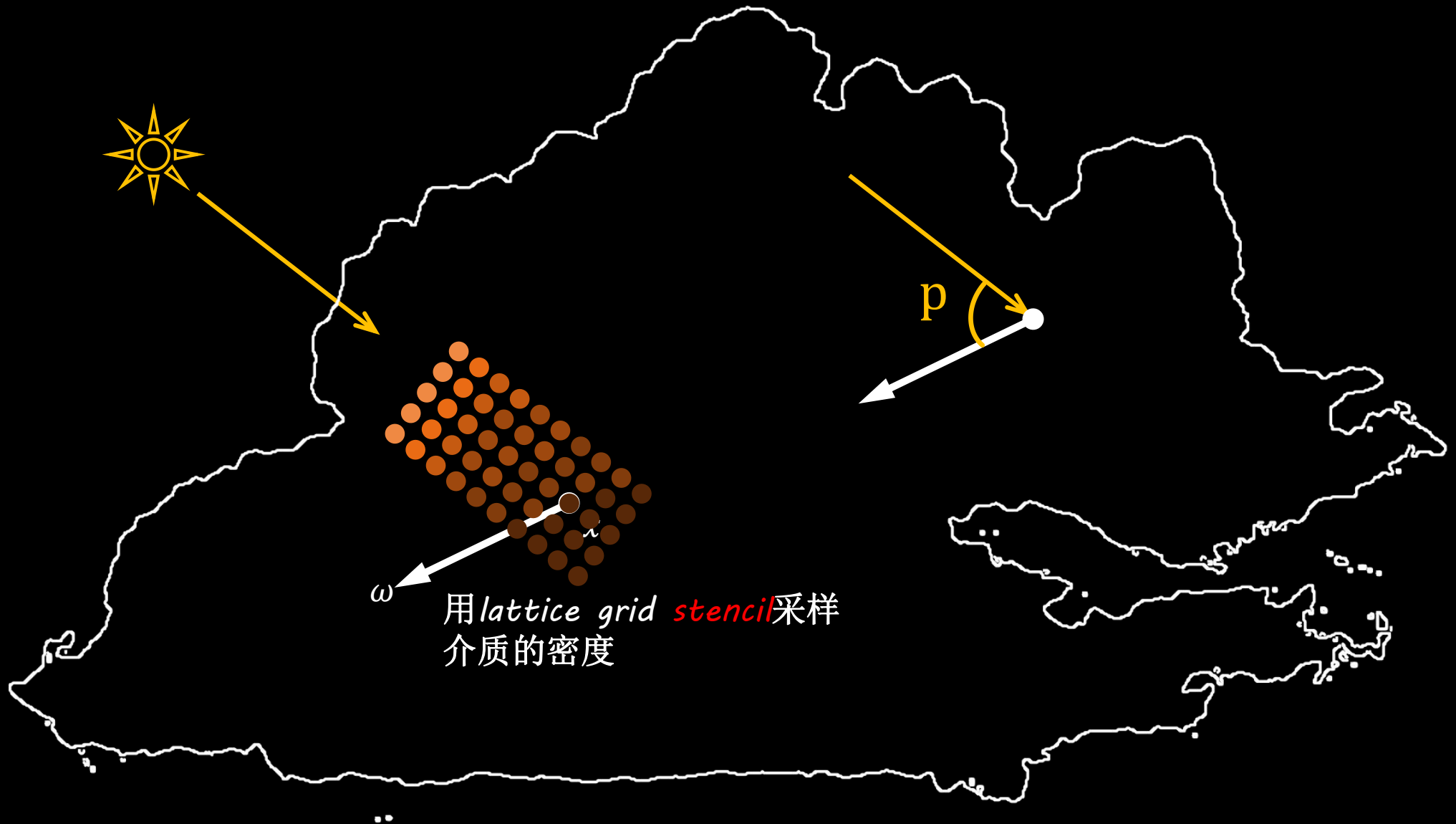
辐射度预测神经网络 (RPNN)



辐射度预测神经网络 (RPNN)



辐射度预测神经网络 (RPNN)



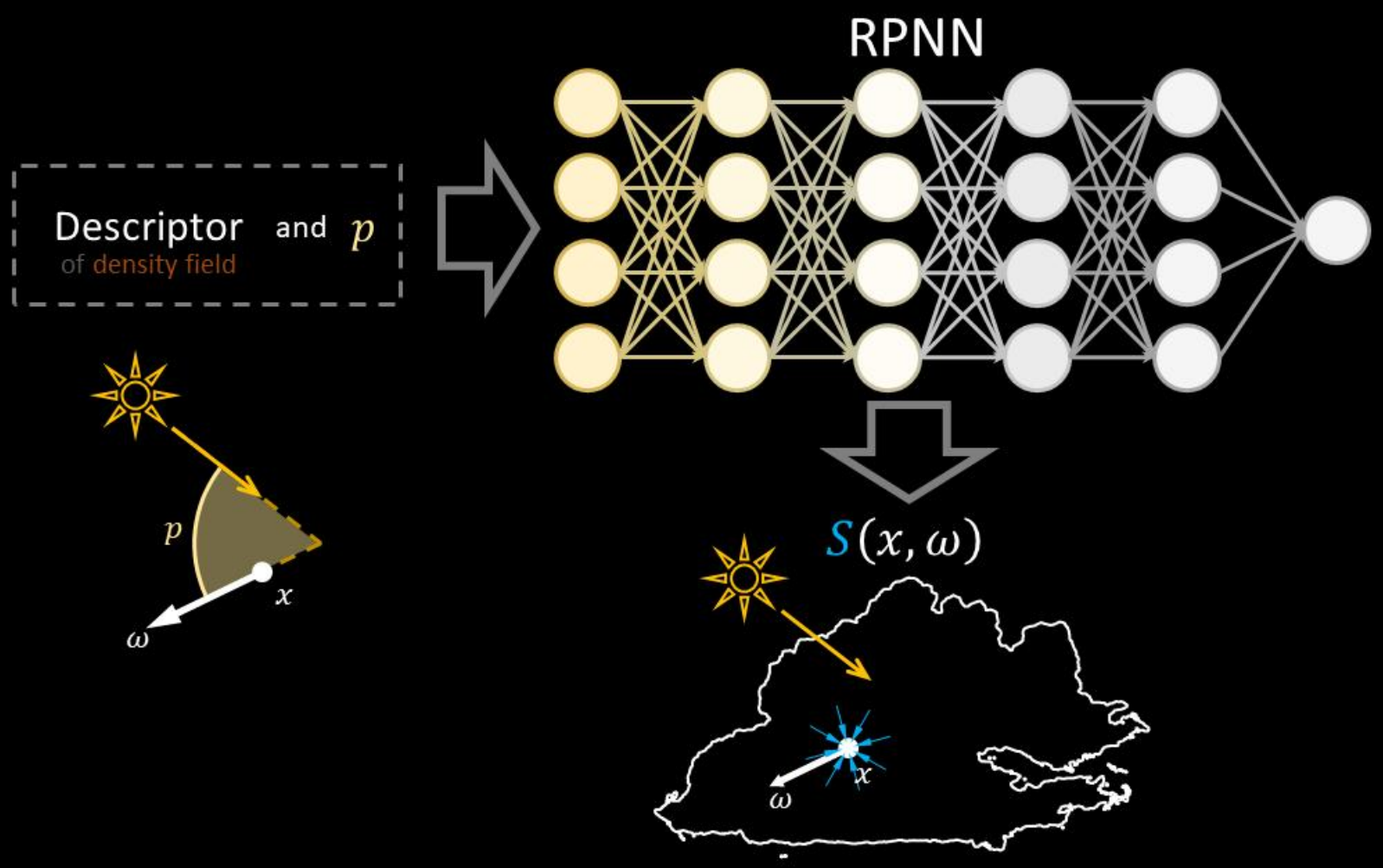
辐射度预测神经网络 (RPNN)

密度场Descriptor = {●●●

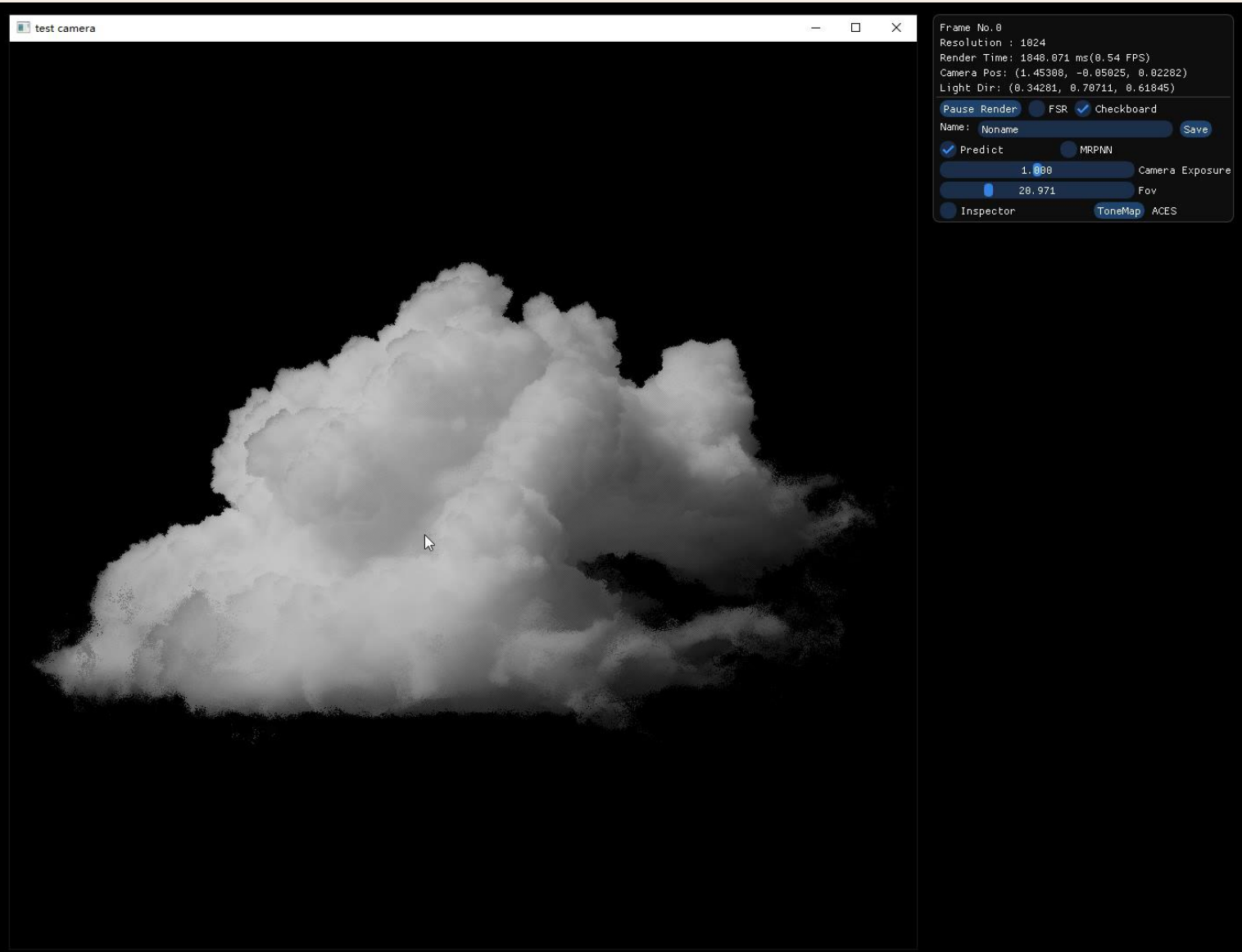
辐射度预测神经网络 (RPNN)

完整 Descriptor = {●●●

辐射度预测神经网络 (RPNN)



结果 (RPNN)


test camera
Frame No.0
Resolution : 1024
Render Time: 1848.071 ms(0.54 FPS)
Camera Pos: (1.45308, -0.05025, 0.02282)
Light Dir: (0.34281, 0.70711, 0.61845)
Pause Render
FSR
Checkboard
Name:
Noname
Save
Predict
MRPNN
1.000
Camera Exposure
20.971
Fov
Inspector
ToneMap
ACES

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依然存在的挑战：

RPNN 还是太慢

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我们的方法 (MRPNN)

- 密度场和S的关系依然很复杂

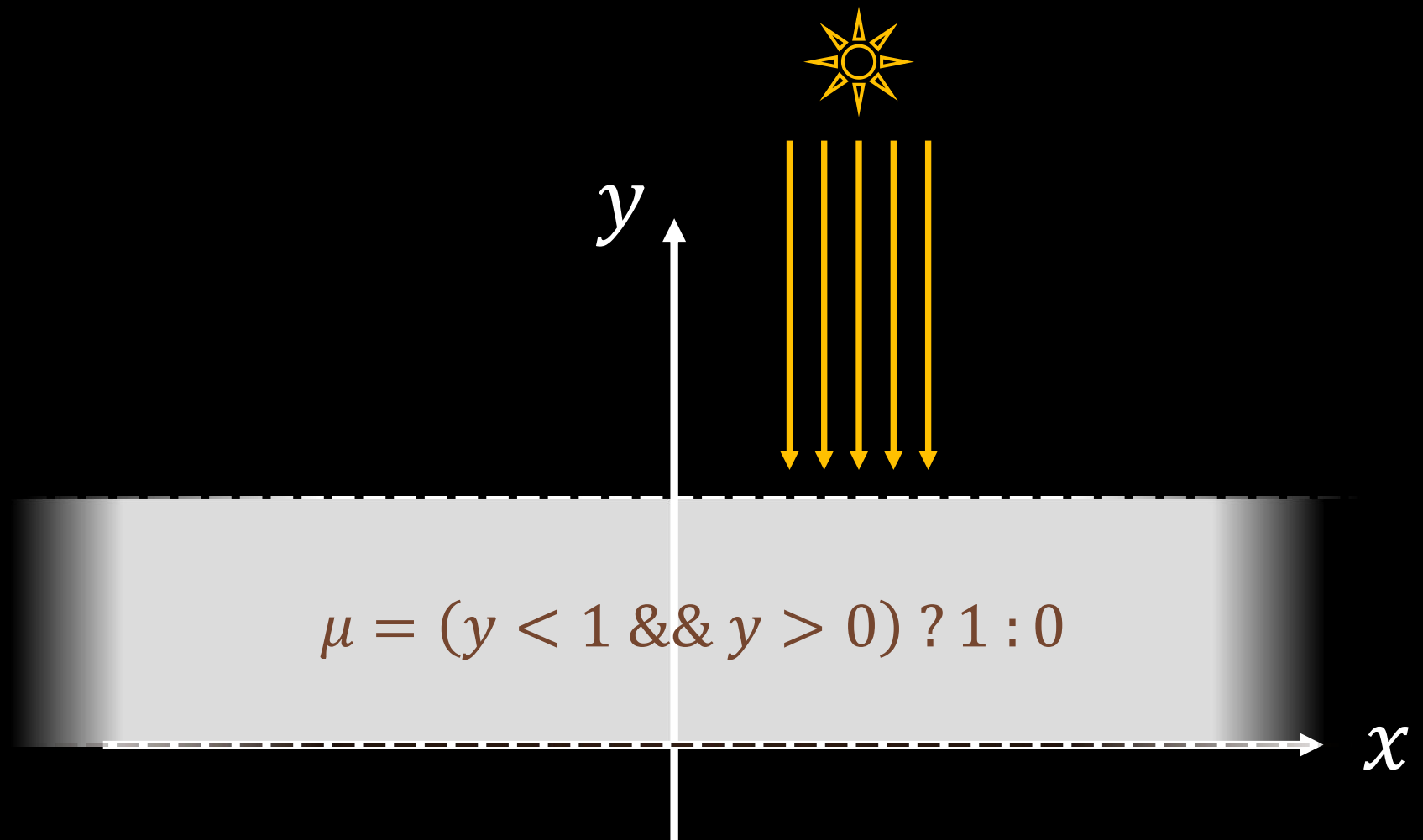
我们的方法 (MRPNN)

- 密度场和S的关系依然很复杂

让我们看看一个简单的例子

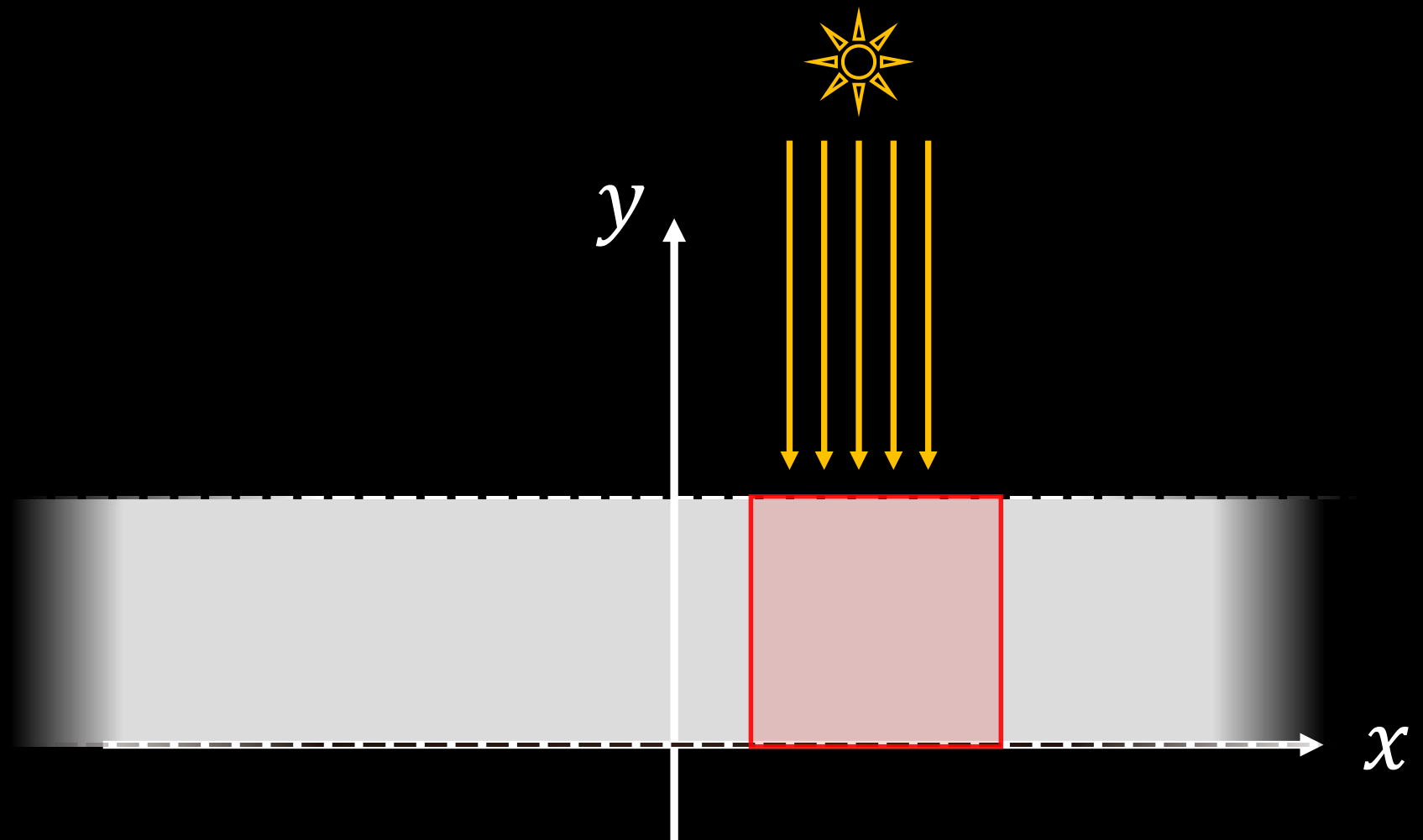
我们的方法 (MRPNN)

一个简单的例子



我们的方法 (MRPNN)

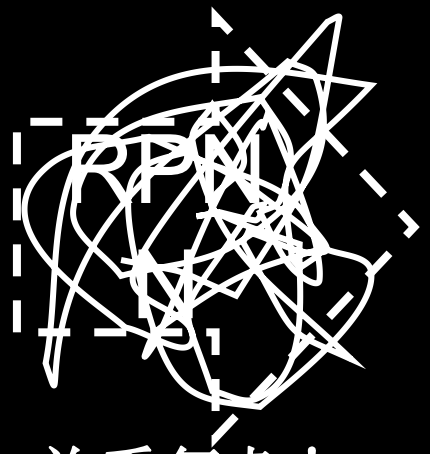
一个简单的例子



我们的方法 (MRPNN)

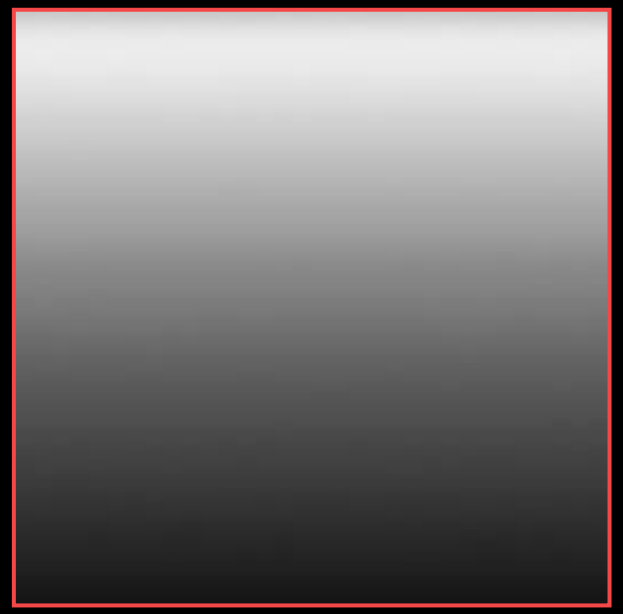
一个简单的例子

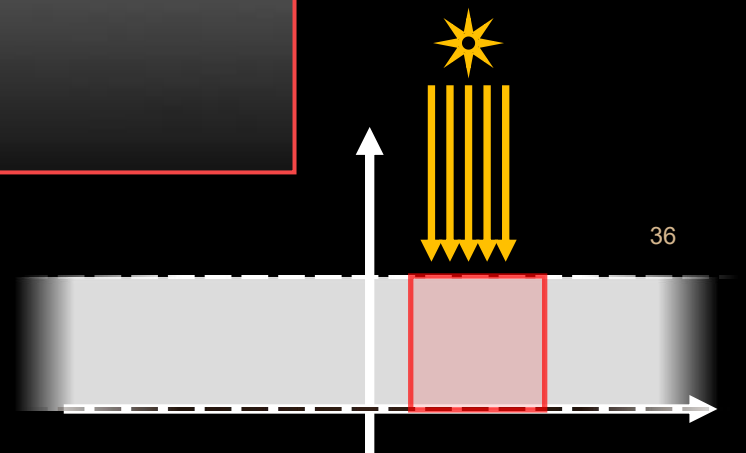
密度场



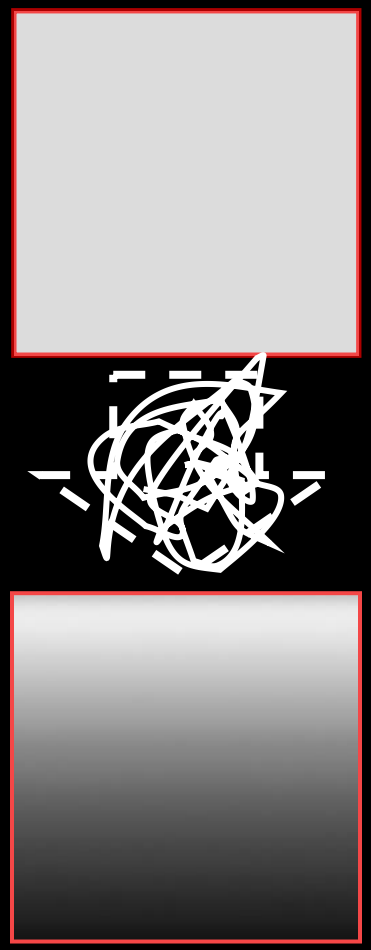
关系复杂！

S 场

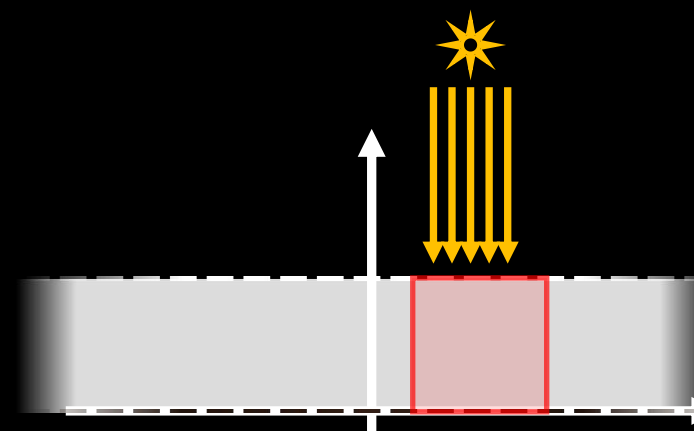




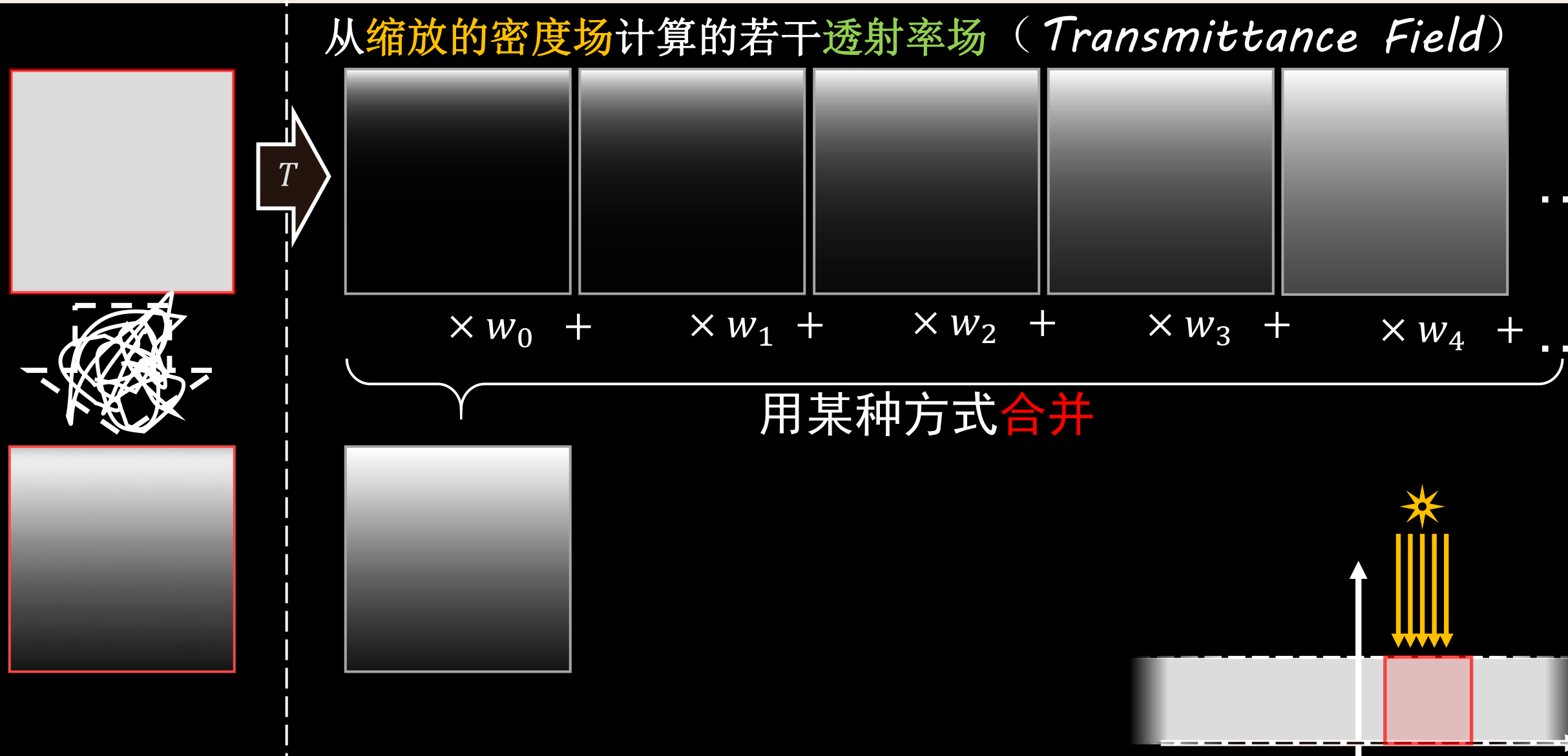
我们的方法 (MRPNN)



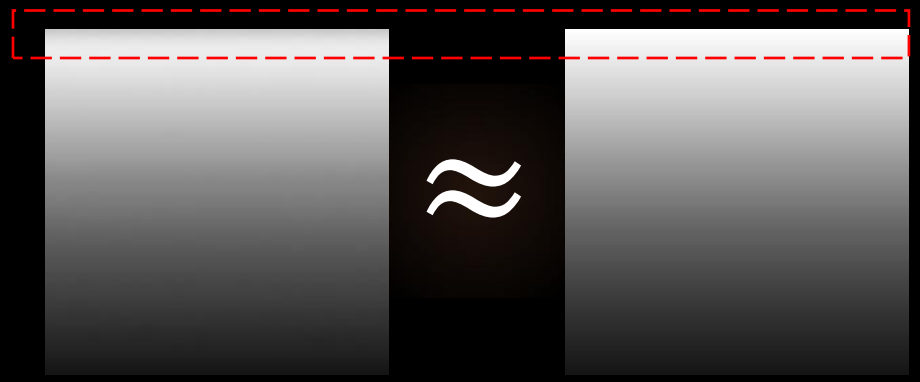
但是，如果我们 ...



我们的方法 (MRPNN)

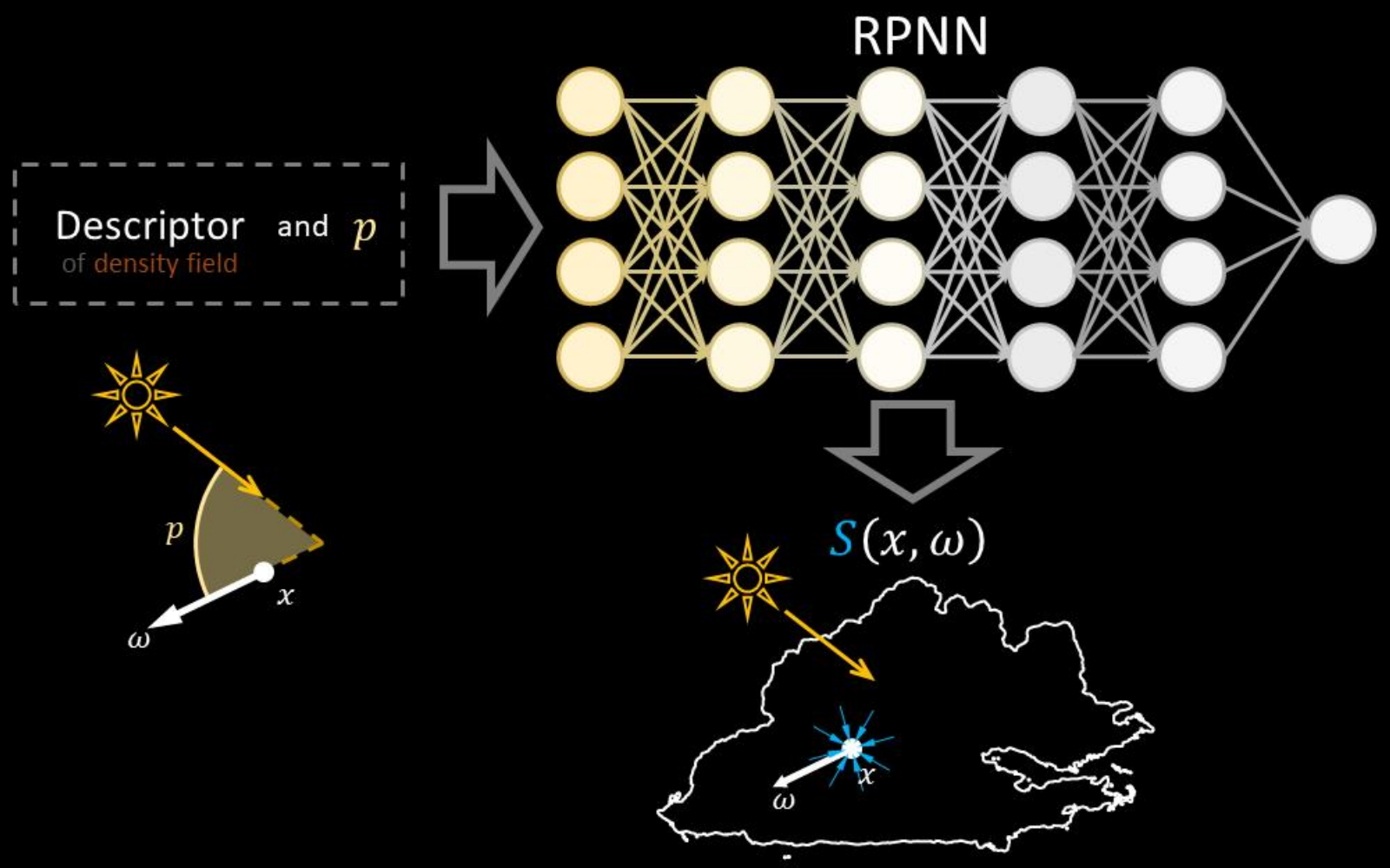

从缩放的密度场计算的若干透射率场（Transmittance Field）
T
$\times w_0$ +
$\times w_1$ +
$\times w_2$ +
$\times w_3$ +
$\times w_4$ +
用某种方式合并

我们的方法 (MRPNN)

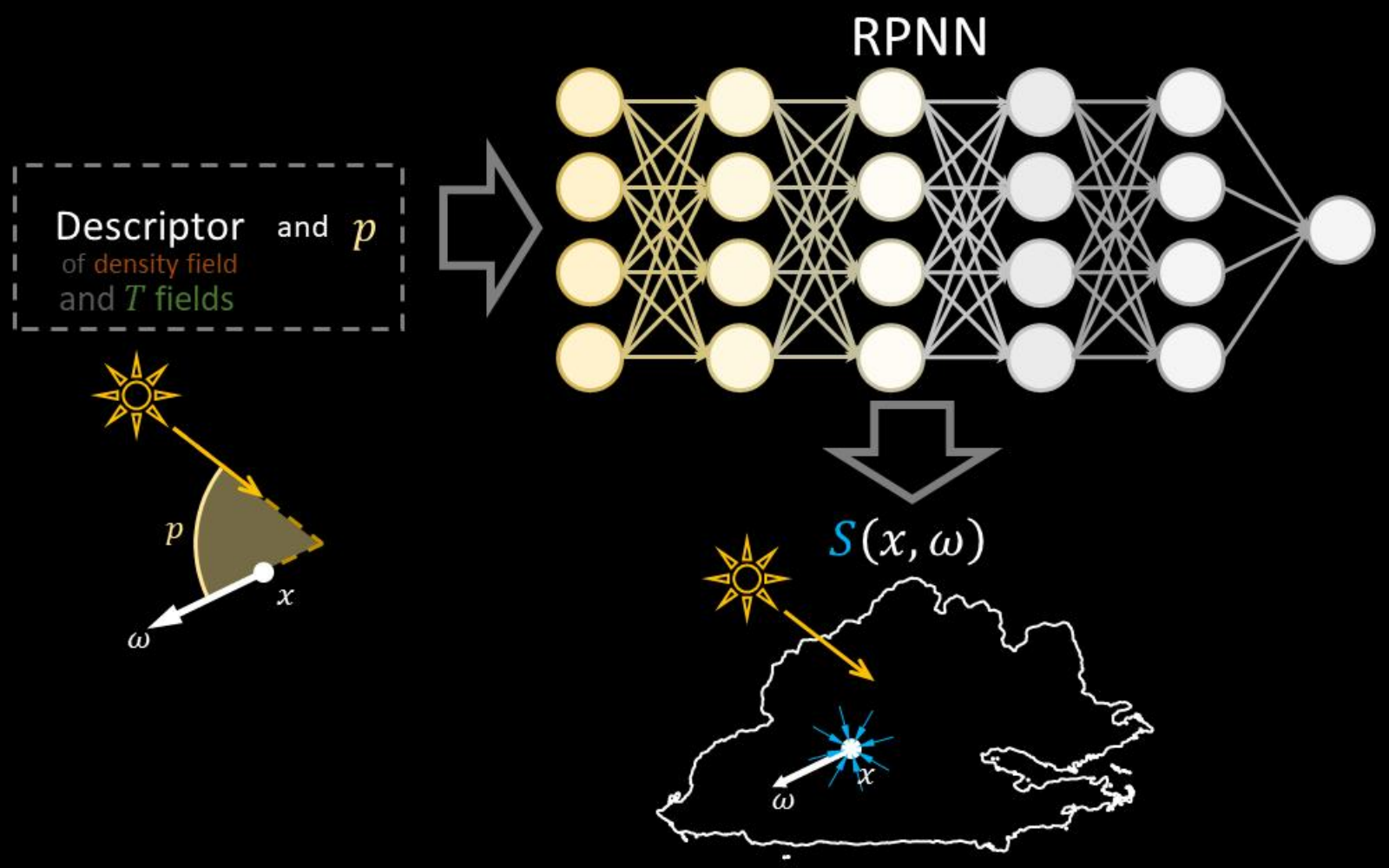


一个很好的粗略估计

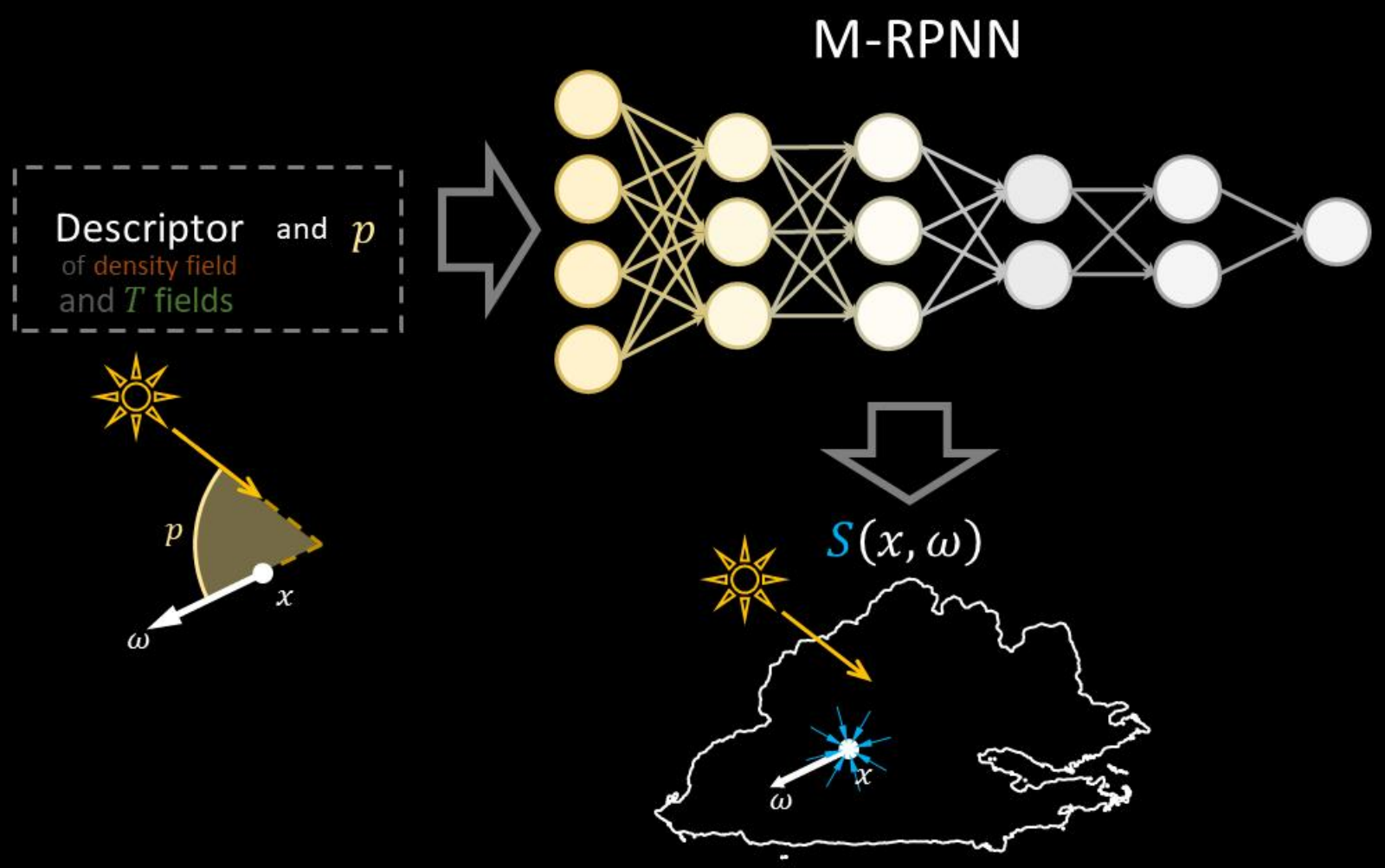
我们的方法 (MRPNN)


RPNN
Descriptor and p
of density field
p
x
ω
$S(x, \omega)$
x
ω

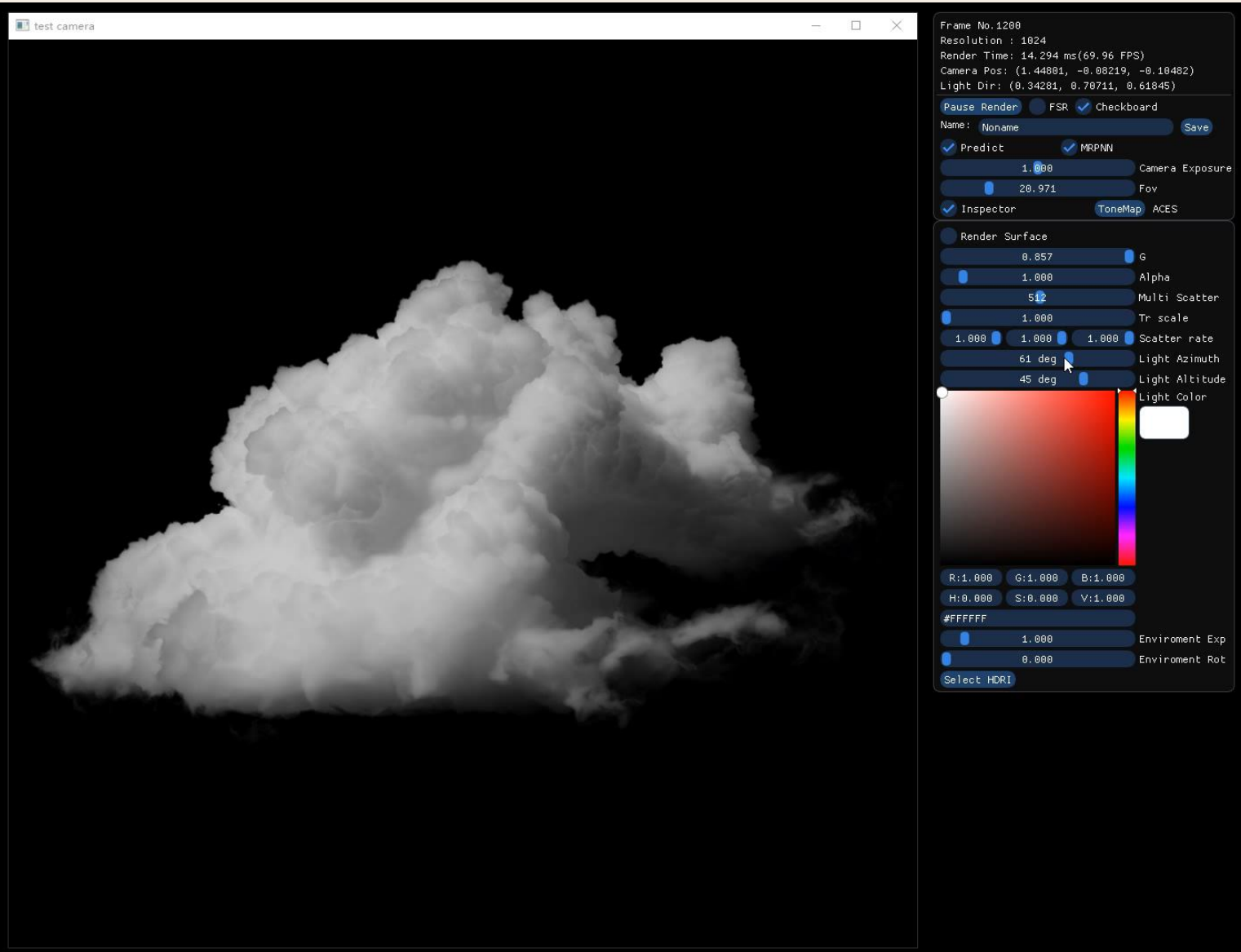
我们的方法 (MRPNN)


RPNN
Descriptor and p
of density field
and T fields
p
x
ω
$S(x, \omega)$
x
ω

我们的方法 (MRPNN)


M-RPNN
Descriptor and p
of density field
and T fields
p
x
ω
$S(x, \omega)$
x
ω

结果 (MRPNN)


test camera
Frame No.1200
Resolution : 1024
Render Time: 14.294 ms(69.96 FPS)
Camera Pos: (1.44801, -0.08219, -0.10482)
Light Dir: (0.34281, 0.70711, 0.61845)
Pause Render
FSR
Checkboard
Name:
Noname
Save
Predict
MRPNN
1.000
Camera Exposure
20.971
Fov
Inspector
ToneMap
ACES
Render Surface
0.857
G
1.000
Alpha
512
Multi Scatter
1.000
Tr scale
1.000
1.000
1.000
Scatter rate
61 deg
Light Azimuth
45 deg
Light Altitude
Light Color
R:1.000
G:1.000
B:1.000
H:0.000
S:0.000
V:1.000
#FFFFFF
1.000
Enviroment Exp
0.000
Enviroment Rot
Select HDRI

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下一个挑战

泛化性

我们的目标不只是云

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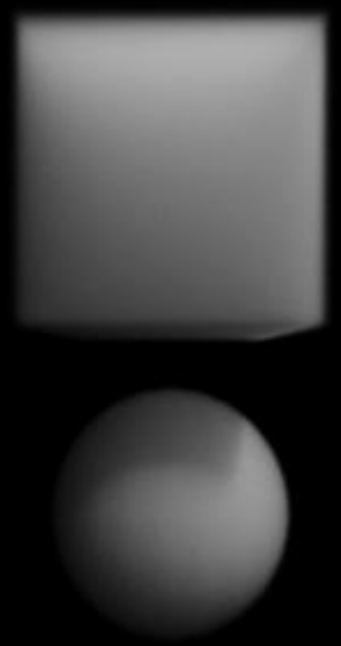
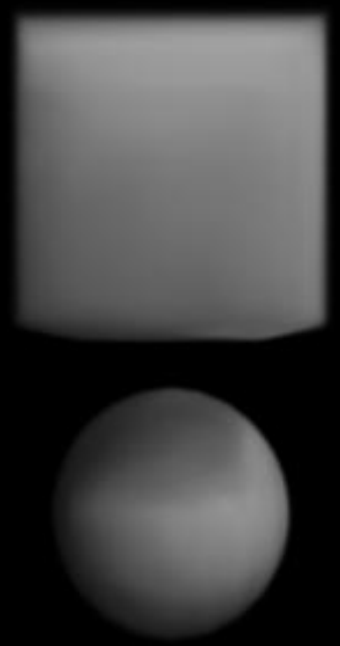
泛化性

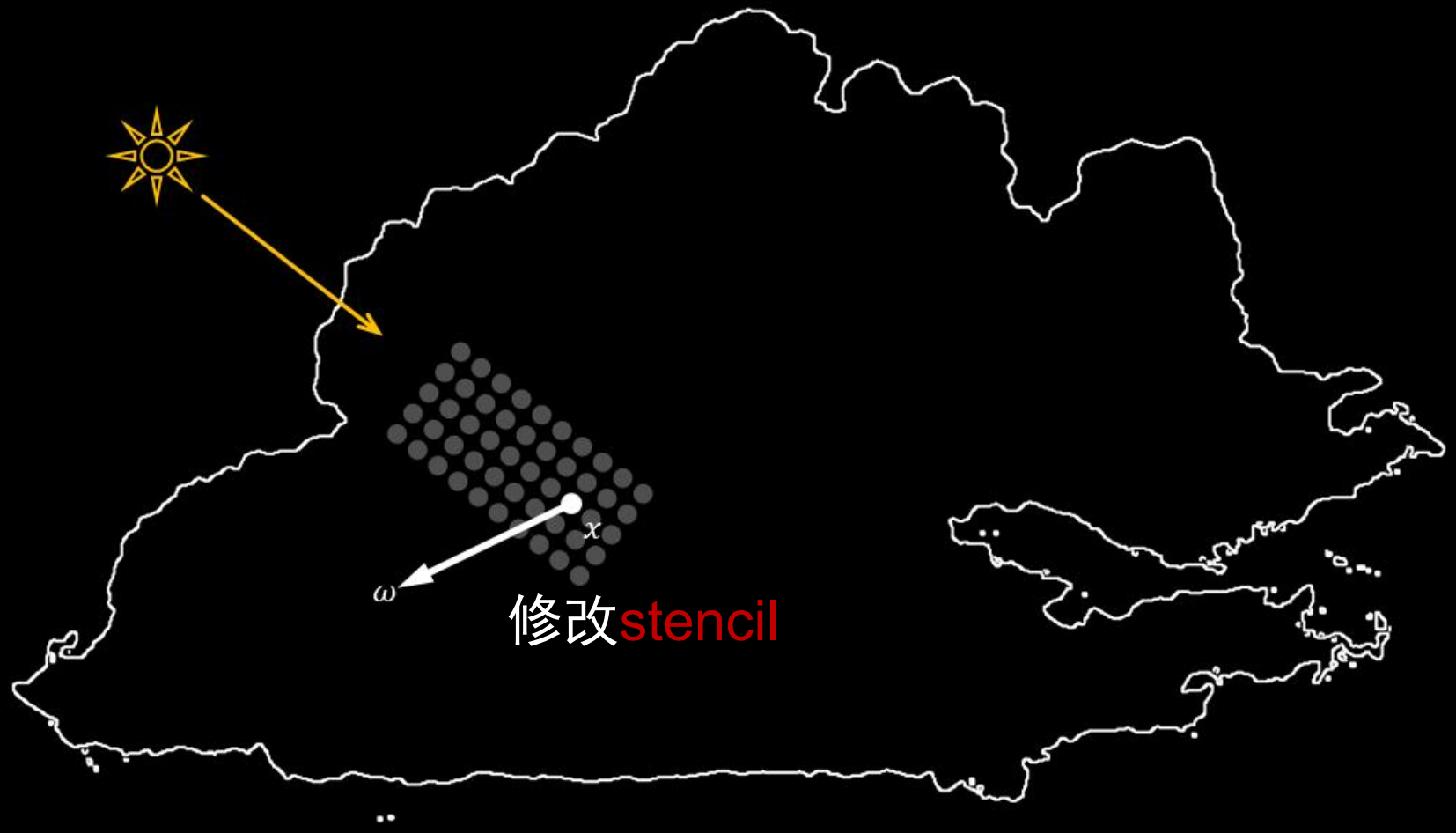


参考

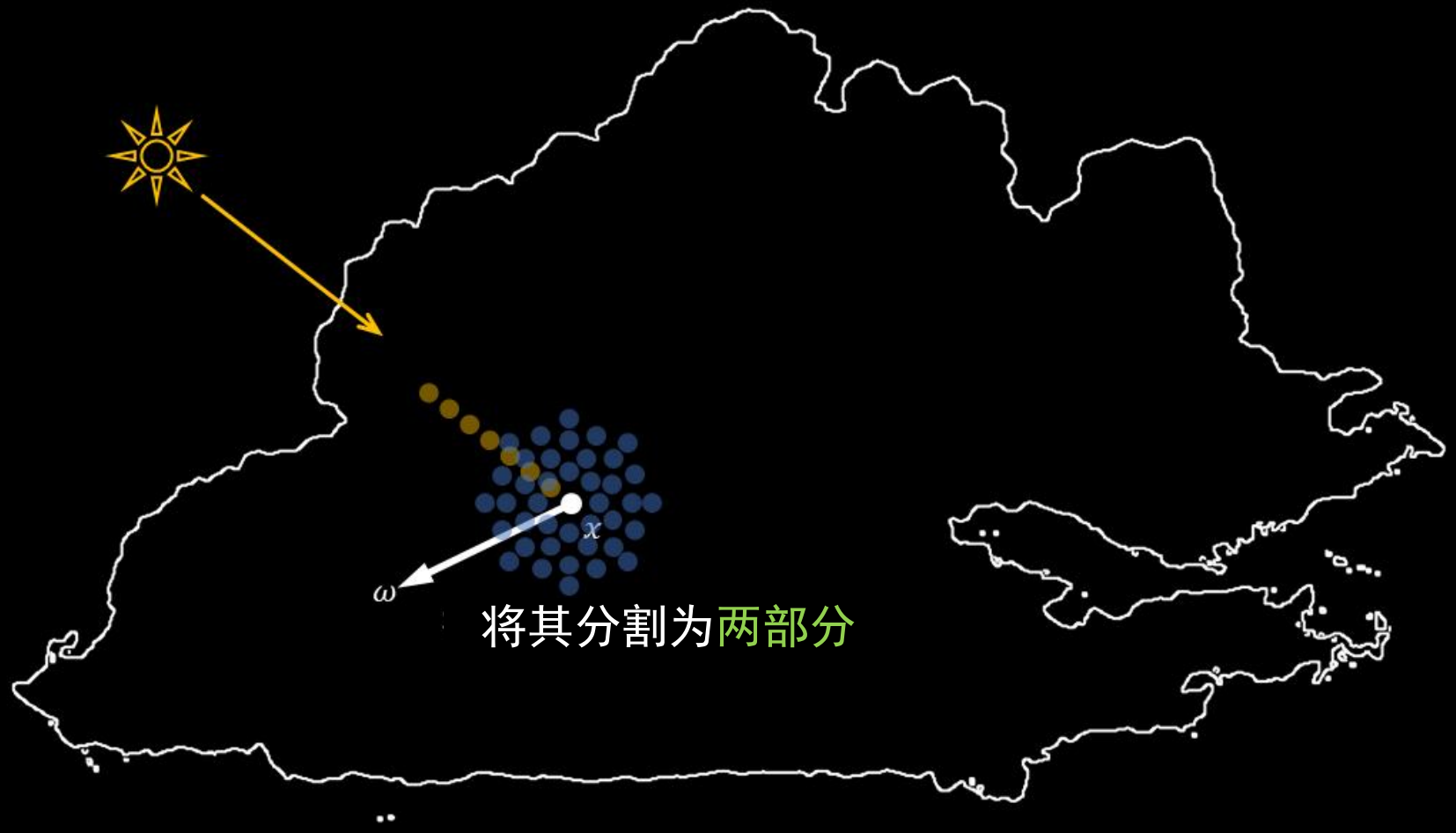


RPNN

泛化性



泛化性

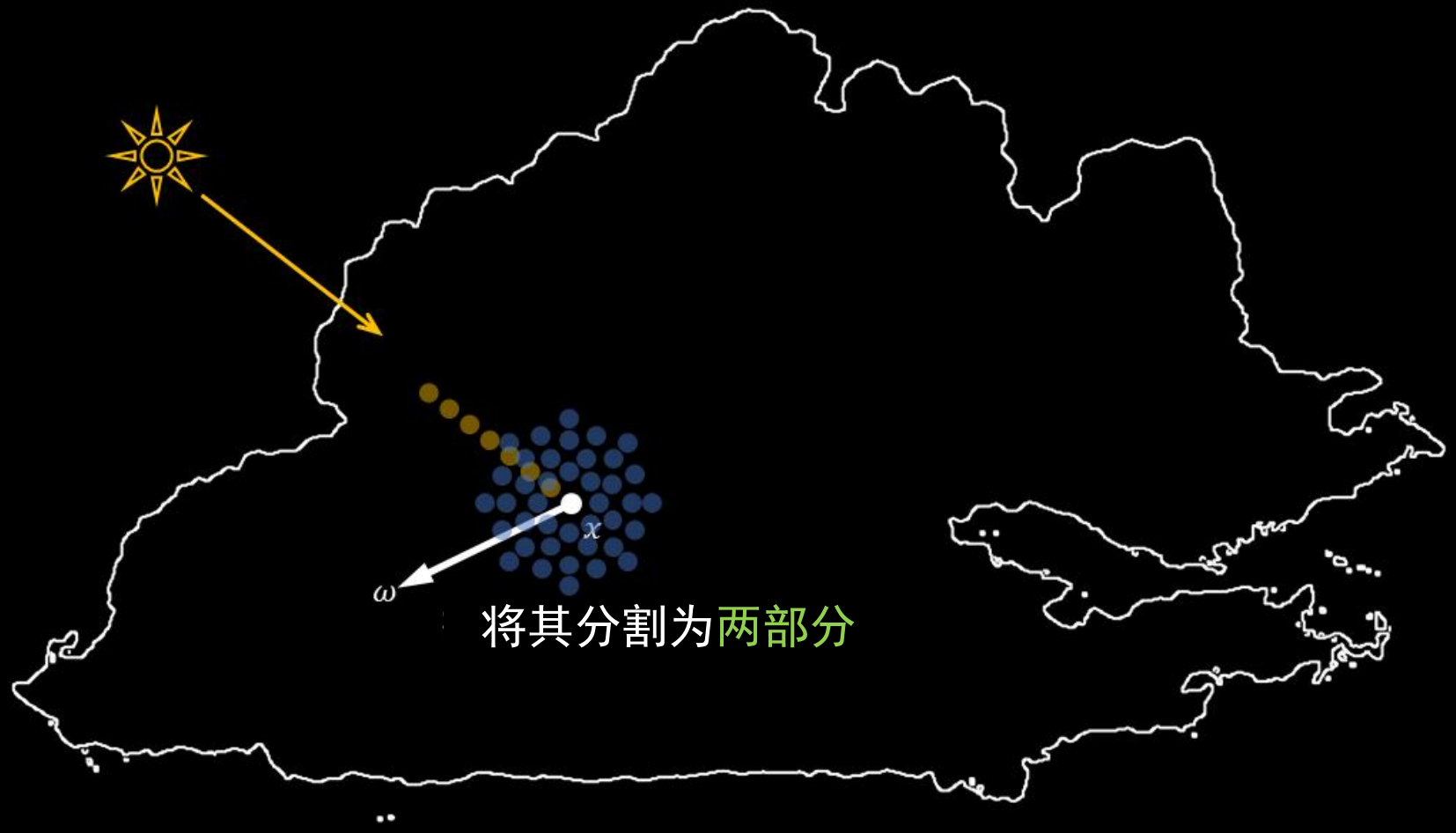


泛化性

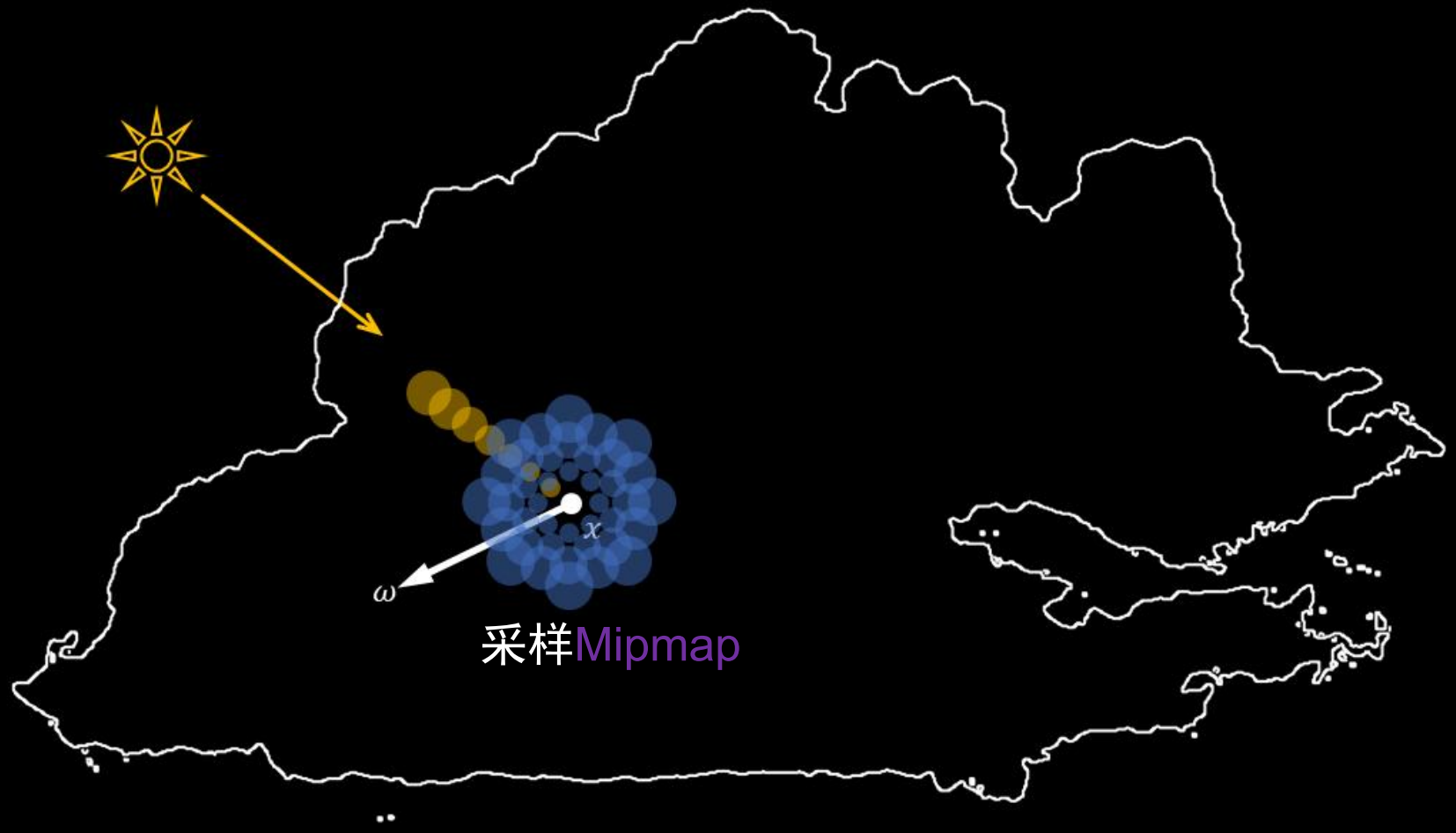
将其分割为两部分：

- 高频部分
  Shadow-sensitive
- 低频部分
  Scattering-sensitive

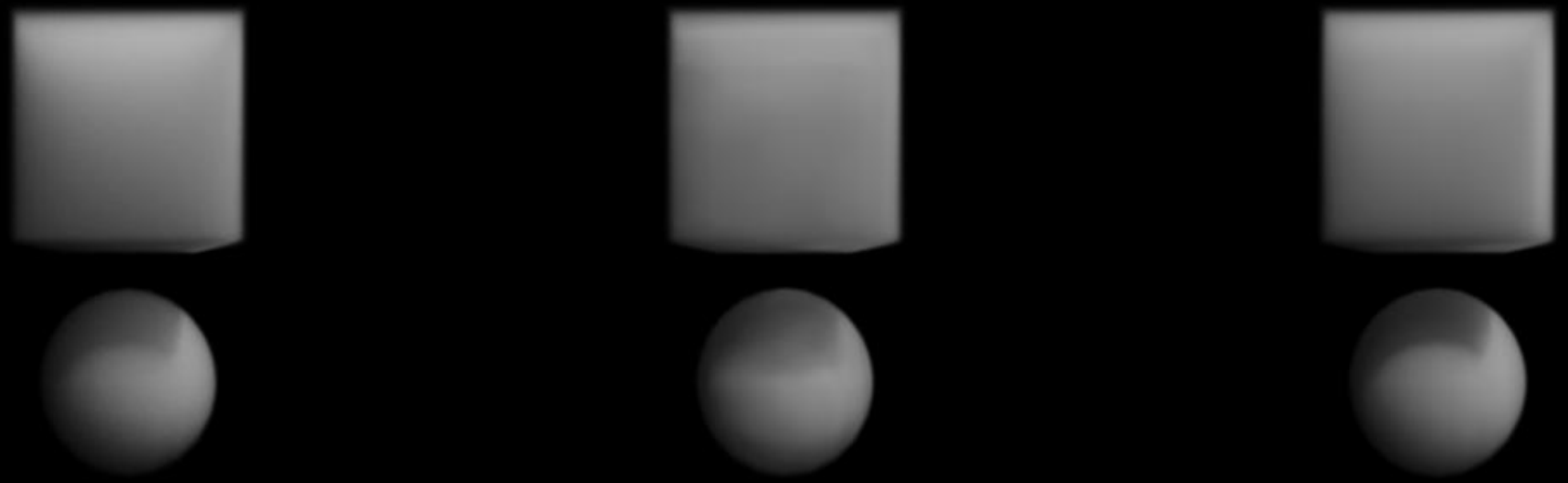
泛化性



泛化性



泛化性



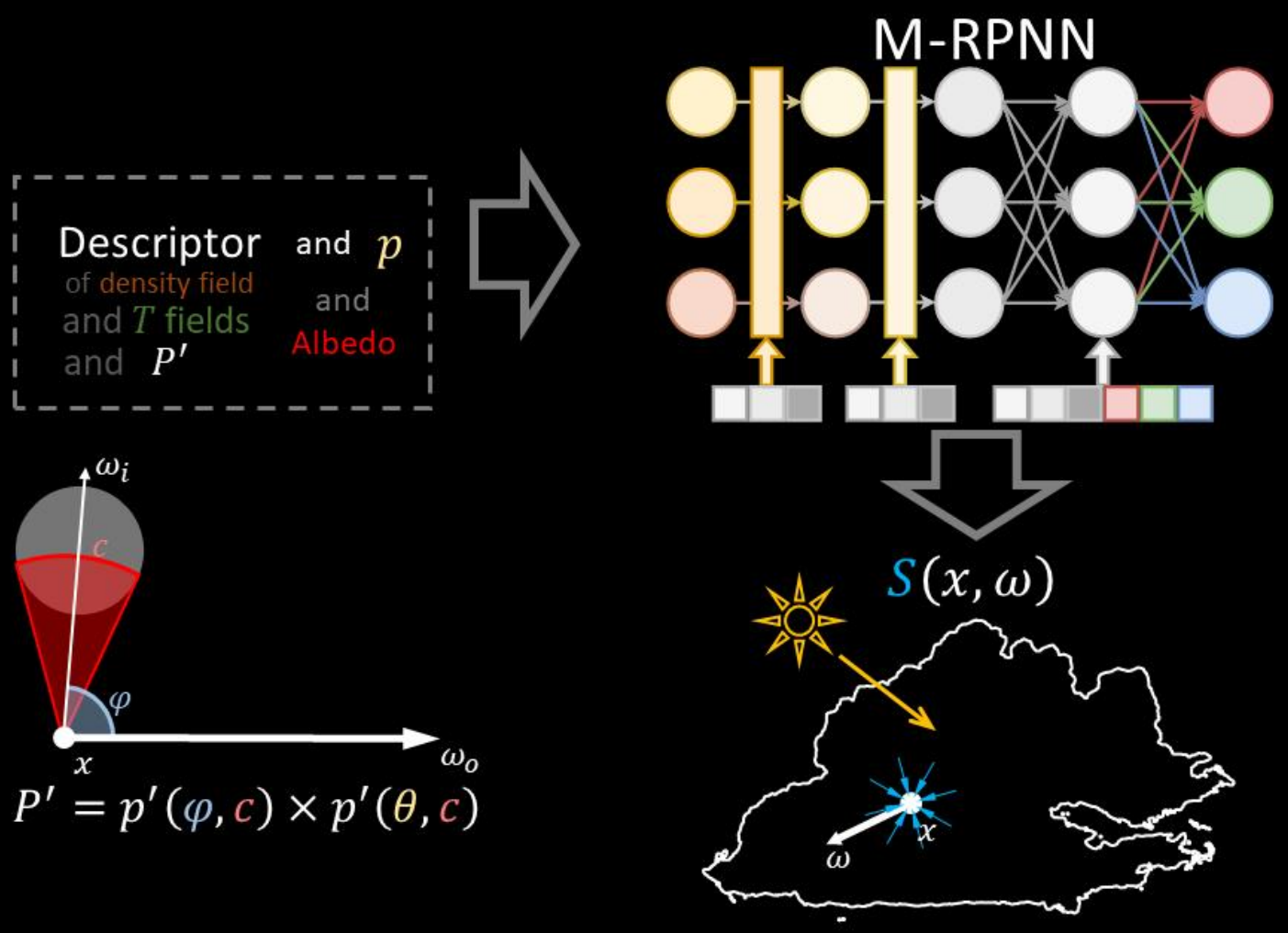
参考

RPNN

MRPNN

(我们的方法)

相位函数 和 反照率


Descriptor
of density field
and T fields
and P'
and p
and
Albedo
M-RPNN
ω_i
c
φ
x
ω_o
$P' = p'(\varphi, c) \times p'(\theta, c)$
$S(x, \omega)$
ω
x

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我们的结果

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我们的结果

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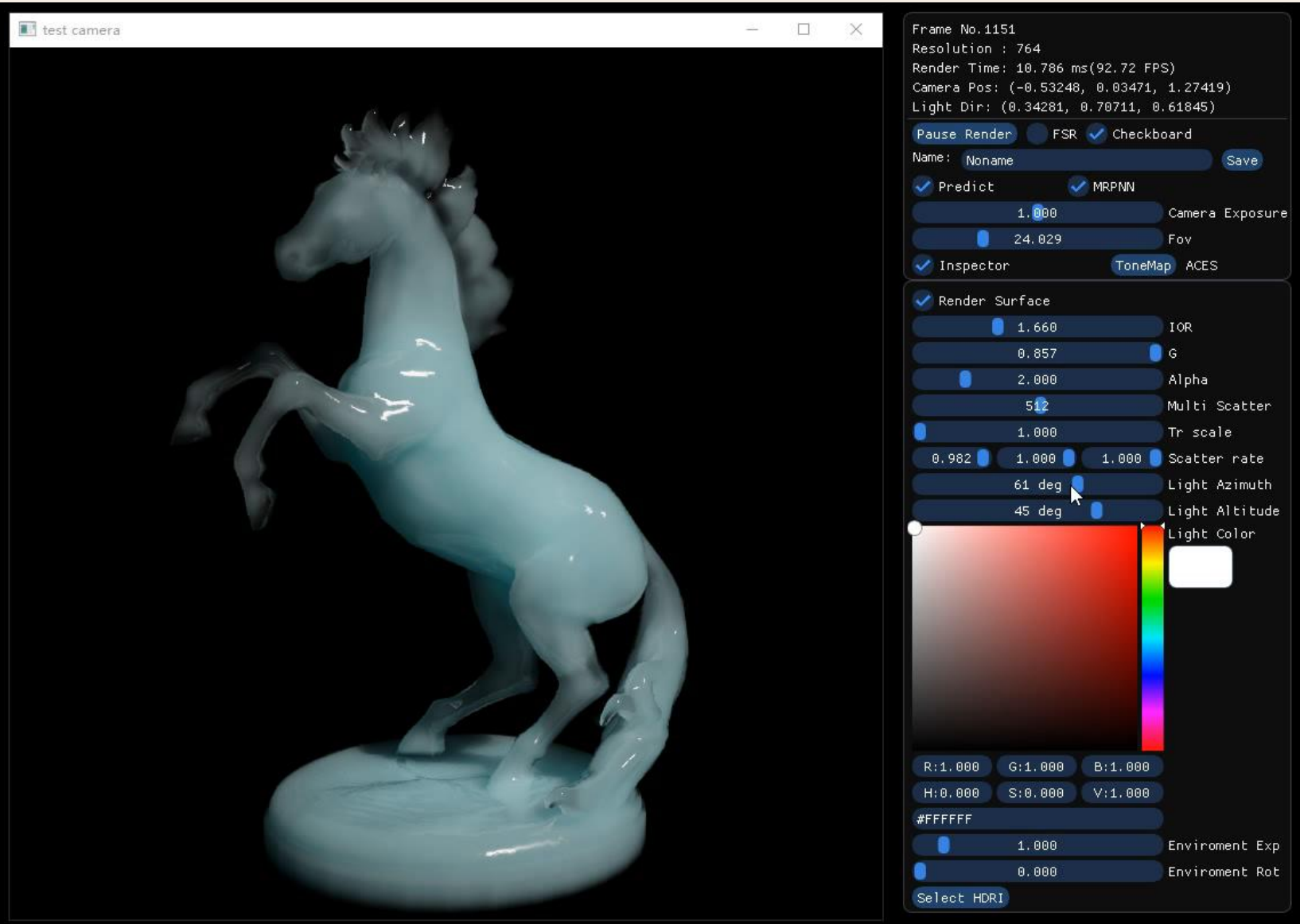
GitHub:



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感谢观看

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