{logotypes}

ÅHUSSTRAND
SEASIDE HOTEL & CONFERENCE FACILITY

LUND UNIVERSITY

COMPUTE
Scientific Discovery Using Computers

{title}

Medical Radiation Physics

How to COMPUTE medical images

{author}

André Ahlgren
Department of Medical Radiation Physics
Clinical Sciences, Lund University

{occasion}

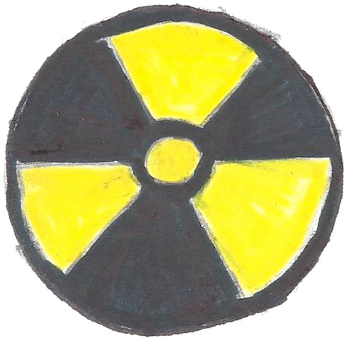
COMPUTE retreat | 20-21 August 2012 | Hotel Åhusstrand

[Instructions]

- 15 minutes + 5 minutes discussion
- ”…present the topic of your research, the work of the research group as well as your own work...”

[Topic]

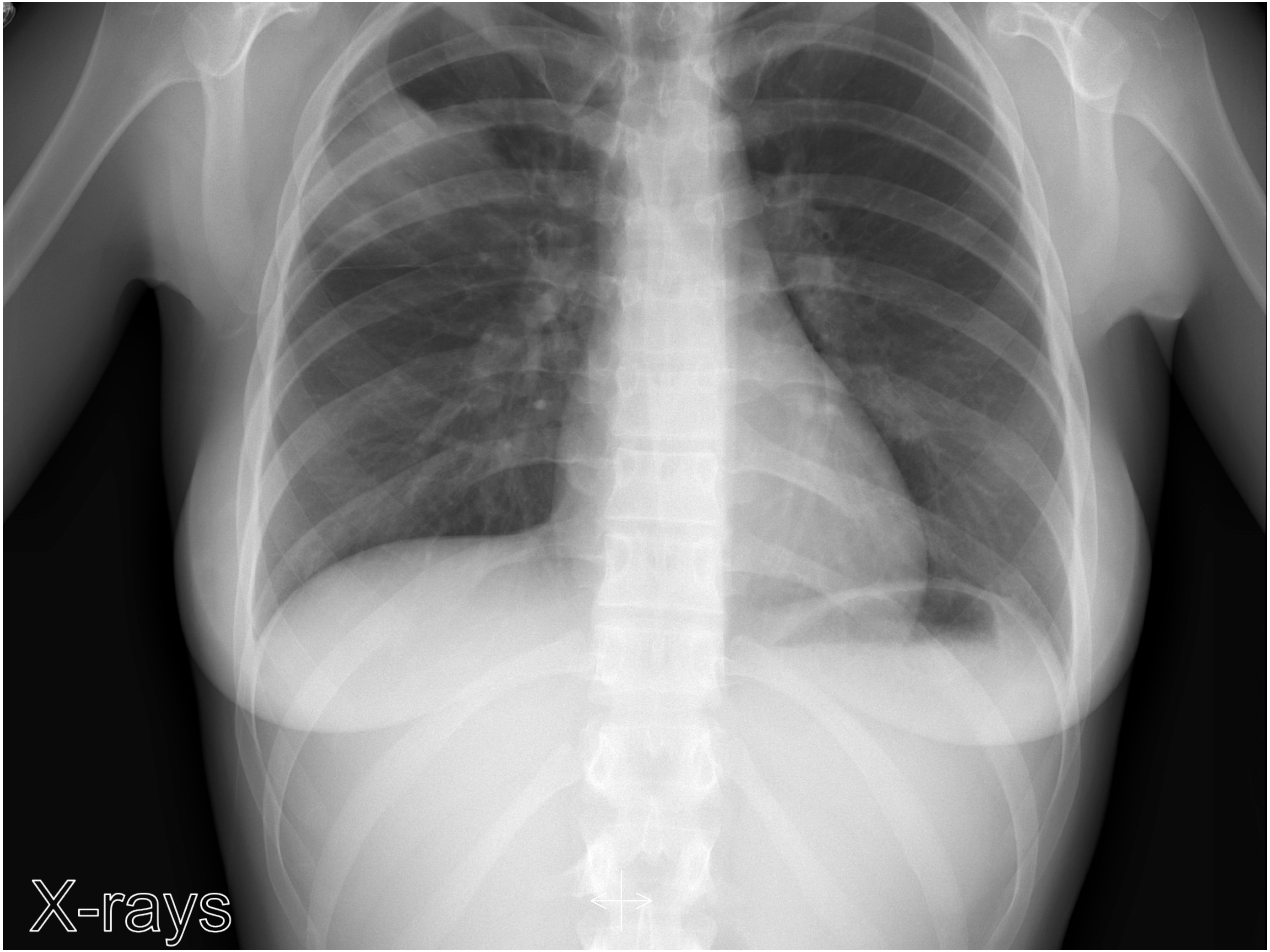
Medical Radiation Physics

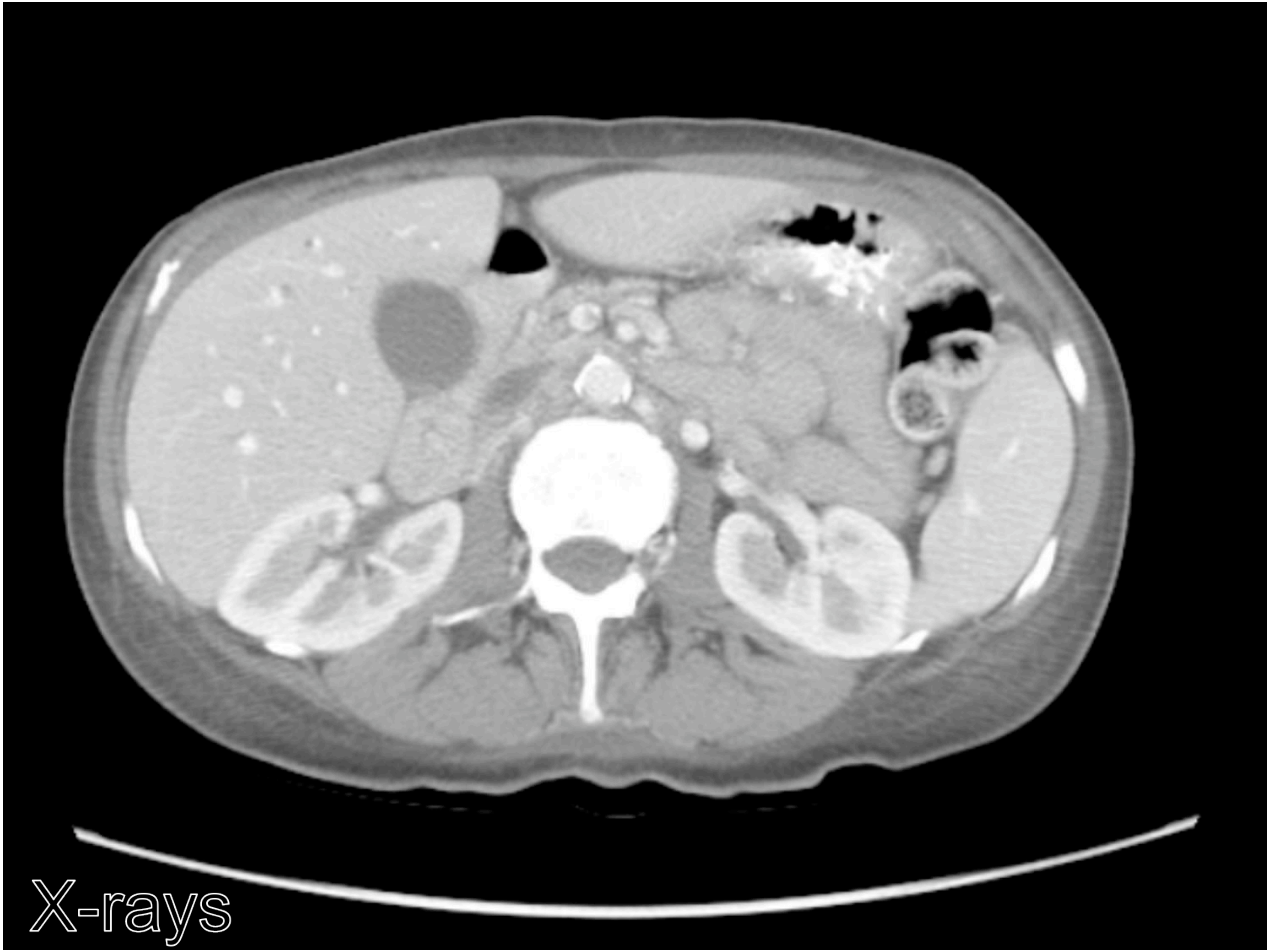


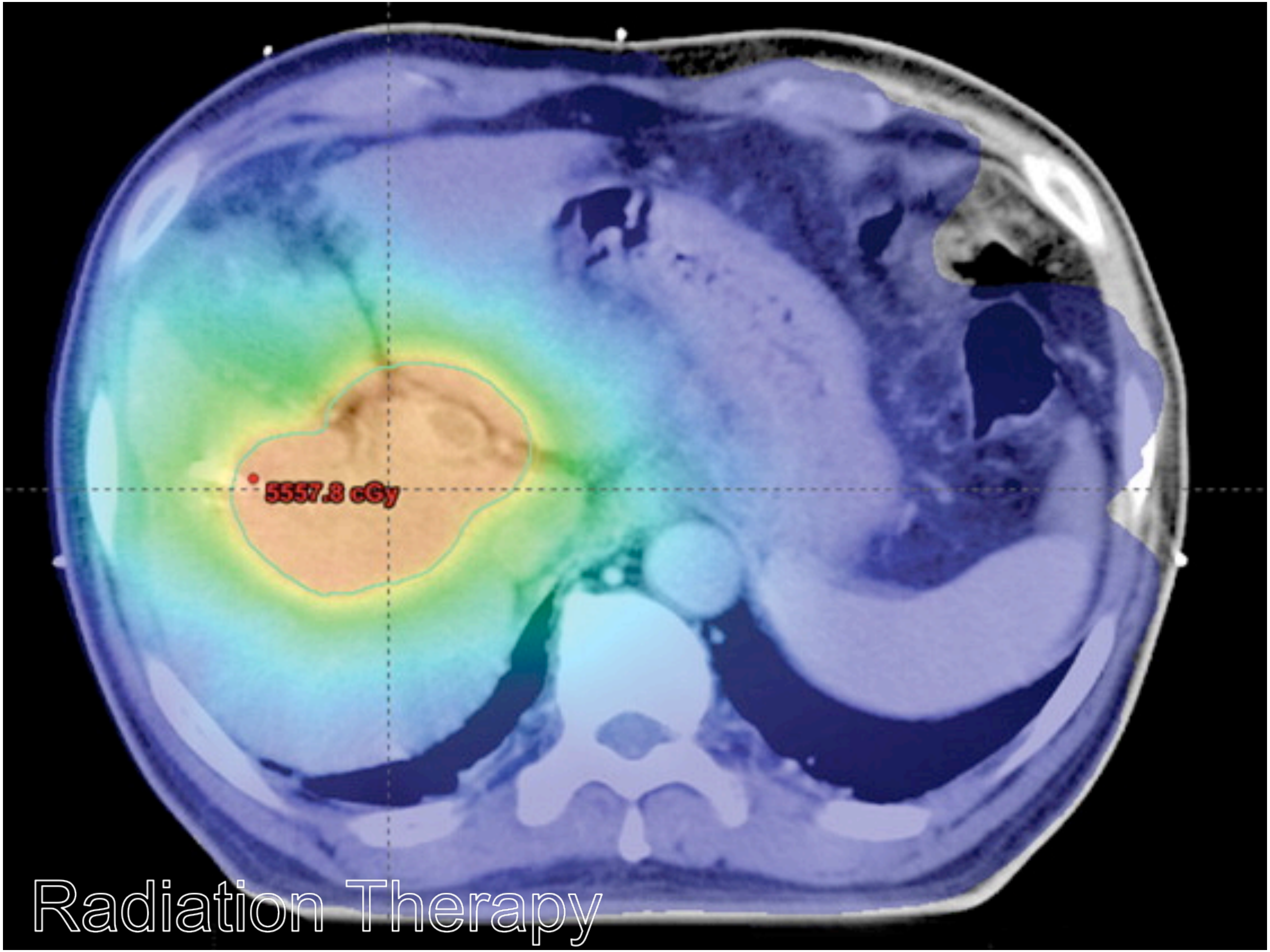
Medical Radiation Physics

[A brief history]

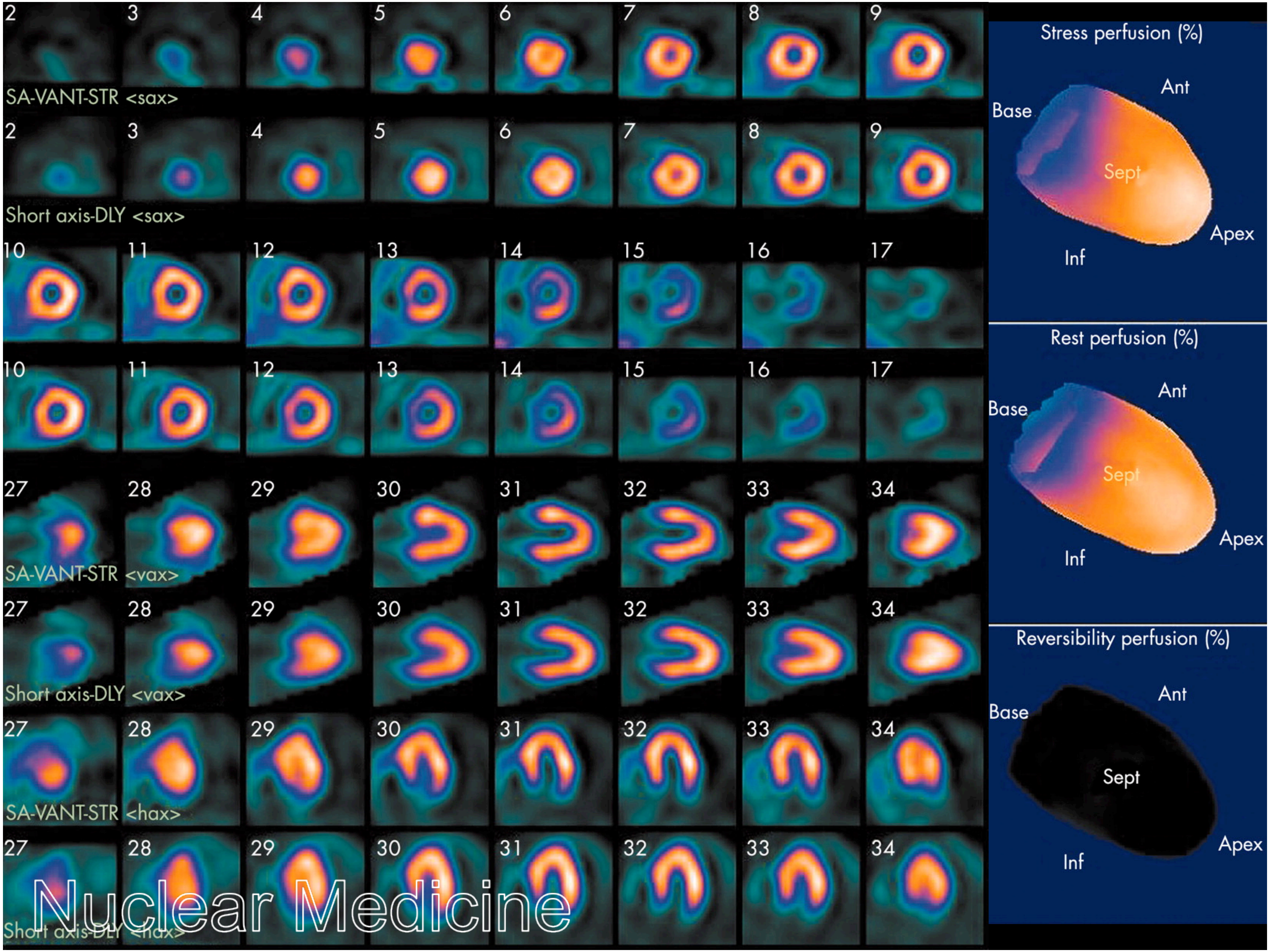
1. X-rays
2. Radiation
3. Nuclear M
4. Magnetic


X-rays


X-rays

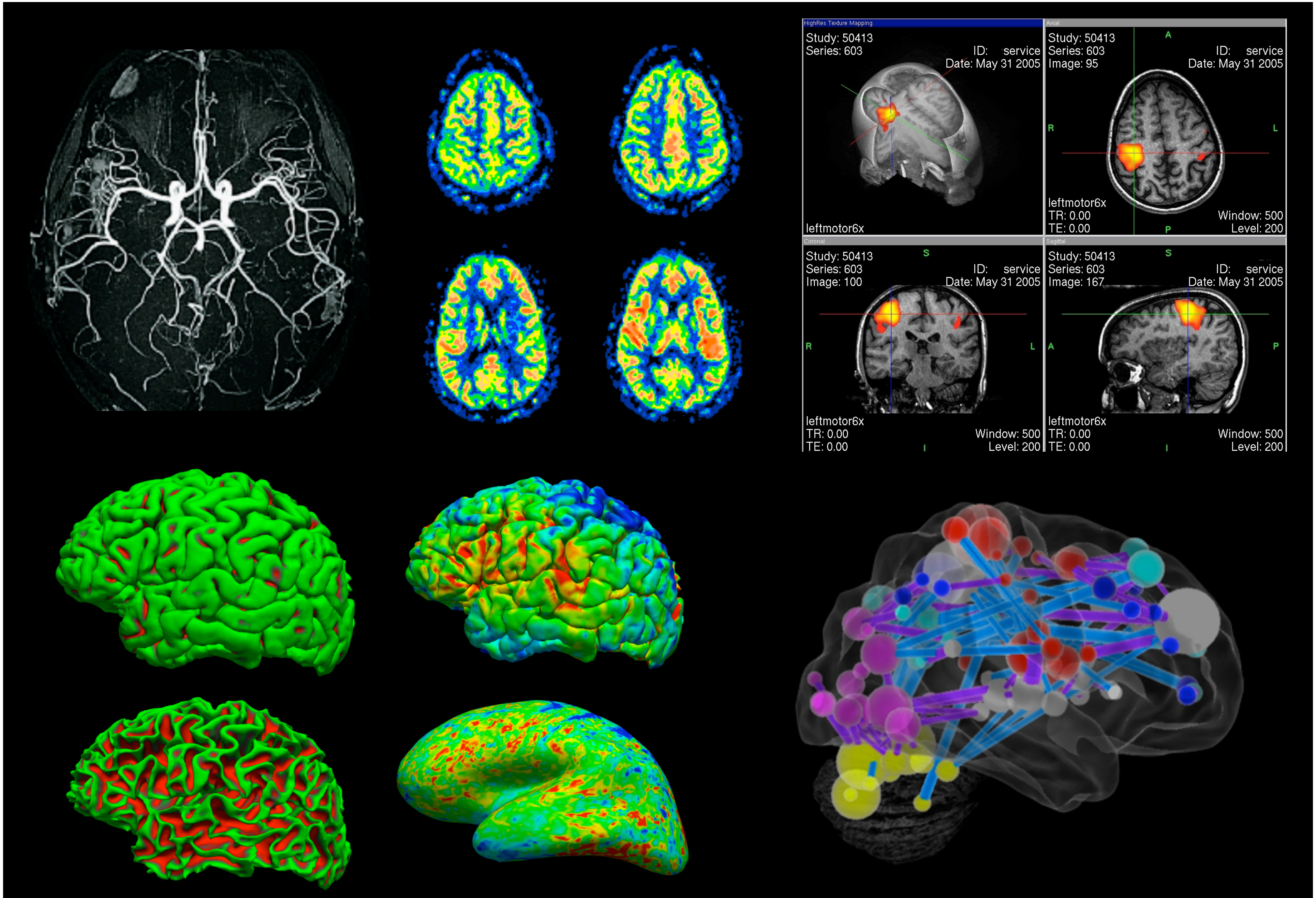

5557.8 cGy
Radiation Therapy

Nuclear Medicine



SA-VANT-STR <sax>
Short axis-DLY <sax>
SA-VANT-STR <vax>
Short axis-DLY <vax>
SA-VANT-STR <hax>
Short axis-DLY <hax>
Stress perfusion (%)
Base
Ant
Sept
Apex
Inf
Rest perfusion (%)
Base
Ant
Sept
Apex
Inf
Reversibility perfusion (%)
Base
Ant
Sept
Apex
Inf
Nuclear Medicine

Magnetic Resonance Imaging



Magnetic Resonance Imaging

[Work of the research group(s)]

Examples

Nuclear Medicine

Gustav Brolin
(the simulation guy)

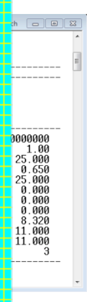
Nuclear Medicine
[Renography]

Nuclear Medicine

[Renography]

[Dig

ware]



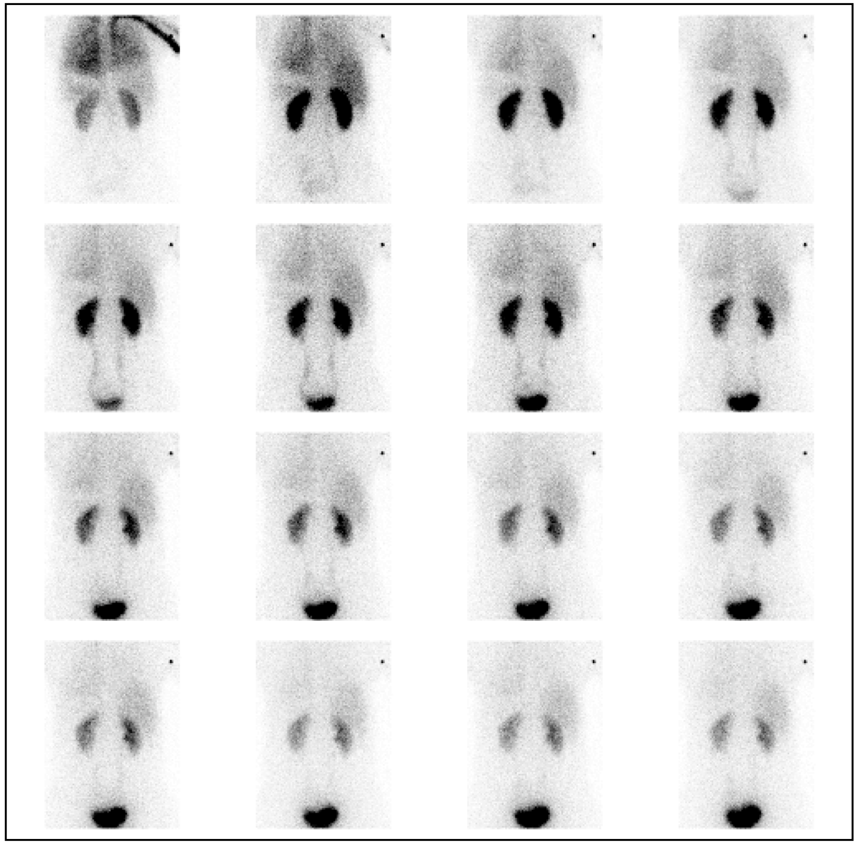
Evaluation of processing methods!

em

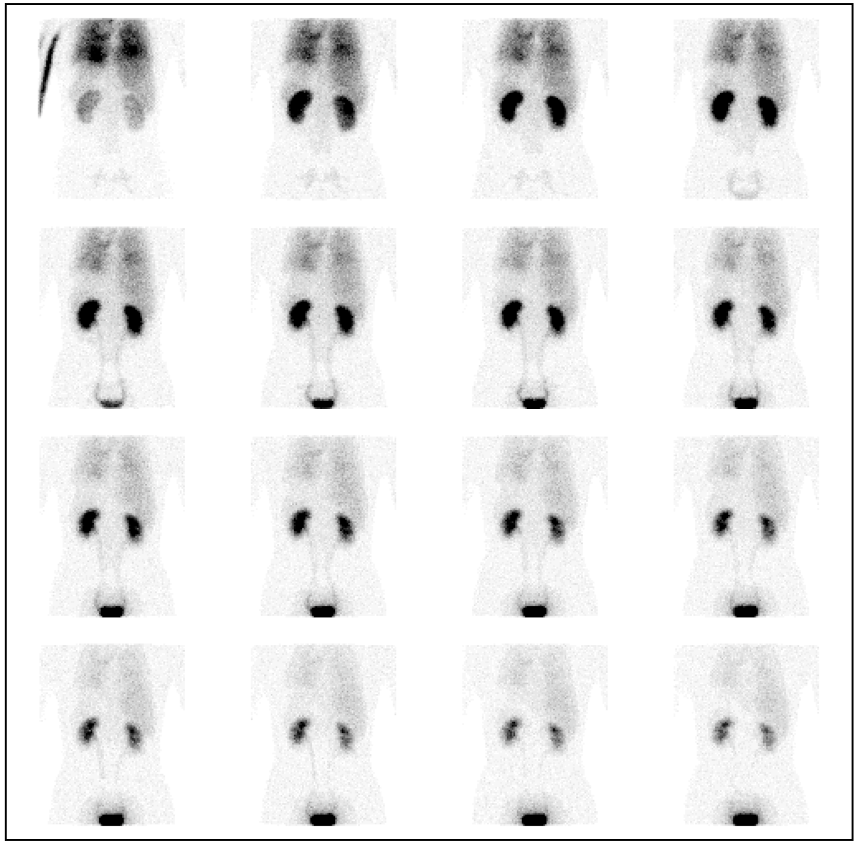
Nuclear Medicine

[Renography]

Quiz-Time!



Simulated?

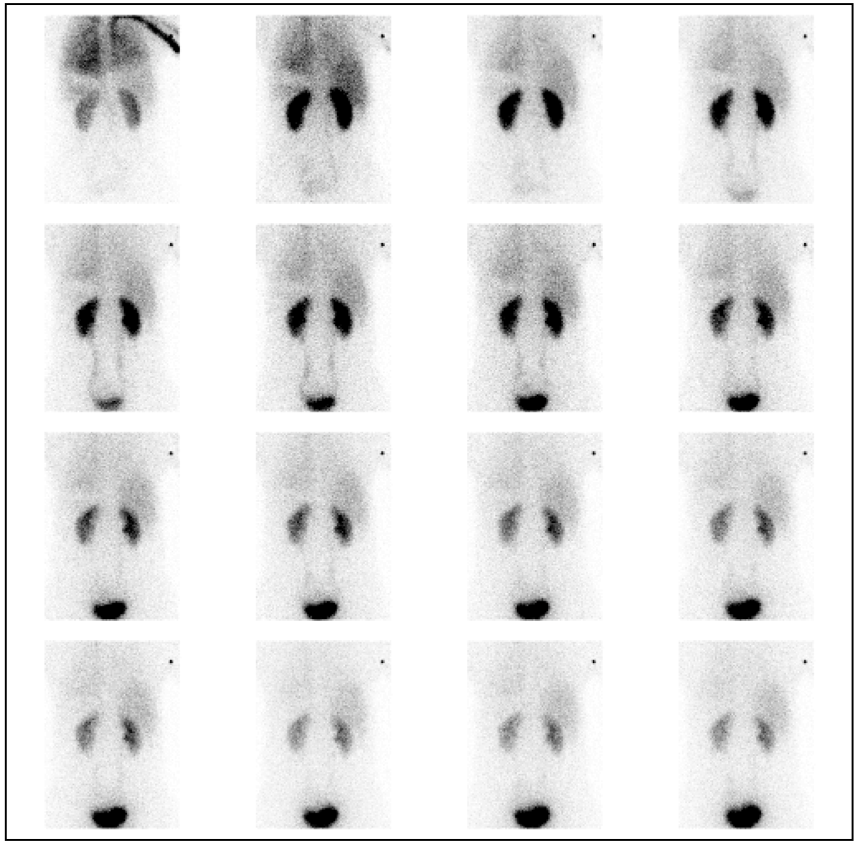


Measured?

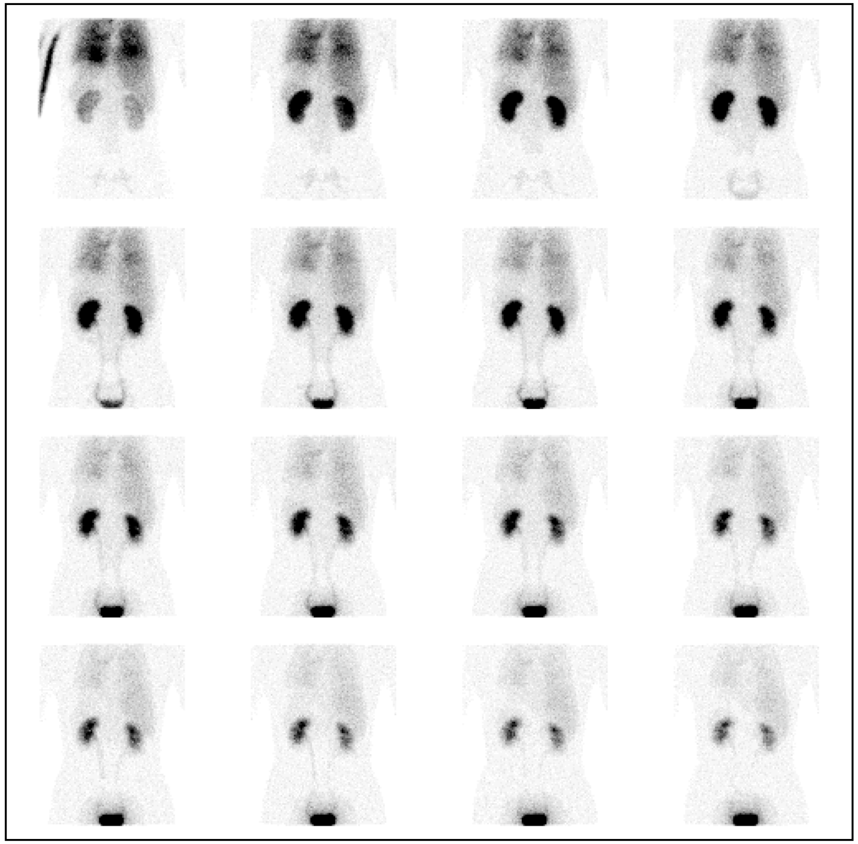
Nuclear Medicine

[Renography]

Quiz-Time!



Measured!



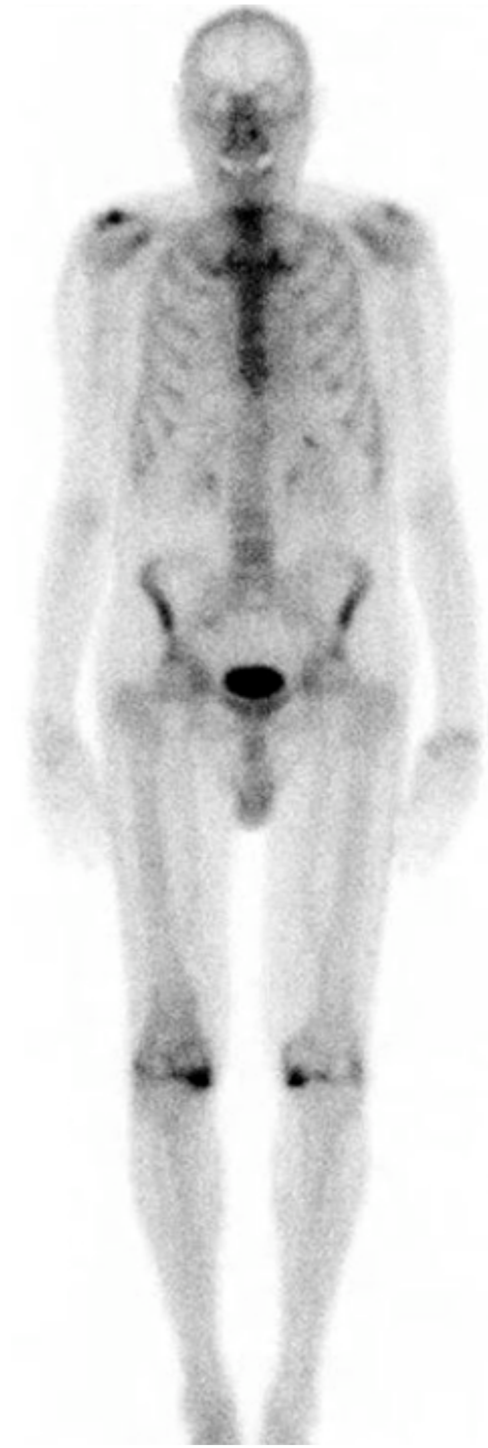
Simulated!

Nuclear Medicine

Johan Gustafsson
(the math guy)

Nuclear Medicine
[Segmentation]

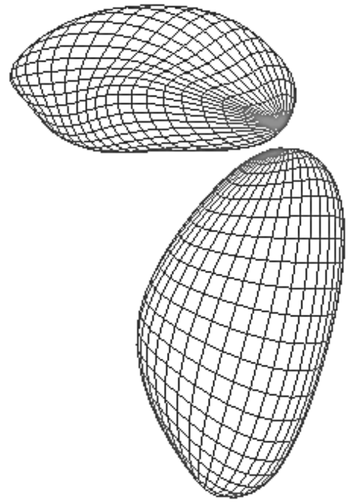
- Radionuclide therapy
- Activity quantification --> Absorbed dose
- Large uncertainties
- Image processing important



Nuclear Medicine
[Segmentation]

- SPECT shows activity uptake
- Delineation of high activity volumes for dosimetry
- Poor spatial resolution, high noise levels
- Fourier surfaces for semiautomatic delineation

Nuclear Medicine
[Segmentation]

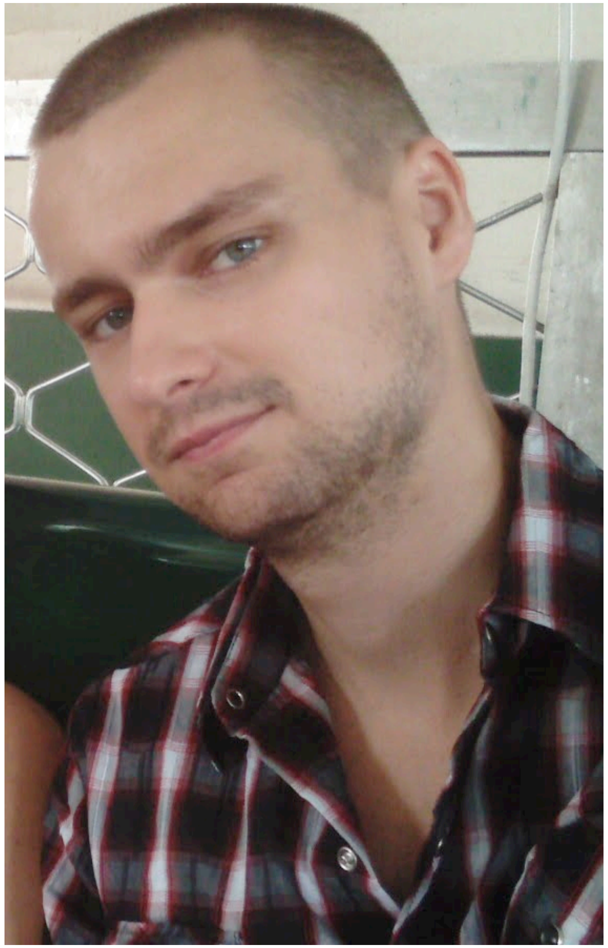


- Surface described by three two-dimensional Fourier series
- Parameters gradually added to the description

$$\begin{cases} x(u,v) = a_{x,0,0} + 2a_{x,0,1}\cos v + 2\sum_{l=1}^{K_2} c_{x,0,1}\sin(lv) + 4\sum_{m=1}^{K_1}\sum_{l=1}^{K_2}\left[c_{x,m,l}\cos(mu)\sin(lv) + d_{x,m,l}\sin(mu)\sin(lv)\right] \\ y(u,v) = a_{y,0,0} + 2a_{y,0,1}\cos v + 2\sum_{l=1}^{K_2} c_{y,0,1}\sin(lv) + 4\sum_{m=1}^{K_1}\sum_{l=1}^{K_2}\left[c_{y,m,l}\cos(mu)\sin(lv) + d_{y,m,l}\sin(mu)\sin(lv)\right] \\ z(u,v) = a_{z,0,0} + 2a_{z,0,1}\cos v + 2\sum_{l=1}^{K_2} c_{z,0,1}\sin(lv) + 4\sum_{m=1}^{K_1}\sum_{l=1}^{K_2}\left[c_{z,m,l}\cos(mu)\sin(lv) + d_{z,m,l}\sin(mu)\sin(lv)\right] \end{cases}$$

$$u \in [0,2\pi), v \in [0,\pi]$$

Diffusion MRI



Filip Szczepankiewicz
(the cool guy)

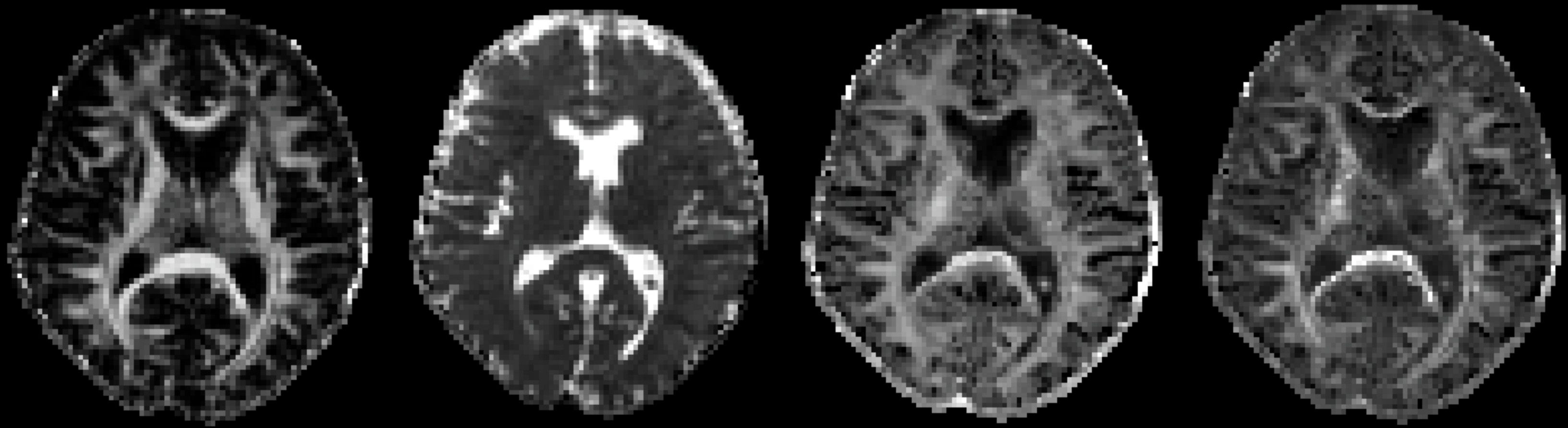
Diffusion MRI

isotropic diffusion

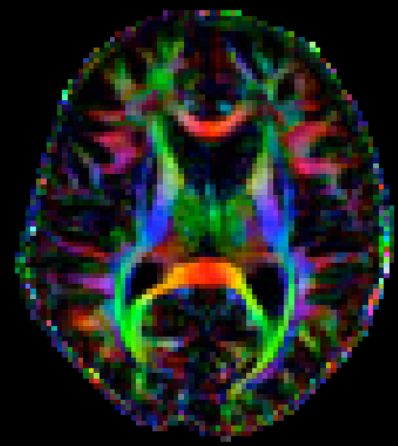
Brownian motion

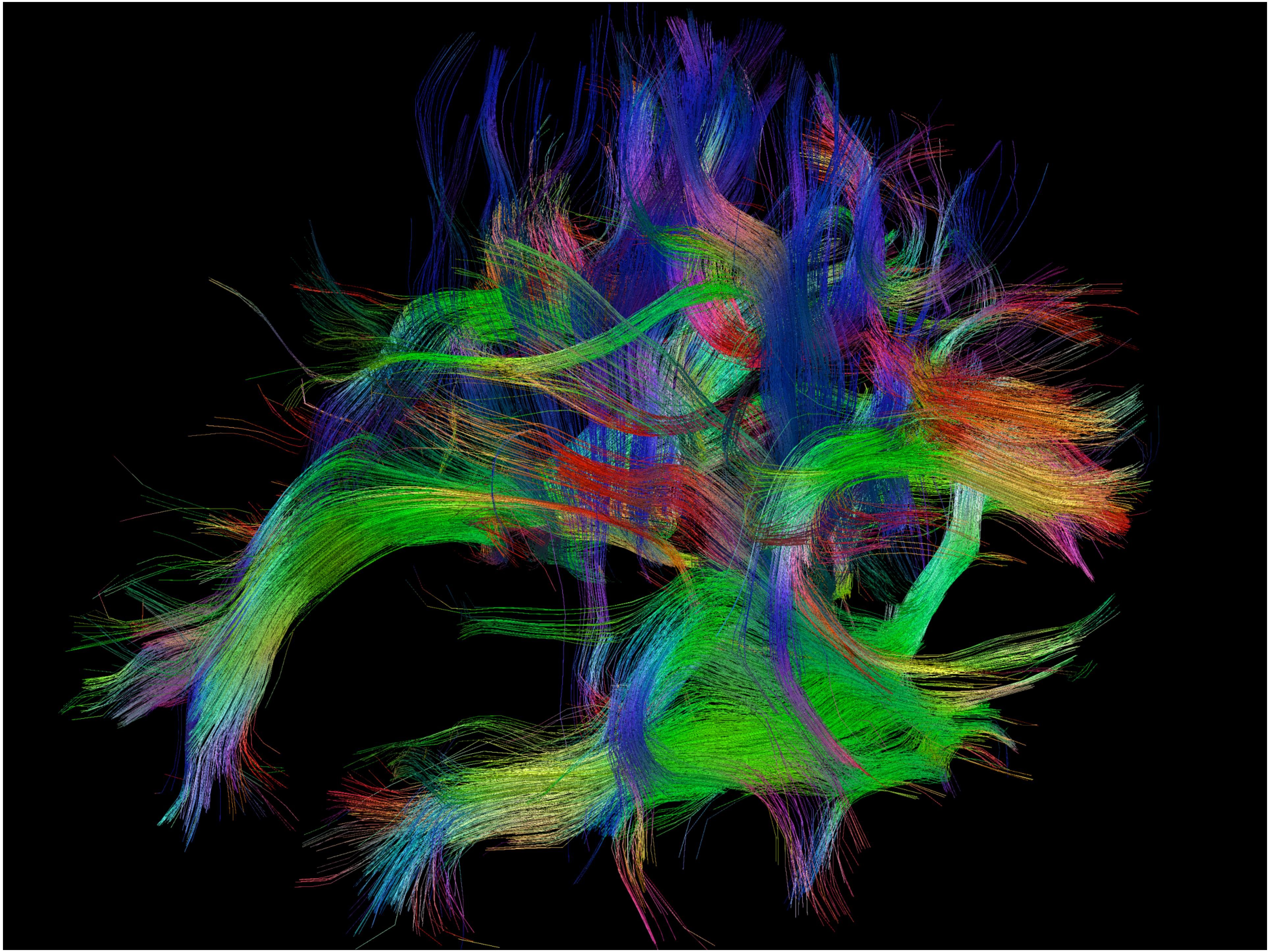
Diffusion MRI

Anisotropy Diffusivity Kurtosis Directional Kurtosis

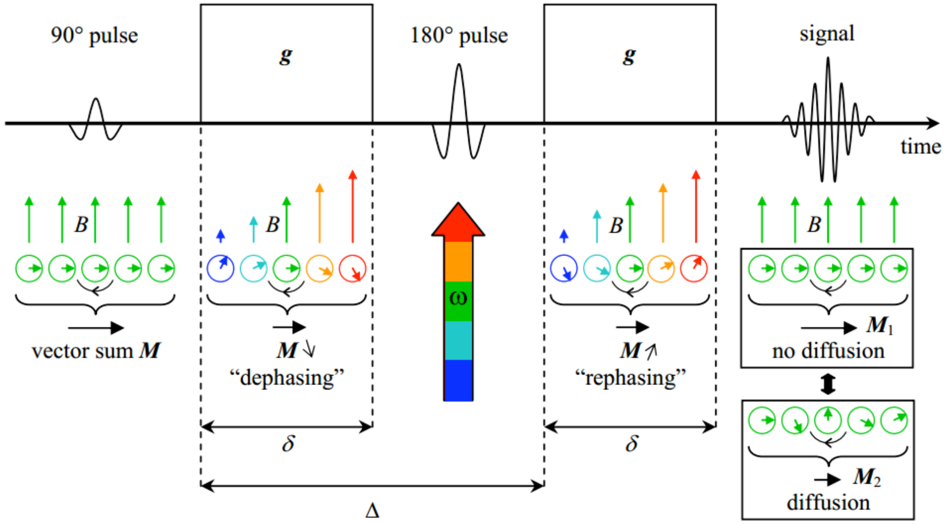


- Water diffusion characterise microstructure
- Metrics generate unique contrast
- Directional information modeled by 2nd order tensor





Diffusion MRI



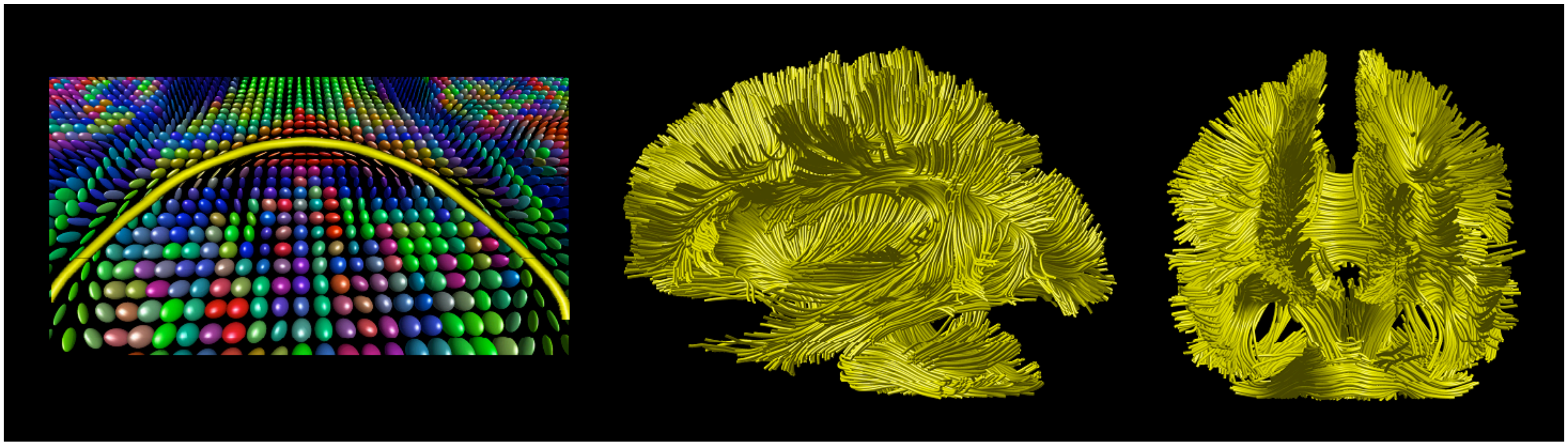
$$S_k(\boldsymbol{r}) = S_0(\boldsymbol{r})\, e^{-b\hat{\boldsymbol{g}}_k^T\cdot \boldsymbol{D}(\boldsymbol{r})\cdot\hat{\boldsymbol{g}}_k} \quad \text{with} \quad \hat{\boldsymbol{g}}_k = \frac{\boldsymbol{g}_k}{\|\boldsymbol{g}_k\|} \quad \text{and} \quad k = 1, \ldots, N$$

$$P_s(\boldsymbol{r}|\boldsymbol{r}', \tau) = \frac{1}{\sqrt{(4\pi\tau)^3|\boldsymbol{D}|}}\, e^{-\frac{(\boldsymbol{r}-\boldsymbol{r}')^T\cdot\boldsymbol{D}^{-1}\cdot(\boldsymbol{r}-\boldsymbol{r}')}{4\tau}}$$

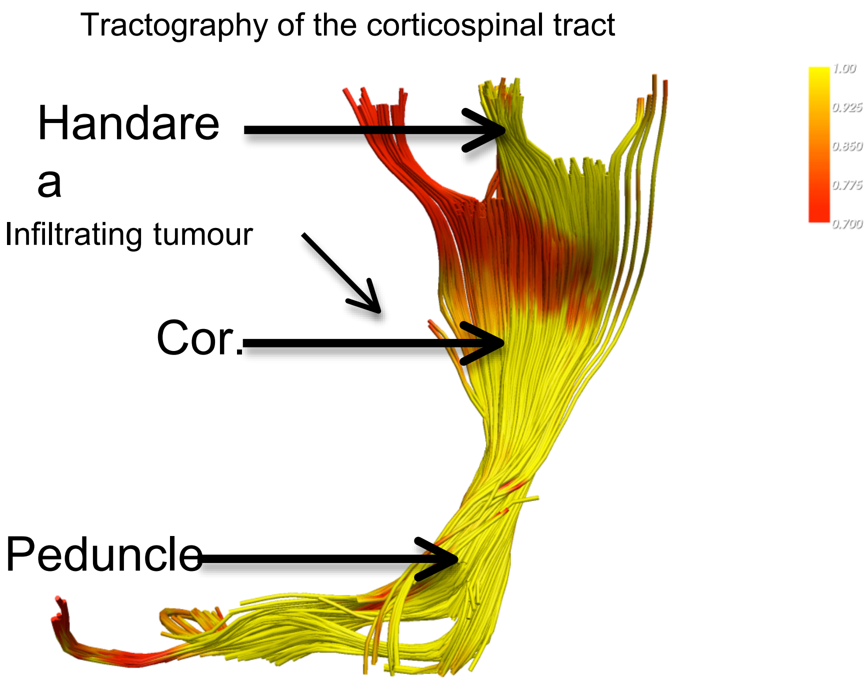
$$S(\mathbf{r}) = S_0(\mathbf{r})\langle e^{i\phi}\rangle$$

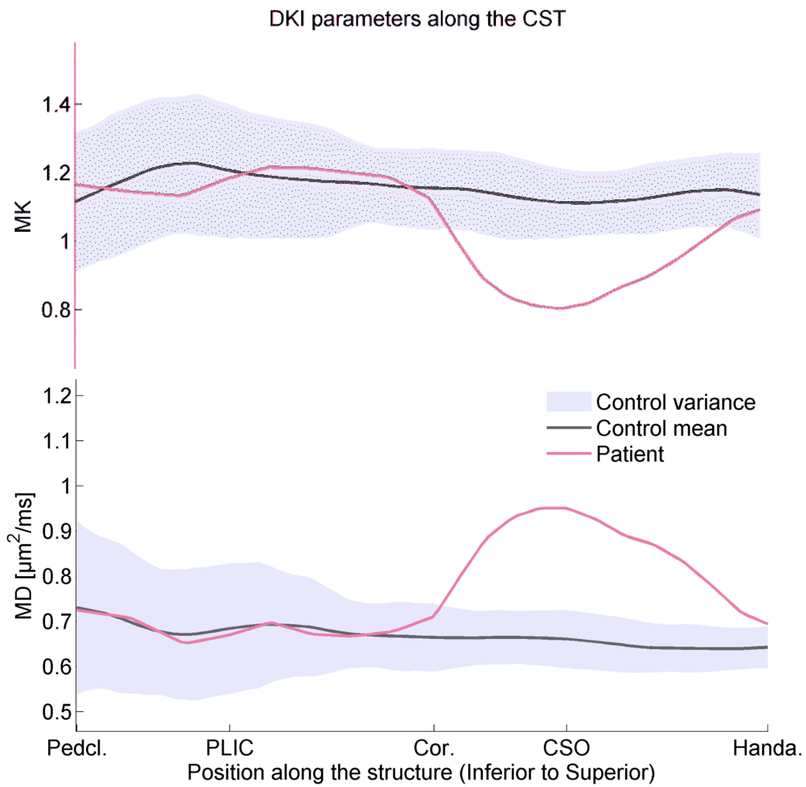
$$\frac{S(\boldsymbol{r})}{S_0(\boldsymbol{r})} = \int P_s(\boldsymbol{r}|\boldsymbol{r}', t)\, e^{i\phi(\boldsymbol{r}'-\boldsymbol{r})}\mathrm{d}\boldsymbol{r} = \mathcal{F}[P_s(\boldsymbol{r}'|\boldsymbol{r}, \tau)]$$

$$b = \gamma^2\delta^2\Delta\|\boldsymbol{g}\|^2$$



Diffusion MRI





- Tractography generated from diffusion tensor
- Parameter maps projected onto tracts
- Parameters compared to normal material

[My own (groups) work]

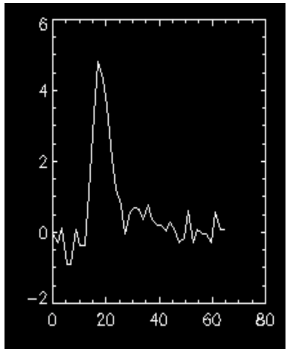
Example

Perfusion MRI

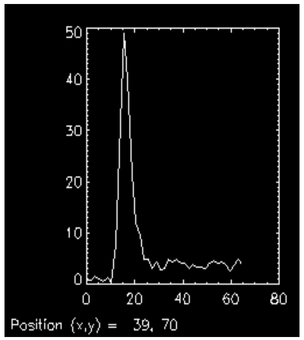
[Example: Mathematical model]

$$C(t) = CBF \cdot AIF(t) \otimes R(t) = CBF \cdot \int_0^t AIF(\tau) \cdot R(t-\tau)\, d\tau$$

Measured concentration

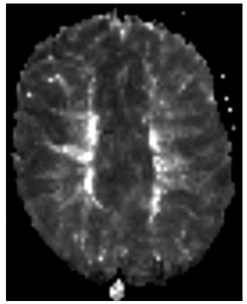


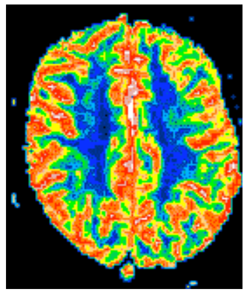
Measured input



R(t)

Transit time





Blood flow

[5 minutes discussion]