

Tumor growth visualization

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<https://cancer-sim.com>



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UiO : Department of Physics
University of Oslo



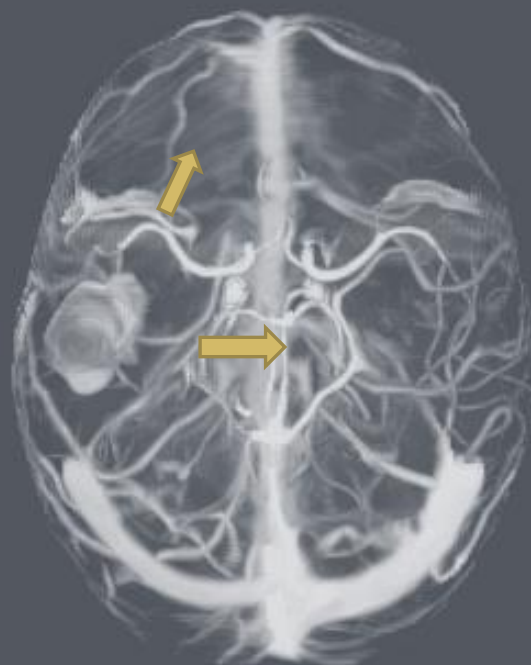
Real
growth
case

T1-
weighted
post-
contrast ~3
years
glioblastom
a

Maximum
Intensity
Projection
(MIP)

(SAILOR)

animation



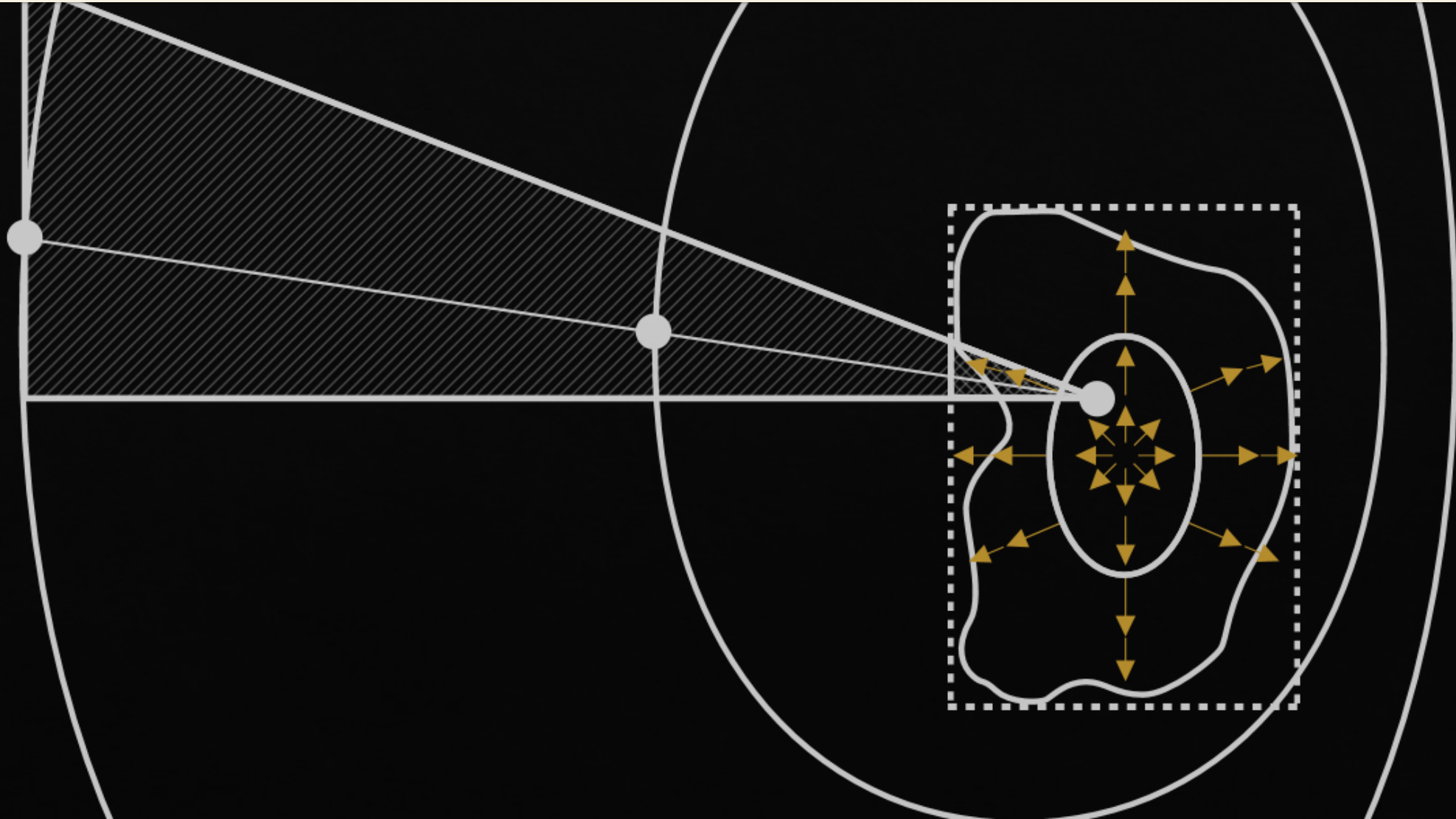
178

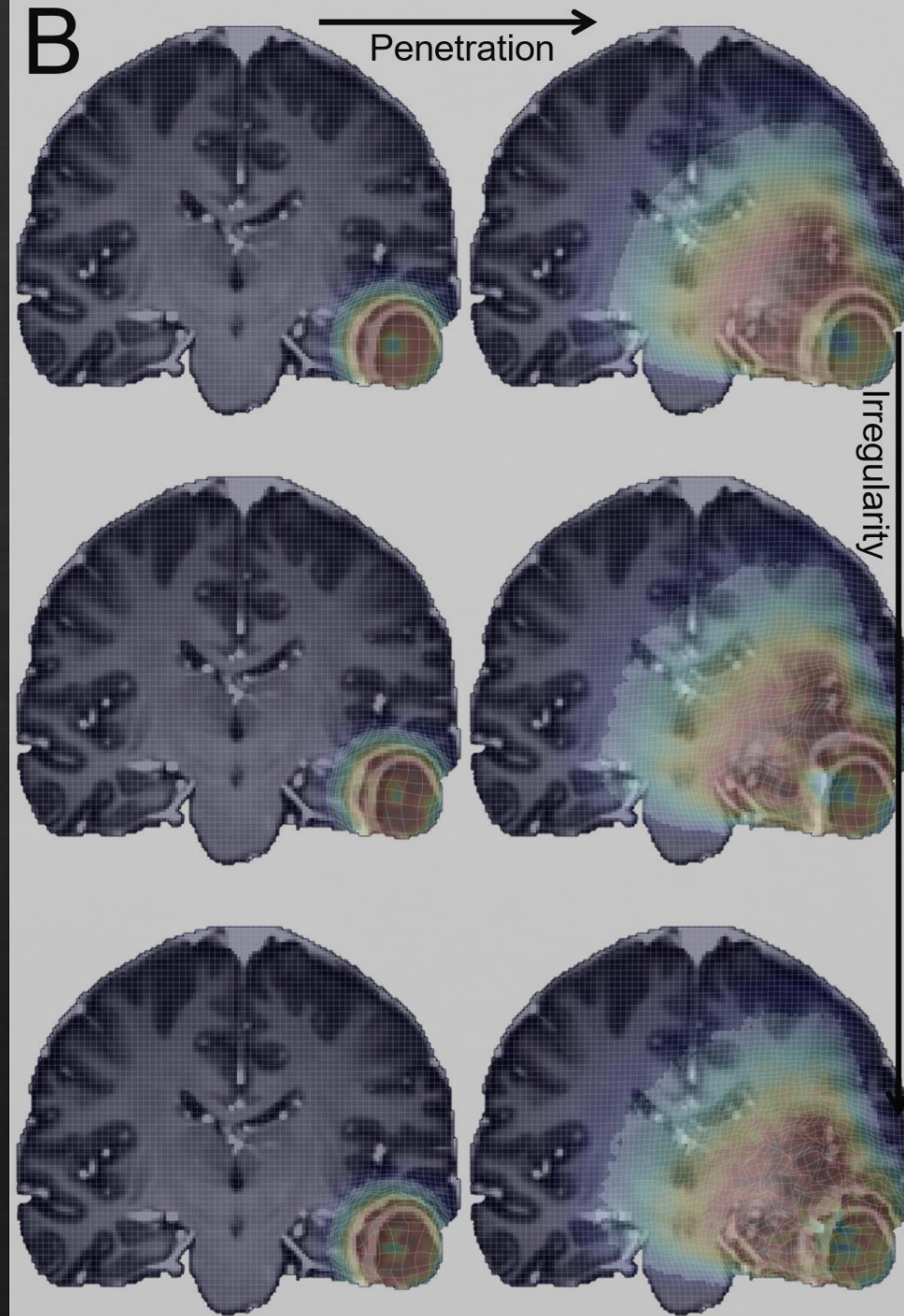
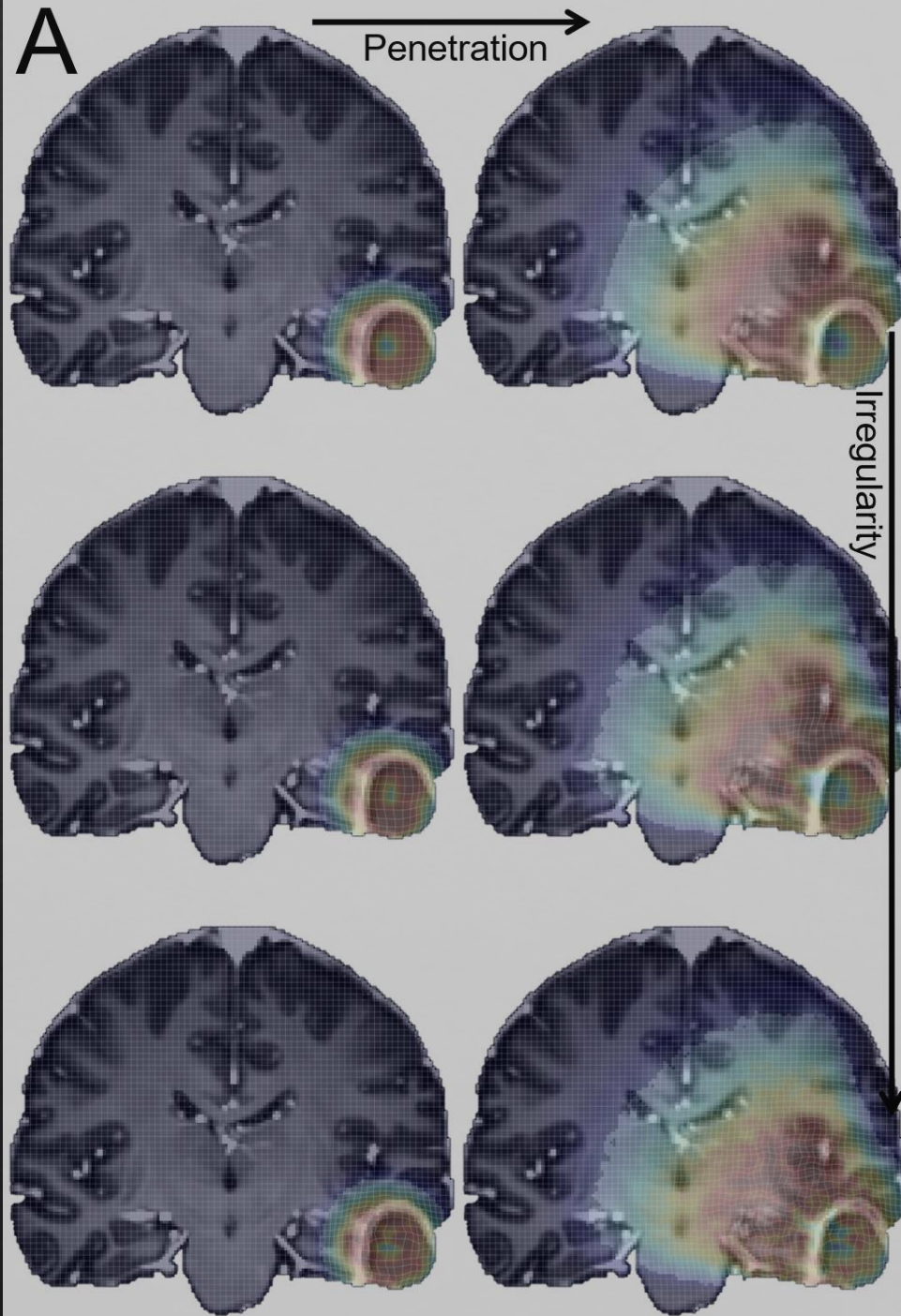
255

Level

Window

Model for deformation from one examination to the next





ITK-SNAP Toolbox

Main Toolbar



Cursor Inspector



Cursor position (x,y,z):

49 115 65

Intensity under cursor:

Layer	Intensity
true	19
synth	44.16
normmask	0

Label under cursor:

0 Clear Label

Segmentation Labels

Active label:

Label 1

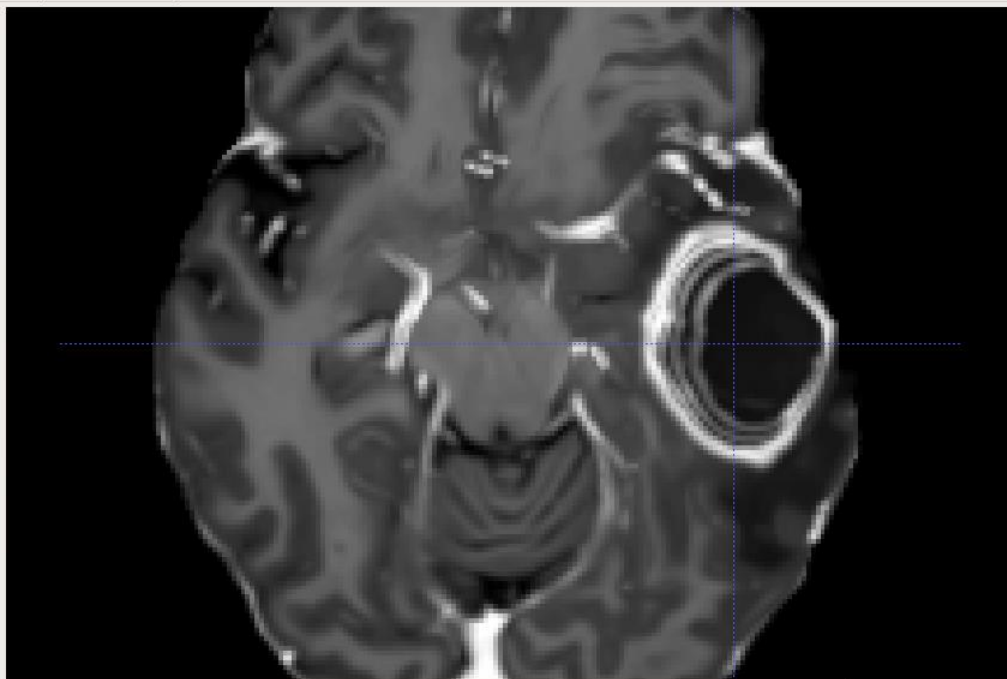
Paint over:

All labels

Overall label opacity:

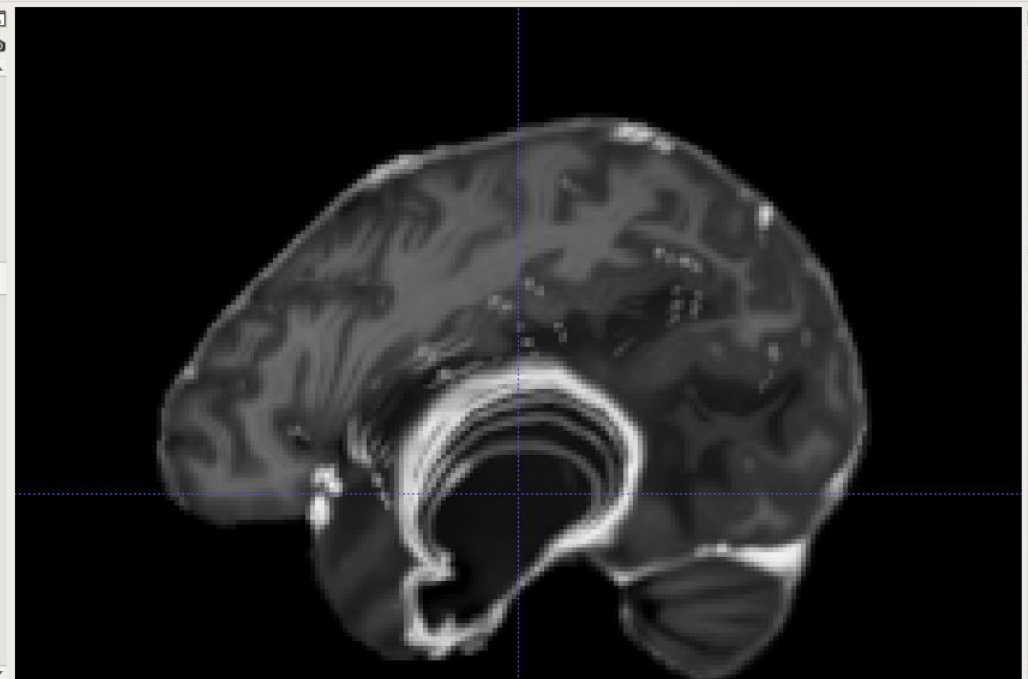
50

3D Toolbar



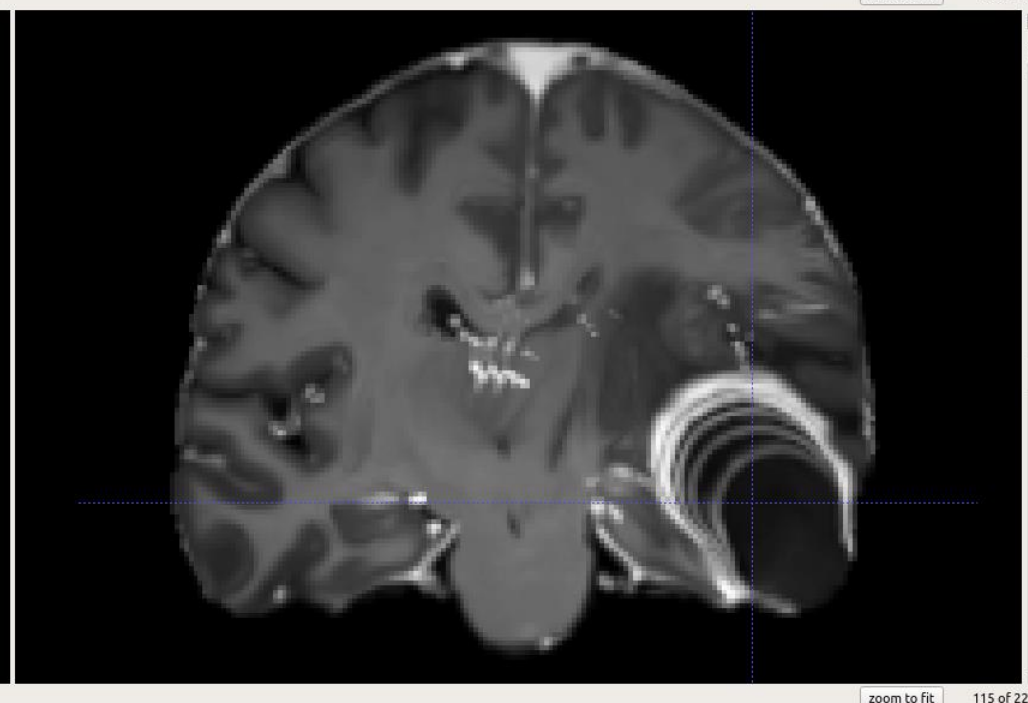
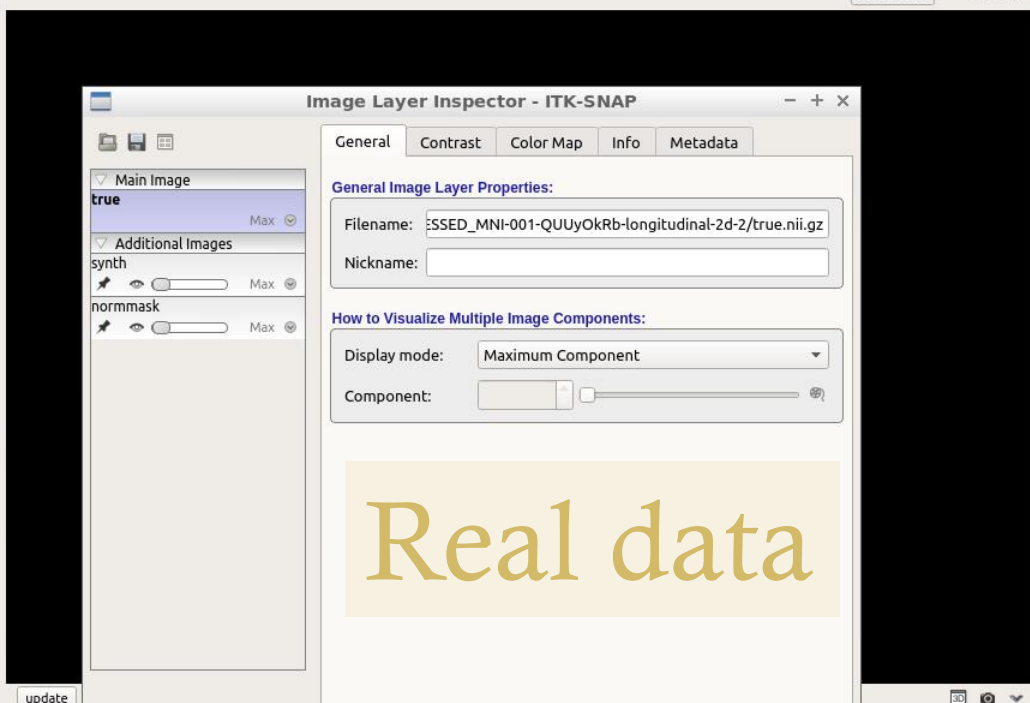
zoom to fit

65 of 193



zoom to fit

49 of 193



zoom to fit

115 of 229



Cursor position (x,y,z):

49 115 65

Intensity under cursor:

Layer	Intensity
true	19
synth	44.16
normmask	0

Label under cursor:

0 Clear Label

Active label:

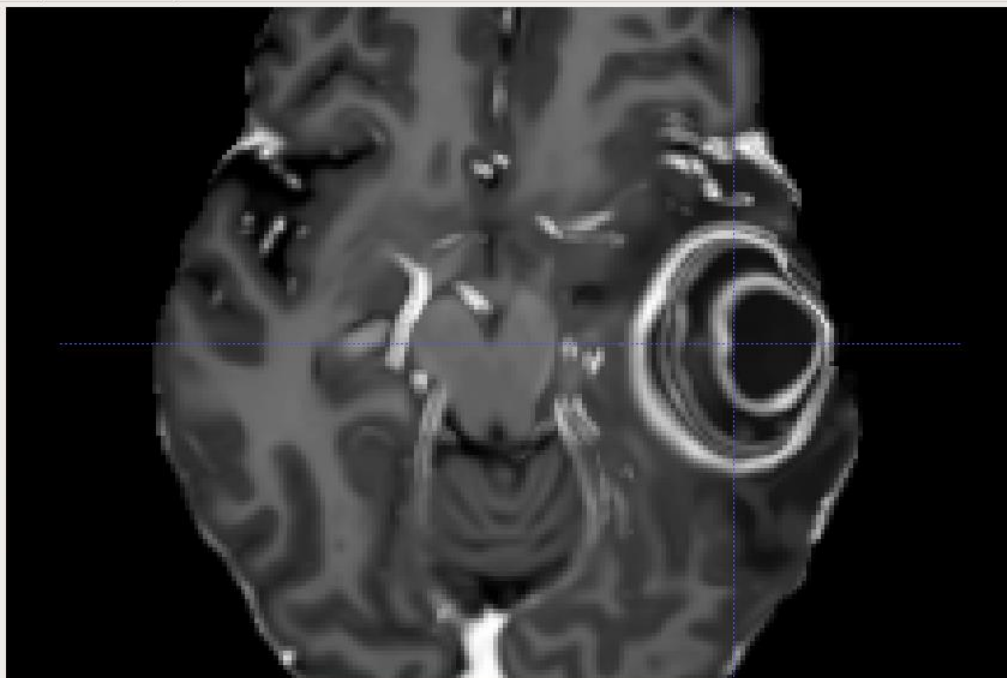
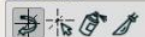
Label 1

Paint over:

All labels

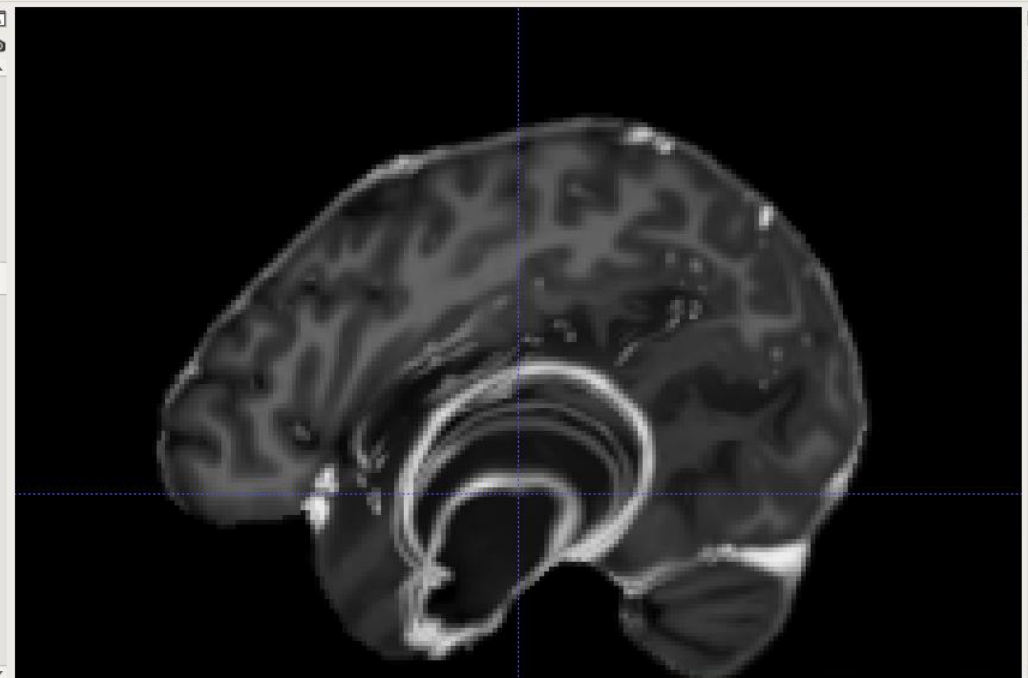
Overall label opacity:

50



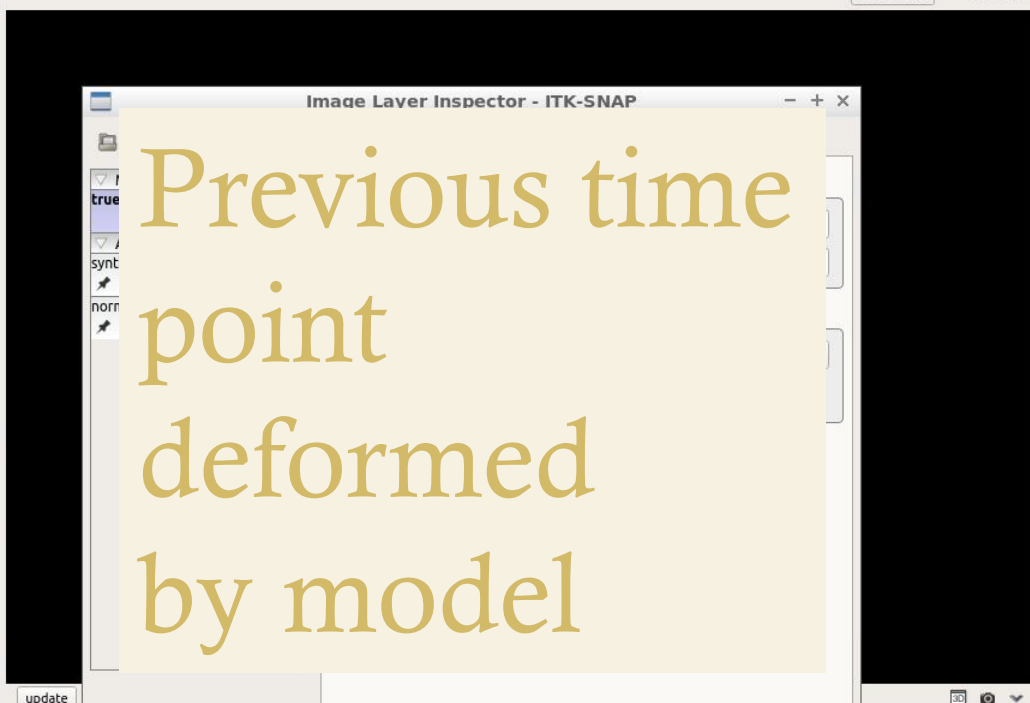
zoom to fit

65 of 193

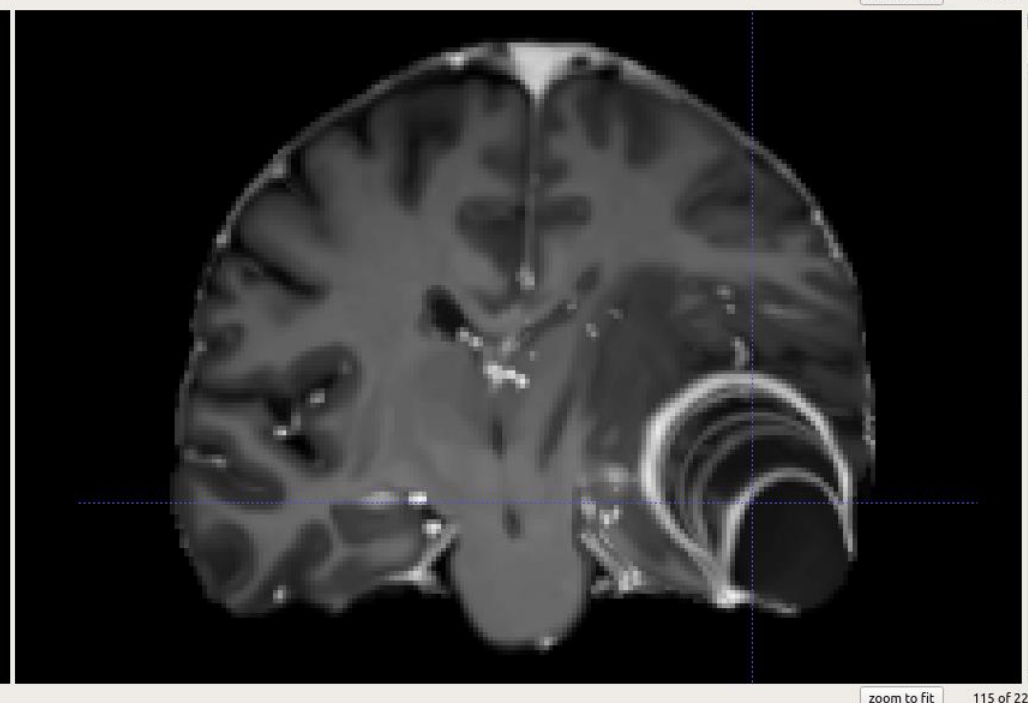


zoom to fit

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update



zoom to fit

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Cursor position (x,y,z):

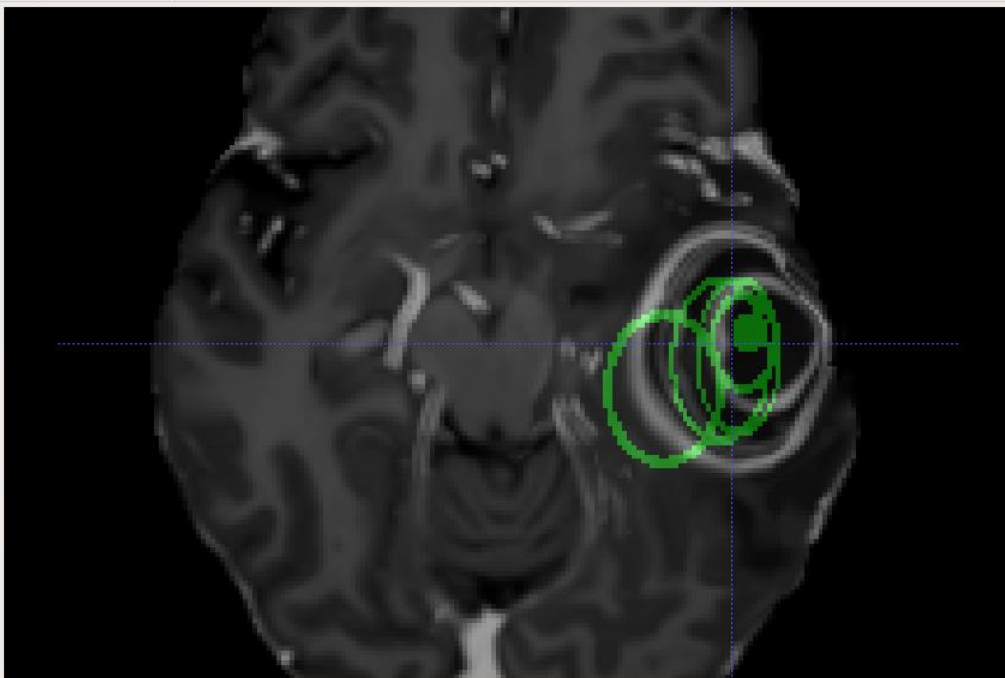
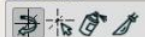
49 115 65

Intensity under cursor:

Layer	Intensity
true	19
synth	44.16
normmask	0

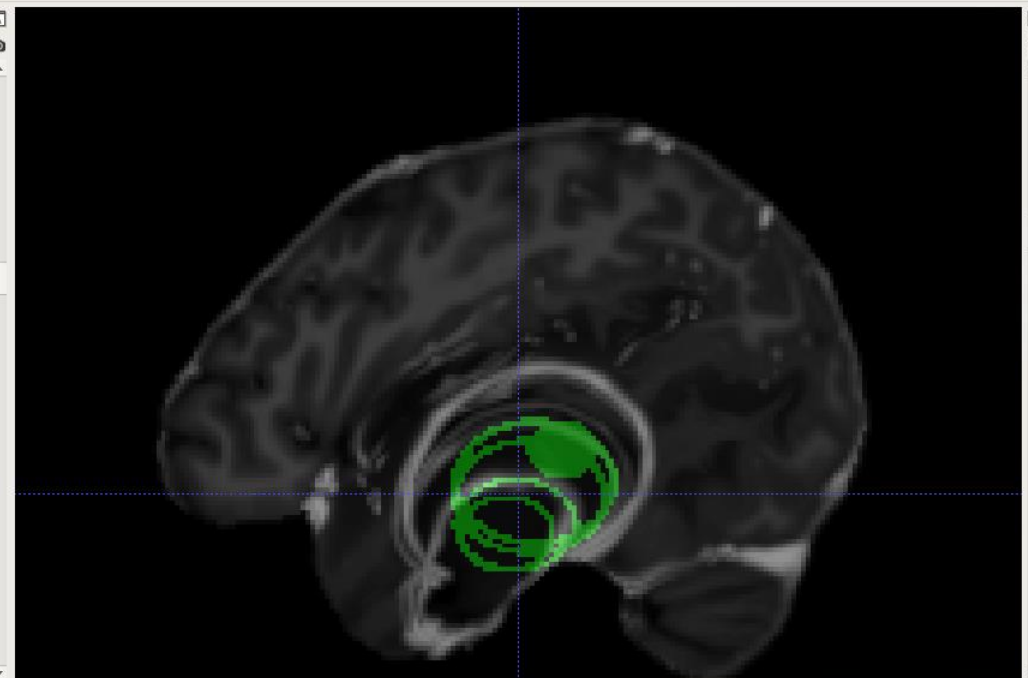
Label under cursor:

0 Clear Label

Active label:
Label 1Paint over:
All labelsOverall label opacity:
50

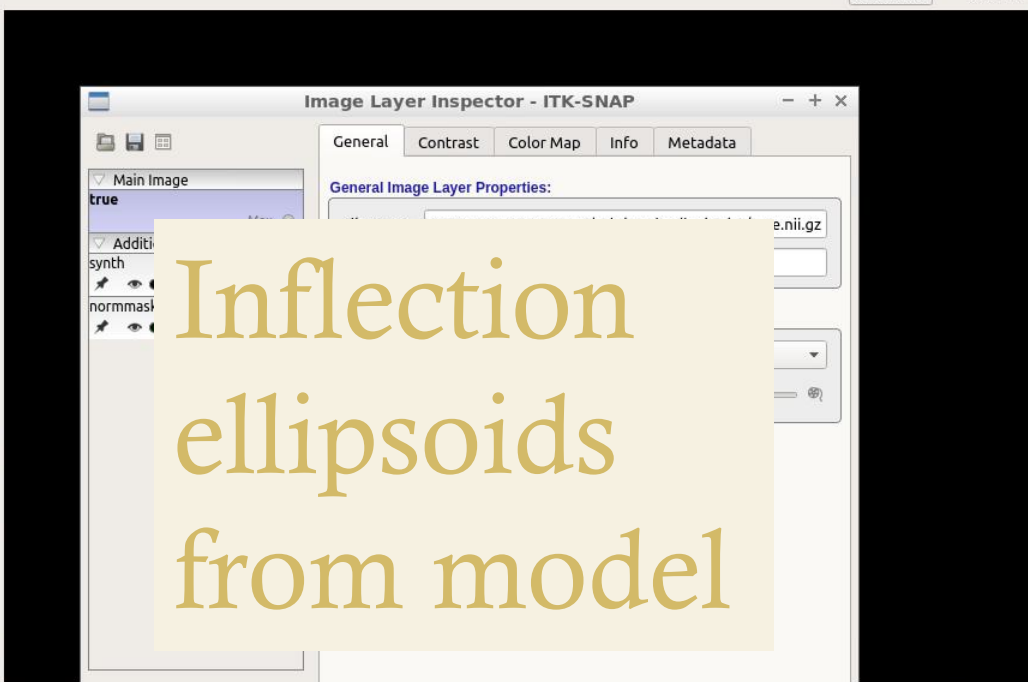
zoom to fit

65 of 193

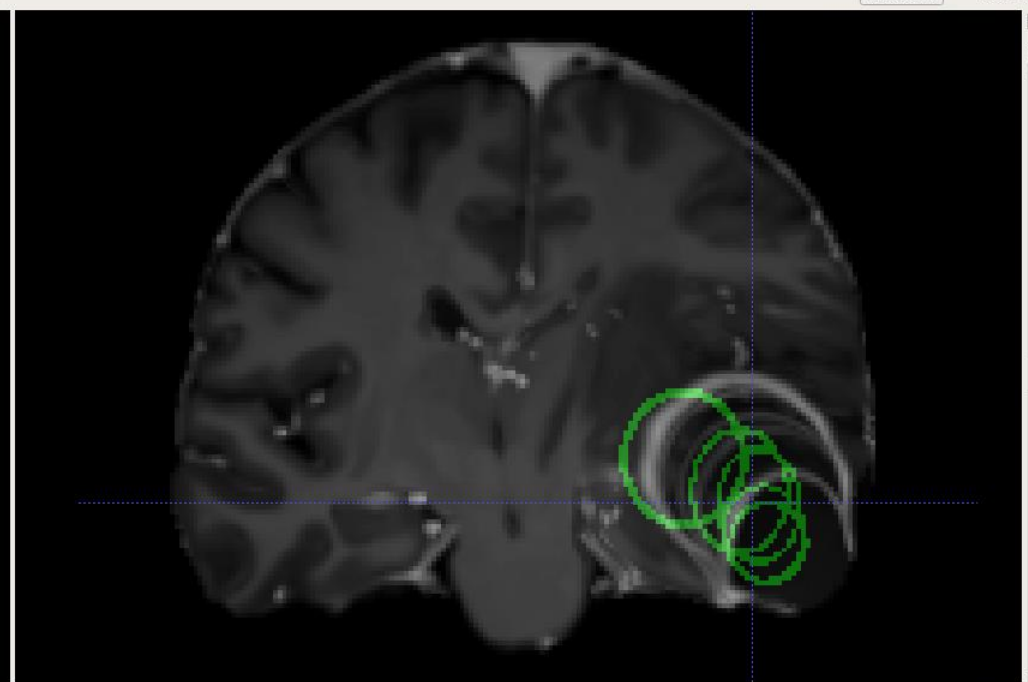


zoom to fit

49 of 193

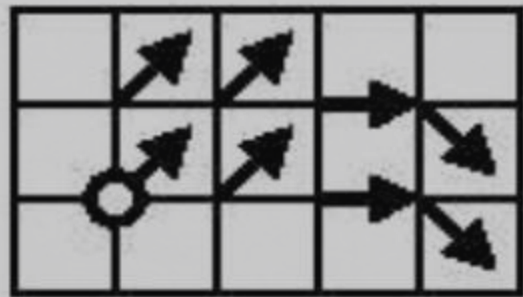


update

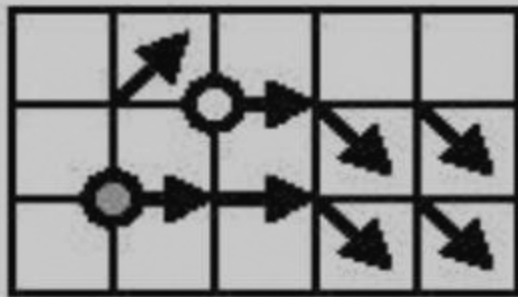


zoom to fit

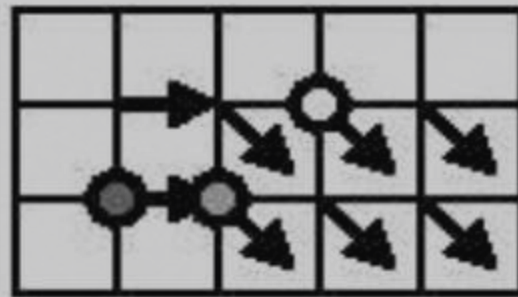
115 of 229



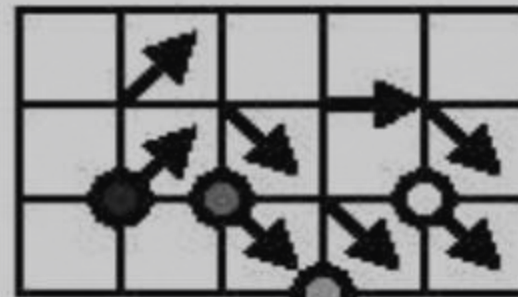
t_0



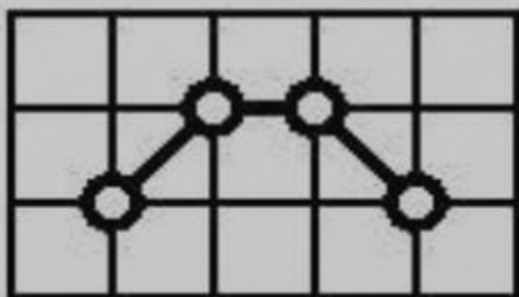
t_1



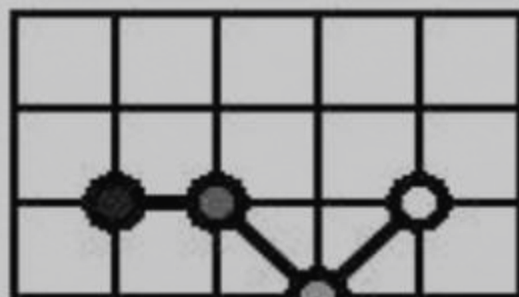
t_2



t_3



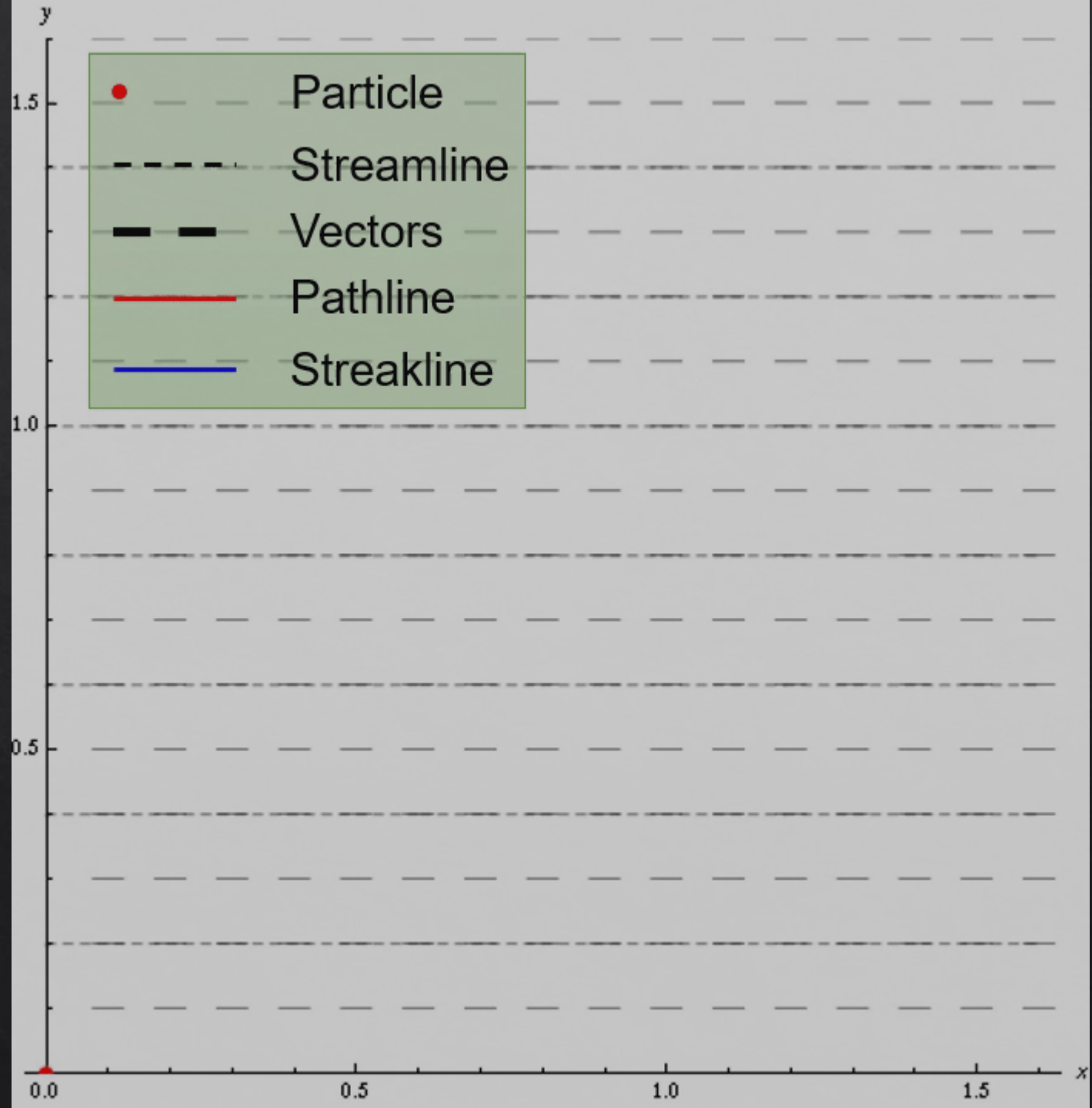
path line



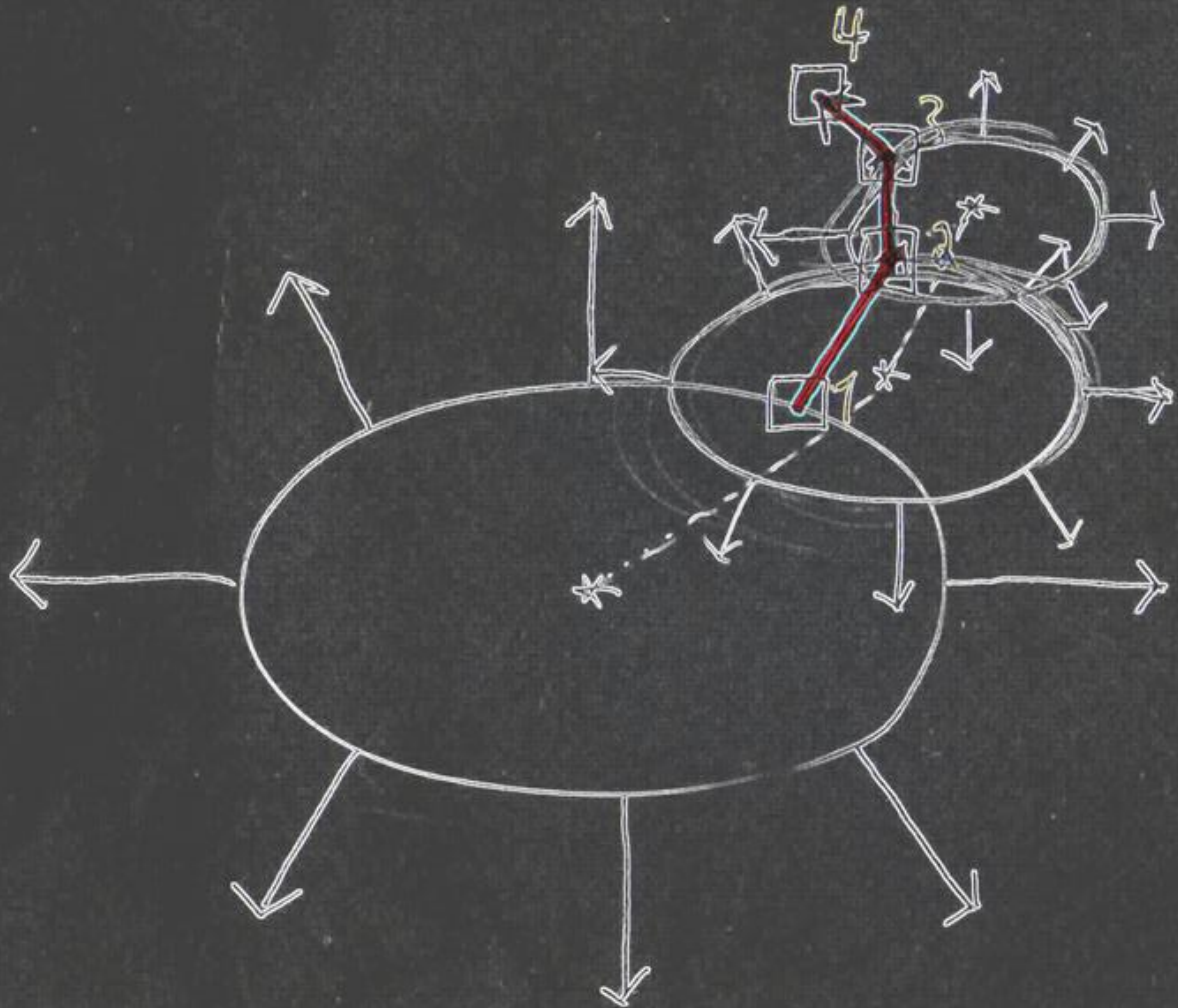
streak line



stream line for t_3



Computing a path line from the model

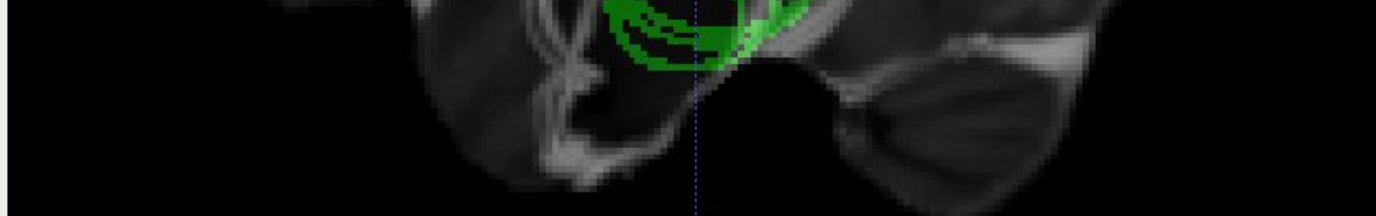


- PATH LINE FOR VOXEL
- VOXEL
- 1-4 TIME POINTS
- PATH OF MODEL
(= CENTER OF TUMOR)



zoom to fit

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zoom to fit

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P

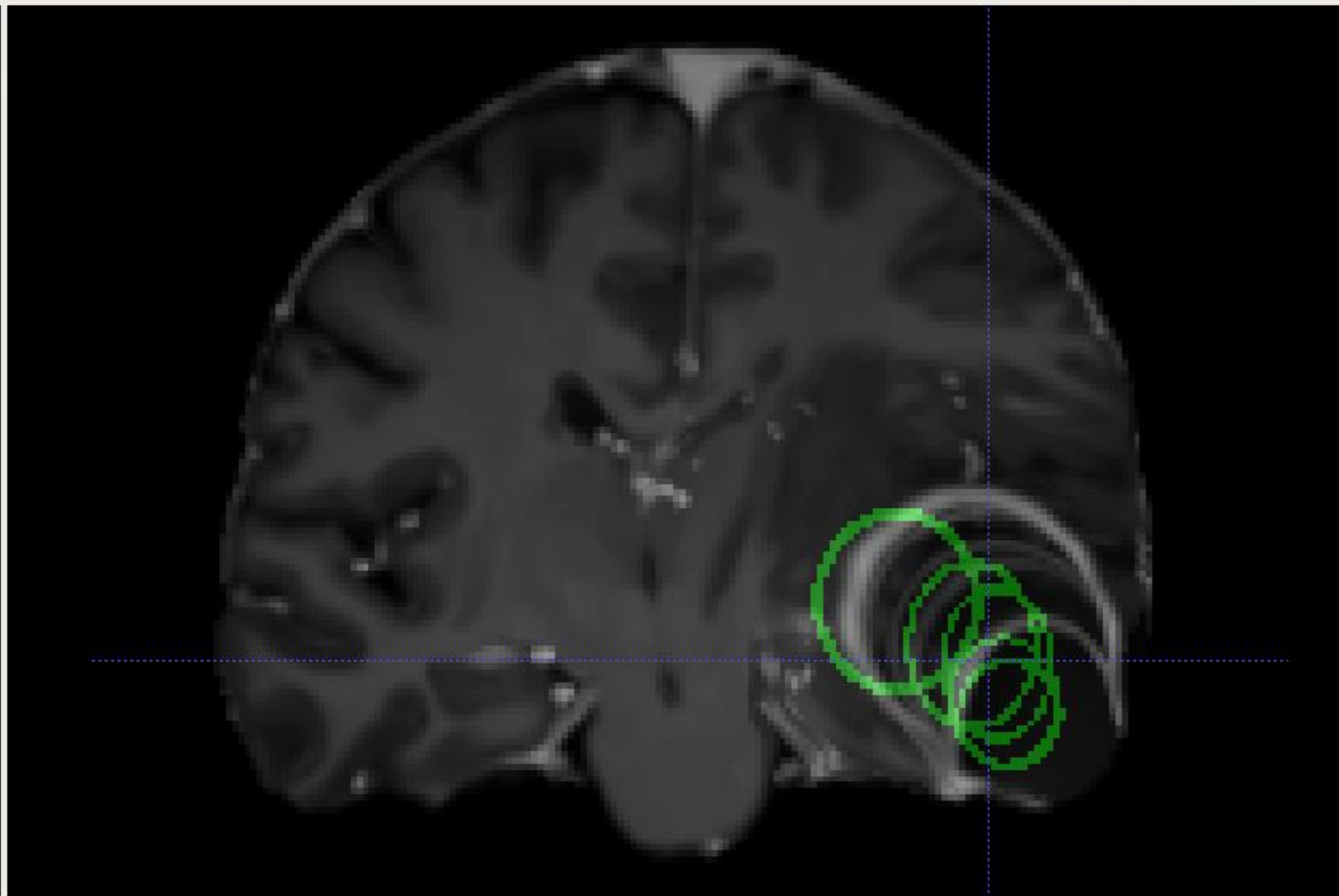
Info Metadata

-longitudinal-2d-2/true.nii.gz

nts:

ent

3D



zoom to fit

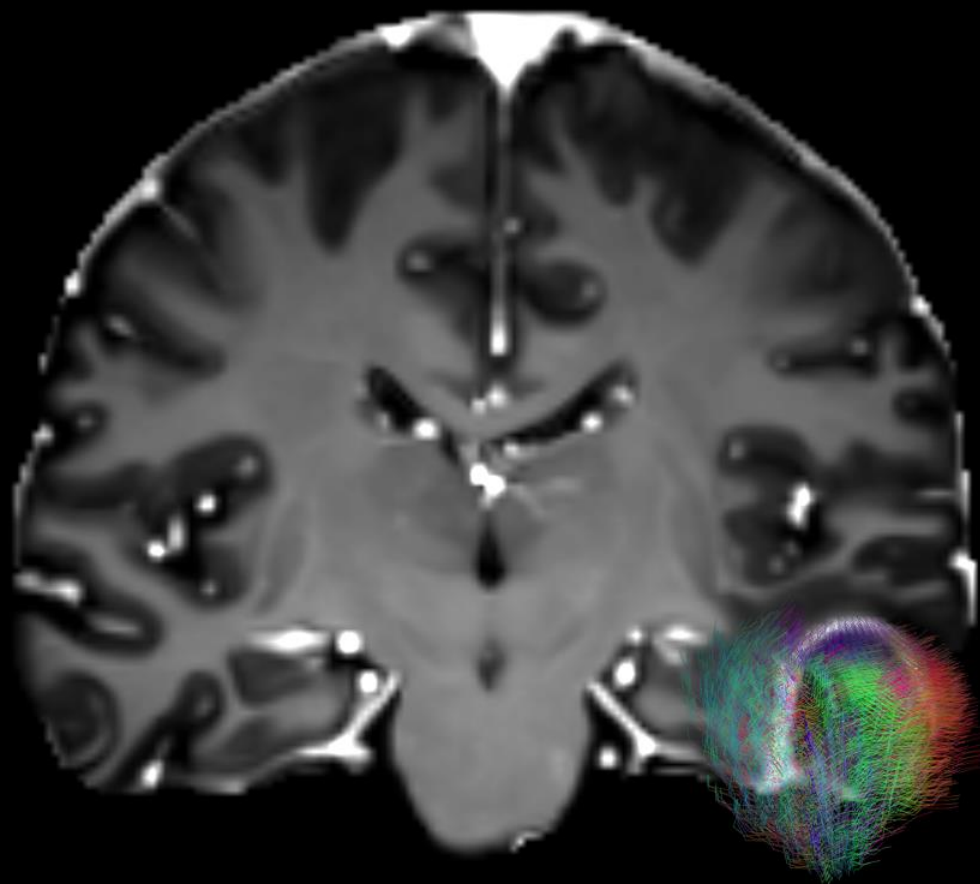
115 of 229

resetCamera

animated

▸ Growth fibers

▸ Tumor volume



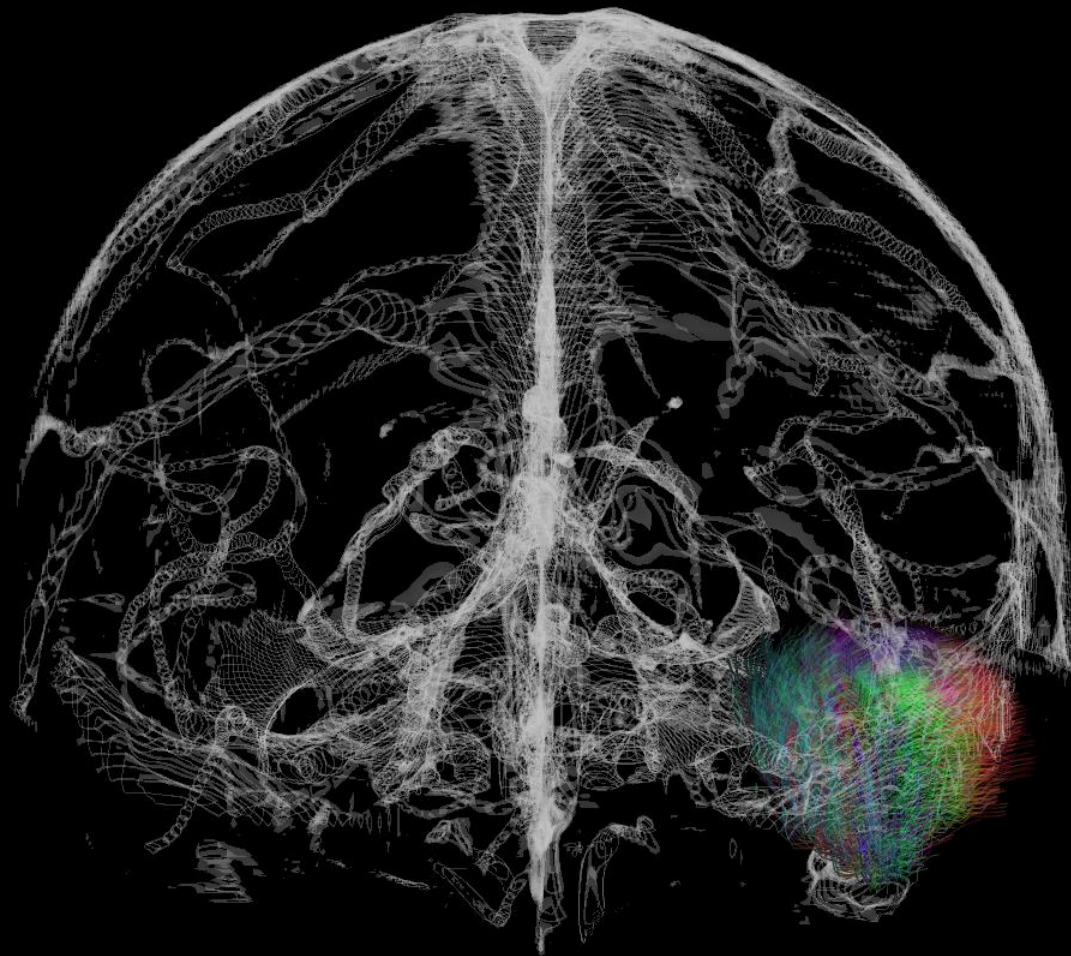
fiber mode: growth pathlines
from contrast-enhanced lesion
using most-fit radial growth model

resetCamera

animated

▸ Growth fibers

▸ Tumor volume



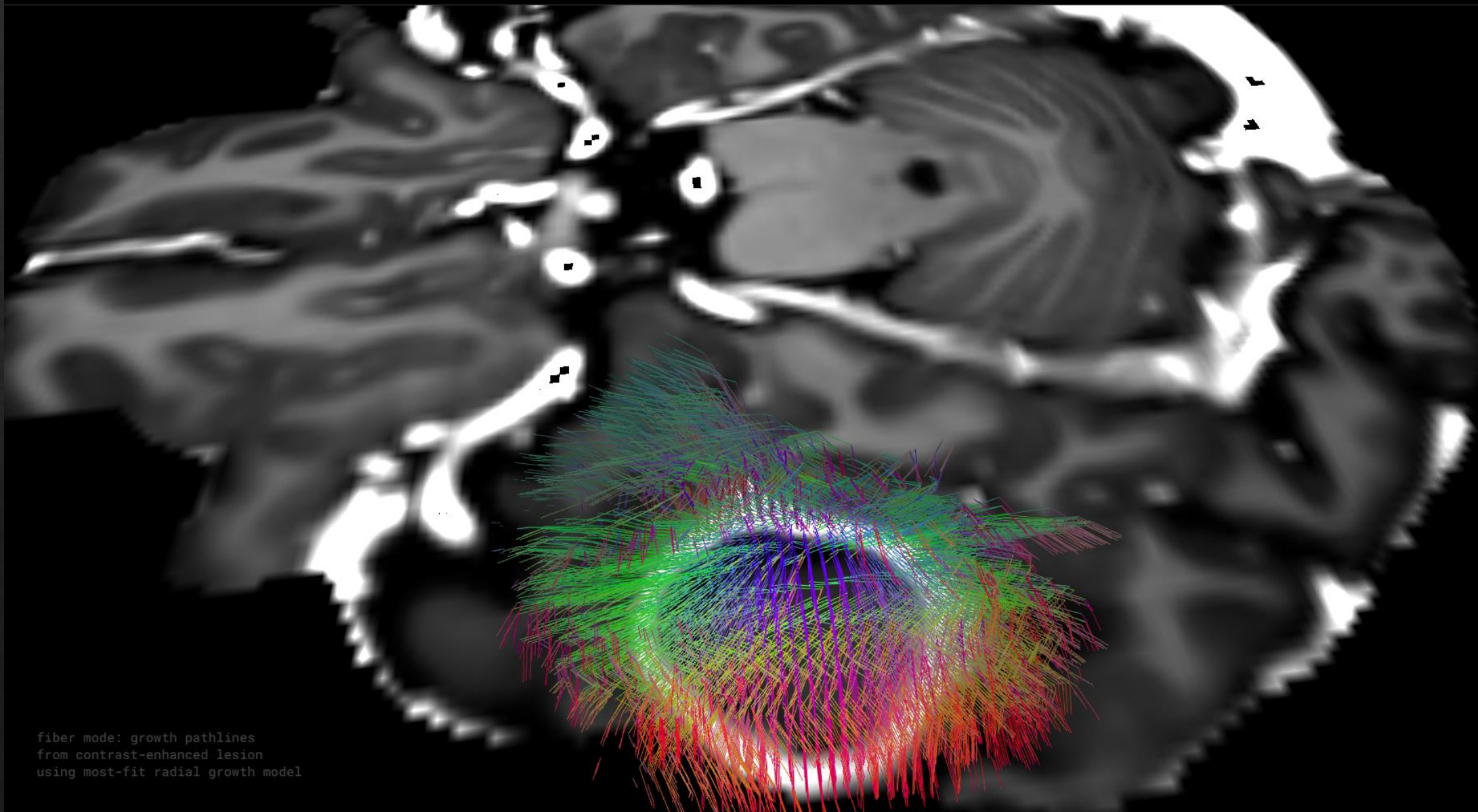
fiber mode: growth pathlines
from contrast-enhanced lesion
using most-fit radial growth model

resetCamera

animated

▸ Growth fibers

▸ Tumor volume



fiber mode: growth pathlines
from contrast-enhanced lesion
using most-fit radial growth model

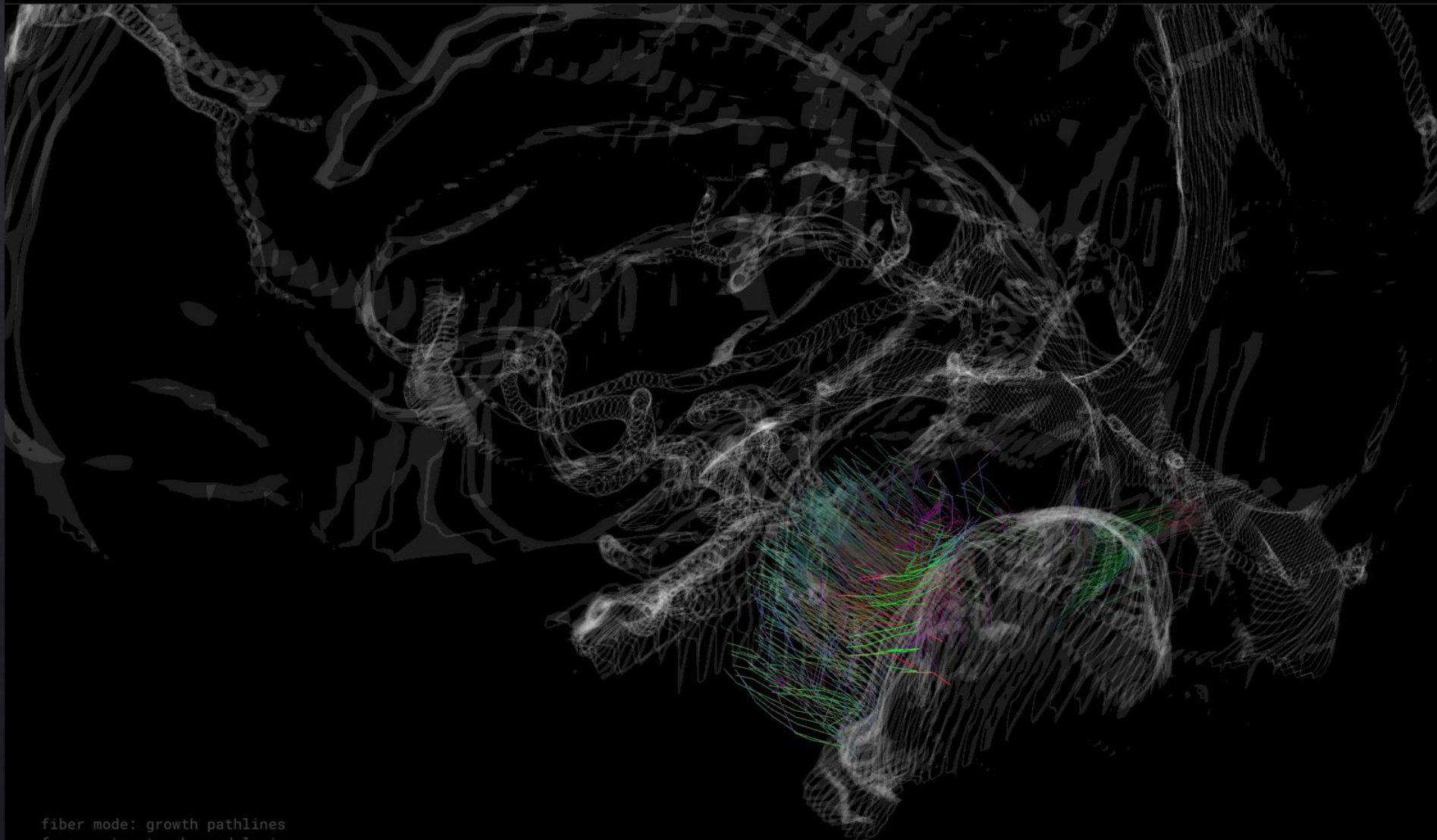
[about](#)

resetCamera

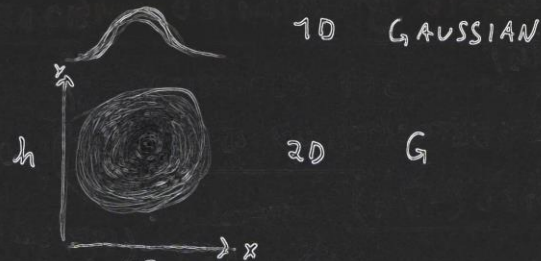
animated

▸ Growth fibers

▸ Tumor volume



fiber mode: growth pathlines
from contrast-enhanced lesion
using most-fit radial growth model



"INFLECTION RING" UNIT VECTOR: $|\vec{n}| = 1$



$-\nabla G = \text{EXPAND } (+)$

$$\nabla = \text{GRADIENT} = \begin{bmatrix} \frac{\partial G}{\partial x} \\ \frac{\partial G}{\partial y} \end{bmatrix}$$



$\nabla G = \text{SHRINK } (-)$

CANCER-SIM PARAMETERS:

MAXIMUM DISPLACEMENT MAGNITUDE M

BRAIN COVERAGE $B \in [0, 1]$, 0 = LARGEST BRAIN COVERAGE.

WHAT CANCER-SIM DOES:

- 1) USES w & h OF THE BOUNDING BOX OF LESION MASK TO CREATE $-\nabla G$
- 2) USES BRAIN MASK ^{to} STRETCH OUT $-\nabla G$ IN DIRECTIONS POSSIBLE, B DETERMINES HOW MUCH.

3) THIS (STEP 2)) LEADS TO INTERPOLATED $-D_6$
 $= \text{INTERPOLATED}(-D_6)$

4) SIMULATED TISSUE DEFORMATION IS $\vec{V}$ FIELD:

$$F = M \cdot \text{INTERPOLATED}(-D_6) \quad (\text{LOW BRAIN COVERAGE})$$

FOR STEP 2):
 1D-EXAMPLE



$B=1$ (LOW BRAIN COVERAGE)

$B=0$ (HIGH BRAIN COVERAGE)

CANCER-SIM OPERATES IN 3D. (2021.5 FEB:
 ONLY WORKS ON EXPANDING DEFORMATION)

TESTING AND FITTING MODEL ON REAL LONGITUDINAL MRI

CANCER-SIM-SEARCH: GRID SEARCH FOR BEST FIT, $\hat{M} \in \hat{B}$

EXAMPLE BETWEEN TIME STEP 1 & 2:

1: T1-W-1 MRI (POST-CONTRAST)
 LESION MASK (EDEMA U ENHANCED U NECROSIS)
 BRAIN MASK

2: T1-W-2

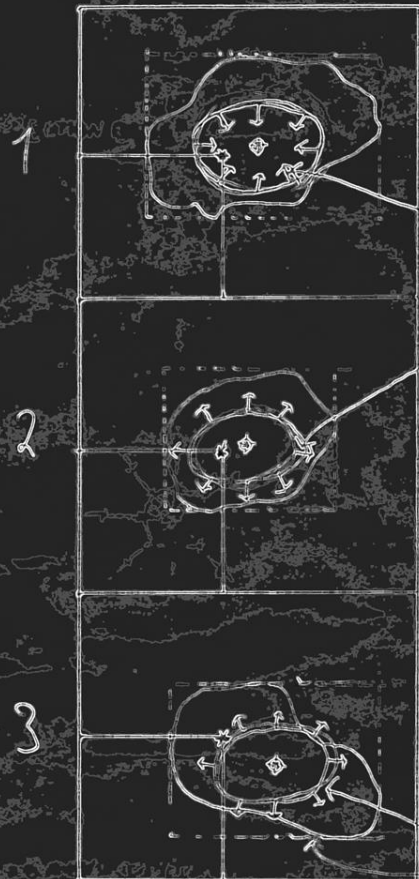
FINDING $\hat{M}$ & $\hat{B}$ FROM HIGHEST CROSS-CORRELATION
 BETWEEN MODELREGION (T1-W-1) & MODELREGION (T2-W1)

CAN RUN CANCER-SIM-SEARCH BETWEEN EACH
 EXAMINATION PAIR IN LONGITUDINAL DATASET
 FOR A PATIENT

→ TRACKING

TRACKING EXAMPLE: THREE TIME POINTS

1, 2, 3: CO-REGISTERED TIC WITH LESION MASK FOR EACH
 TIME POINT, AND A BRAIN MASK.



* FIXED SPATIAL LOCATION
 FOR COMPARISON

LESION BOUNDING BOX

ELLIPTIC "INFLECTION RING"

$$\hat{M} \cdot \hat{N}, \hat{M} < 0 (-)$$

FROM GRID SEARCH ON 1-2

$$\hat{M} \cdot \hat{N}, \hat{M} > 0 (+)$$

FROM GRID SEARCH ON 2-3

MAYBE SHRINKING
 FROM TREATMENT?

MAYBE CANCER
 RECURRENCE?

THIS BOUNDING
 BOX & ELLIPSIS NOT USED IN
 EXAMPLE

TRACKING
 VISUALIZATION

1-2 (-)
 2-3 (+)
 3-4 (+)
 ETC.

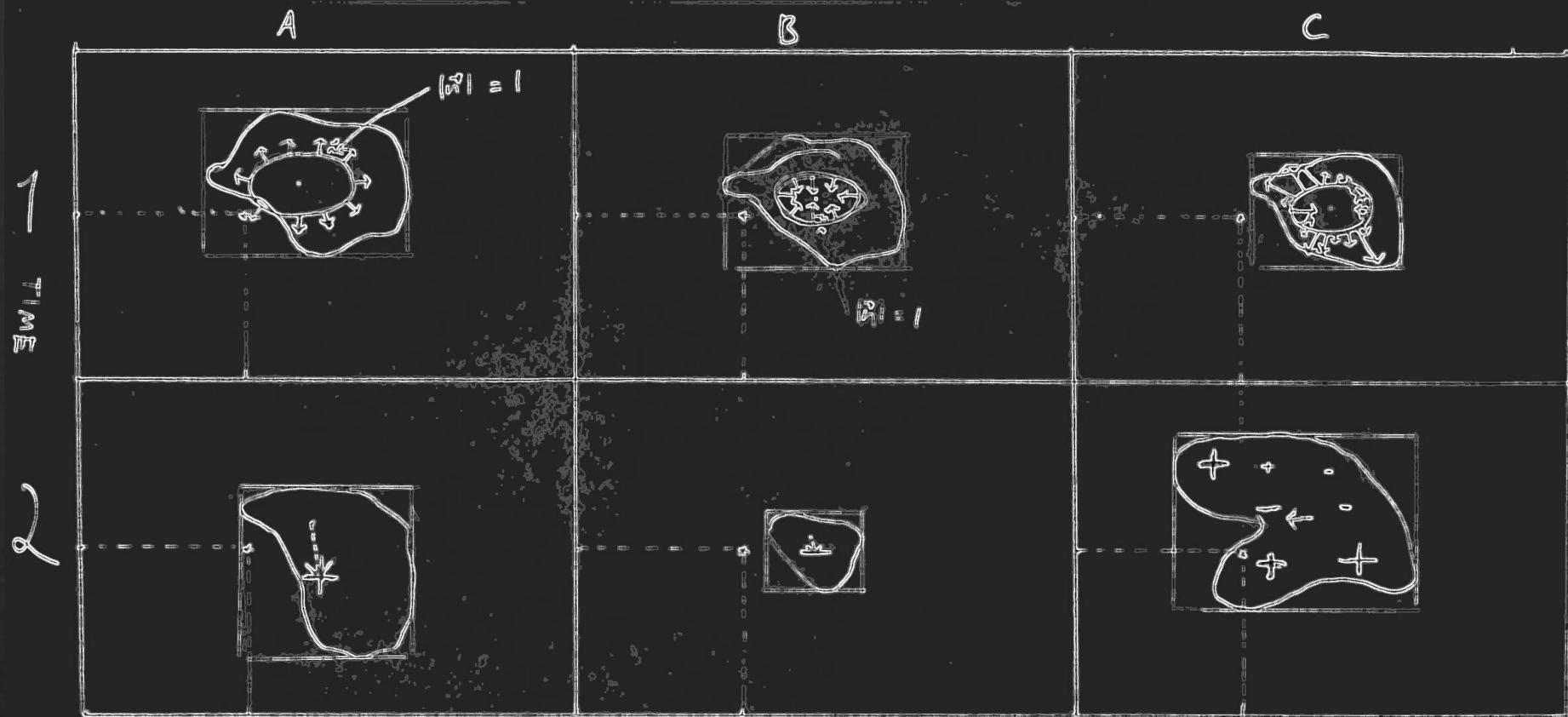
RESULT & CLINICAL MOTIVATION:

• NO BUST MEASUREMENT OVERALL DISPLACEMENT &
 BRAIN COVERAGE IN EACH TIME INTERVAL

• ROBUST (SIMPLE) CENTER-OF-MASS ^{TUMOR} LOCATION TRACKING.

• ROBUST MEASUREMENT OF OVERALL SHRINK & EXPAND
 DEFORMATION IN EACH TIME INTERVAL.





CANCER-SIM V1 (PAPER #2)

• EXPAND DEFORMATION

CANCER-SIM V2

• EXPAND & SHRINK DEFORMATION

CANCER-SIM V3

• EXPAND & SHRINK DEFORMATION (INITIALIZATION)
& REGULARIZATION

• GRADIENT-BASED OPTIMIZATION
OF "INFLECTION RING" $\Rightarrow$ VARIABLE GROWTH RATE