Resting state fMRI and ICA

静息态fMRI和ICA

- Resting state fMRI（静息态fMRI)
- Independent Component Analysis (ICA)
  （独立成分分析)
- Single-subject ICA clean-up（单样本ICA去噪)
- Multi-subject ICA and dual regression
  （多样本ICA和双回归)

中文翻译：魏朝行 孔亚卓

Resting state methods

ICA

- Multivariate voxel-based approach
  基于体素的多变量方法
- Finds interesting structure in the data
  寻找数据中的感兴趣结构
- Exploratory “model-free” method
  探索性的“无模型”方法
- Spatial approach
  空间维度

Network modelling (网络建模)

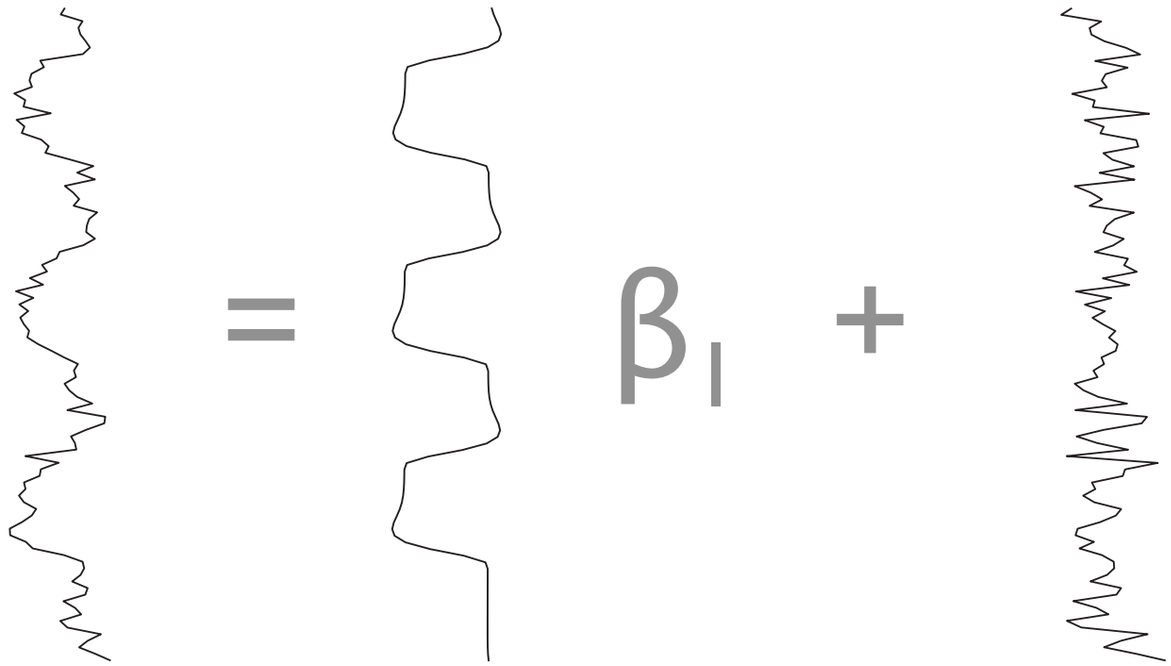
- Node-based approach (first need to parcellate the brain into functional regions)
  基于节点的方法（首先需要将大脑分为不同的功能区域）
- Map connections between specific brain regions (connectomics)
  特定脑区之间的连接图谱（连接组学）
- Temporal approach
  时间维度

Resting state fMRI

静息态fMRI

Model-based (GLM) analysis

基于模型（GLM的）分析



- Model each measured time-series as a linear combination of signal and noise 将每个时间序列建模为信号和噪声的线性组合
- If the design matrix does not capture every signal, we typically get wrong inferences! 如果设计矩阵没有捕获每个信号，我们通常会得到错误的推论

Data Analysis

Confirmatory确定性的

- "How well does my model fit to the data?"
  (我的模型与数据的匹配程度如何？)

Problem ⇨ Data ⇨

Model ⇨ Analysis

⇨ Results

- results depend on the model 结果取决于模型

Exploratory探索性的

- "Is there anything interesting in the data?"
  (数据中有什么有趣的东西吗？)

Problem ⇨ Data ⇨

Analysis ⇨ Model

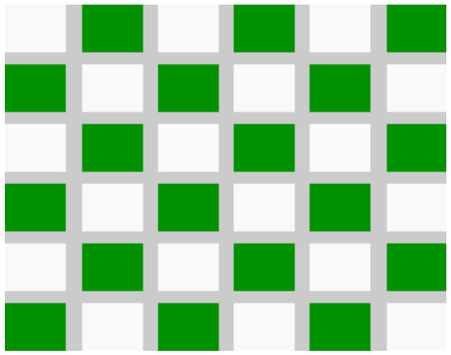
⇨ Results

- can give unexpected results 可以有预料之外的结果

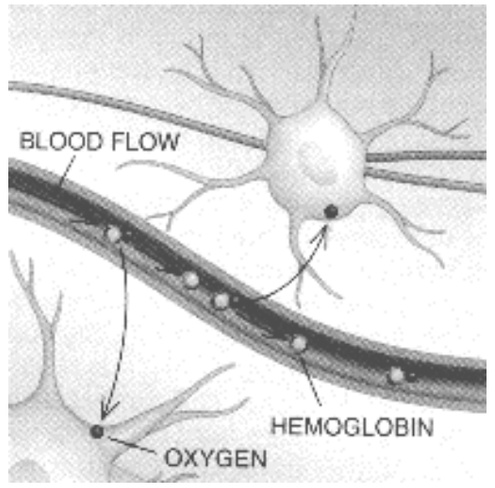
FMRI inferential path

fMRI推论路径

Experiment 实验



Physiology 生理

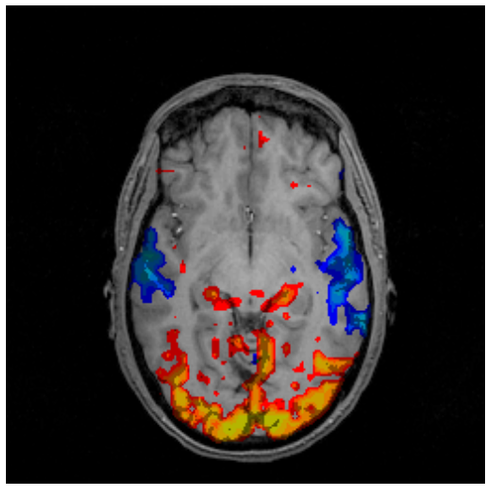


MR Physics MR物理

Analysis 分析

Interpretation of final results

解释最终结果



Variability in FMRI

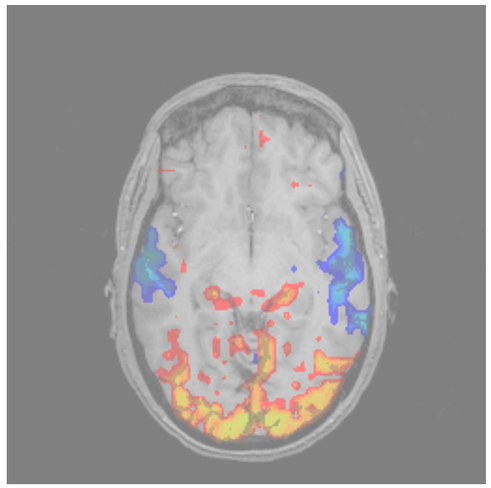
fMRI的变异性

Experiment

suboptimal event timing，不适合的事件发生时间

inefficient design, etc.无效的设计

Interpretation of final results



Physiology

secondary activation, ill-defined baseline, resting-fluctuations etc.

次级激活，基线不明确，静息波动等

Analysis

filtering & sampling artefacts, design misspecification, stats & thresholding issues etc.

滤波、采样伪影，design错误设定,统计和阈值问题等

MR Physics

MR noise,MR噪声

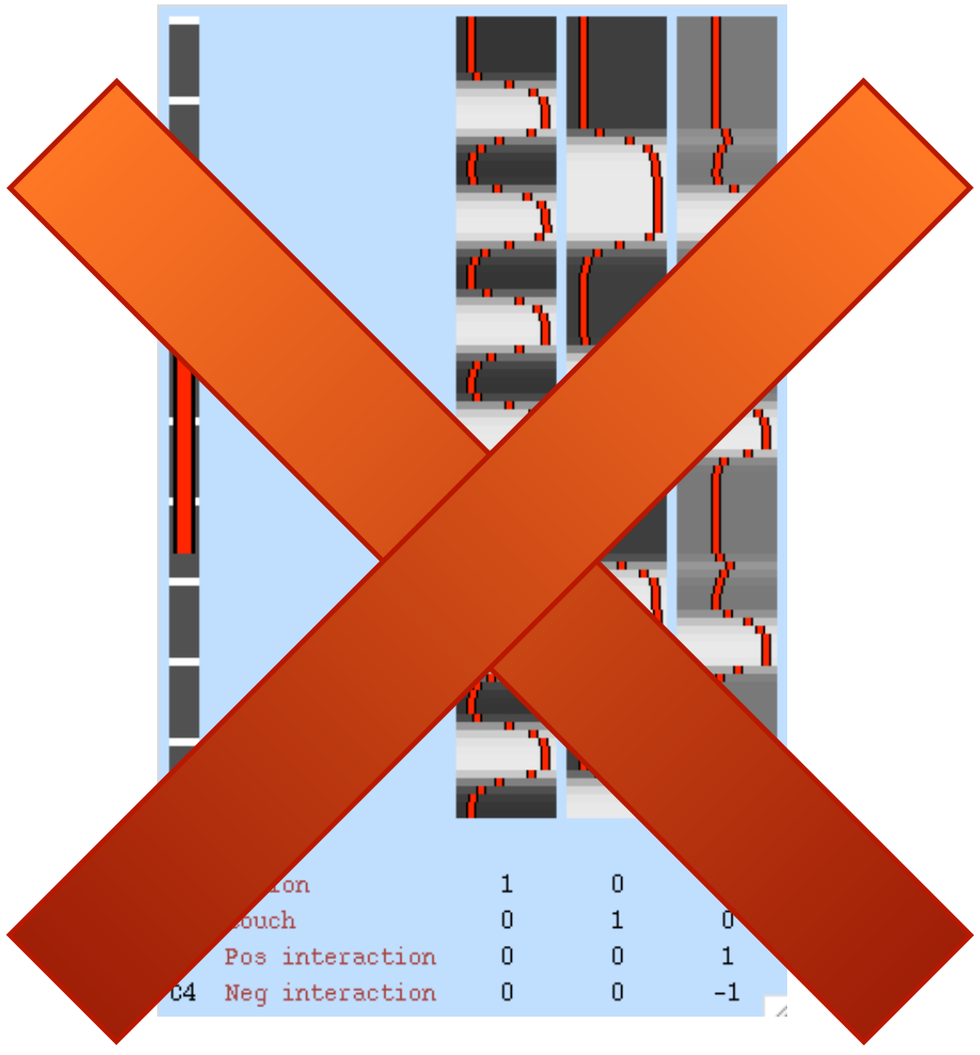
field inhomogeneity,磁场不均匀

MR artefacts etc.MR伪影等

Independent Component Analysis

独立成分分析

Model-free? 无模型?

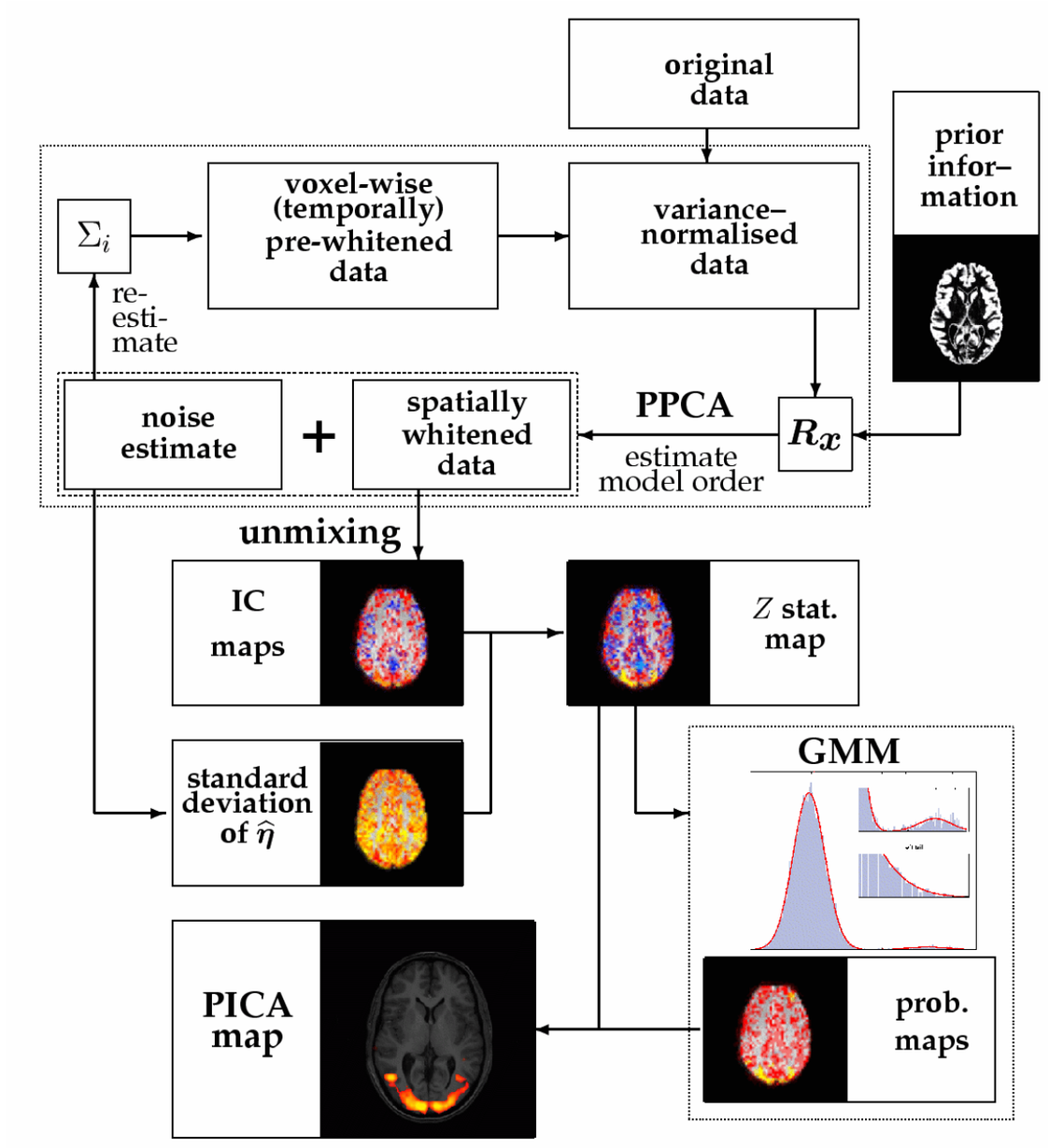


There is no explicit time-series model of assumed ‘activity’

没有明确的假设“激活”的时间序列模型

Model-free? 无模型?

$$Y^i = S^i A^i + E^i, \quad \text{where} \quad E^i_{\cdot j} \sim \mathcal{N}(0, \sigma^2_Y \boldsymbol{I})$$



There is an underlying mathematical (generative) model

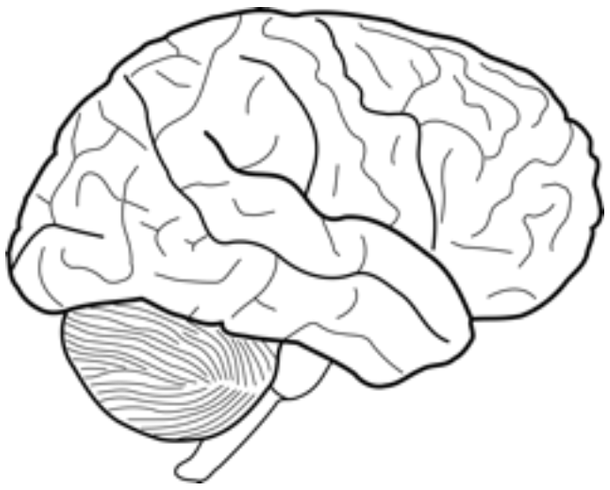
潜在的数学（生成）模型

Decomposition techniques分解技术

- try to ‘explain’ / represent the data（试着解释或表示数据）
  - by calculating quantities that summarise the data
    通过计算汇总数据的数量
  - by extracting underlying ‘hidden’ features that are ‘interesting’ 通过提取“有趣”的潜在“隐藏”特征
- differ in what is considered ‘interesting’“有趣”的定义不同
  - are localised in time and/or space (Clustering)
    聚焦于时间和/或空间（聚类分析）
  - explain observed data variance (PCA, FDA, FA)
    解释观察到的数据差异
  - are maximally independent (ICA)最大程度的独立成分

Melodic

multivariate linear decomposition: 多元线性分解



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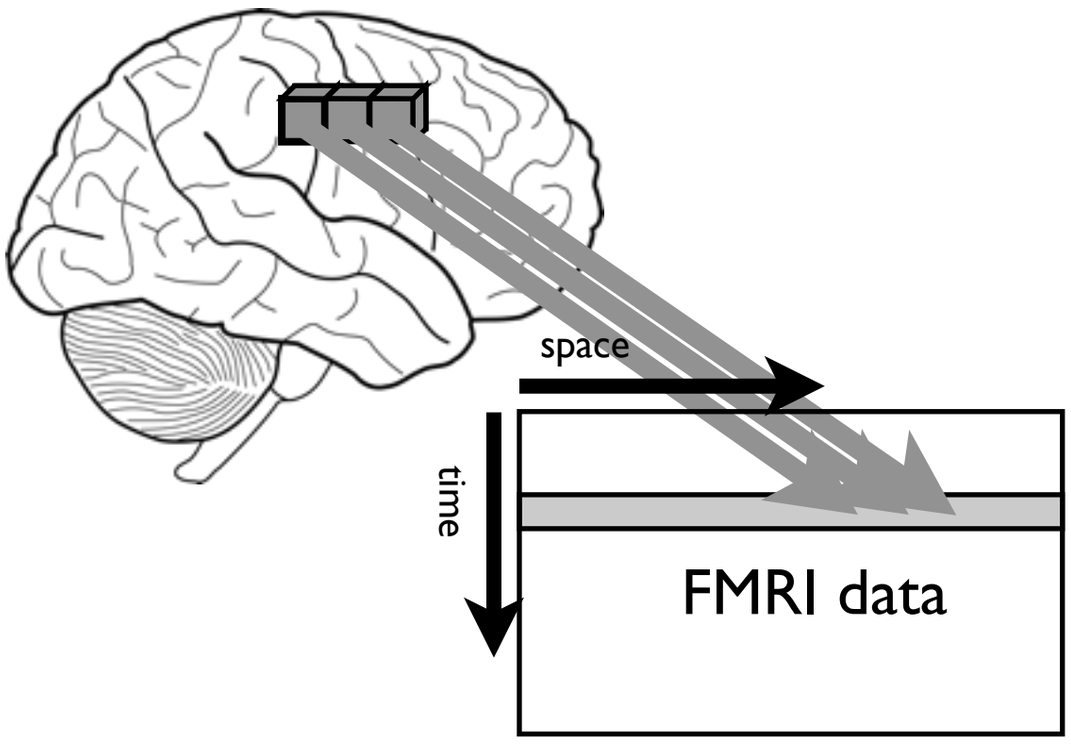

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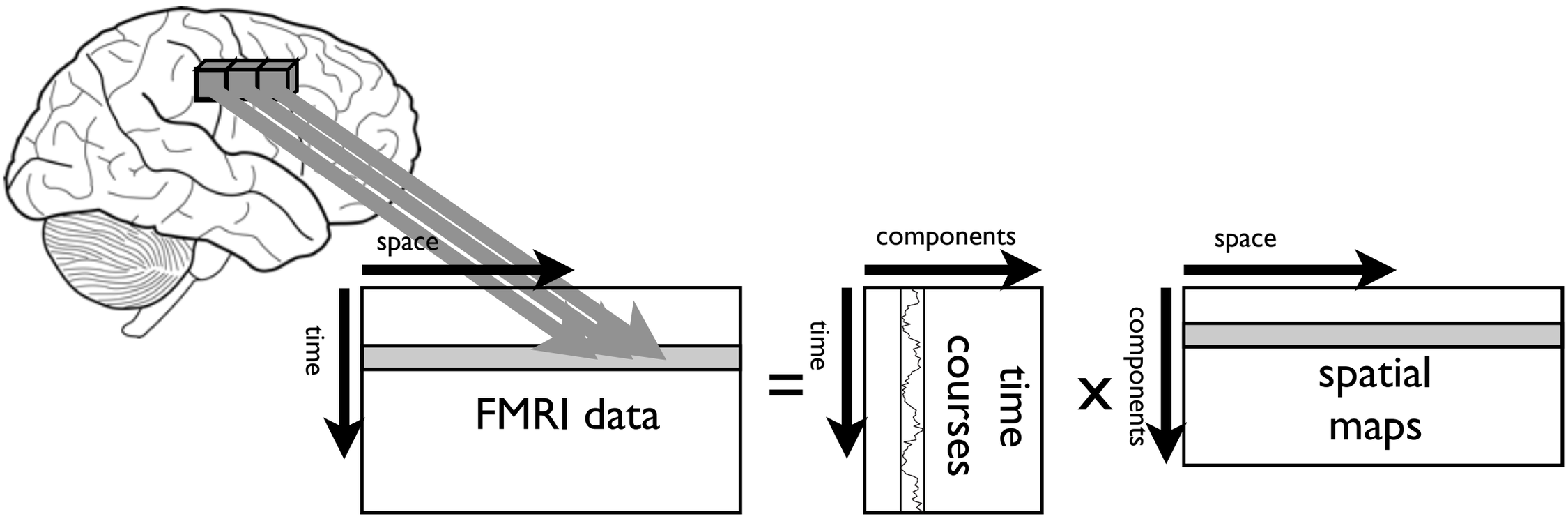

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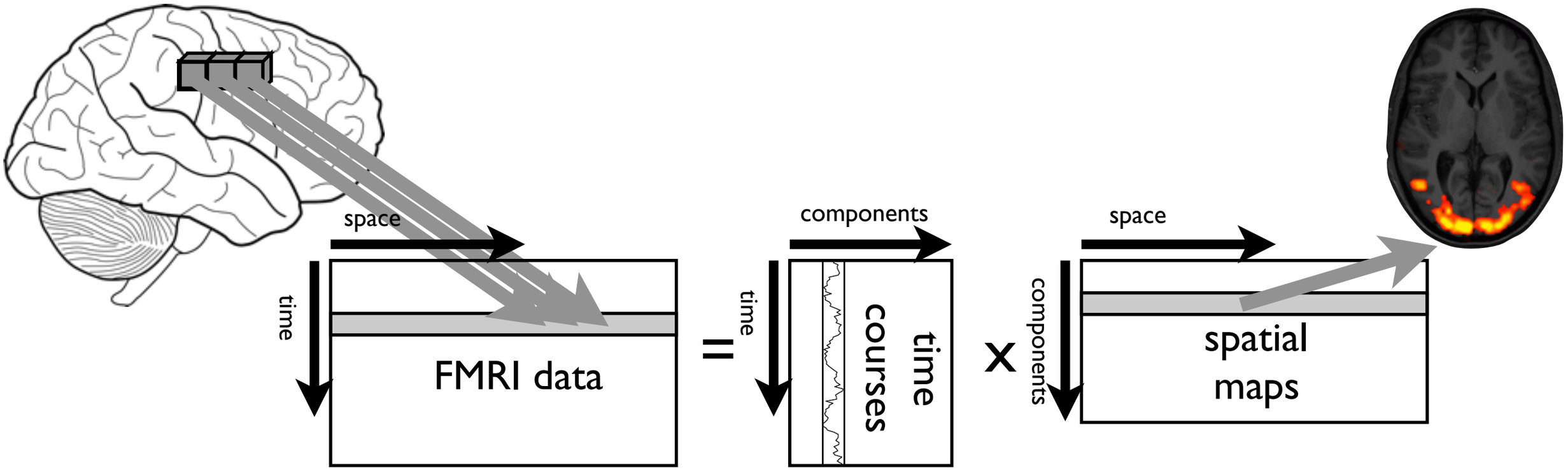

Data is represented as a 2D matrix and decomposed into components

数据被转化为2维矩阵并分解成不同成分

Melodic

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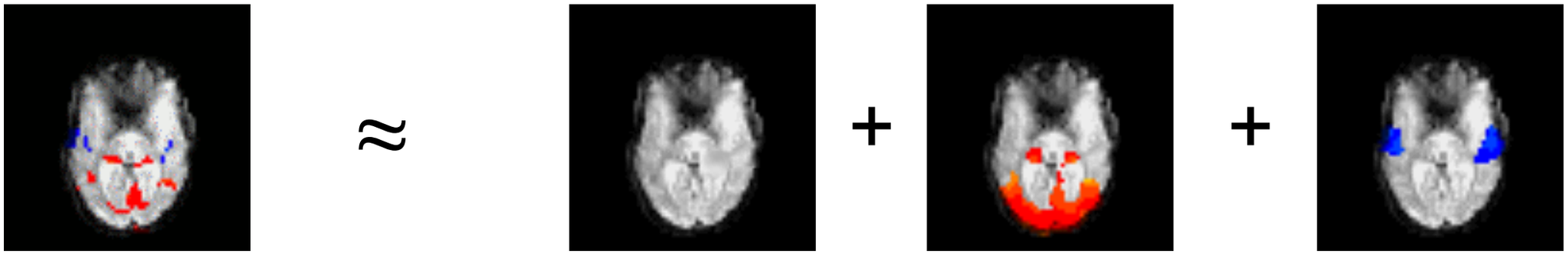
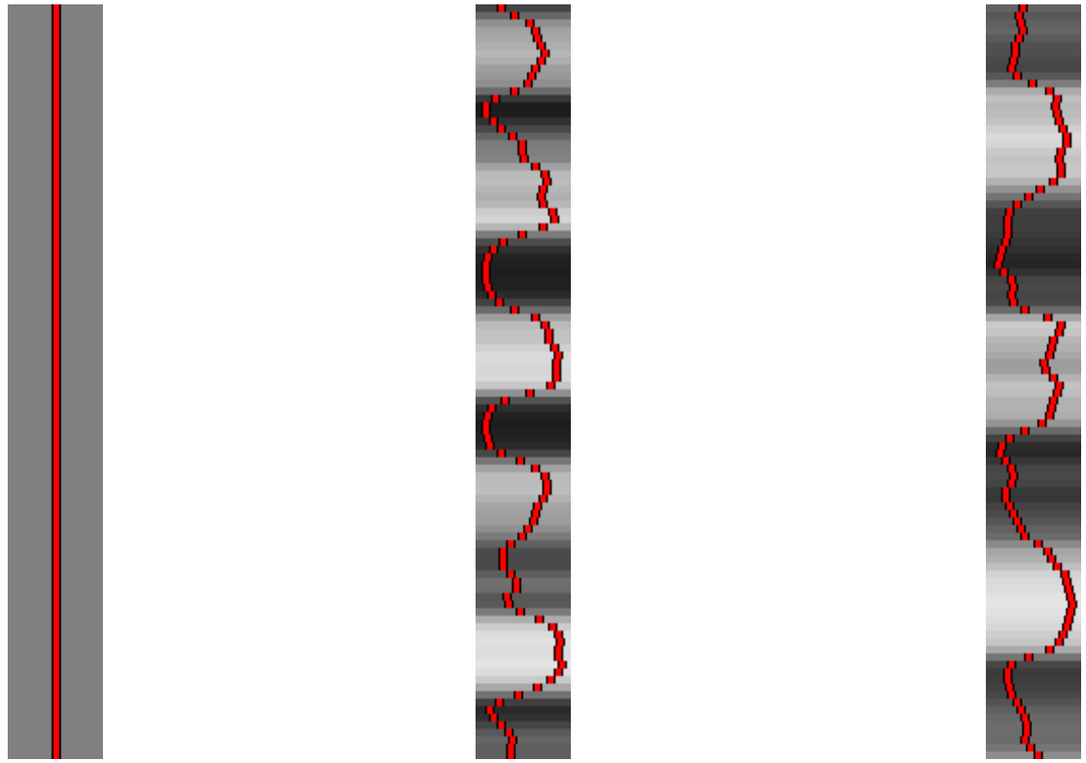
数据被转化为2维矩阵并分解成不同成分

What are components?什么是成分?

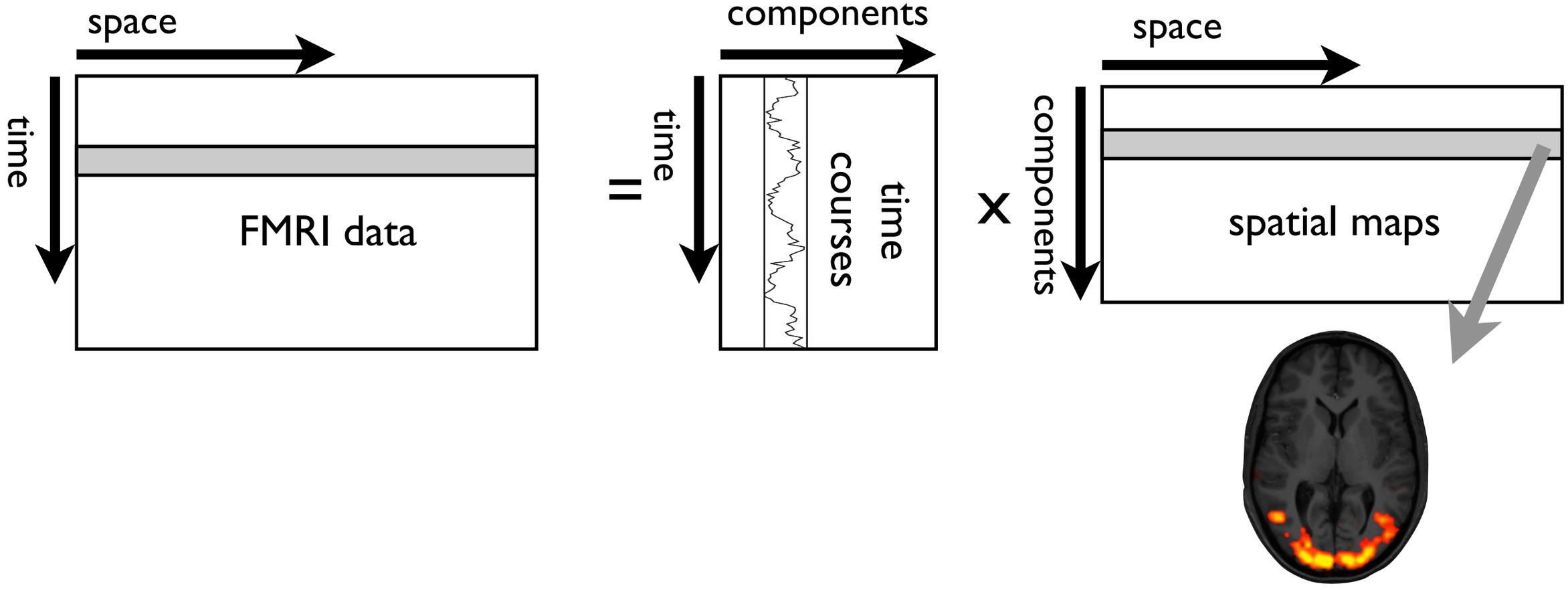


- express observed data as linear combination of spatio-temporal processes
  通过线性组合时-空加工过程表达观察到的数据
- techniques differ in the way data is represented by components
  技术差异阻碍了通过成分代表数



Spatial ICA for FMRI

fMRI的空间ICA



- data is decomposed into a set of spatially independent maps and a set of time-courses

数据被分解成一组空间独立的图像和一组时间序列

McKeown et al. HBM 1998

Independence

独立成分

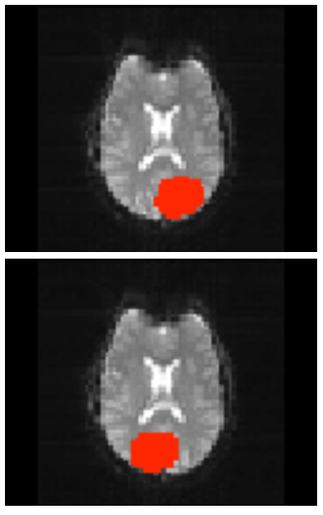
PCA vs. ICA ?

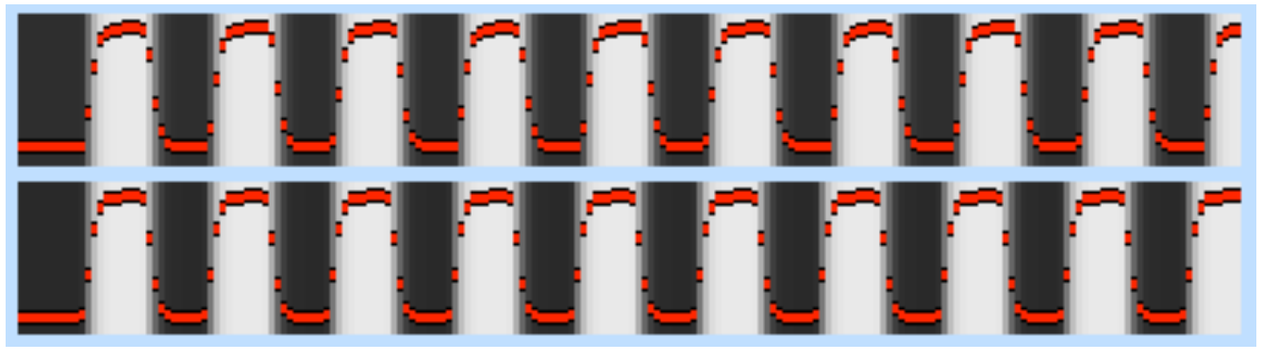
Simulated Data

模拟数据

(2 components, slightly different time courses)

2个成分，时间序列略有不同





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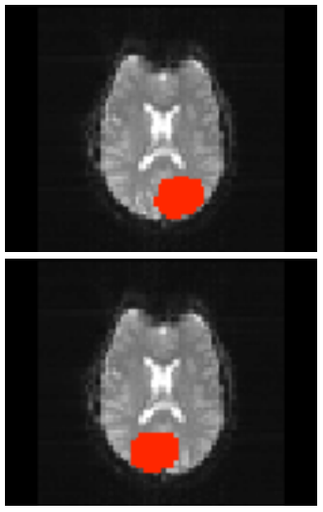

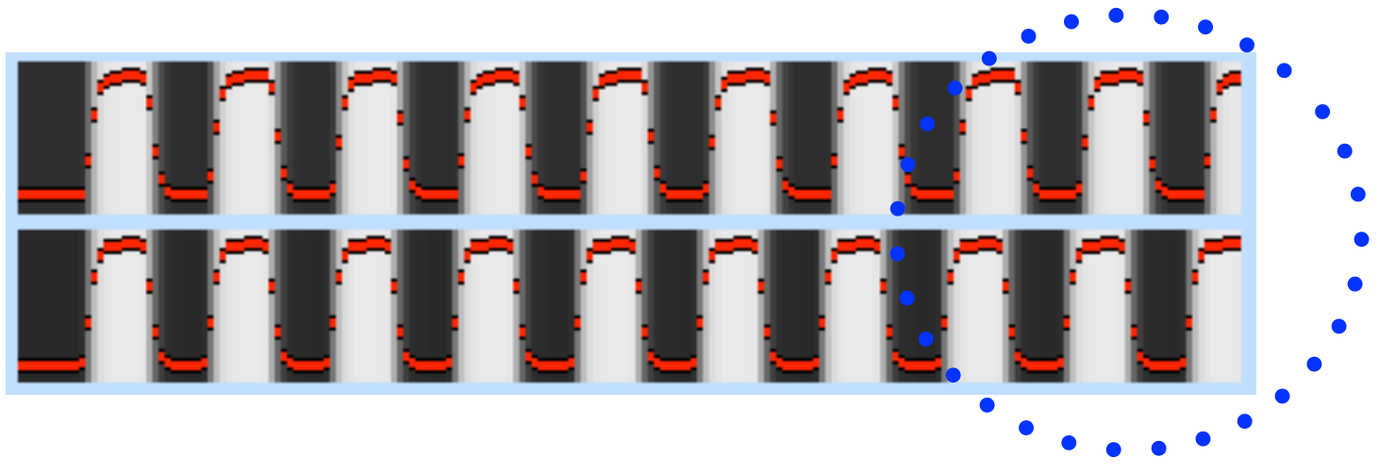

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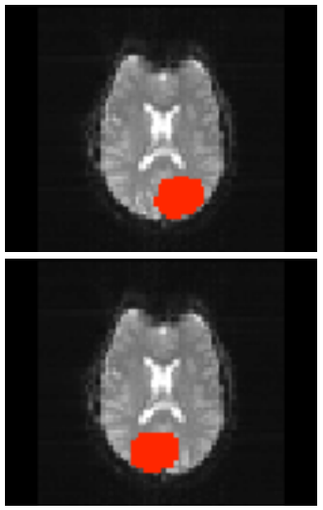
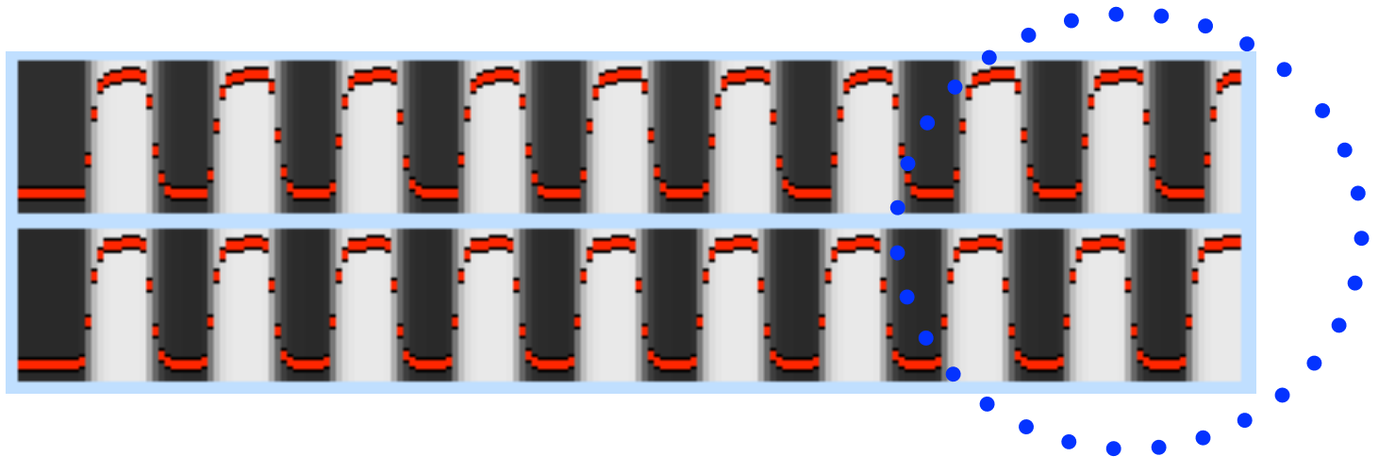
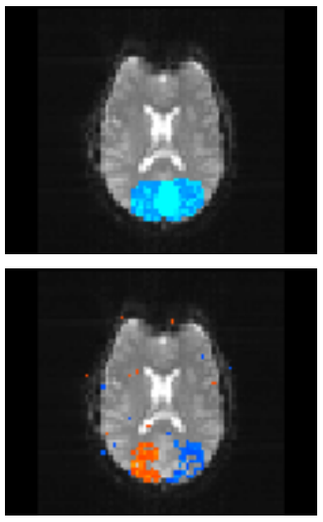
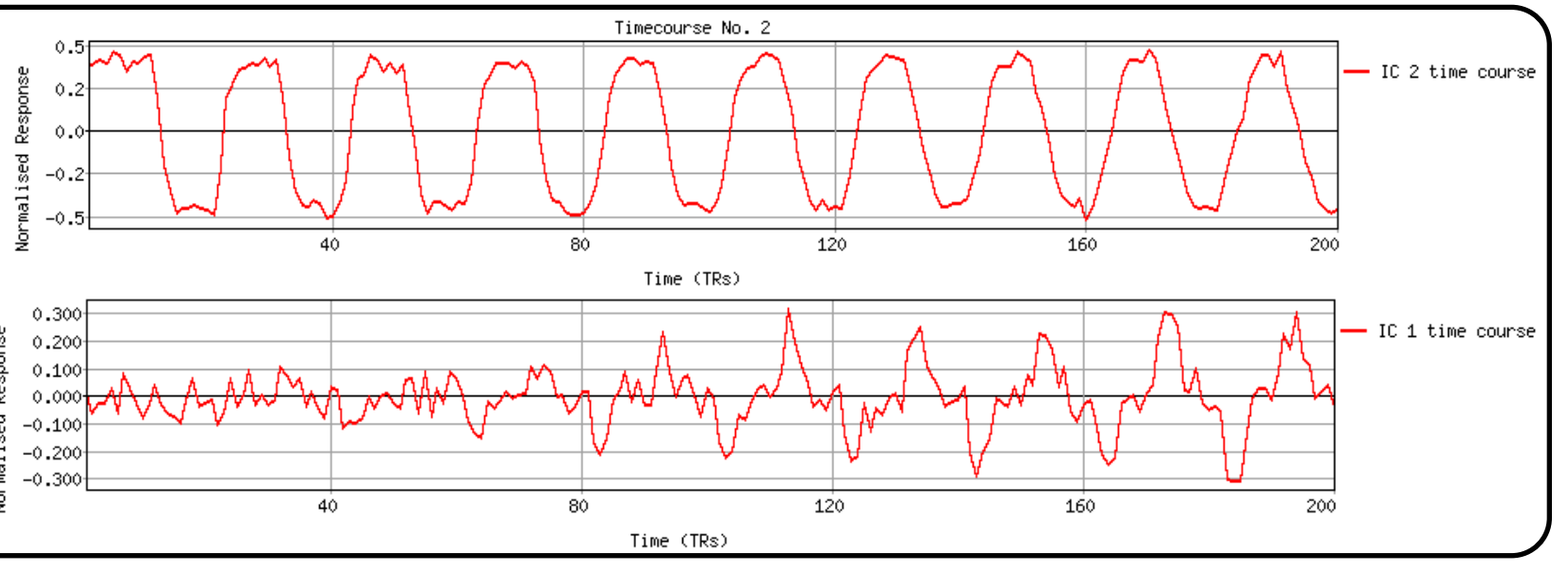




PCA

- Timecourses orthogonal
  时间序列正交
- Spatial maps and timecourses “wrong”空间图像和时间序列有差





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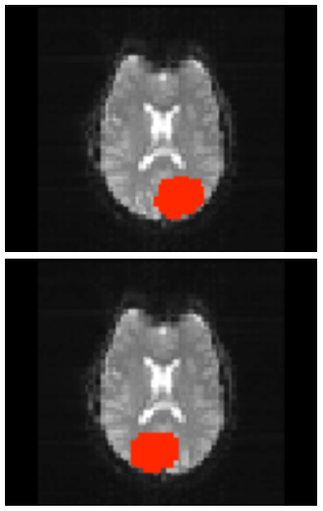

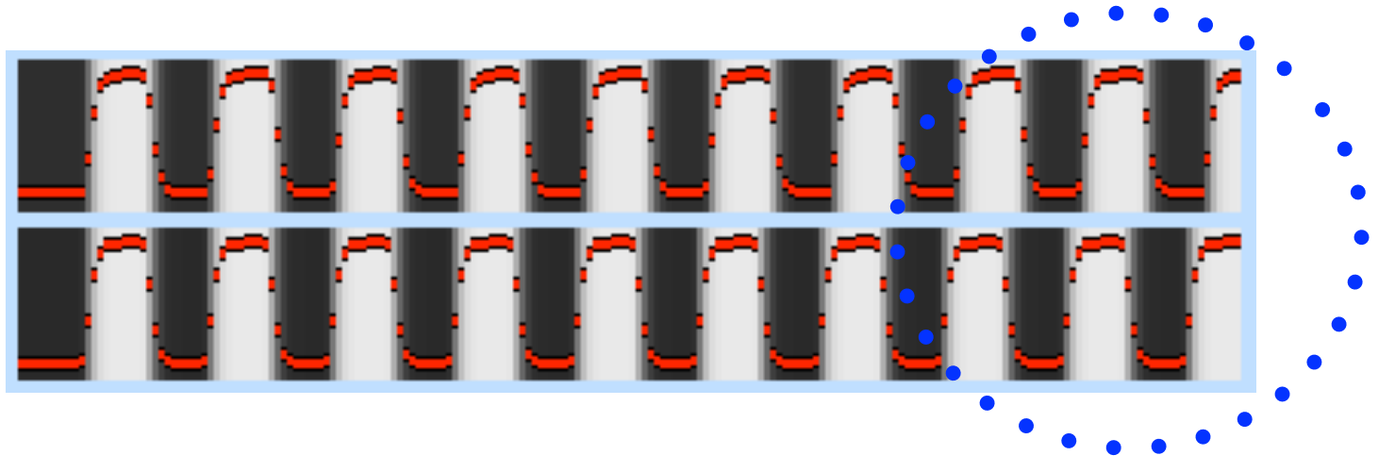

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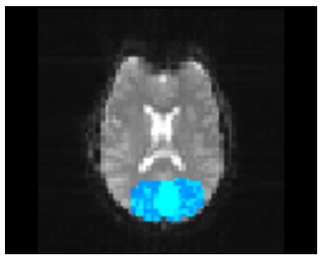
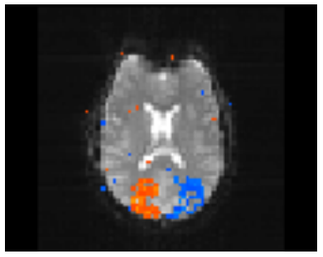
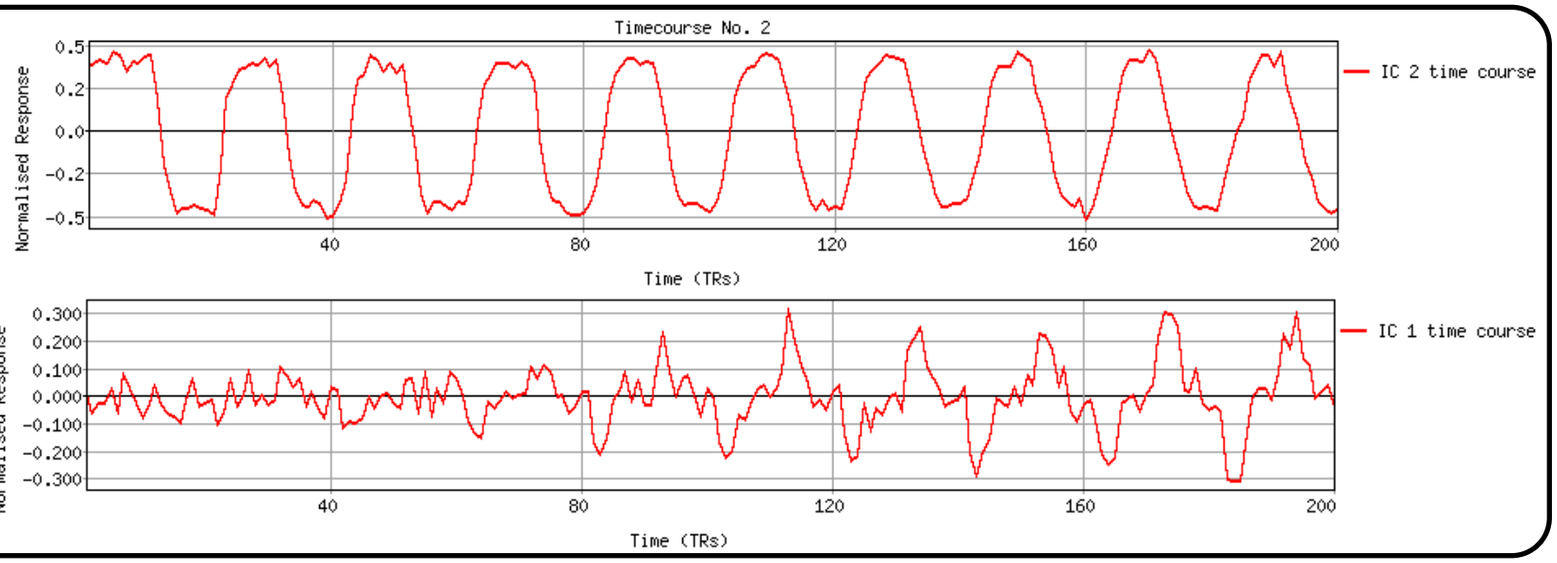
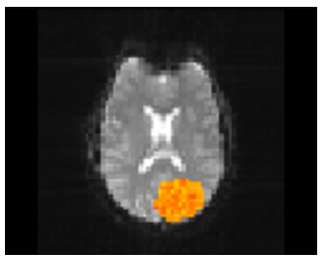


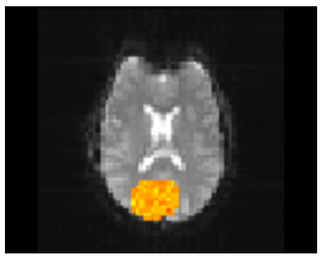


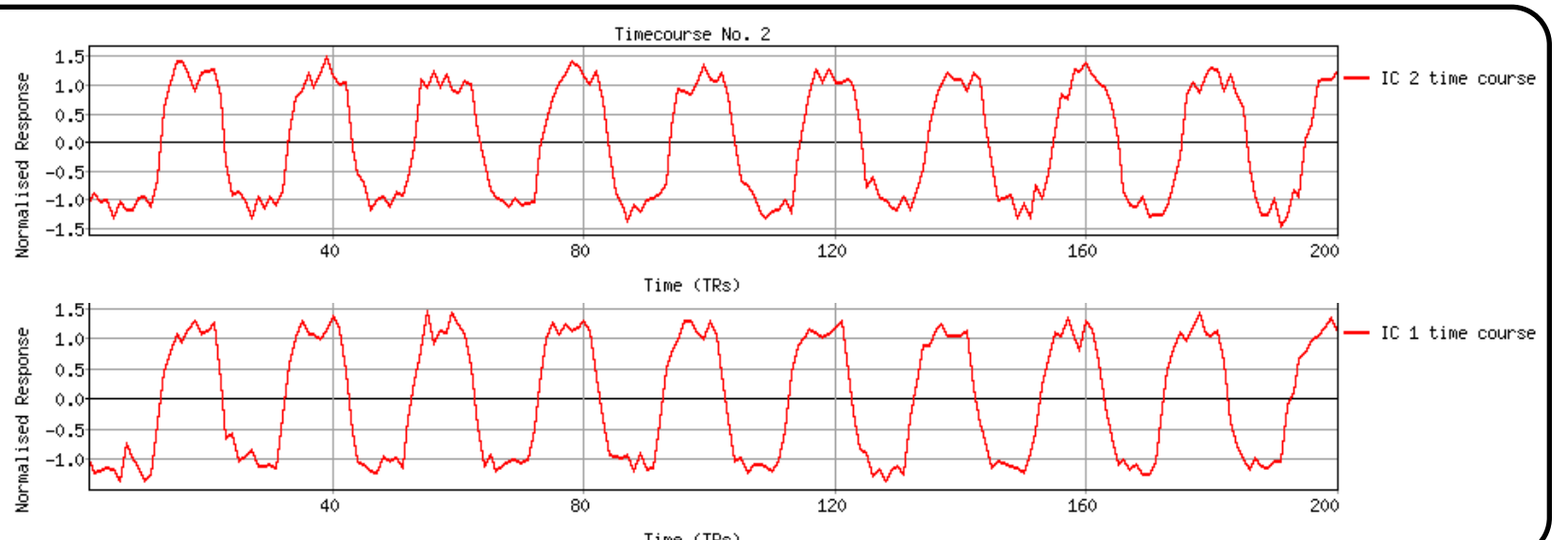


ICA

- Timecourses non-co-linear时间序列非线性
- Spatial maps and timecourses "right"空间图像和时间序列相对应

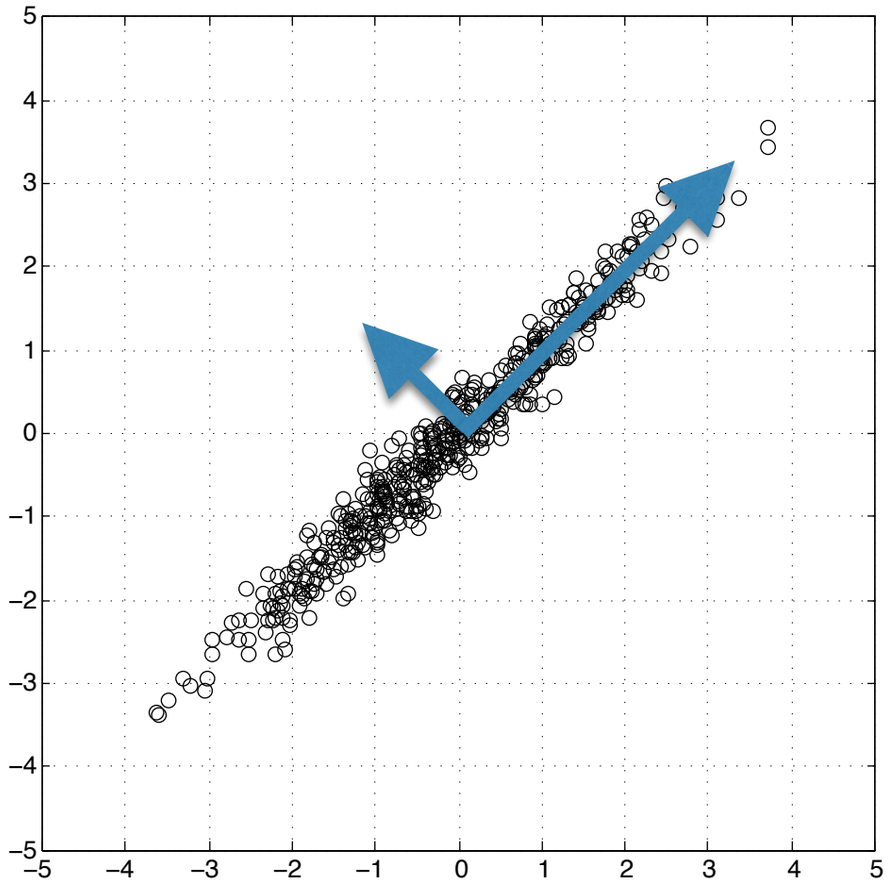






PCA vs. ICA

- PCA finds projections of maximum amount of variance in Gaussian data (uses 2nd order statistics only)
  PCA 在高斯数据中寻找最多方差值的投射（仅使用二阶统计）



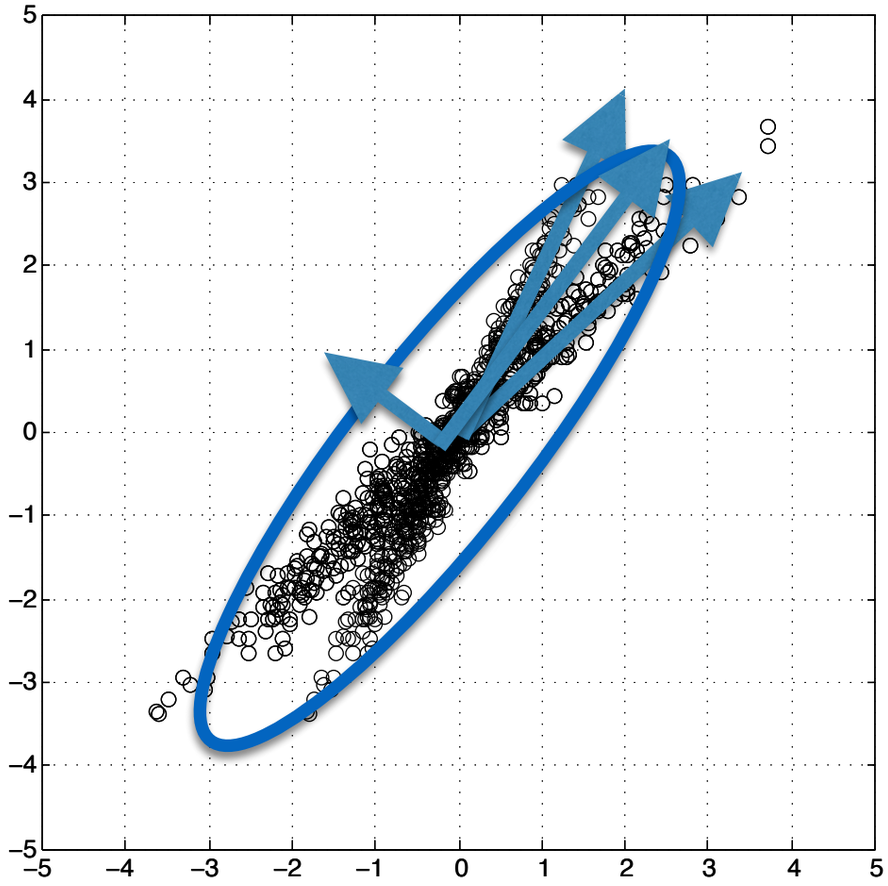
Gaussian data

PCA vs. ICA

- PCA finds projections of maximum amount of variance in Gaussian data (uses 2nd order statistics only)

- Independent Component Analysis (ICA) finds projections of maximal independence in non-Gaussian data (using higher-order statistics)

独立成分分析（ICA） 在非正态数据中寻找最大程度独立的投射（使用高阶统计数据）

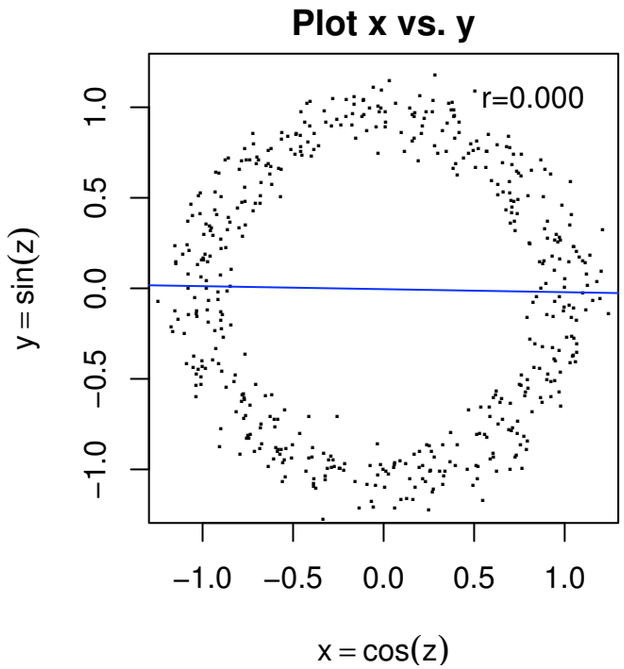


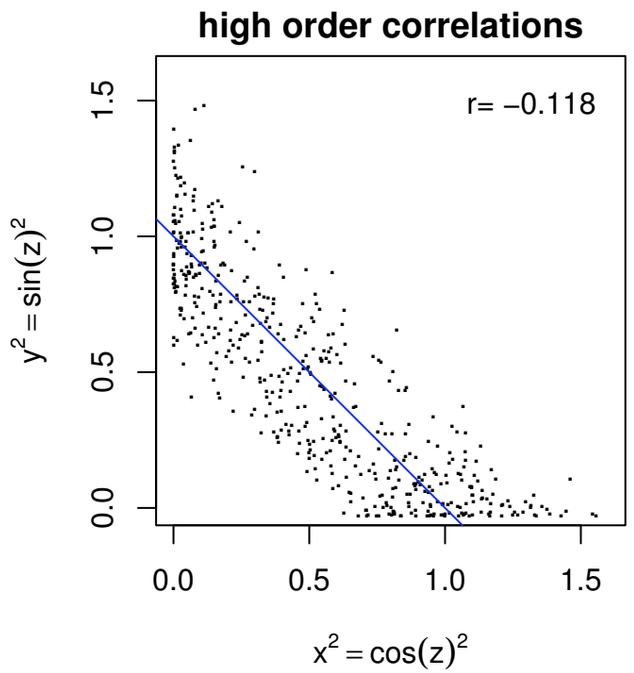
non-Gaussian data

Correlation vs. independence

相关与独立性

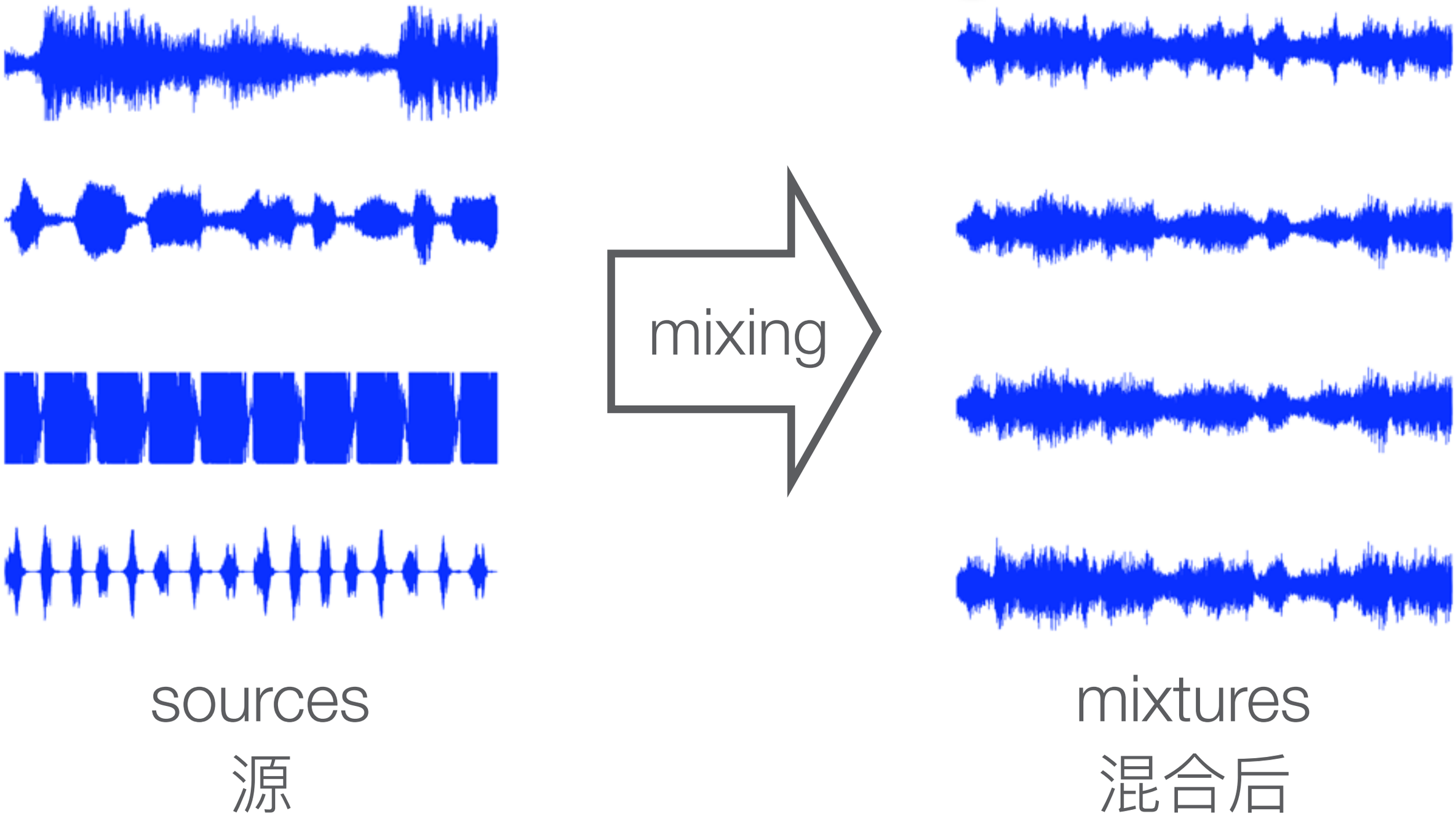
- de-correlated signals can still be dependent
  不相关的成分也可能是非独立的
- higher-order statistics (beyond mean and variance) can reveal these dependencies
  高阶统计信息（超出平均值和方差）可以揭示这些依赖关系





- Stone et al. 2002

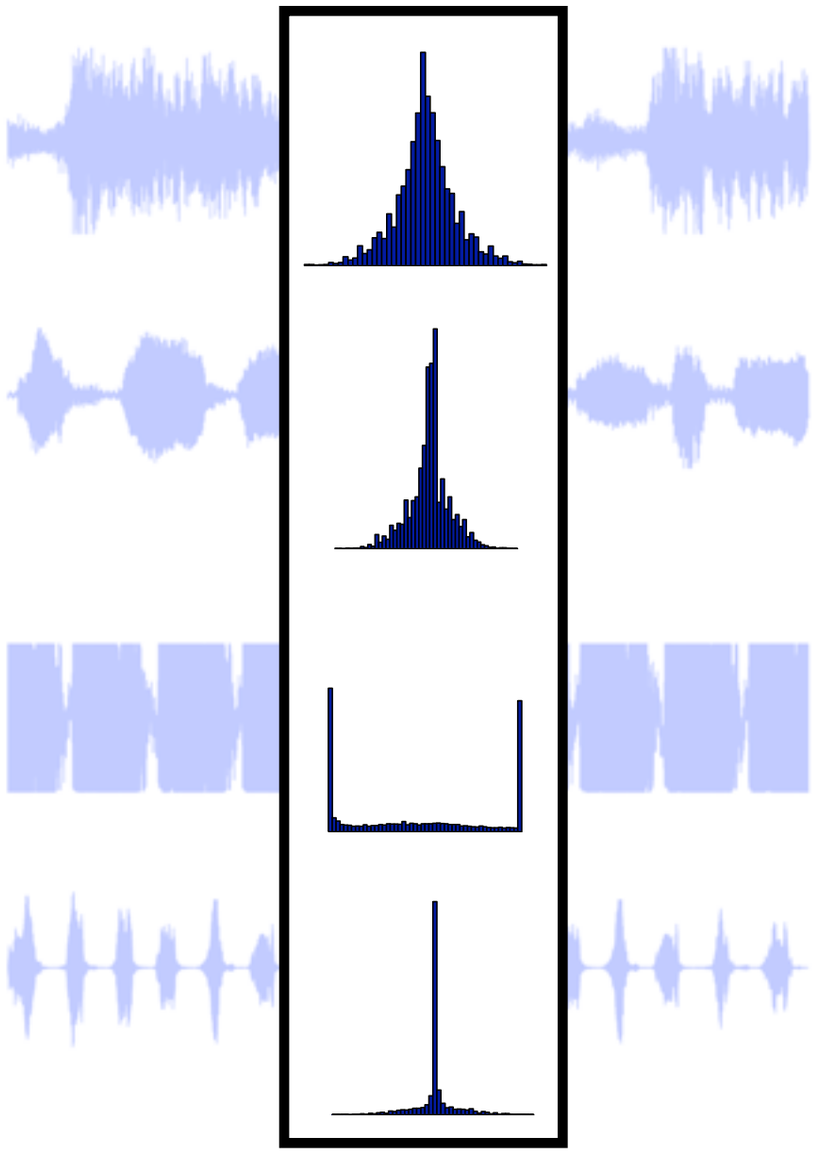
Non-Gaussianity非正态的



sources
源

mixtures
混合后

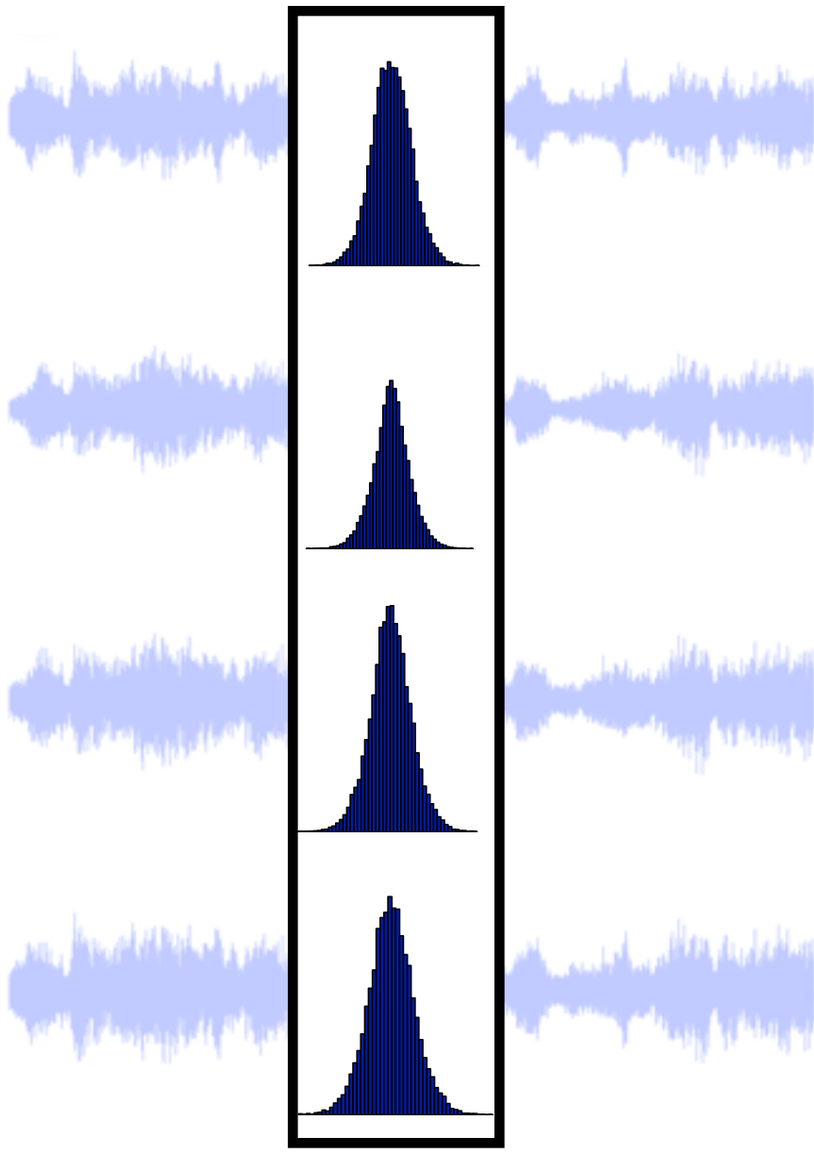
Non-Gaussianity



non-Gaussian

非正态

mixing



Gaussian

正态

ICA estimation

- Random mixing results in more Gaussian-shaped PDFs (Central Limit Theorem)
  随机混合产生更多高斯形状的概率密度方程分布（中央极限定理）

- conversely: 相反

  if mixing matrix produces less Gaussian-shaped PDFs this is unlikely to be a random result
  如果混合矩阵产生的高斯形概率密度较少，那这不太可能是随机的结果

  ➡ measure non-Gaussianity测量非正态性

- can use neg-entropy as a measure of non-Gaussianity 可以用负熵作为非正态性的度量指标

Hyvärinen & Oja 1997

ICA estimation

- need to find an unmixing matrix such that the dependency between estimated sources is minimised需要找到一个与估计来源依赖关系最低的无混合矩阵
- need (i) a contrast (objective/cost) function to drive the unmixing which measures statistical independence and (ii) an optimisation technique:
需要：（i）对比（目标/成本）功能来驱动测量统计独立性的解码过程（ii）优化的技术
- kurtosis or cumulants & gradient descent (Jade)
峰度或累积量&梯度下降
- maximum entropy & gradient descent (Infomax)
最大熵 &梯度下降
- neg-entropy & fixed point iteration (FastICA)
负熵 &定点迭代

Overfitting & thresholding

过度拟合 &阈值

The ‘overfitting’ problem

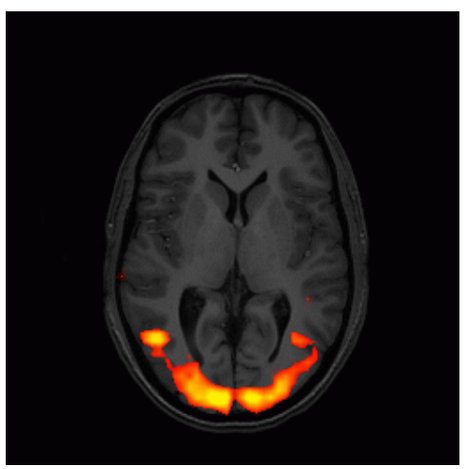
过度拟合问题

fitting a noise-free model to noisy observations:

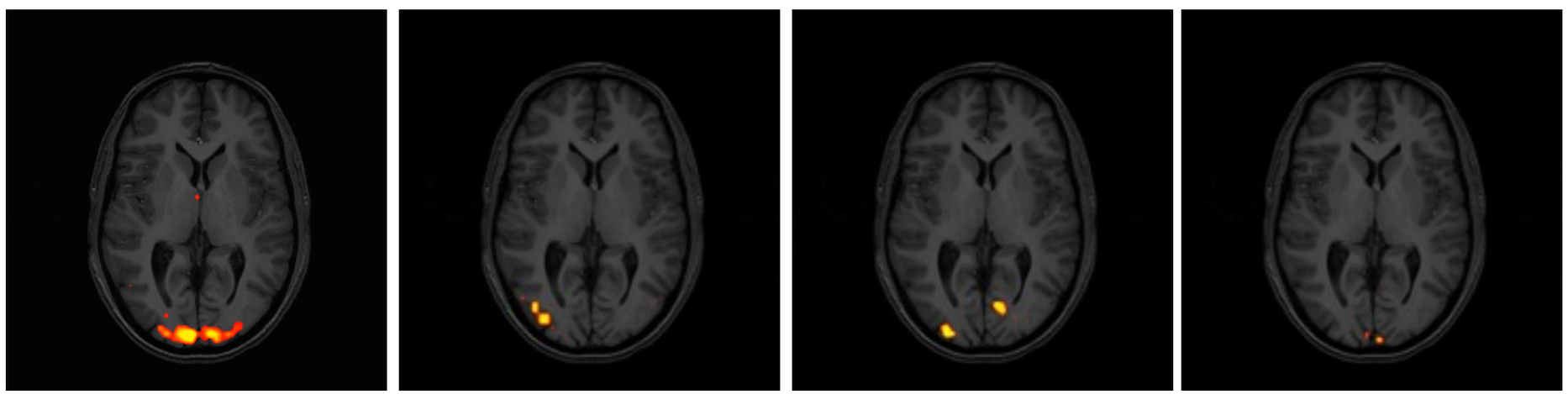
将无噪声模型拟合到噪声观测结果：

- no control over signal vs. noise (non-interpretable results)对信号与噪声没有控制（不可解释的结果）
- statistical significance testing not possible

无法进行统计显著性测试



GLM analysis

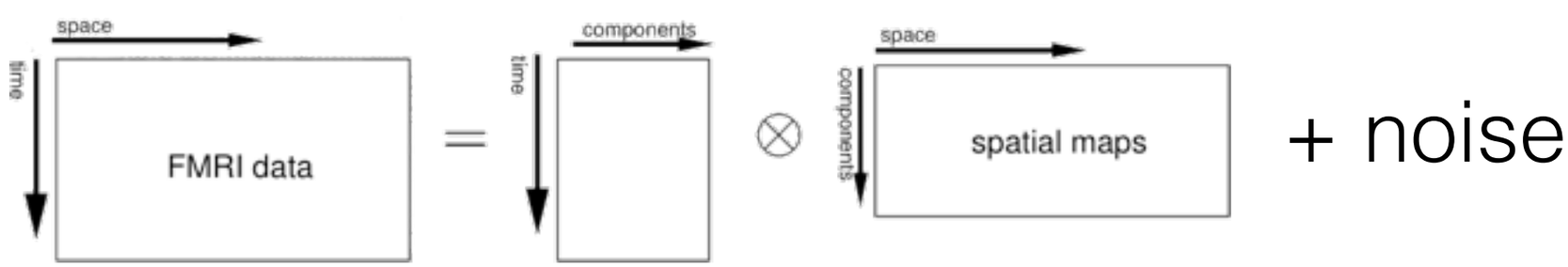


standard ICA (unconstrained)

Probabilistic ICA model

概率 ICA 模型

statistical “latent variables” model: we observe linear mixtures of hidden sources in the presence of Gaussian noise 统计"潜变量"模型：在高斯噪声存在的情况下，我们观察到隐藏源的线性混合物



Y = X B + E

Issues:

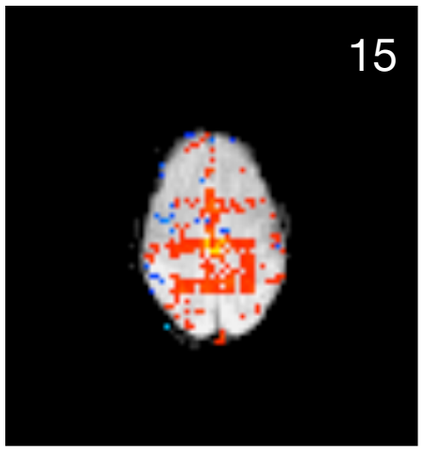
- Model Order Selection: how many components?

  模型选择：多少个成分合适?

- Inference: how to threshold ICs?如何为独立成分设置阈值?

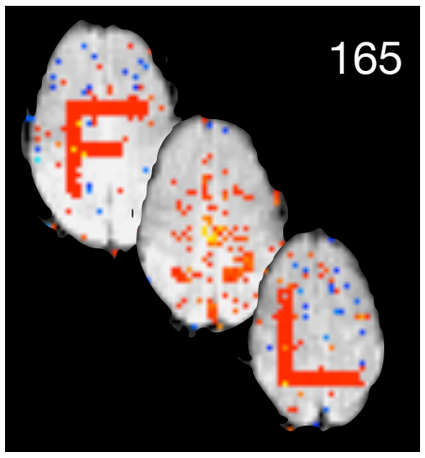
Model Order Selection

‘How many components’?



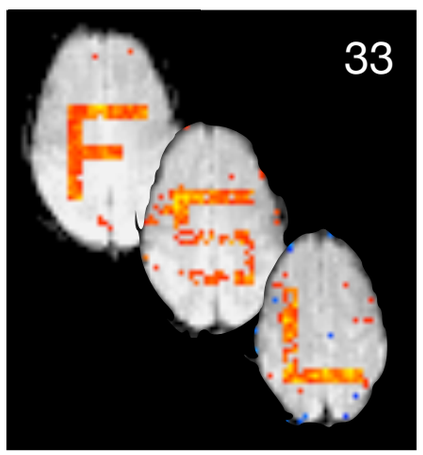
under-fitting: the amount of explained data variance is insufficient to obtain good estimates of the signals

拟合不足：解释的数据方差量不足以获得信号的良好估计值



over-fitting: the inclusion of too many components leads to fragmentation of signal across multiple component maps, reducing the ability to identify the signals of interest

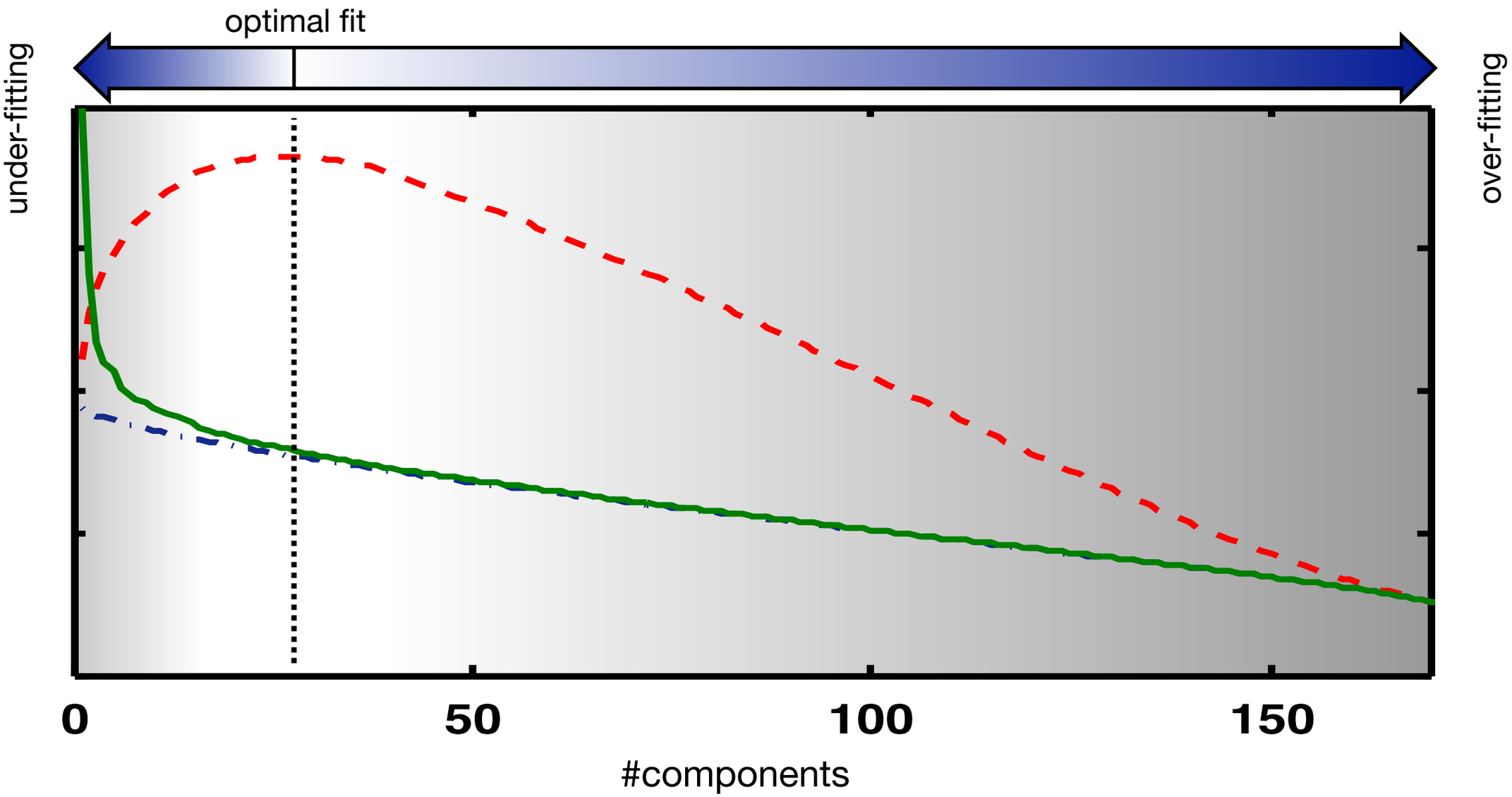
过度拟合：包含太多成分会导致多个成分对应信号碎片化，降低识别感兴趣信号的能力



optimal fitting: the amount of explained data variance is sufficient to obtain good estimates of the signals while preventing further splits into spurious components

最佳拟合：解释的数据方差数量足以获得信号的良好估计值，同时防止进一步拆分无用成分

Model Order Selection

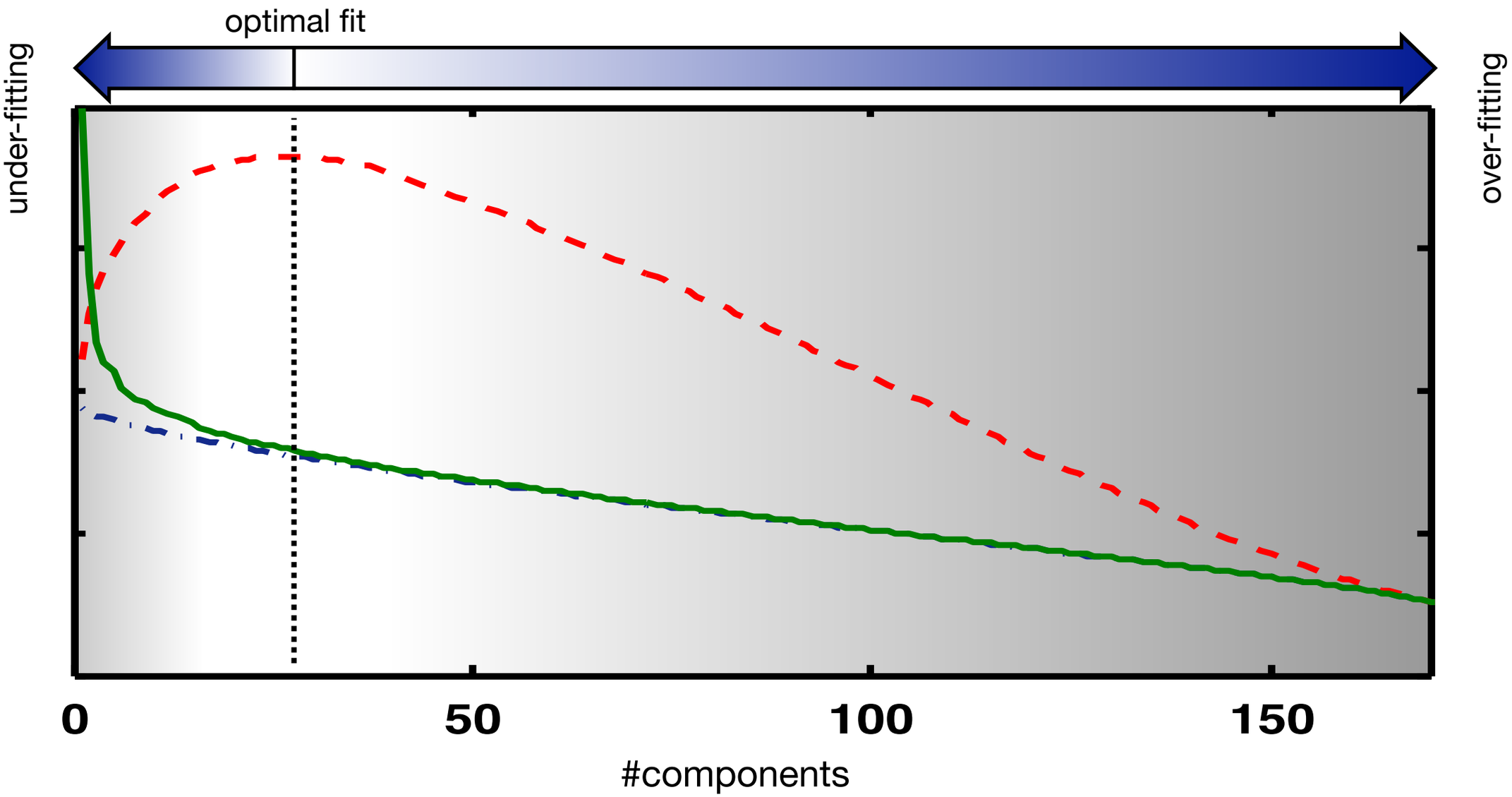


observed Eigenspectrum of the data covariance matrix

Laplace approximation of the posterior probability of the model order

theoretical Eigenspectrum from Gaussian noise

Model Order Selection



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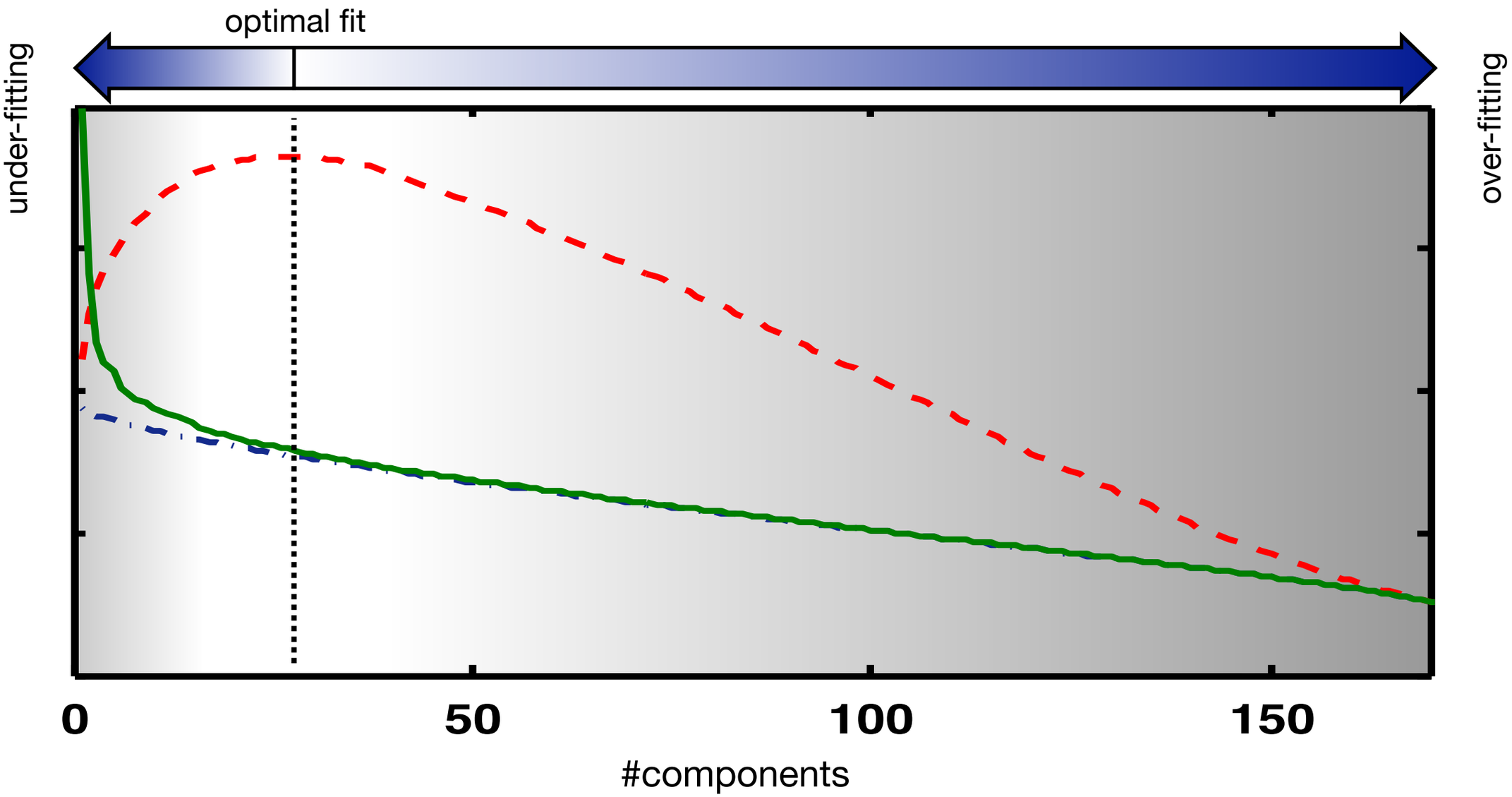

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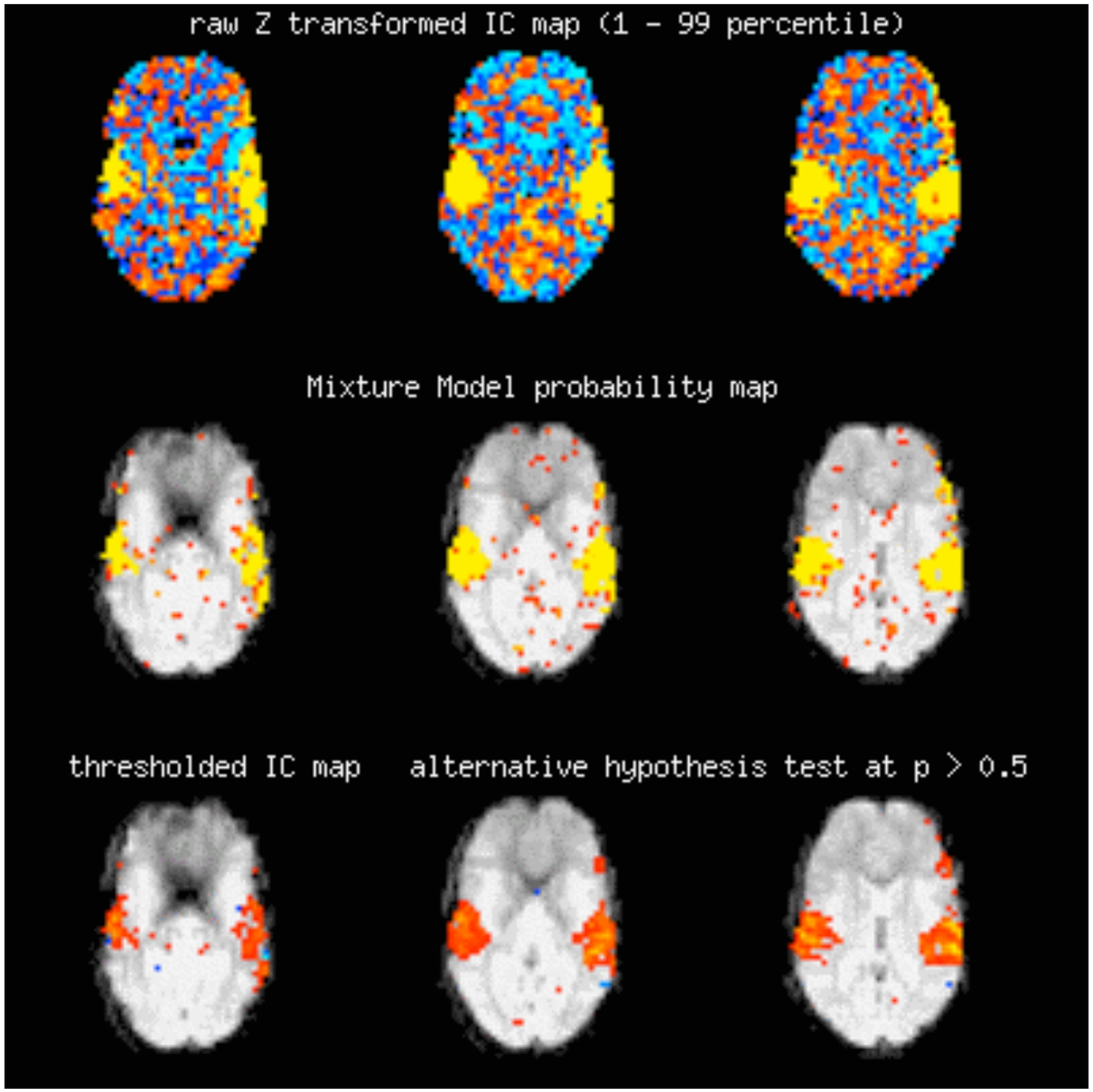
Thresholding

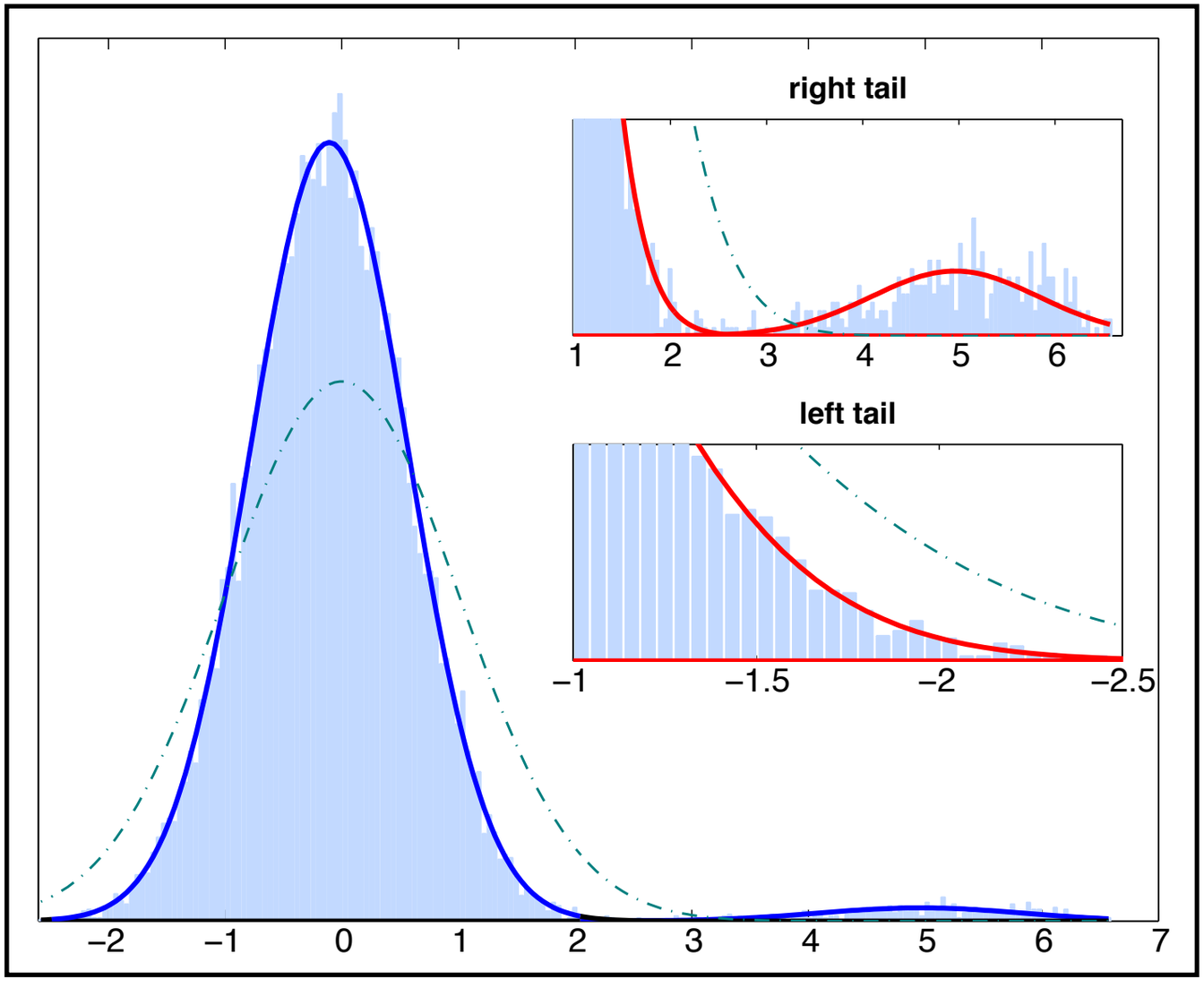
设阈值



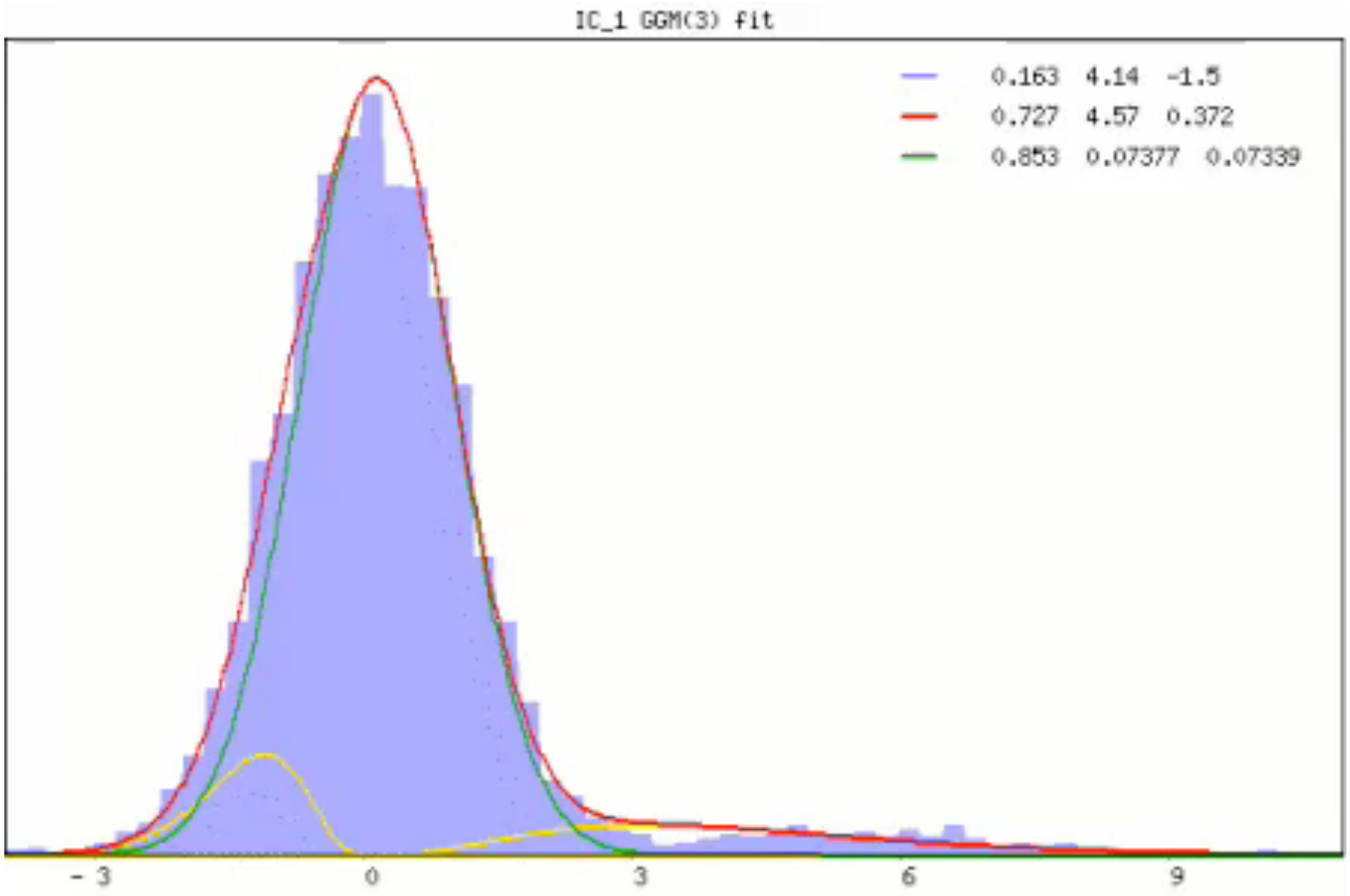
Thresholding

设阈值

- classical null-hypothesis testing is invalid
  经典的零假设检验无效
- data is assumed to be a linear combination of signals and noise数据被假定为信号和噪声的线性组合
- the distribution of the estimated spatial maps is a mixture distribution!
  估计空间图像的分布是混合分布



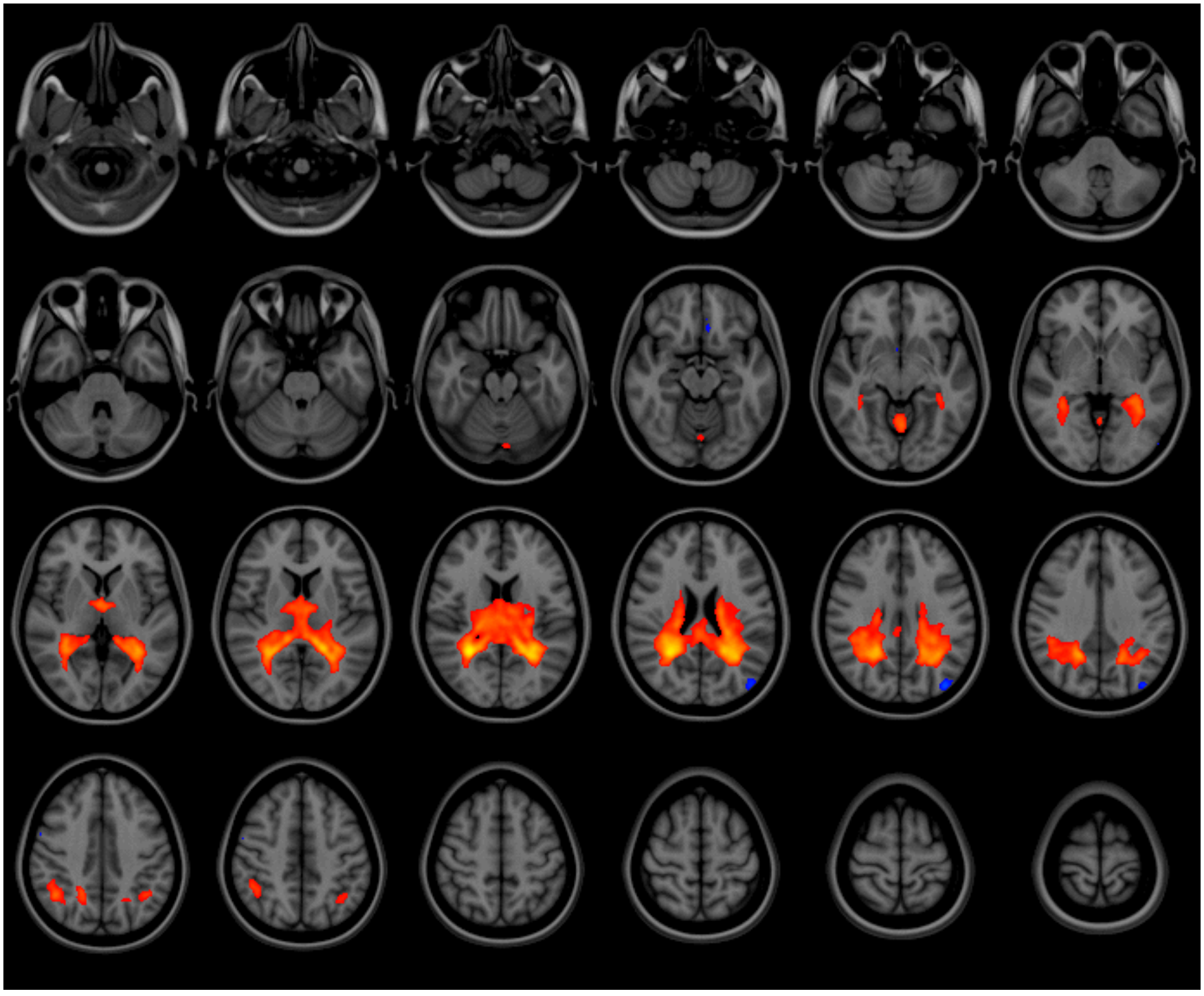
Alternative Hypothesis Test



- use Gaussian/Gamma mixture model fitted to the histogram of intensity values (using EM) 使用高斯/伽玛混合模型拟合的强度值直方图

What about overlap?

重叠怎么办?



What about overlap?

重叠怎么办?

Sources源

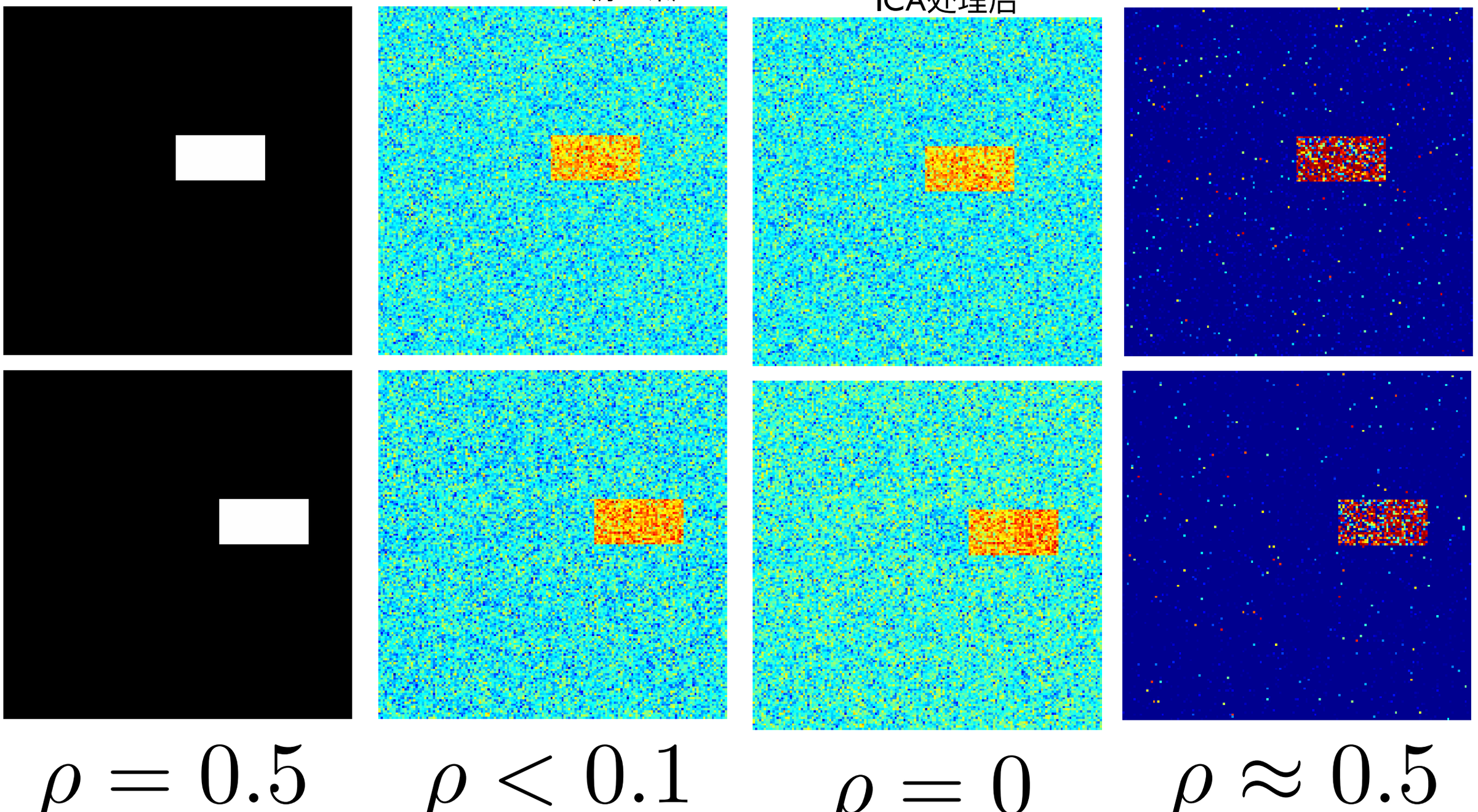
Sources + noise 源+噪声

ICA solution

ICA处理后

after thresholding

设阈值以后



$\rho = 0.5$ $\rho < 0.1$ $\rho = 0$ $\rho \approx 0.5$

ICA cleanup

ICA 数据清理

Artefact detection

伪迹检测

- FMRI data contain a variety of source processes

  FMRI 数据包含各种来源的加工过程

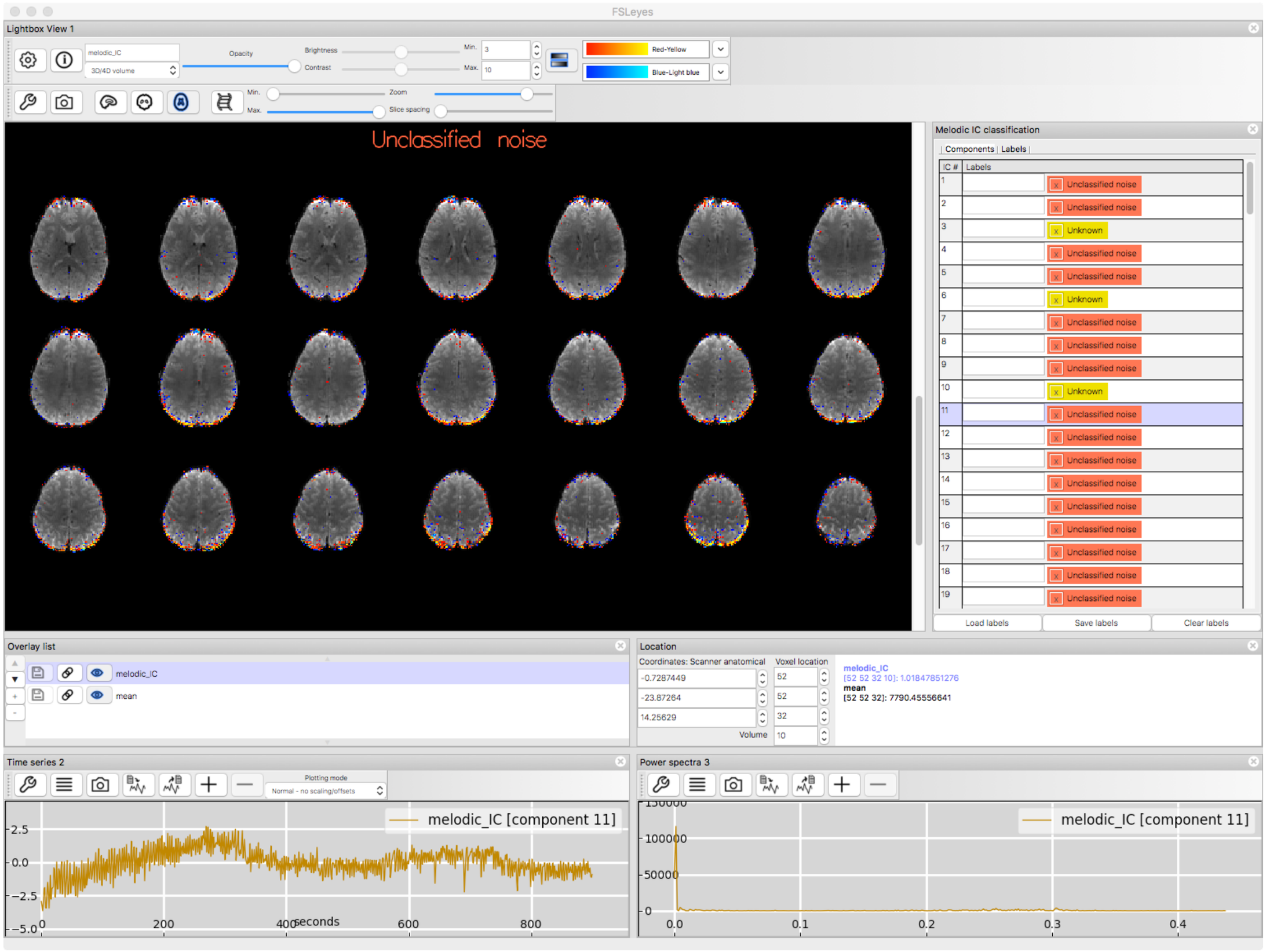
- Artifactual sources typically have unknown spatial and temporal extent and cannot easily be modelled accurately

  伪迹源通常具有未知的空间和时间范围，并且不容易准确建模

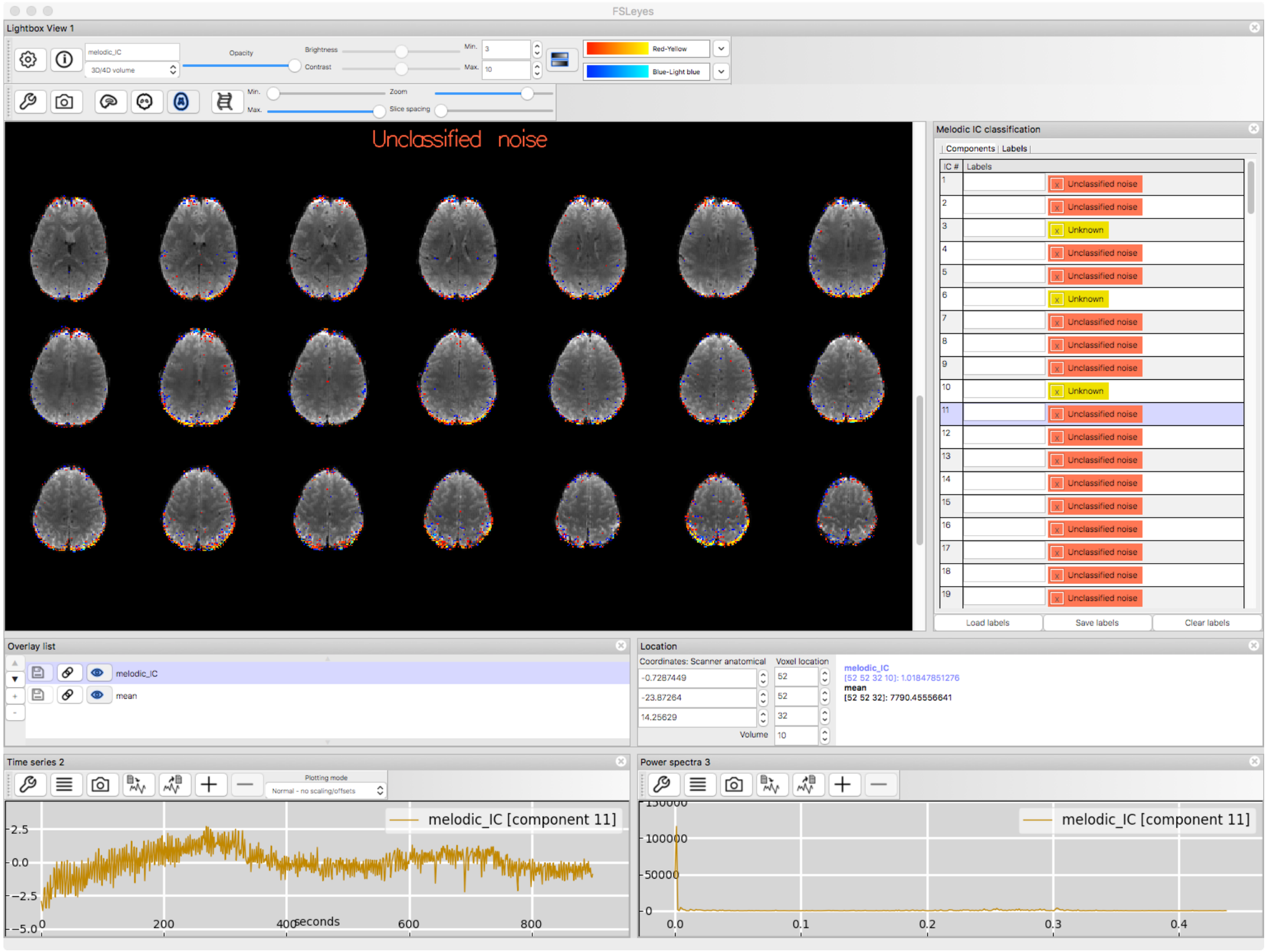
- Exploratory techniques do not require a priori knowledge of time-courses and spatial maps

  探索性技术不需要事先了解时间序列和空间图像

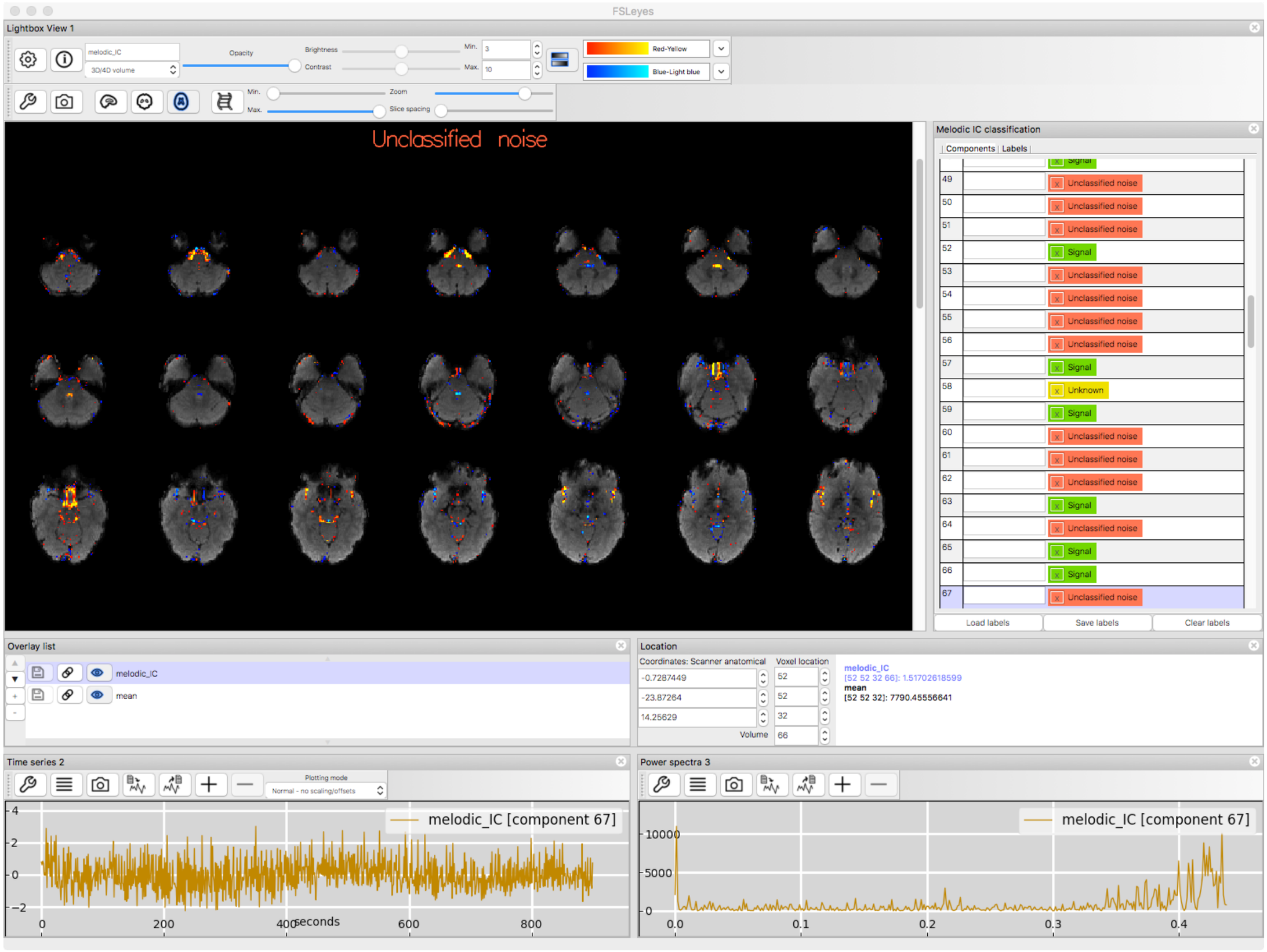
FSLeyes Melodic Mode



motion头动


FSLeyes
Lightbox View 1
melodic_IC
3D/4D volume
Opacity
Brightness
Contrast
Min. 3
Max. 10
Red-Yellow
Blue-Light blue
Min.
Max.
Zoom
Slice spacing
Unclassified noise
Melodic IC classification
Components | Labels
IC # | Labels
1 Unclassified noise
2 Unclassified noise
3 Unknown
4 Unclassified noise
5 Unclassified noise
6 Unknown
7 Unclassified noise
8 Unclassified noise
9 Unclassified noise
10 Unknown
11 Unclassified noise
12 Unclassified noise
13 Unclassified noise
14 Unclassified noise
15 Unclassified noise
16 Unclassified noise
17 Unclassified noise
18 Unclassified noise
19 Unclassified noise
Load labels
Save labels
Clear labels
Overlay list
melodic_IC
mean
Location
Coordinates: Scanner anatomical
Voxel location
-0.7287449 52
-23.87264 52
14.25629 32
Volume 10
melodic_IC
[52 52 32 10]: 1.01847851276
mean
[52 52 32]: 7790.45556641
Time series 2
Plotting mode
Normal - no scaling/offsets
melodic_IC [component 11]
2.5
0.0
−2.5
−5.0
0
200
400
seconds
600
800
Power spectra 3
melodic_IC [component 11]
100000
50000
0
0.0
0.1
0.2
0.3
0.4

cardiac 心脏


FSLeyes
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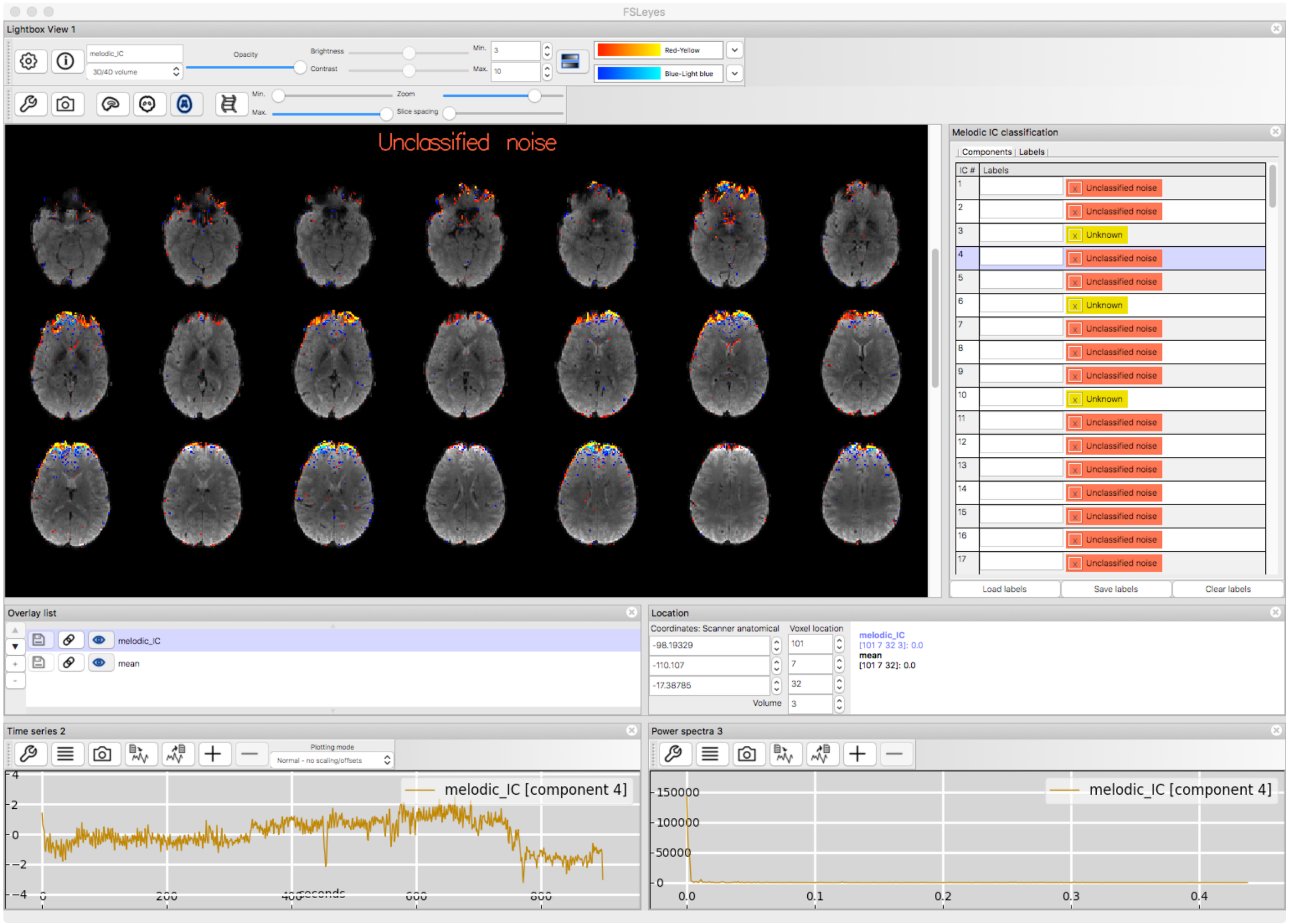
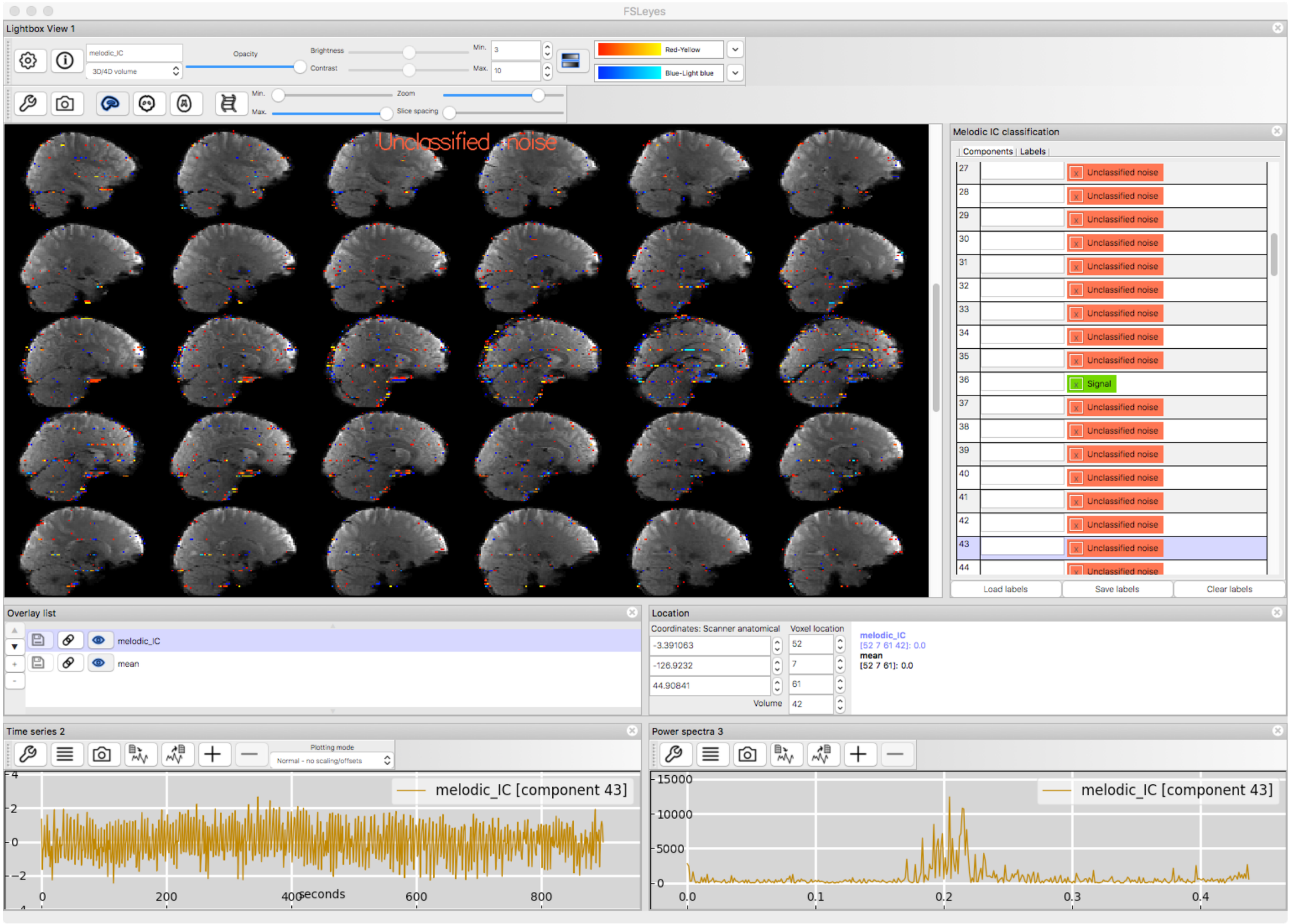
melodic_IC
3D/4D volume
Opacity
Brightness
Contrast
Min.
3
Max.
10
Red-Yellow
Blue-Light blue
Zoom
Slice spacing
Unclassified noise
Melodic IC classification
Components
Labels
49 Unclassified noise
50 Unclassified noise
51 Unclassified noise
52 Signal
53 Unclassified noise
54 Unclassified noise
55 Unclassified noise
56 Unclassified noise
57 Signal
58 Unknown
59 Signal
60 Unclassified noise
61 Unclassified noise
62 Unclassified noise
63 Signal
64 Unclassified noise
65 Signal
66 Signal
67 Unclassified noise
Load labels
Save labels
Clear labels
Overlay list
melodic_IC
mean
Location
Coordinates: Scanner anatomical
Voxel location
-0.7287449
-23.87264
14.25629
Volume
52
52
32
66
melodic_IC
[52 52 32 66]: 1.51702618599
mean
[52 52 32]: 7790.45556641
Time series 2
Plotting mode
Normal - no scaling/offsets
melodic_IC [component 67]
seconds
Power spectra 3
melodic_IC [component 67]

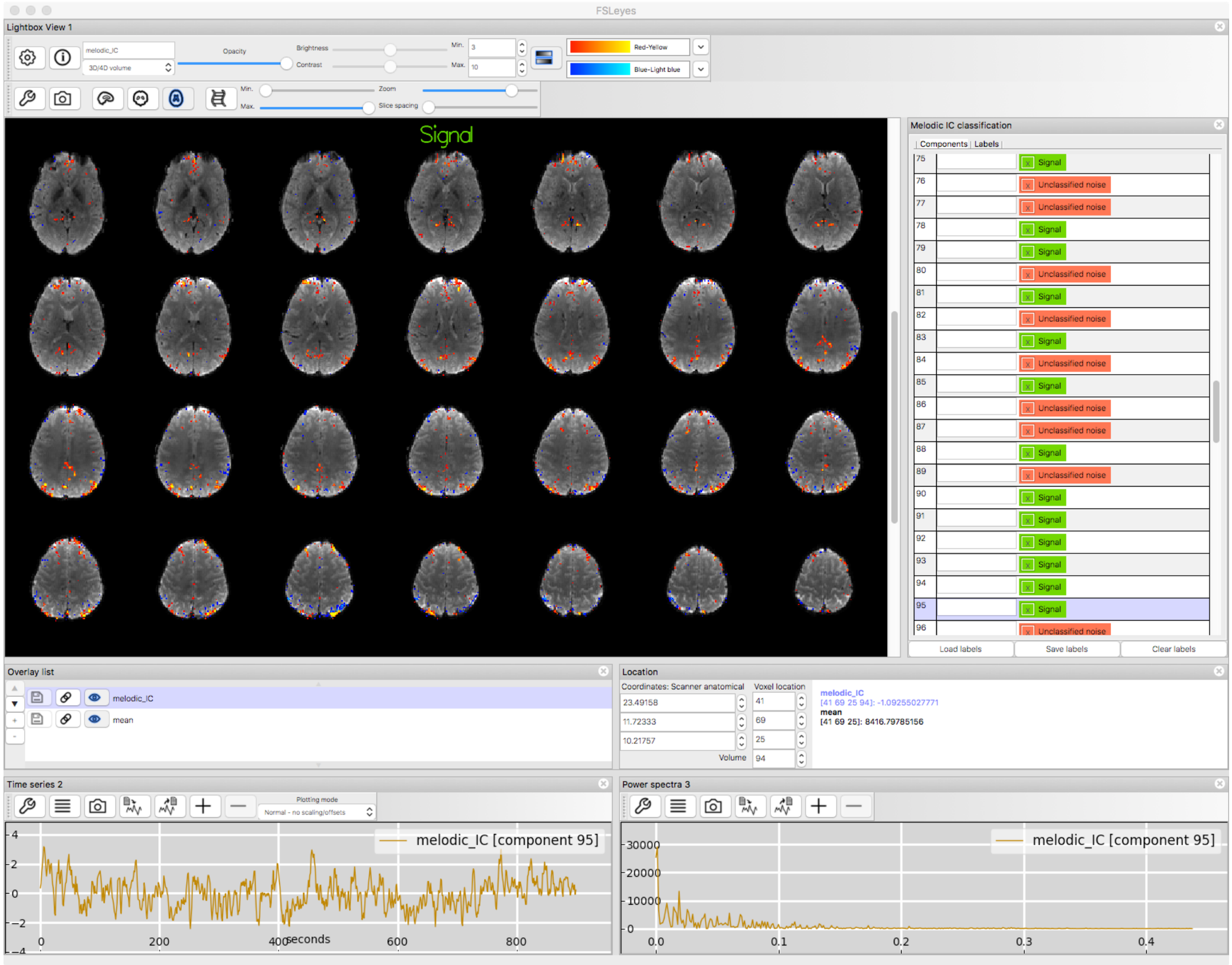
susceptibility motion 磁化率敏感头动



multiband多频带



signal信号


FSLeyes
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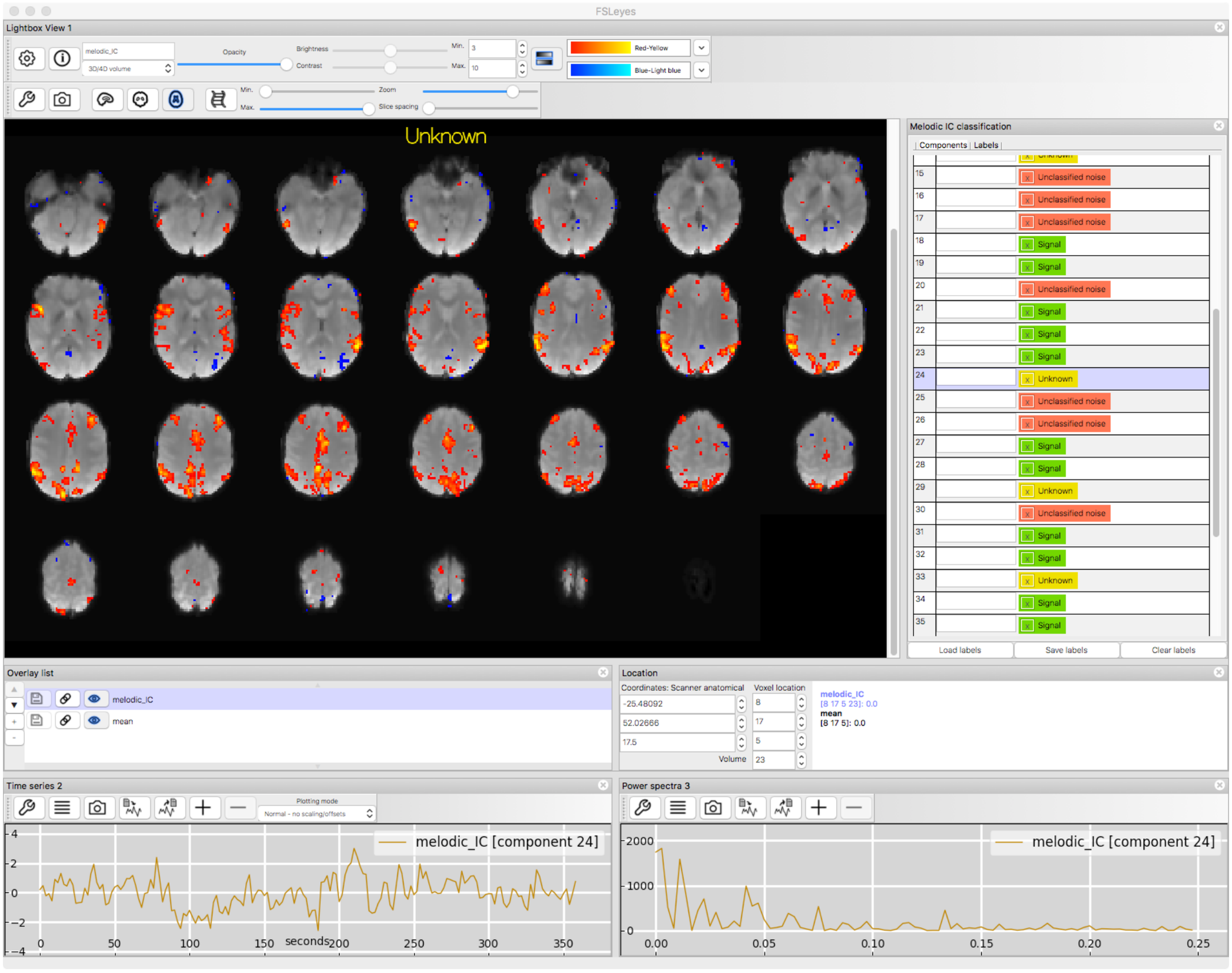
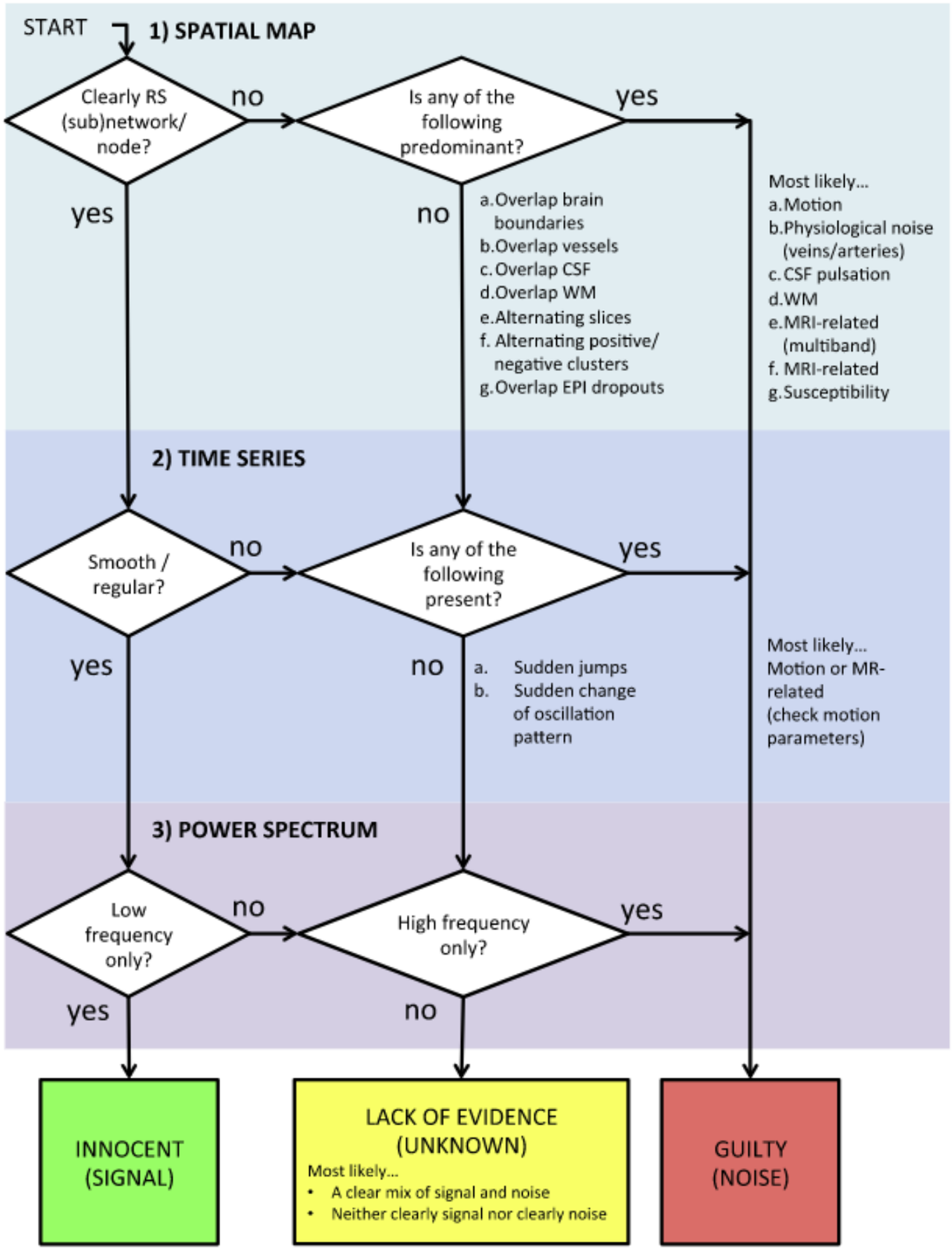
Blue-Light blue
Min.
Max.
Zoom
Slice spacing
Signal
Melodic IC classification
Components
Labels
75 Signal
76 Unclassified noise
77 Unclassified noise
78 Signal
79 Signal
80 Unclassified noise
81 Signal
82 Unclassified noise
83 Signal
84 Unclassified noise
85 Signal
86 Unclassified noise
87 Unclassified noise
88 Signal
89 Unclassified noise
90 Signal
91 Signal
92 Signal
93 Signal
94 Signal
95 Signal
96 Unclassified noise
Load labels
Save labels
Clear labels
Overlay list
melodic_IC
mean
Location
Coordinates: Scanner anatomical
Voxel location
23.49158
11.72333
10.21757
Volume
41
69
25
94
melodic_IC
[41 69 25 94]: -1.09255027771
mean
[41 69 25]: 8416.79785156
Time series 2
Plotting mode
Normal - no scaling/offsets
melodic_IC [component 95]
seconds
Power spectra 3
melodic_IC [component 95]

effects of scan parameters扫描参数效应



manual classification手动分类



Griffanti et al (2016).
https://doi.org/10.1016/j.neuroimage.2016.12.036

semi-automatic classification

半自动分类

semi-automatic classification

半自动分类

- FIX (fsl.fmrib.ox.ac.uk/fsl/fslwiki/FIX)
  - Classifier with many features具有许多功能的分类器
  - Requires manually labelled training data需要手动标记训练数据
  - 99% accuracy on high-quality data高质量数据 99% 的准确率

semi-automatic classification

半自动分类

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  - 99% accuracy on high-quality data高质量数据 99% 的准确率

- ICA-AROMA (github.com/rhr-pruim/ICA-AROMA)
  - Simple classifier with only 4 features

    仅具有 4 个功能的简单分类器
  - No training data required无需训练数据
  - Mainly designed for motion artefacts主要用于头动伪迹

Multi-subject ICA

多被试ICA

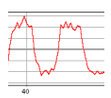
Different ICA models不同的ICA模型

Single-Session ICA

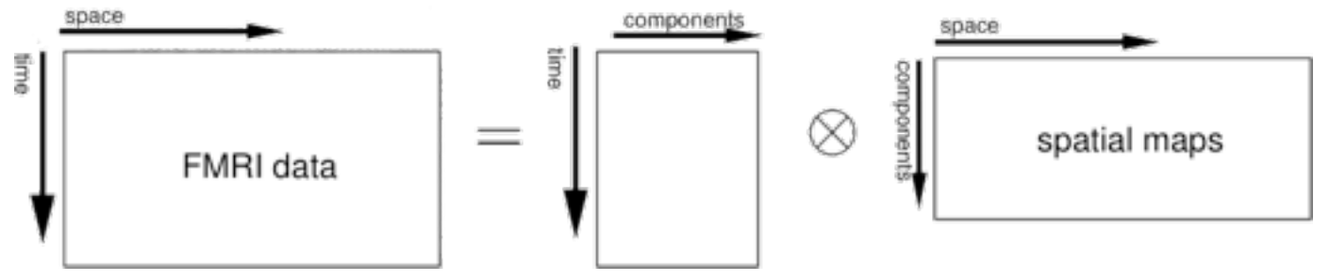
单阶段ICA

each ICA component comprises:

spatial map & timecourse



每个ICA成分包括空间图和时间序列



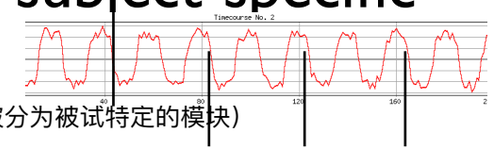
Multi-Session or Multi-Subject ICA: Concatenation approach

多阶段/多被试ICA 串联方法

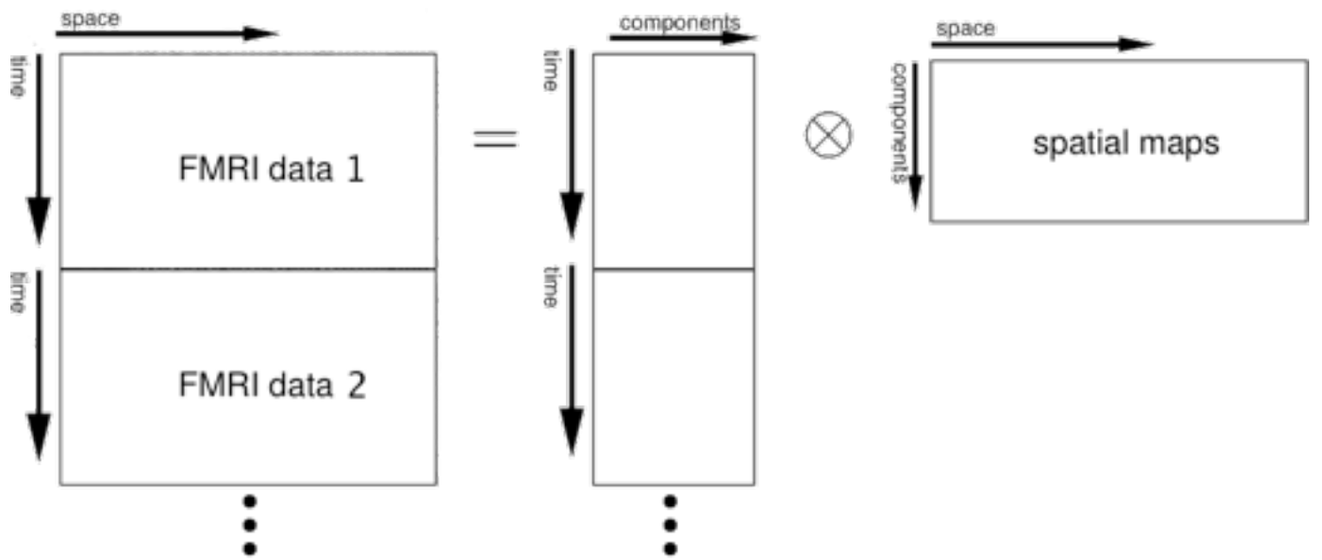
each ICA component comprises:

spatial map & timecourse

(that can be split up into subject-specific chunks)



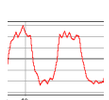
每个ICA成分包括空间图和时间序列（可以被分为被试特定的模块）

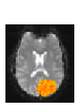


Multi-Session or Multi-Subject ICA: Tensor-ICA approach

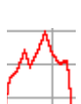
多阶段/多被试ICA 张量-ICA方法

each ICA component comprises:

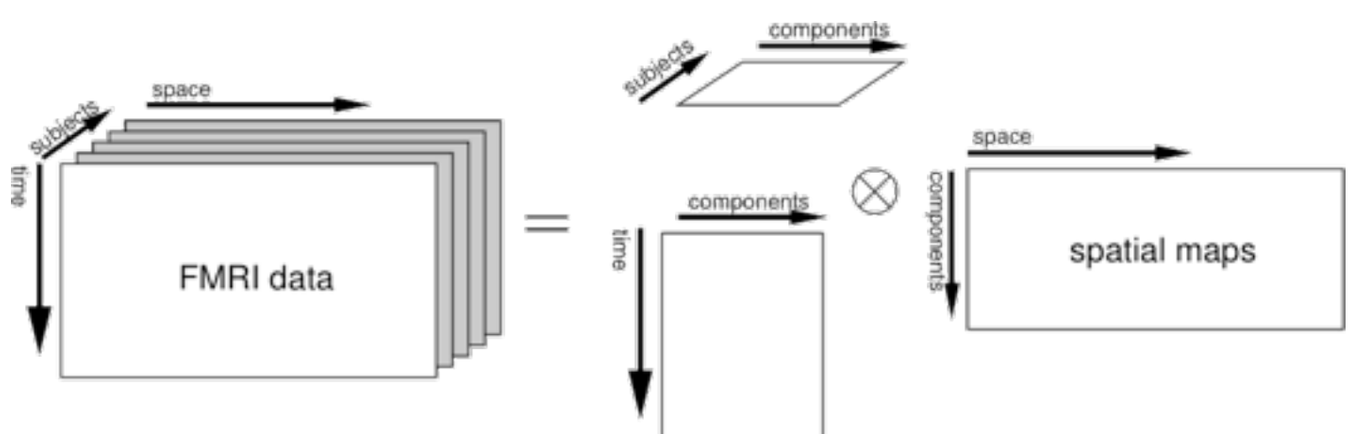




spatial map, session-long-timecourse & subject-strength plot



每个ICA成分包括空间图和时间序列以及被试强度图



Different ICA models不同的ICA模型

Single-Session ICA

单阶段ICA

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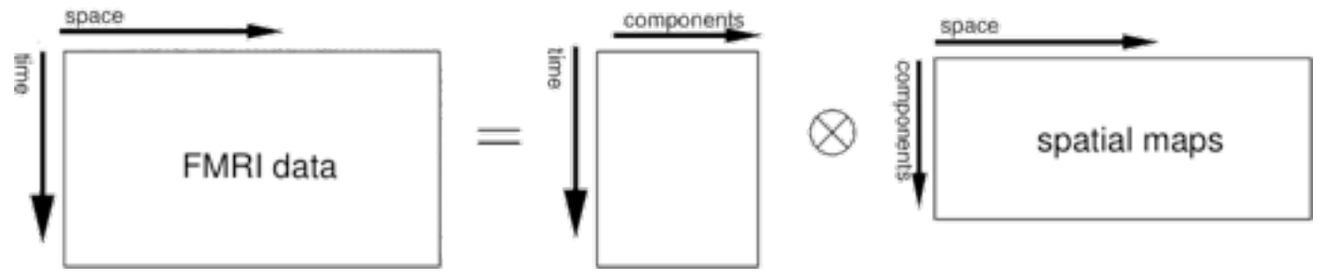
每个ICA成分包括空间图和时间序列



Multi-Session or Multi-Subject ICA:

Concatenation approach

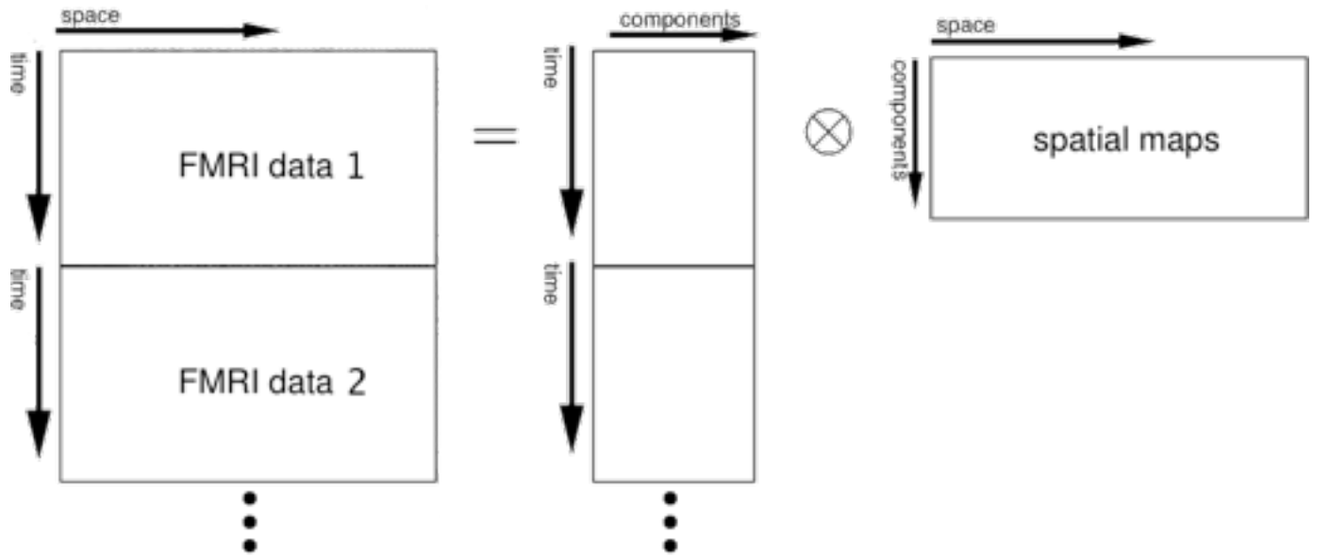
多阶段/多被试ICA 串联方法

good when:

each subject has DIFFERENT timeseries

e.g. resting-state FMRI

适用于每个被试有不同的时间序列时，如静息态fMRI



Multi-Session or Multi-Subject ICA:

Tensor-ICA approach

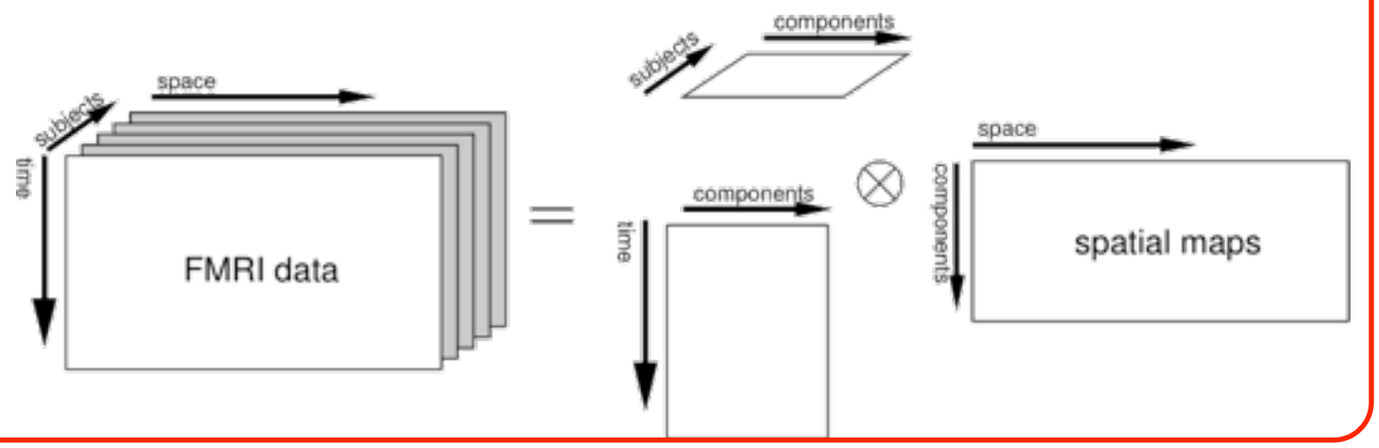
多阶段/多被试ICA 张量-ICA方法

good when:

each subject has SAME timeseries

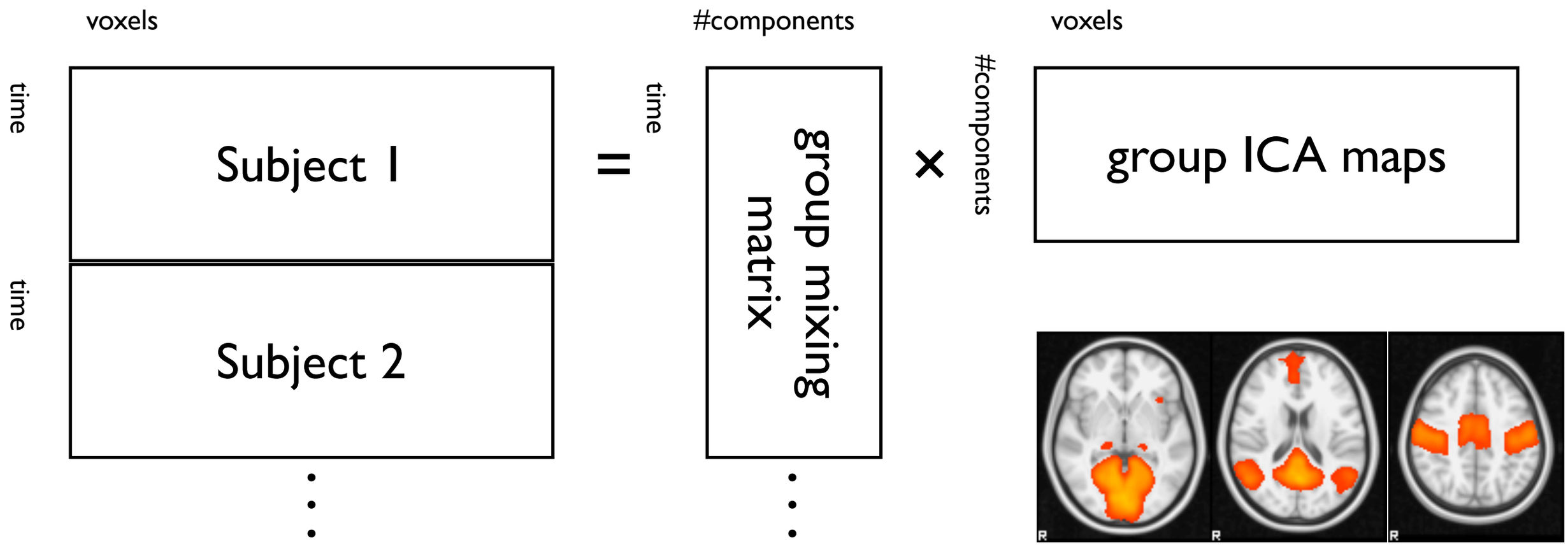
e.g. activation FMRI

适用于每个被试有相同的时间序列时，如激活fMRI



Concatenated ICA串联ICA

- Concatenate all subjects' data temporally 在时间上串联所有被试的数据
- Then run ICA 然后运行ICA
- More appropriate than tensor ICA (for RSNs) 比张量ICA（对于RSN）更合适



Resting state multi-subject ICA

静息态多被试ICA

- Why not just run ICA on each subject separately?

  为什么不只对每个被试分别运行ICA?

  - Correspondence problem (eg RSNs across subjects) 对应问题（例如跨被试的RSN）

  - Different splittings sometimes caused by small changes in the data (naughty ICA!)

    有时由于数据的微小变化而导致不同的分裂形式（调皮的ICA！）

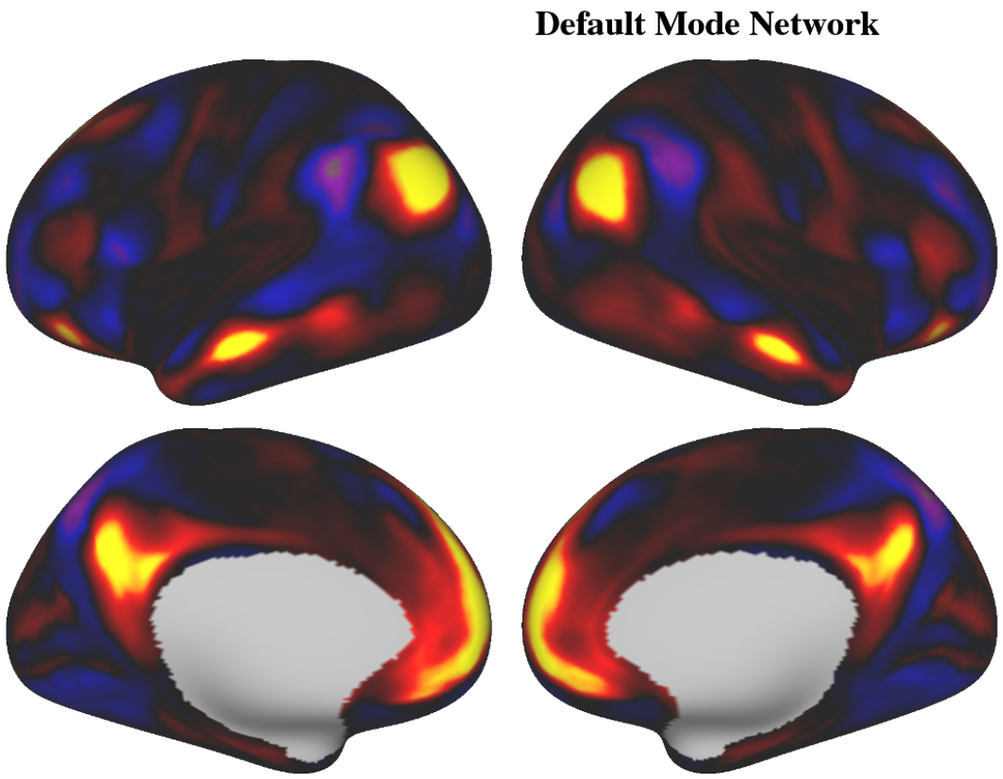
- Instead - start with a “group-average” ICA

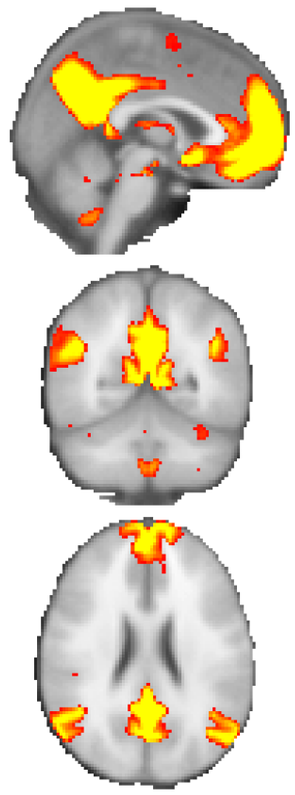
  - But then need to relate group maps back to the individual subjects

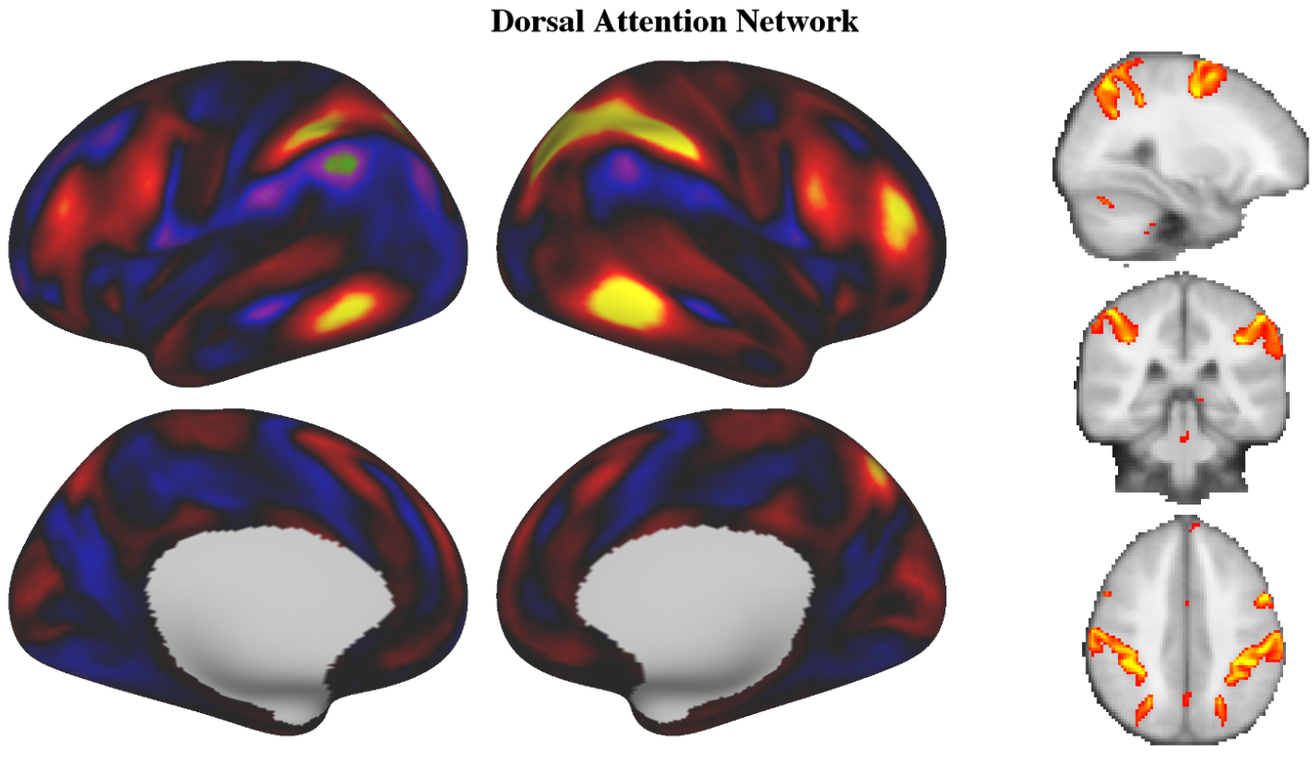
    相反-从“组平均” ICA开始

    但随后需要将组水平图映射回单被试水平

Resting state networks静息态网络

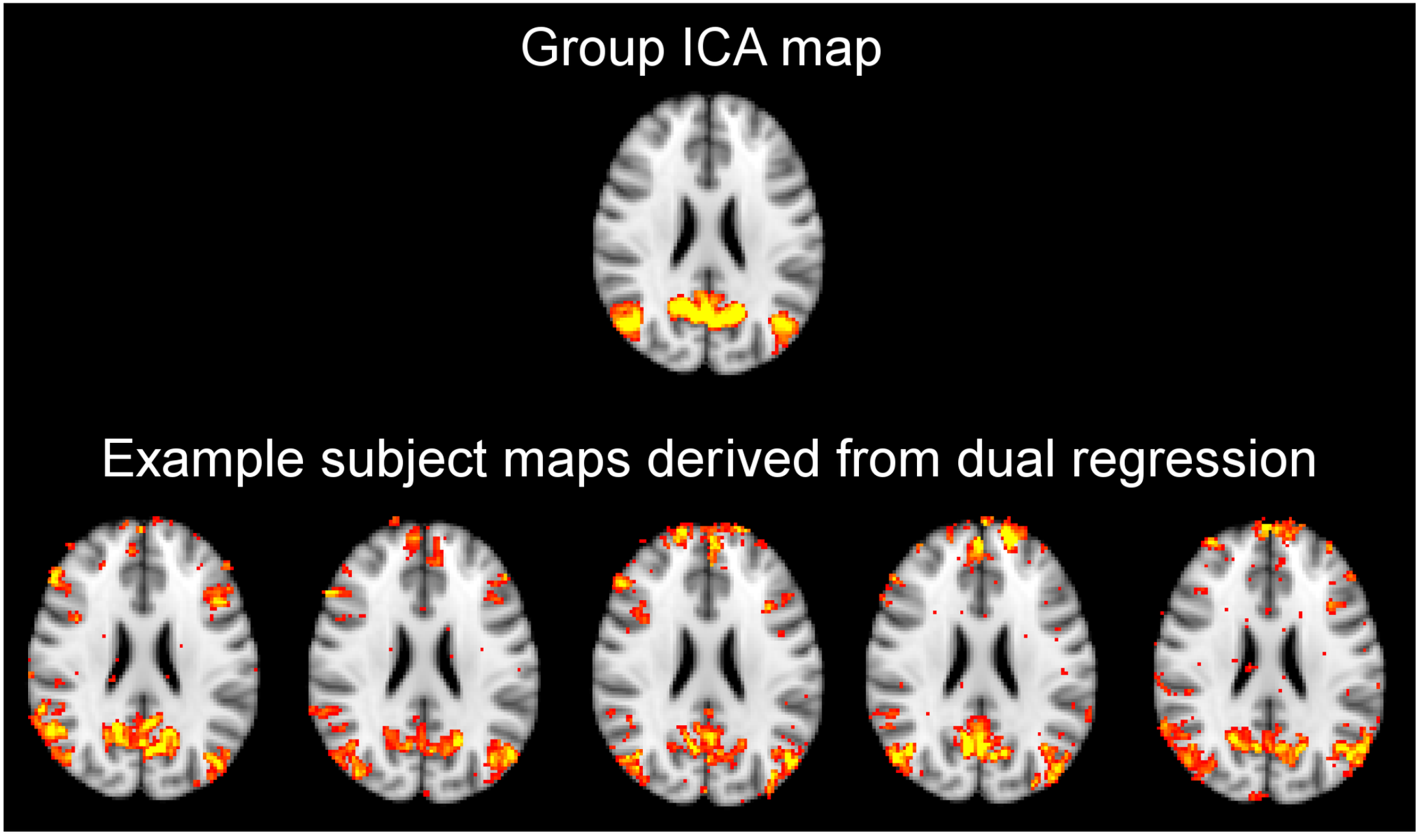






Resting state multi-subject ICA

静息态多被试ICA



Dual Regression双回归

Two steps that both involve multiple regression:

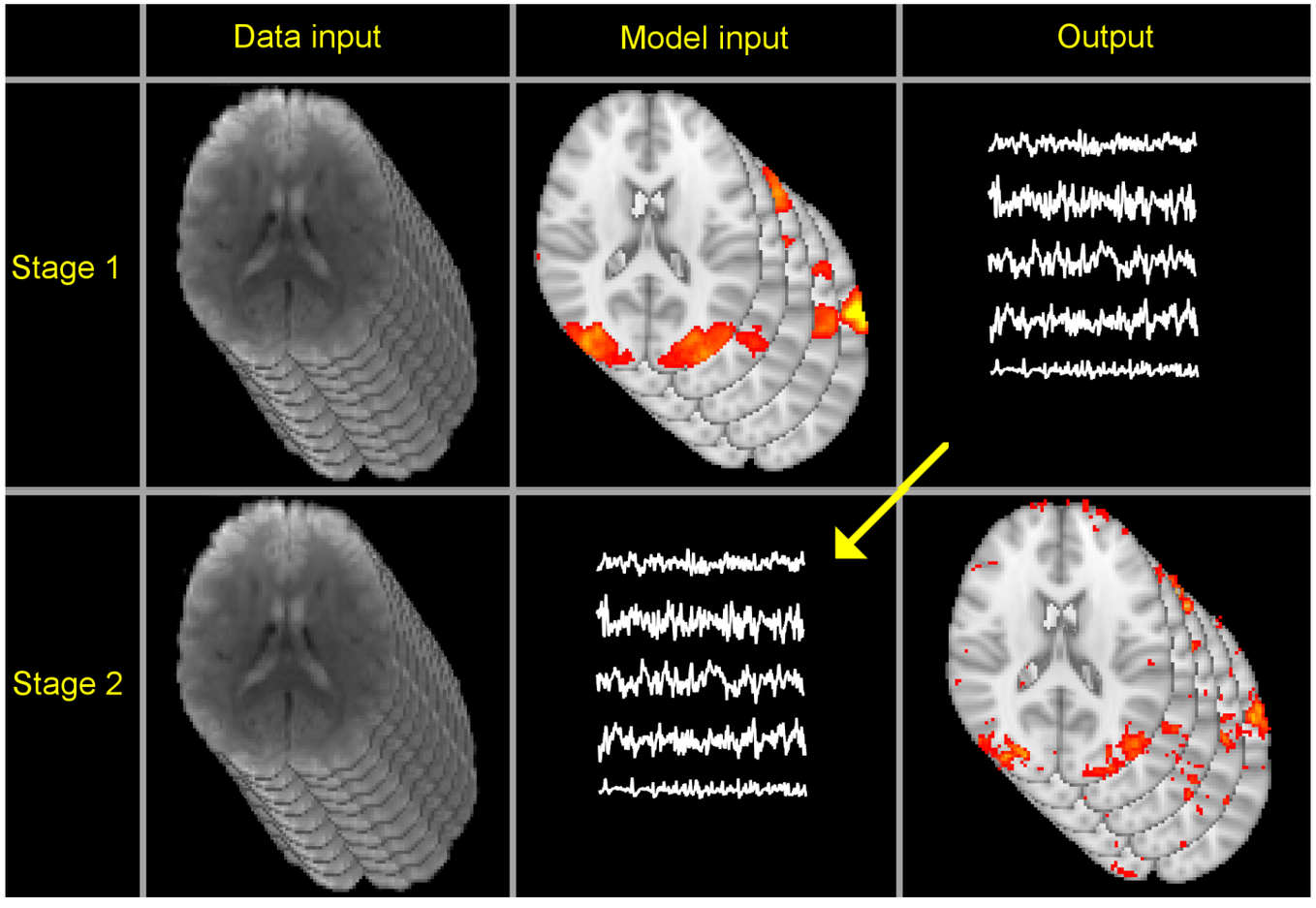
两个步骤都涉及多元回归：

1. Extract subject timeseries

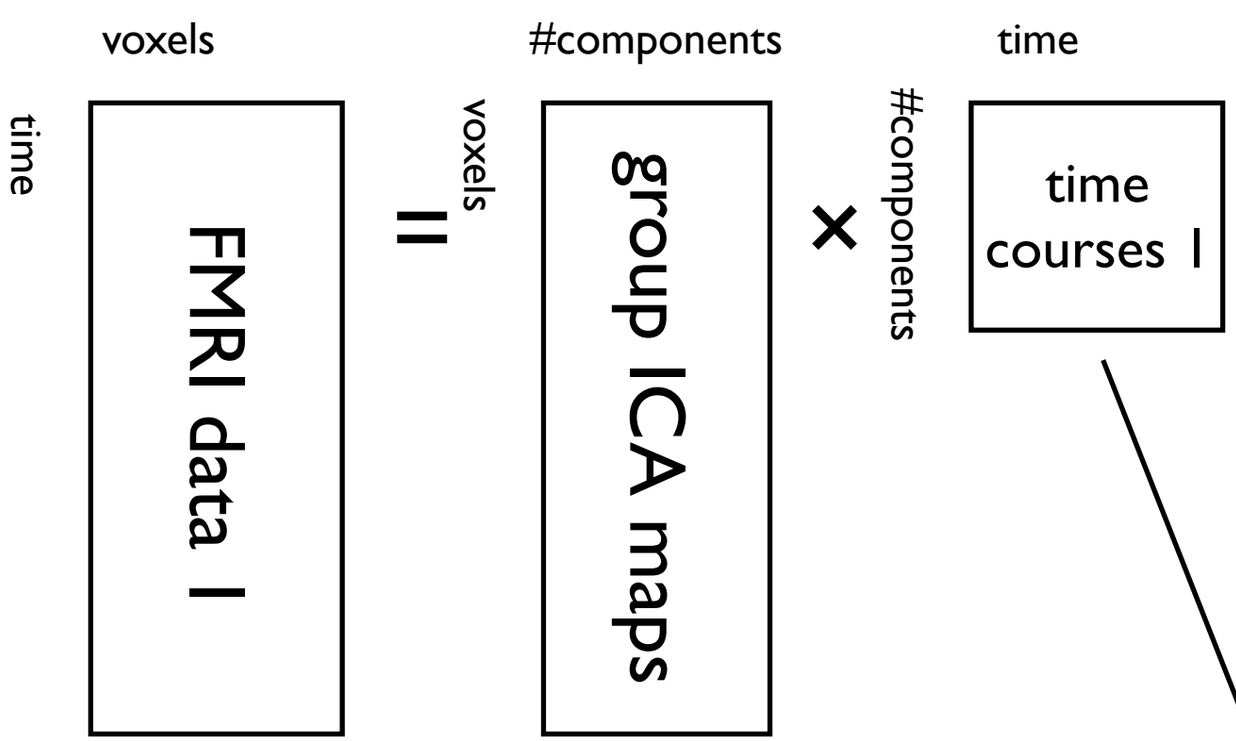
提取被试时间序列

2. Extract subject maps

提取被试空间图



Dual Regression双回归

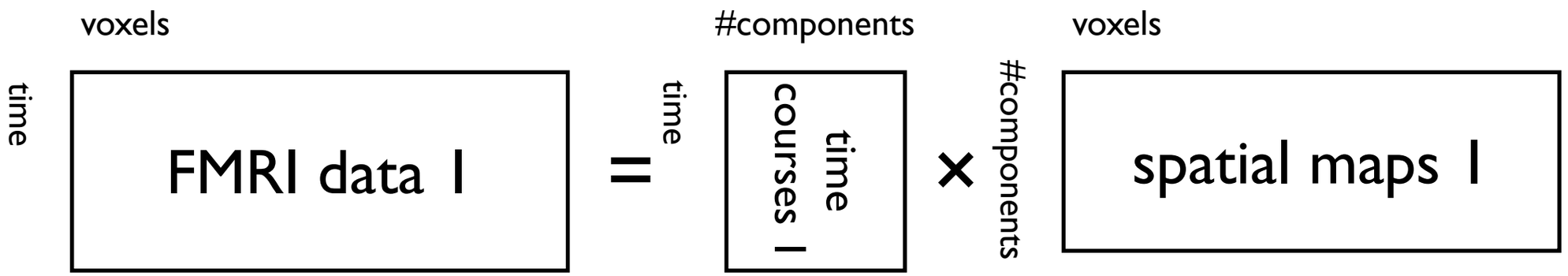


1. Regress group maps into each subject's 4D data to find subject-specific timecourses

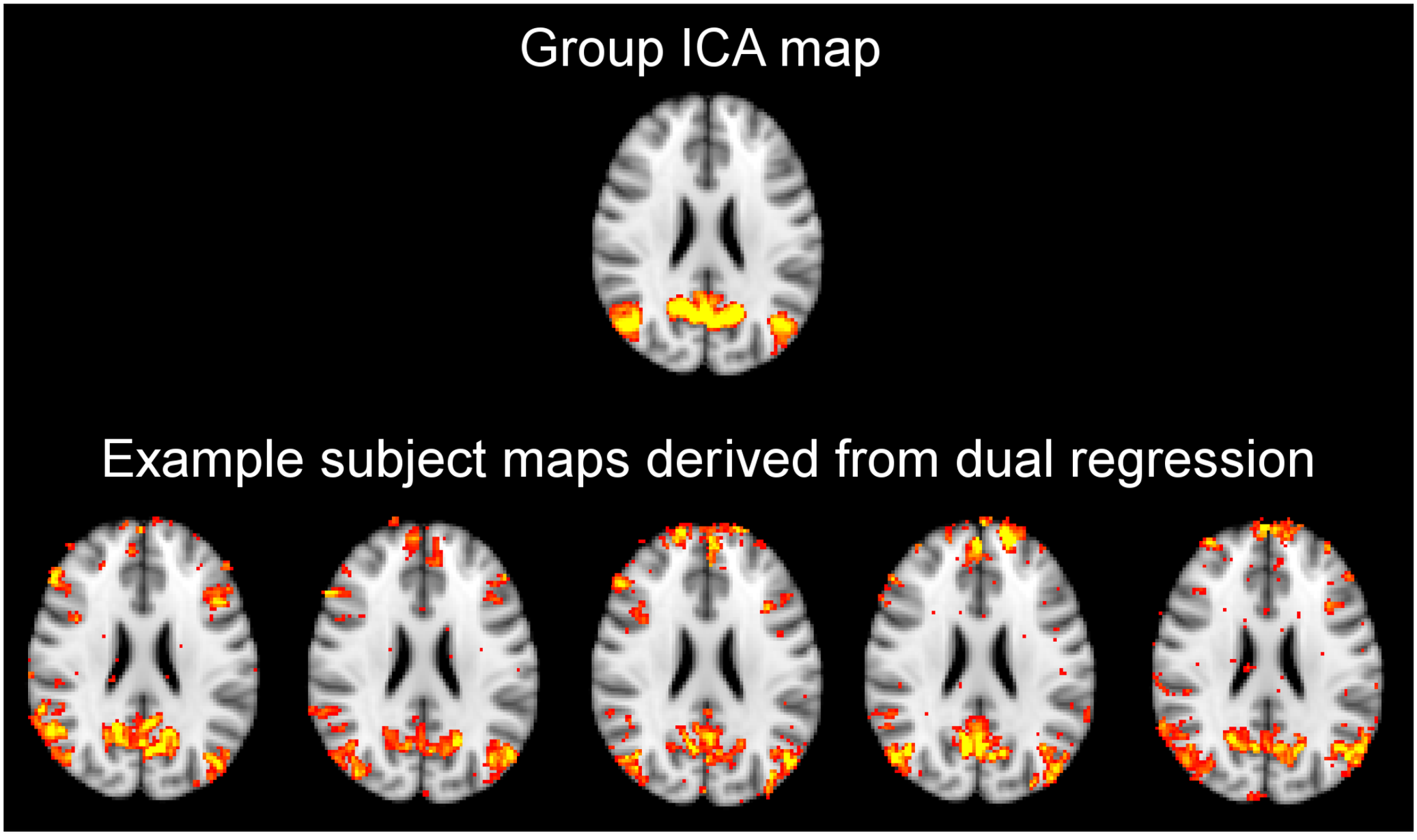
回归组图到每个被试的4D数据中以获得单被试的时间序列

2. Regress these timecourses back into the 4D data to find subject-specific spatial maps

将这些时间序列回归到4D数据中，以找到单被试的空间图



Dual Regression双回归



Running dual_regression运行双回归

beckmann — bash — bash — 142×23

```
[islay:~] dual_regression.sh

dual_regression v0.5 (beta)

***NOTE*** ORDER OF COMMAND-LINE ARGUMENTS IS DIFFERENT FROM PREVIOUS VERSION

Usage: dual_regression <group_IC_maps> <des_norm> <design.mat> <design.con> <n_perm> <output_directory> <input1> <input2> <input3> .....
e.g.   dual_regression groupICA.gica/groupmelodic.ica/melodic_IC 1 design.mat design.con 500 grot `cat groupICA.gica/.filelist`

<group_IC_maps_4D>          4D image containing spatial IC maps (melodic_IC) from the whole-group ICA analysis
<des_norm>                  0 or 1 (1 is recommended). Whether to variance-normalise the timecourses used as the stage-2 regressors
<design.mat>                Design matrix for final cross-subject modelling with randomise
<design.con>                Design contrasts for final cross-subject modelling with randomise
<n_perm>                    Number of permutations for randomise; set to 1 for just raw tstat output, set to 0 to not run randomise at all.
<output_directory>          This directory will be created to hold all output and logfiles
<input1> <input2> ...       List all subjects' preprocessed, standard-space 4D datasets

<design.mat> <design.con>   can be replaced with just
-1                          for group-mean (one-group t-test) modelling.
If you need to add other randomise option then just edit the line after "EDIT HERE" below

[islay:~]
```

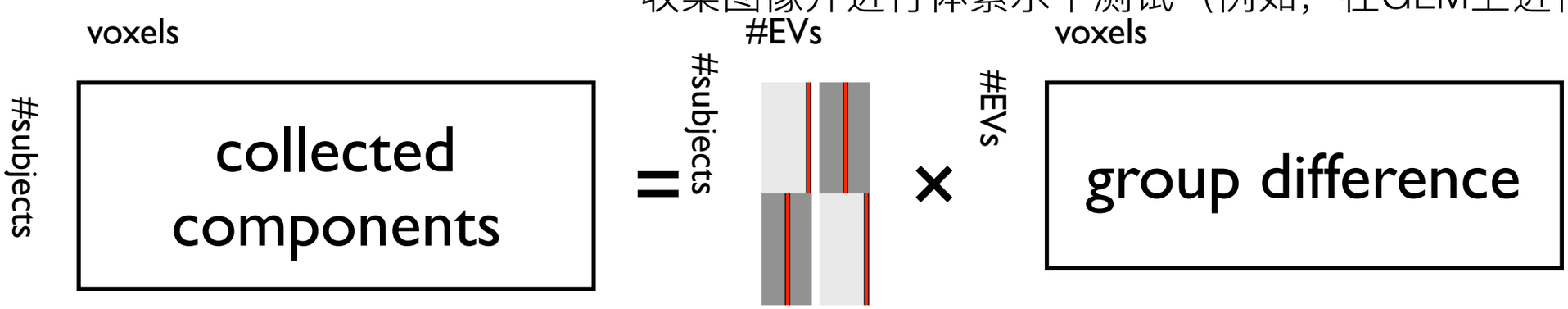
- FSL command line tool, combining:FSL命令行工具，包含：
  - DR to create subject-wise estimates (stage 1 + stage 2)

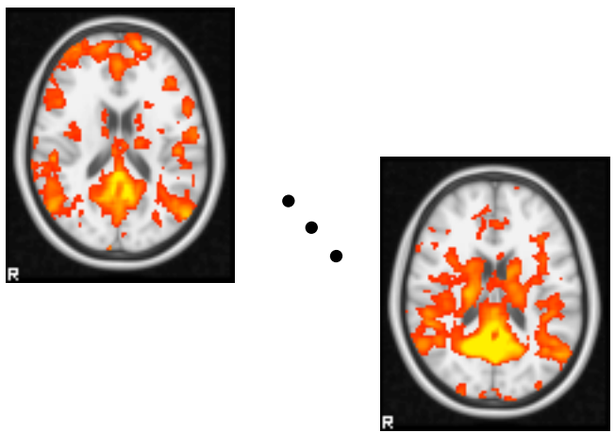
    双回归创建个体水平的估计值（阶段1 +阶段2）
  - Group comparison using randomise (stage 3)
    - randomise进行组水平比较

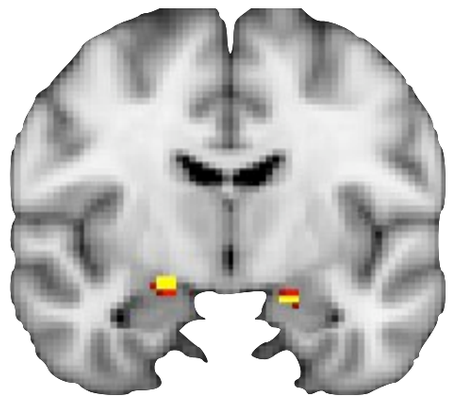
Group comparison组水平比较

- Collect maps and perform voxel-wise test (e.g. randomisation test on GLM)

收集图像并进行体素水平测试（例如，在GLM上进行随机化测试）





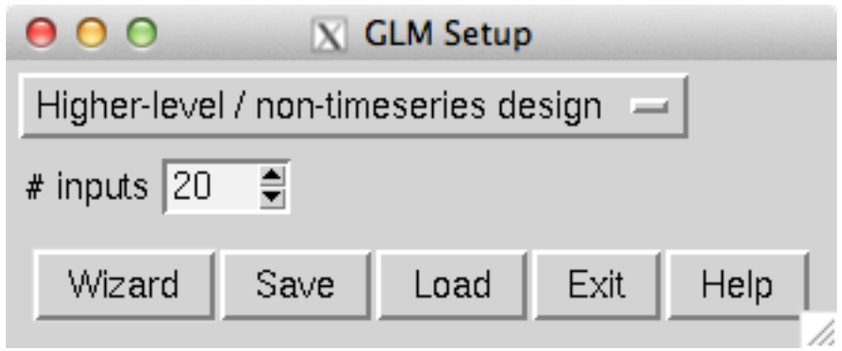


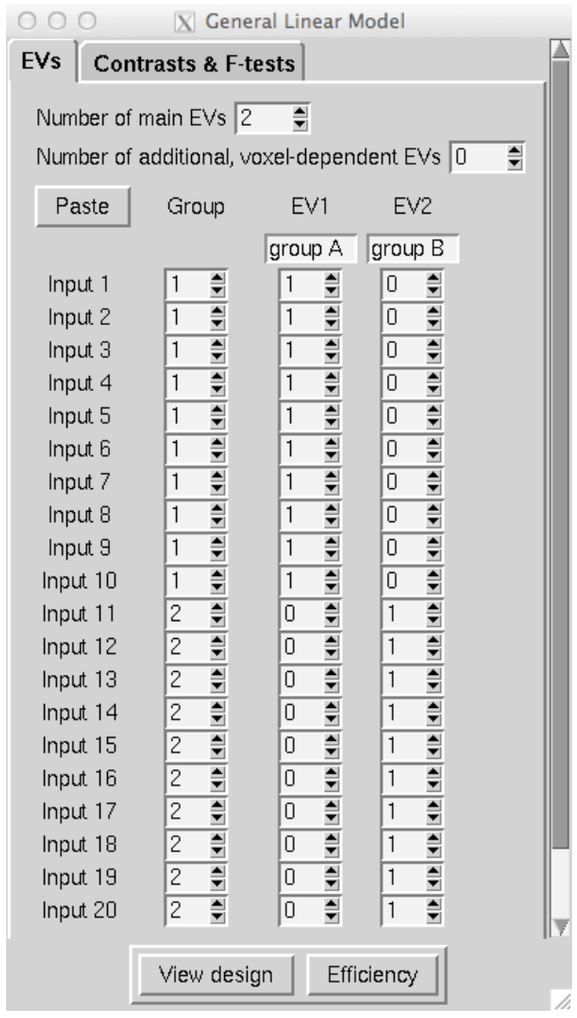
- Can now do voxelwise testing across subjects, separately for each original group ICA map
- Can choose to look at strength-and-shape differences

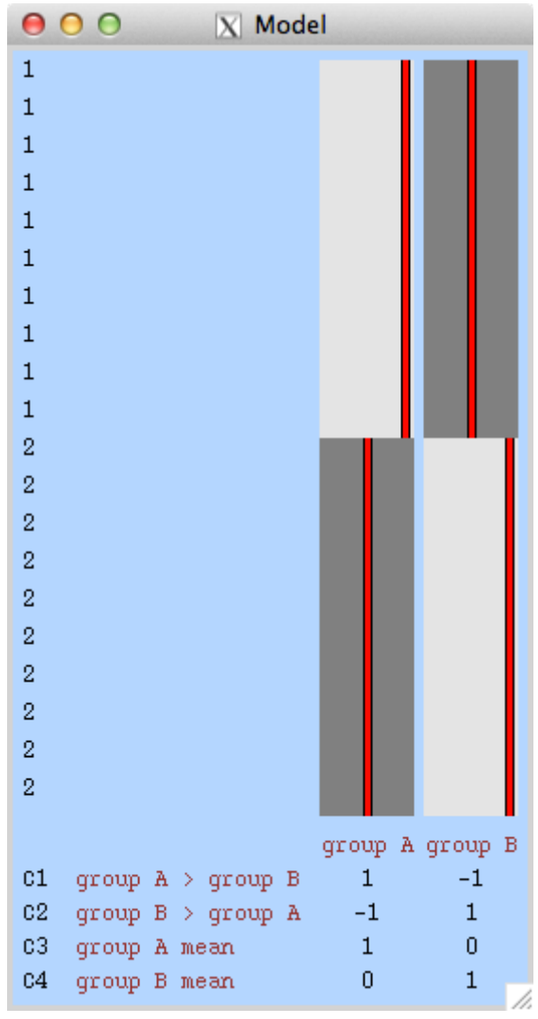
现在可以对每个原始组水平ICA图进行被试间的体素水平检验

可以选择查看差异的强度和形状

Group analysis on maps 空间图像组分析





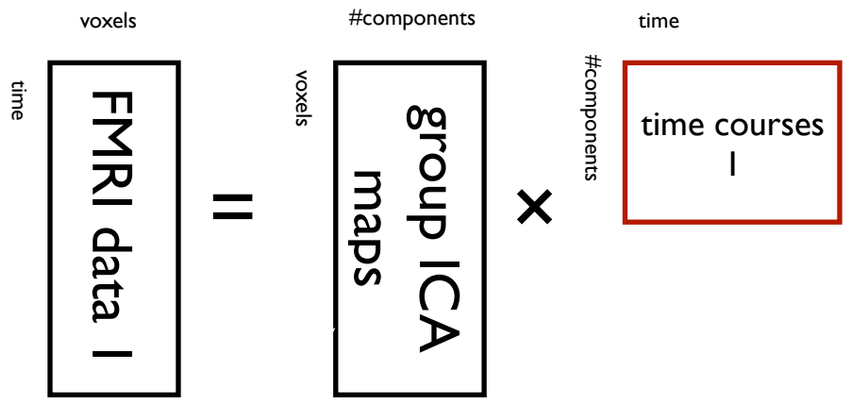


- can use the Glm tool (Glm_gui on mac) to create GLM design and contrast matrices

可以使用Glm工具（在Mac上为Glm_gui）来创建GLM设计和对比矩阵

Dual regression outputs双回归的输出

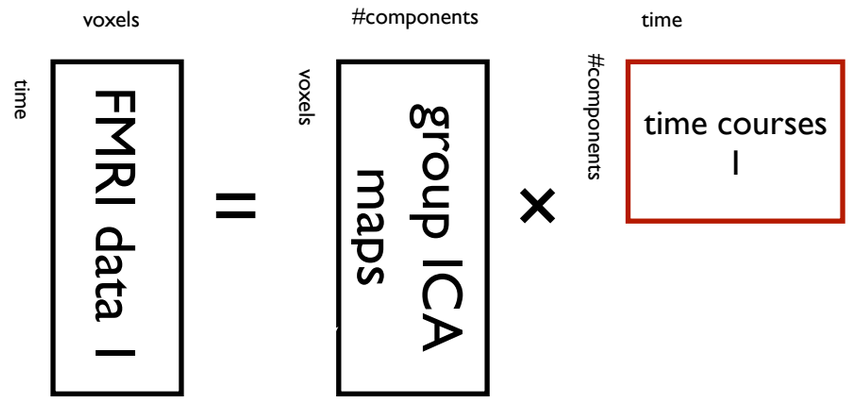
- dr_stage1_subject[#SUB].txt - the timeseries outputs of stage 1 of the dual-regression.
  双回归第一阶段的时间序列输出值

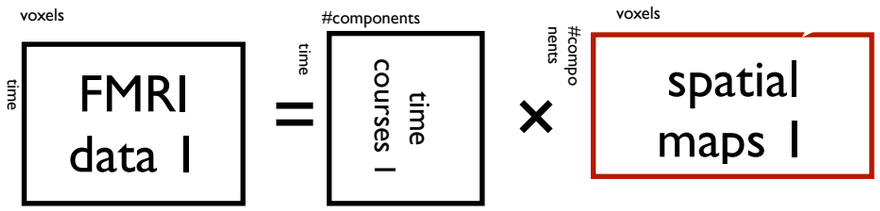


Dual regression outputs双回归的输出

- dr_stage1_subject[#SUB].txt - the timeseries outputs of stage 1 of the dual-regression.
  双回归第一阶段的时间序列输出值

- dr_stage2_subject[#SUB].nii.gz - the spatial maps outputs of stage 2 of the dual-regression.
  双回归第二阶段的空间图输出





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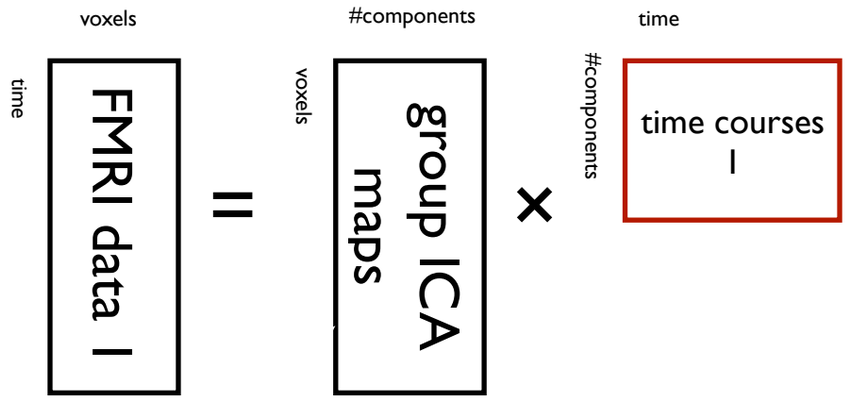
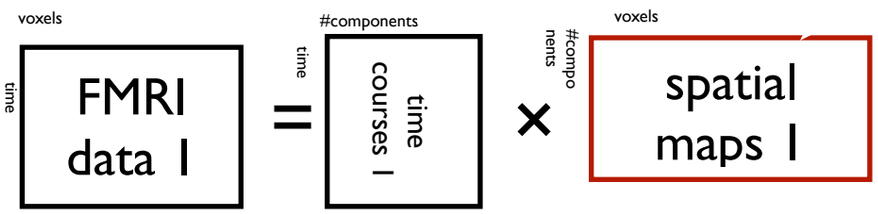
  双回归第二阶段的空间图输出



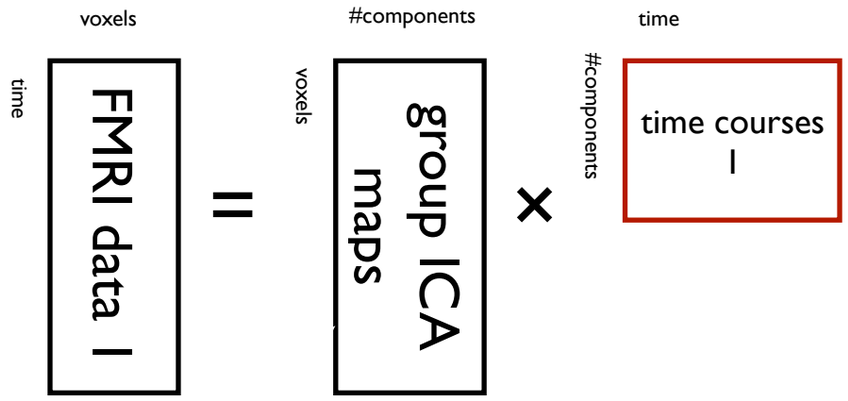
- dr_stage2_ic[#ICA].nii.gz - the re-organised parameter estimate images
  估计图像的重建参数



Dual regression outputs双回归的输出

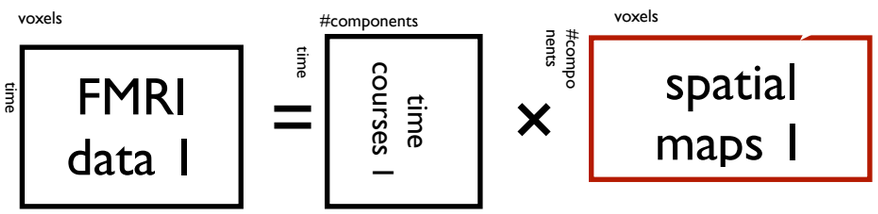
- dr_stage1_subject[#SUB].txt - the timeseries outputs of stage 1 of the dual-regression.
  双回归第一阶段的时间序列输出值

- dr_stage2_subject[#SUB].nii.gz - the spatial maps outputs of stage 2 of the dual-regression.
  双回归第二阶段的空间图输出



- dr_stage2_ic[#ICA].nii.gz - the re-organised parameter estimate images
  估计图像的重建参数

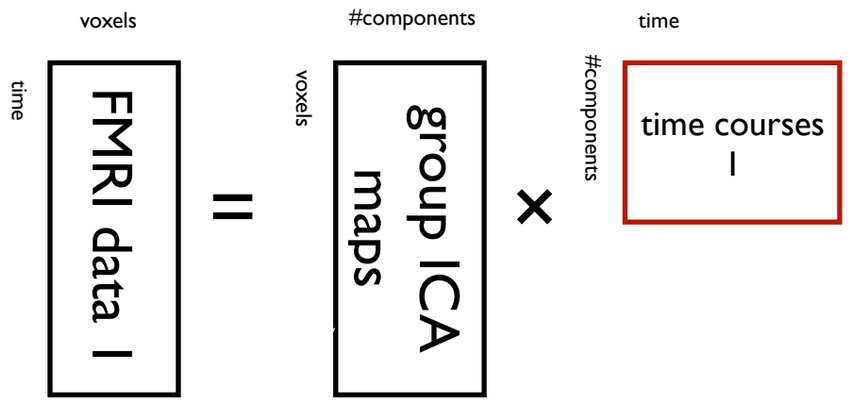
- dr_stage3_ic[#ICA]_tstat[#CON].nii.gz - the output from randomise
  非参置换检验randomise的输出值



Dual regression outputs双回归的输出

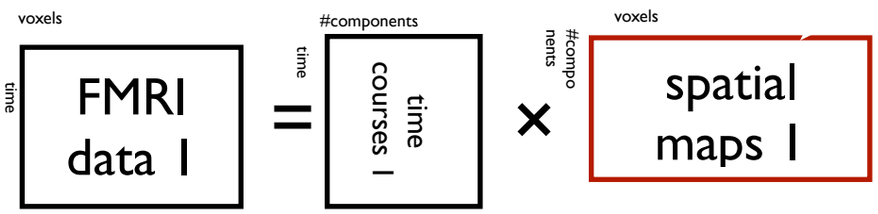
- dr_stage1_subject[#SUB].txt - the timeseries outputs of stage 1 of the dual-regression.
  双回归第一阶段的时间序列输出值

- dr_stage2_subject[#SUB].nii.gz - the spatial maps outputs of stage 2 of the dual-regression.
  双回归第二阶段的空间图输出



- dr_stage2_ic[#ICA].nii.gz - the re-organised parameter estimate images
  估计图像的重建参数

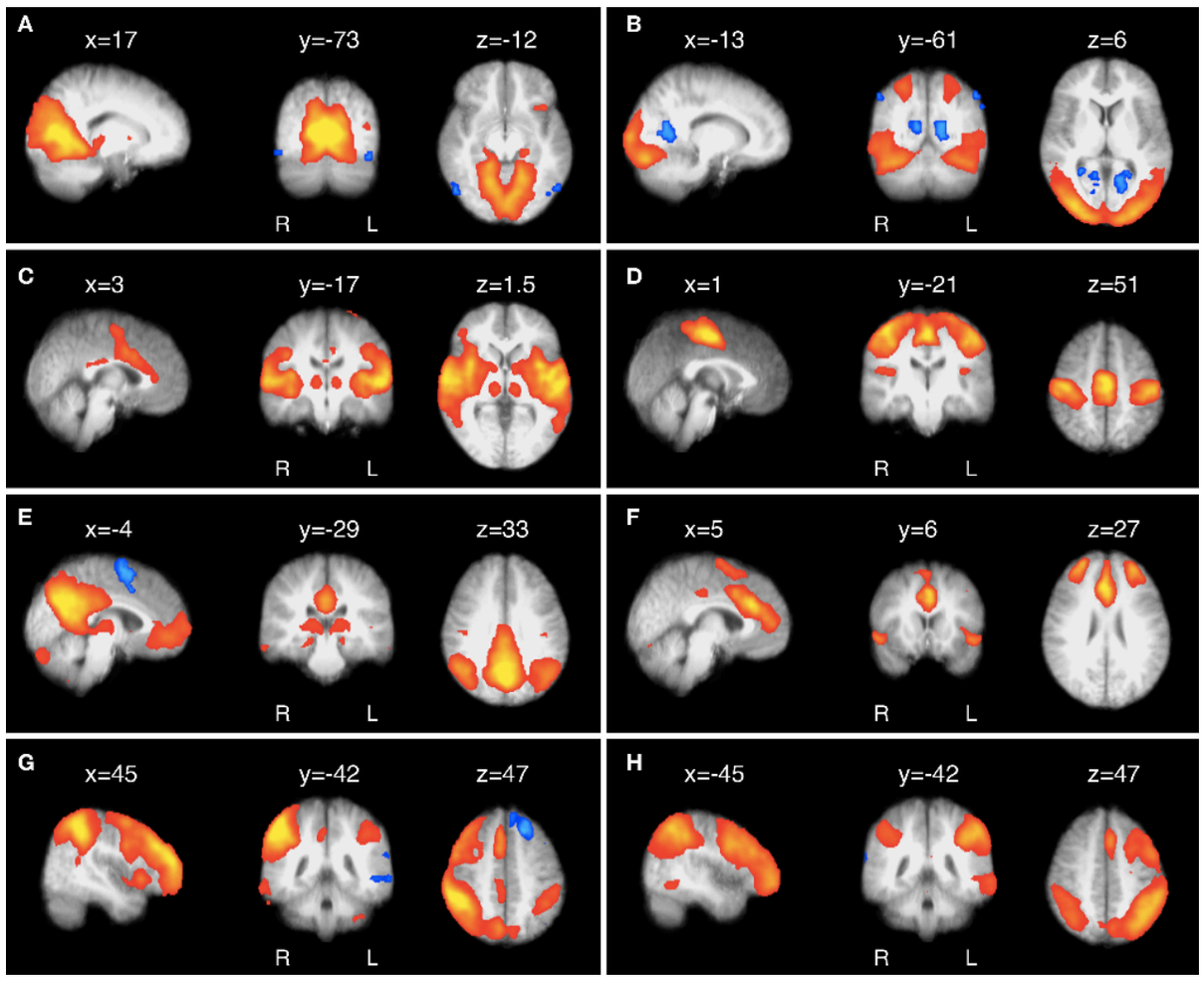
- dr_stage3_ic[#ICA]_tstat[#CON].nii.gz - the output from randomise
  非参置换检验randomise的输出值



(corrected for multiple comparisons across voxels but not across #components!!)
进行体素水平的多重比较校正而不是成分水平

Group template maps组模板图

- Generate from the data using ICA
  使用ICA从数据生成
  - use all data to get unbiased templates
    使用所有数据获取无偏的模板

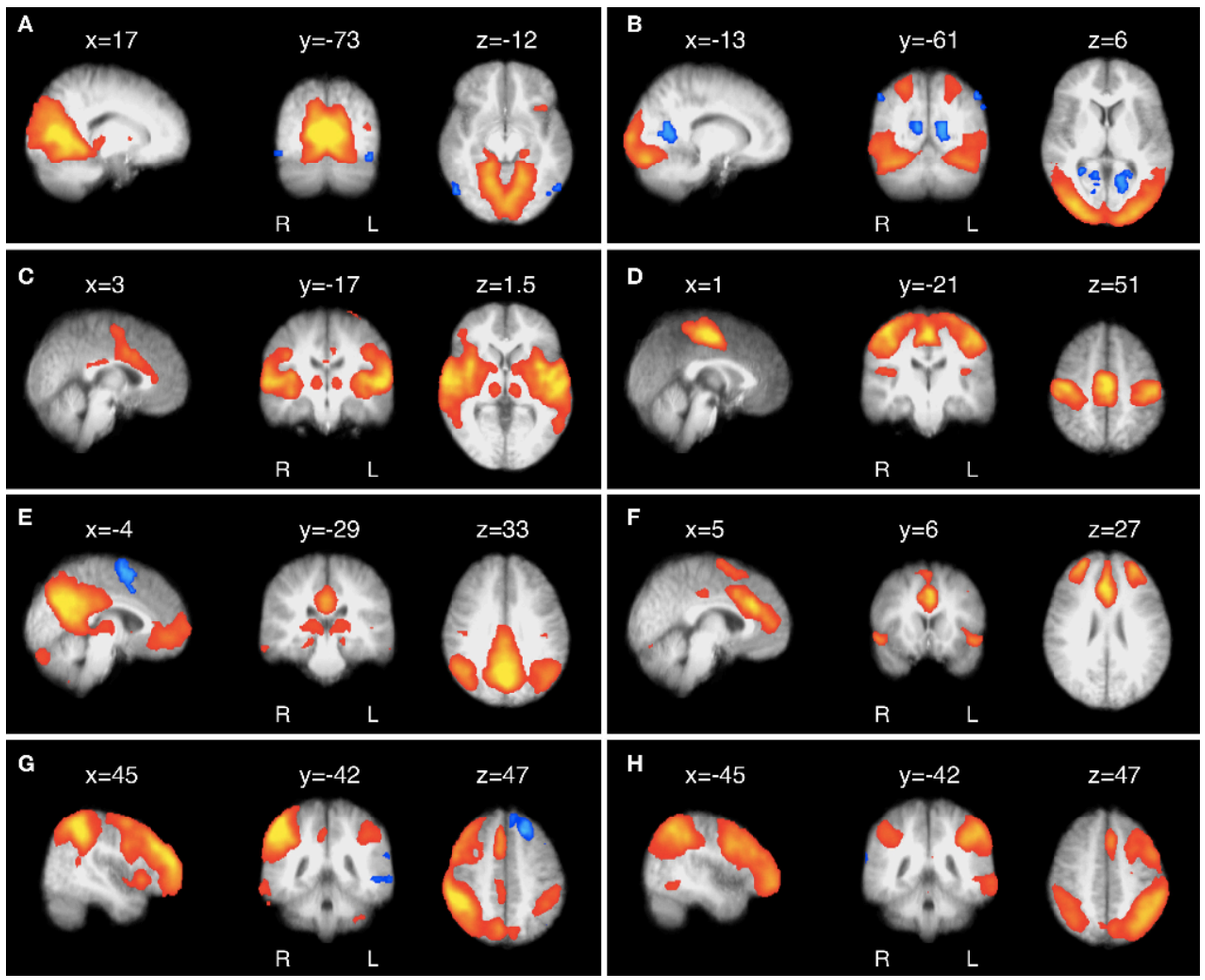


template RSNs

http://www.fmrib.ox.ac.uk/analysis/research

Group template maps组模板图

- Generate from the data using ICA 使用ICA从数据生成
  - use all data to get unbiased templates 使用所有数据获取无偏的模板
  - use independent control group 使用独立的对照组
  - will model signals and artefacts 为信号和伪影建模



template RSNs

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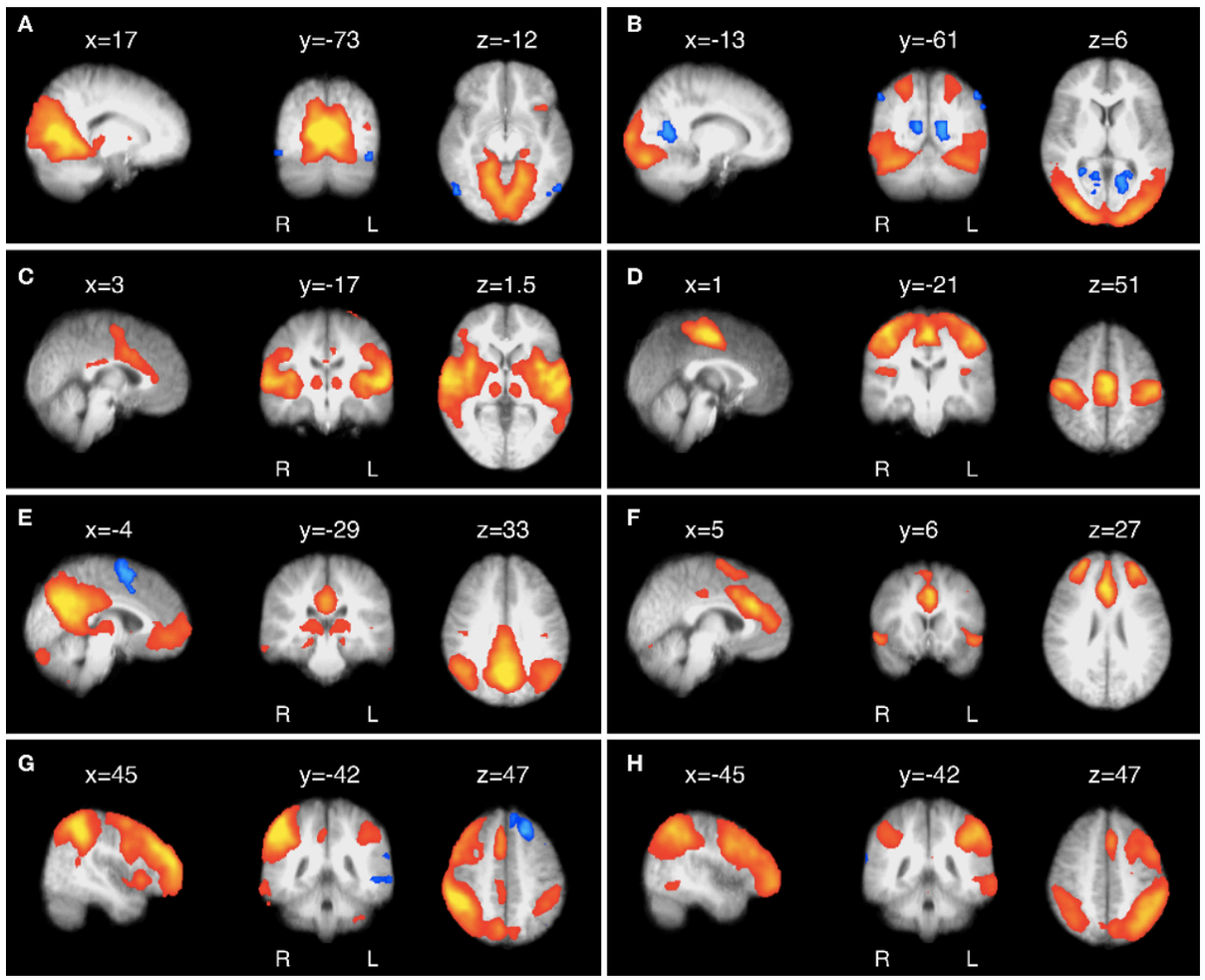
Group template maps组模板图

- Generate from the data using ICA 使用ICA从数据生成
  - use all data to get unbiased templates 使用所有数据获取无偏的模板
  - use independent control group 使用独立的对照组
  - will model signals and artefacts 为信号和伪影建模
- use existing template 使用现有模板



template RSNs

http://www.fmrib.ox.ac.uk/analysis/research

The book:

RRP: £22.99

That’s all folks