Probing white matter microstructure at high spatial resolution combining CHARMED protocol optimization and a high performance gradient set

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The CHARMED model of white matter

• Multiple compartment model based on diffusion:
  – Restricted diffusion in cylinders of radius r (NEUMAN 1974)
  – 3D Gaussian displacement distribution (DTI)

• Resolves crossing fibers

\[ E(q, \Delta) = f_r E_r(q, \Delta) + f_h E_h(q, \Delta) \]
Protocol optimization

De Santis, et al. (2013)

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High performance gradients

• **dMRI & the Prisma**
  - Big gradients
    - 80 mT/m amplitude
    - 200 T/m/s slew rate
    - 50cm Field-of-view
  - Big coils

• **Improvements for dMRI**
  - High spatial resolution
  - High b-value
  - High coverage

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Multi-band imaging

- Excite *multiple* slices simultaneously

- Each coil yields a linear combination of signals from the different slices (weighted by sensitivity profiles)

- Matrix inversion provides a solution to separate slices

## Tested protocols

| MB2G2                  | Bvalue (s/mm²) | Resolution (mm) | Delta (ms) | delta (ms) | TE (ms) | TR (ms) | Total Scan Time (mm:ss) | Bandwidth (Hz/Px) | Echo Spacing (ms) | |Gj (mT/m) | #dirs | Tot. Readout Time (ms) |
|------------------------|----------------|-----------------|------------|------------|---------|---------|-------------------------|--------------------|------------------|-----------------|-------|-----------------|
| 6000                   | 2              | 45.9            | 29.4       | 94         | 4613    | 4:52    | 1602                    | 0.71               | 51,836           | 45              | 26,980 |                 |
| 6000                   | 1.5            | 45.6            | 25.7       | 94         | 6016    | 9:03    | 1598                    | 0.71               | 58,547           | 72              | 35,500 |                 |
| 6000                   | 1.3            | 45.4            | 22.3       | 94         | 6993    | 14:43   | 1544                    | 0.73               | 66,639           | 108             | 43,618 |                 |

| EP2DG2                 | Bvalue (s/mm²) | Resolution (mm) | Delta (ms) | delta (ms) | TE (ms) | TR (ms) | Total Scan Time (mm:ss) | Bandwidth (Hz/Px) | Echo Spacing (ms) | |Gj (mT/m) | #dirs | Tot. Readout Time (ms) |
|------------------------|----------------|-----------------|------------|------------|---------|---------|-------------------------|--------------------|------------------|-----------------|-------|-----------------|
| 6000                   | 2              | 43.6            | 33.7       | 94         | 10000   | 9:02    | 1602                    | 0.71               | 47,76            | 45              | 26,980 |                 |
| 6000                   | 1.5            | 43.4            | 30.8       | 94         | 12100   | 16:22   | 1598                    | 0.71               | 51,65            | 72              | 35,500 |                 |
| 6000                   | 1.3            | 43.2            | 27.5       | 94         | 16200   | 31:37   | 1544                    | 0.73               | 57,08            | 108             | 43,618 |                 |

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FR difference maps (1)

Mean = -0.0367, std = 0.0755
Mean = -0.0573, std = 0.0848
Mean = -0.0206, std = 0.0772

Mean = -0.0596, std = 0.0726
Mean = -0.0804, std = 0.0851
Mean = -0.0208, std = 0.0740

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FR difference maps (2)

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