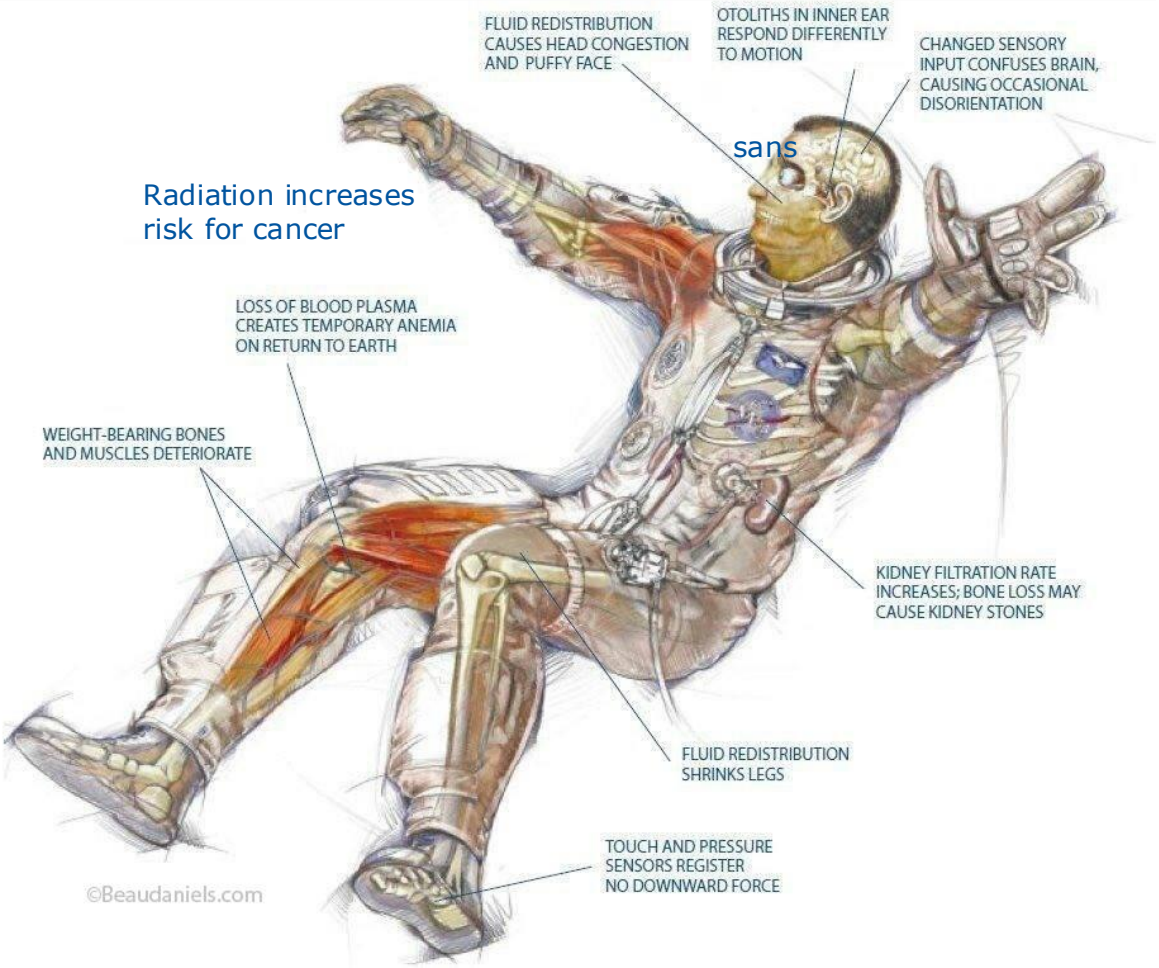
Effect of spaceflight on the human brain and the need for Artificial Gravity

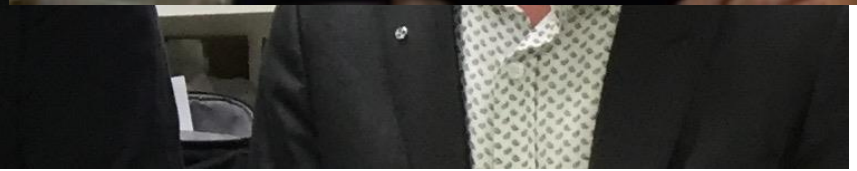
Prof dr Floris L. Wuyts

Minister of Science of Asgardia

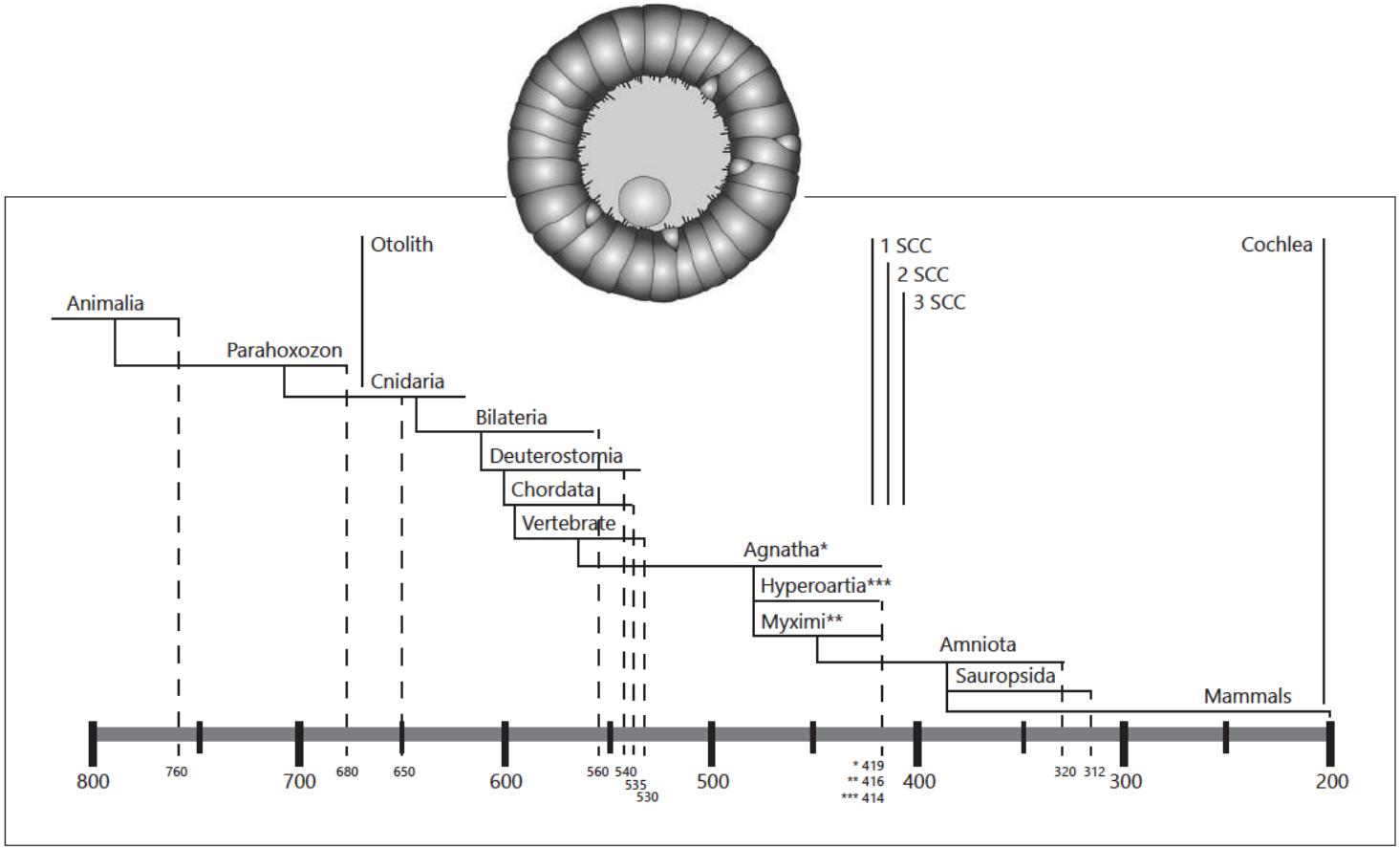
Effects of Space Flight on Human Body:




proxima
esa



Gravity detection is old and dates back at least 600 million years ago



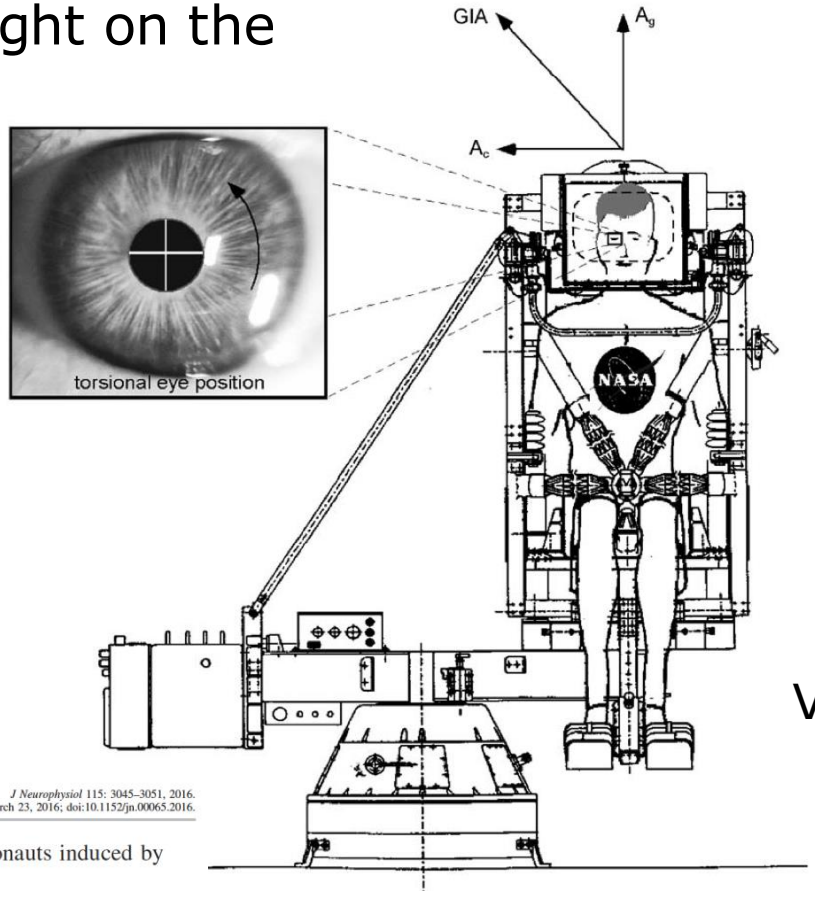
Million years ago

Ref: The superiority of the otolith system, Ramos et al, Audiol Neurotol, 2020

Astronauts returning from space


iSkysoft
HEIDEMARIE STEFANYSHYN-PIPER
ASTRONAUT
KPRC
CNN

Impact of spaceflight on the otolith system?



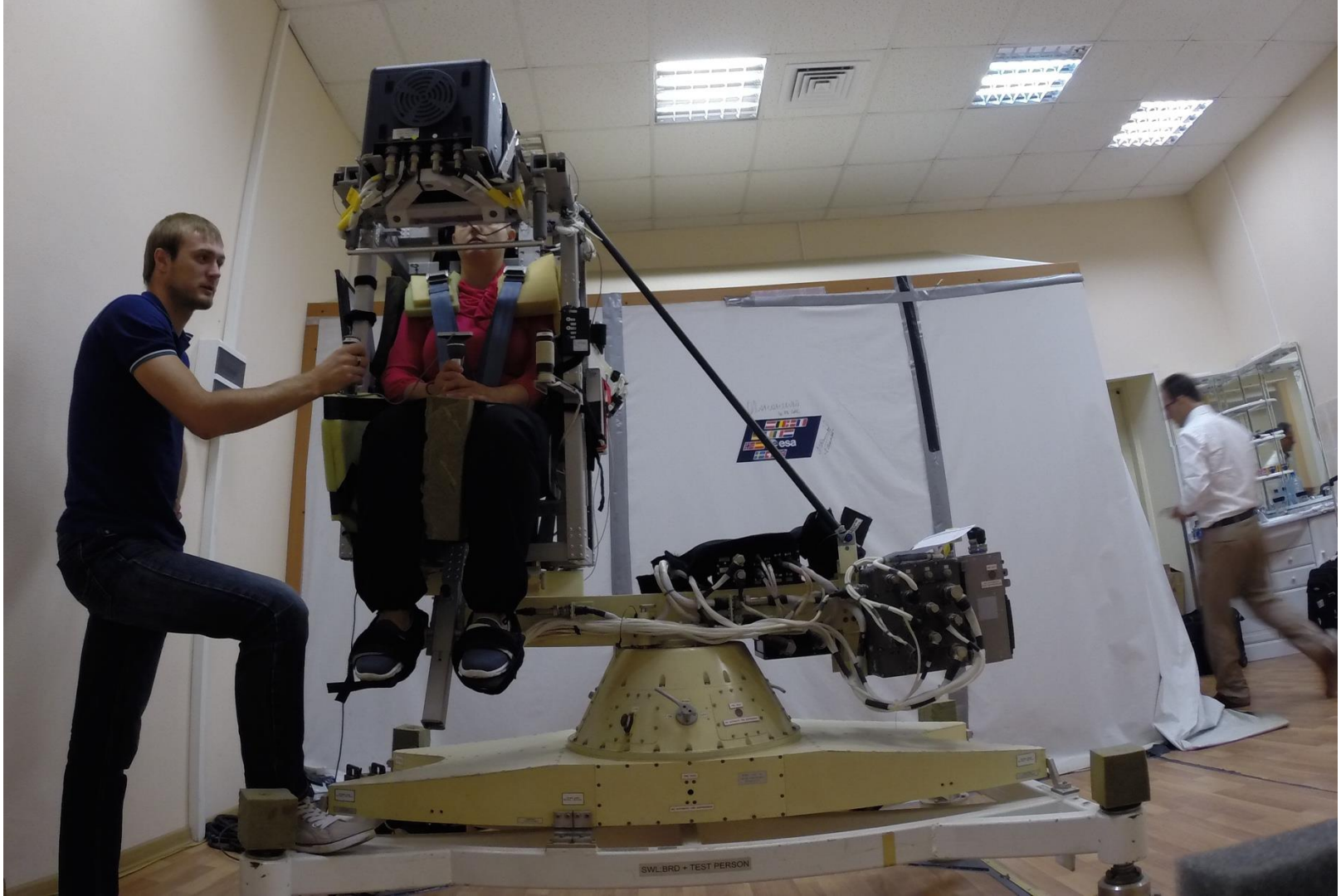
VVIS – Neurolab

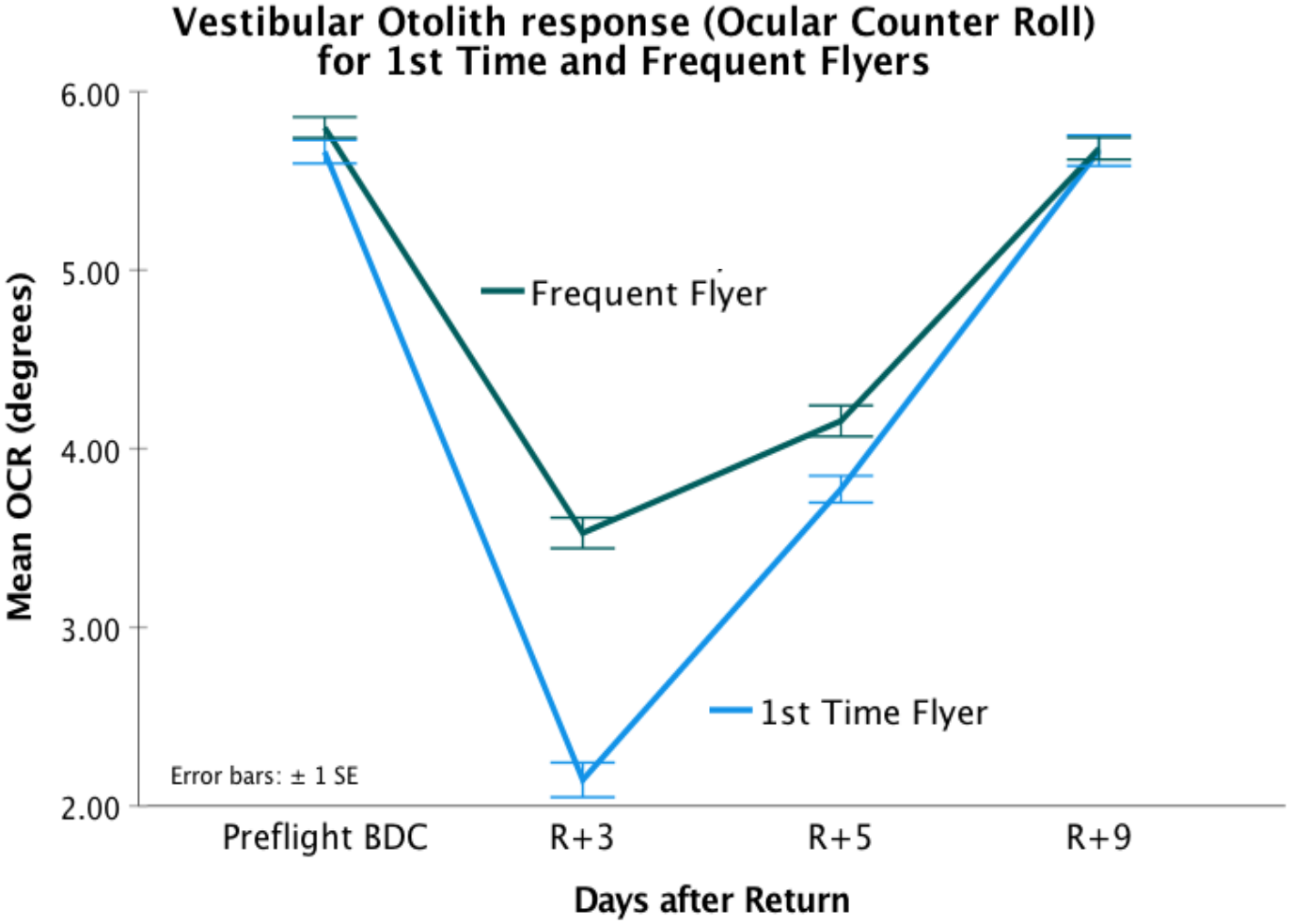
J Neurophysiol 115: 3045–3051, 2016.
First published March 23, 2016; doi:10.1152/jn.00065.2016.

Decreased otolith-mediated vestibular response in 25 astronauts induced by long-duration spaceflight

Emma Hallgren,[1] Ludmila Kornilova,[2] Erik Fransen,[3] Dmitrii Glukhikh,[2] Steven T. Moore,[4] Gilles Clément,[5] Angelique Van Ombergen,[1] Hamish MacDougall,[6] Ivan Naumov,[2] and Floris L. Wuyts[1]

TEHM
Urine


SWL:BRD + TEST PERSON


Vestibular Otolith response (Ocular Counter Roll)
for 1st Time and Frequent Flyers
Mean OCR (degrees)
6.00
5.00
4.00
3.00
2.00
Frequent Flyer
1st Time Flyer
Error bars: ± 1 SE
Preflight BDC
R+3
R+5
R+9
Days after Return

npj | microgravity

www.nature.com/npjmgrav

ARTICLE OPEN

Check for updates

Ocular counter-roll is less affected in experienced versus novice space crew after long-duration spaceflight

Catho Schoenmaekers[1], Chloë De Laet[1], Ludmila Kornilova[2], Dmitrii Glukhikh[2], Steven Moore[3], Hamish MacDougall[4], Ivan Naumov[2], Erik Fransen[5], Leander Wille[1], Steven Jillings[1] and Floris L. Wuyts[1] ✉

July 2022

Objectives BRAIN-DTI
ESA project/Roscosmos – initiated in 2009

- Determine biomarkers of neuroplasticity in vestibular signal processing using the model of microgravity and by means of advanced MRI techniques

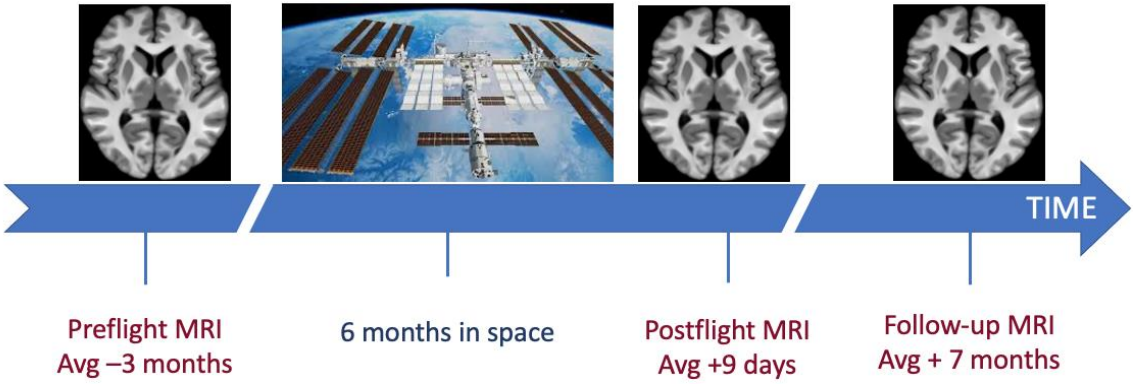
- Obtain knowledge on how astronauts adapt to microgravity by comparison of their brain before and after spaceflight

- Gain insight in which specific regions of interest (ROI) are involved in spatial disorientation, vertigo and convergence of otolith and semicircular canal signals.

- Understand mechanisms of (lacking) neuroplasticity in patients with vestibular dysfunction and the elderly.

BRAIN-DTI (2009)

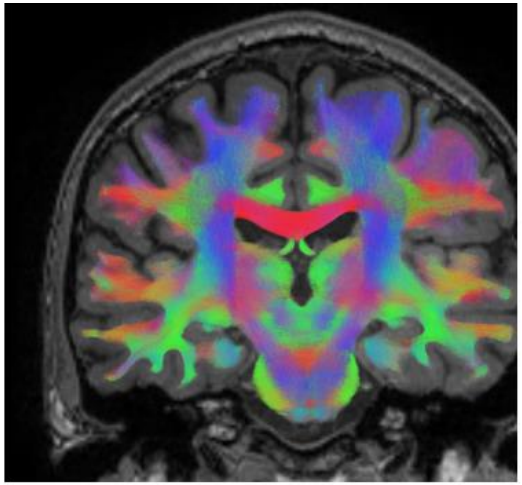
Aim: Study impact of spaceflight on the human brain with MRI methods

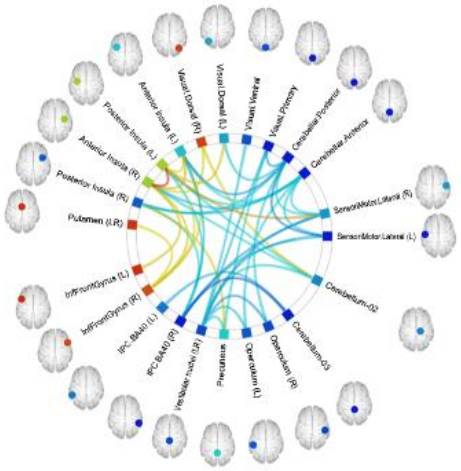


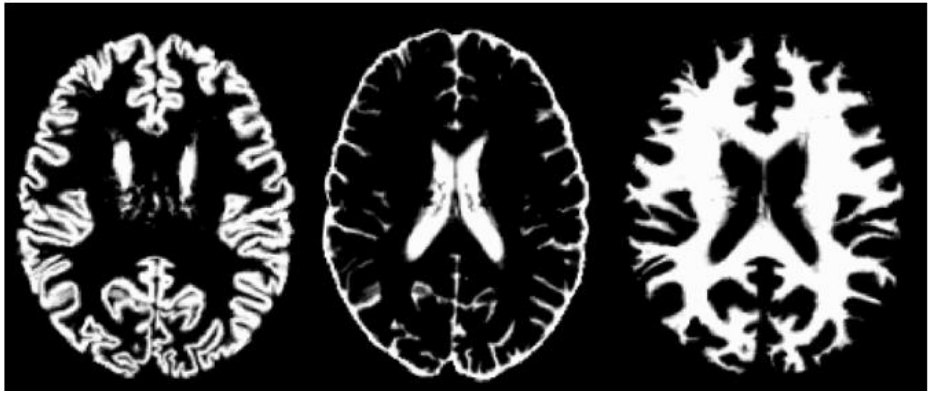
3 MRI modalities

Diffusion MRI (DTI,…)

→nerve fibre orientation
(front to back,
left to right,



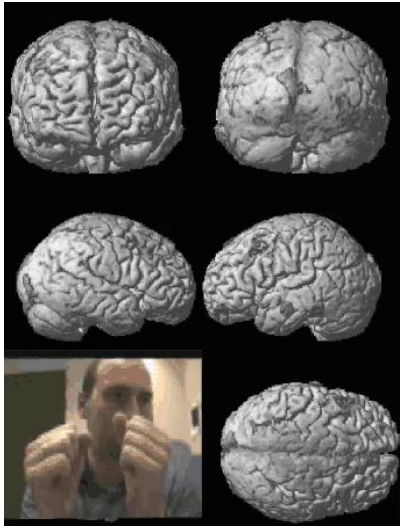




Anatomical MRI → volumes of MRI images segmented into grey matter cerebrospinal fluid white matter.

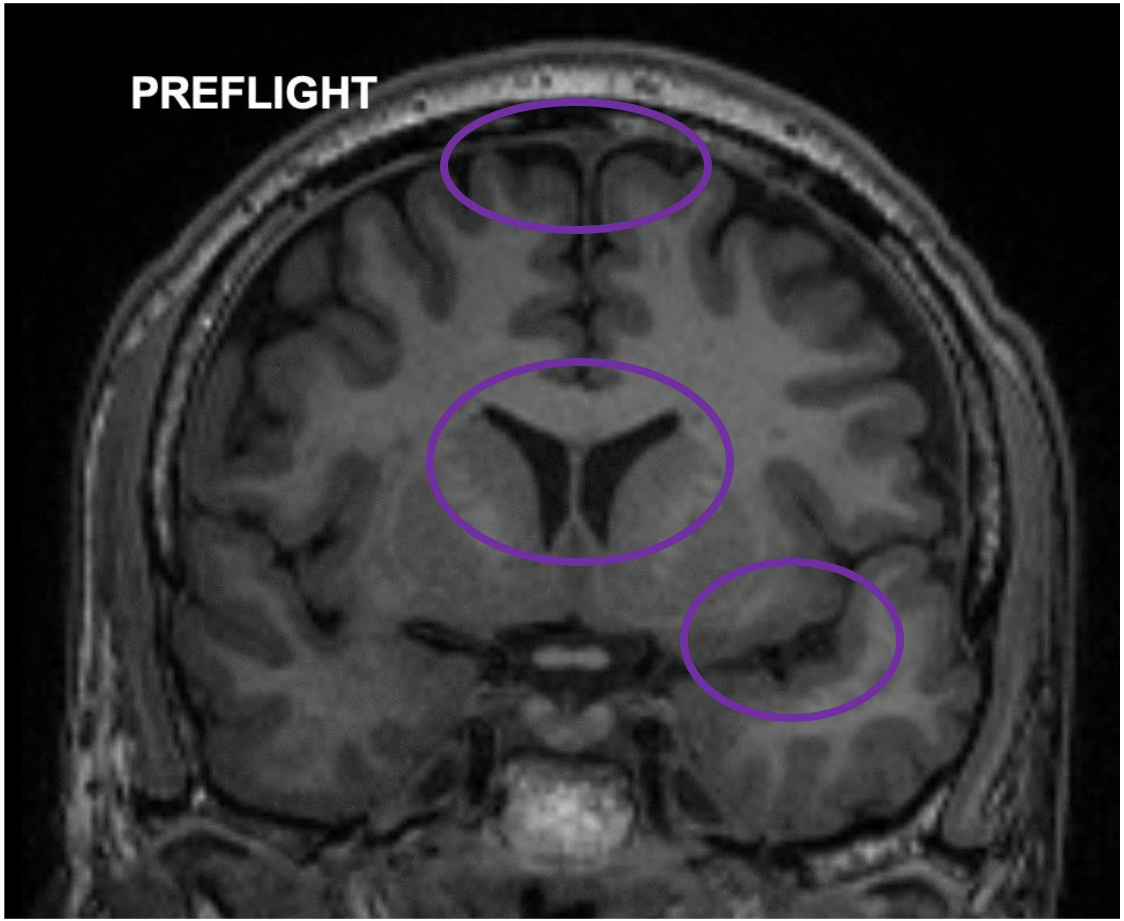
Functional MRI and resting state fMRI

→ functional connectivity



Measure **blood oxygenation as marker for neural activity** (blood-oxygenation level dependent: BOLD signal). Courtesy of Stefan Sunaert

Upward brain shift



Courtesy Steven Jillings

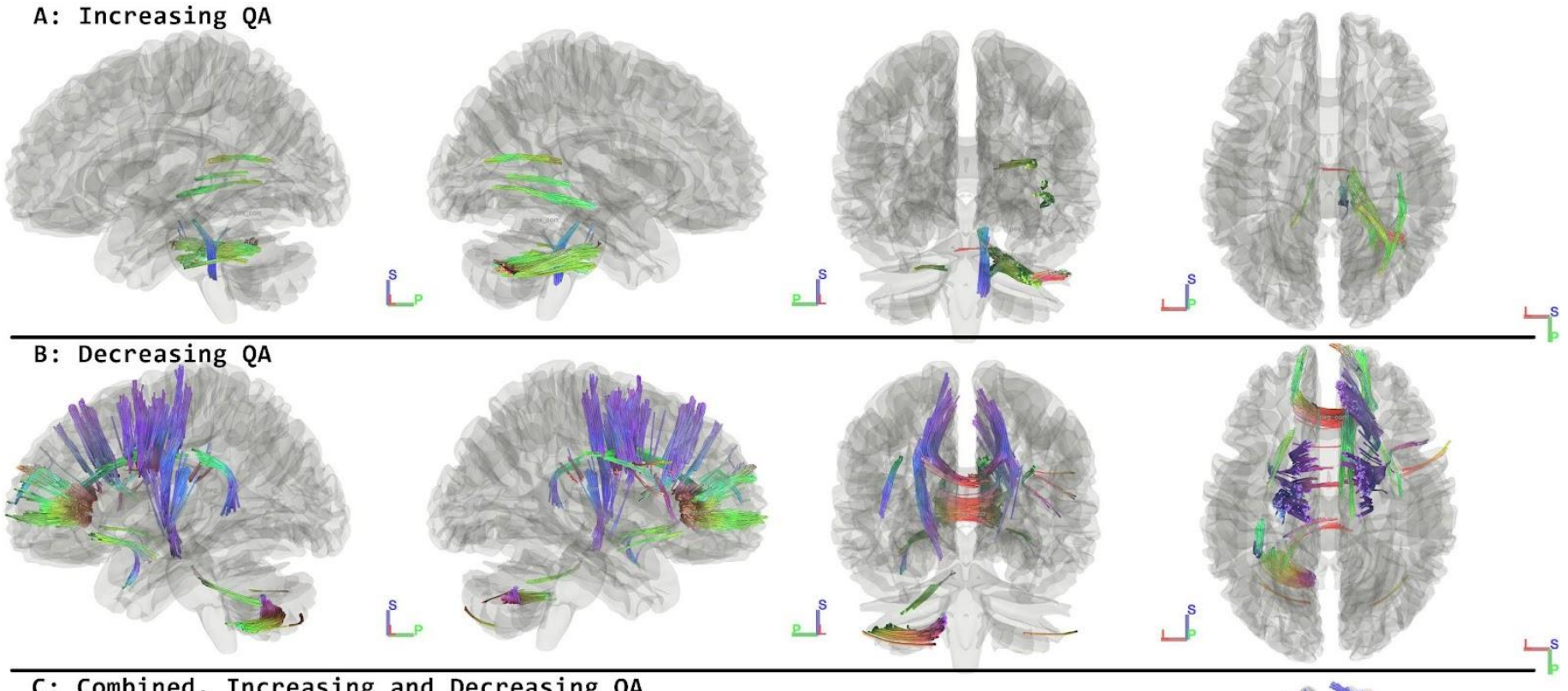
frontiers in Neural Circuits

ORIGINAL RESEARCH
published: 18 February 2022
doi: 10.3389/fncir.2022.815838

Brain Connectometry Changes in Space Travelers After Long-Duration Spaceflight

*Andrei Doroshin[1], Steven Jillings[2], Ben Jeurissen[3], Elena Tomilovskaya[4], Ekaterina Pechenkova[5], Inna Nosikova[4], Alena Rumshiskaya[6], Liudmila Litvinova[6], Ilya Rukavishnikov[4], Chloë De Laet[2], Catho Schoenmaekers[2], Jan Sijbers[3], Steven Laureys[7], Victor Petrovichev[6], Angelique Van Ombergen[2,8], Jitka Annen[7], Stefan Sunaert[9], Paul M. Parizel[10], Valentin Sinitsyn[11], Peter zu Eulenburg[12], Karol Osipowicz[1] and Floris L. Wuyts[2]**

Fig 2 *- Tracts Associated with changes post minus preflight. Increasing quantitative anisotropy (QA) shows tracts increasing in the middle cerebellar peduncle, lemniscus, and corpus callosum (FDR-0.0033) (**A**). Decreasing QA shows changes in the frontal lobes, corpus callosum, and cerebellum (FDR-0.0009) (**B**). Blue indicates superior - inferior. Green indicates anterior - posterior. Red indicates left - right*



Different Spaceflight-Associated Changes in the Perivascular Spaces of Astronauts and Cosmonauts

Giuseppe Barisano, Farshid Sepehrband, Heather R. Collins, Steven Jillings, Ben Jeurissen, James A. Taylor, Catho Schoenmaekers, Chloe De Laet, Ilya Rukavishnikov, Inna Nosikova, Liudmila Litvinova, Alena Rumshiskaya, Jitka Annen, Jan Sijbers, Steven Laureys, Angelique Van Ombergen, Victor Petrovichev, Valentin Sinitsyn, Ekaterina Pechenkova, Alexey Grishin, Peter zu Eulenburg, Meng Law, Stefan Sunaert, Paul M. Parizel, Elena Tomilovskaya, Donna R. Roberts and Floris L. Wuyts

Universiteit Antwerpen

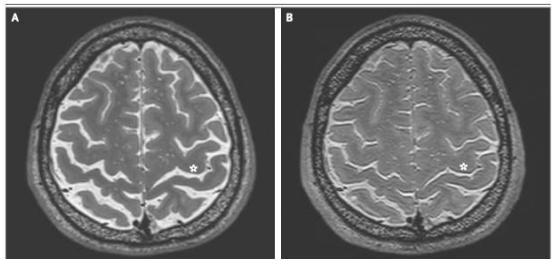
Lab for Equilibrium Investigations and Aerospace

ИМБП

belspo

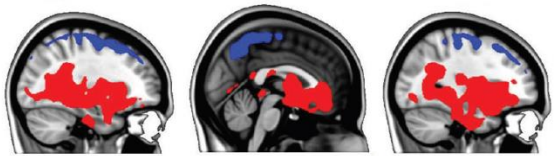
esa

Summary of structural changes

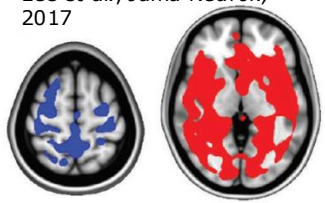


Roberts et al., *N. Eng. J. Med.*, 2017

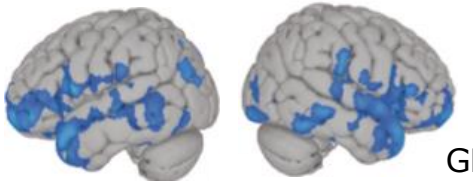
Upward brain shift
Narrowing of sulci
Crowding of GM tissue



Lee et al., *Jama Neurol.*, 2017



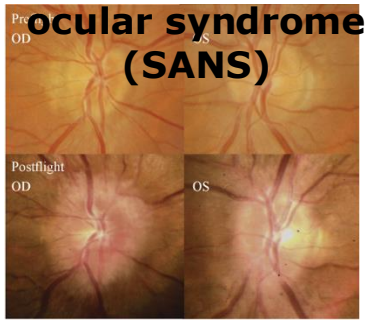
Fluid fraction changes

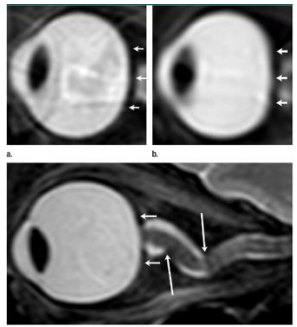


GM remodeling

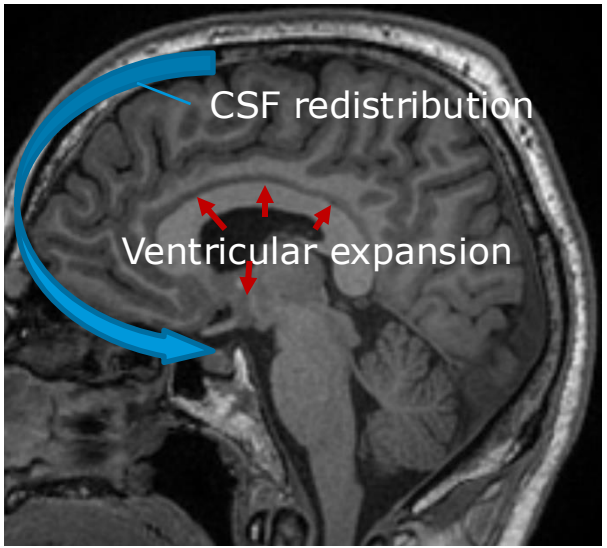
Koppelmans et al., *NPJ Microgravity*, 2016

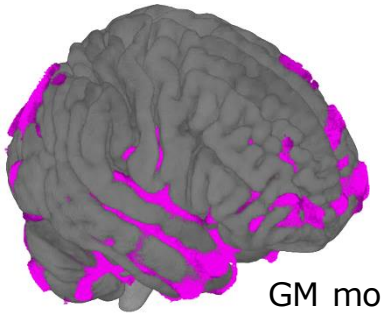
Spaceflight-associated neuro-ocular syndrome (SANS)





Mader et al., *Ophthalmology*, 2011

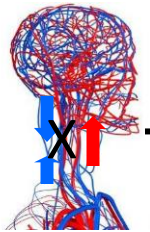




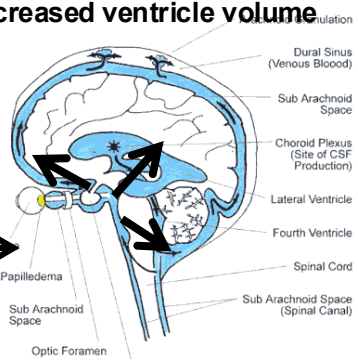
GM morphological changes >> remodeling

Space Associated Neuro-ocular syndrome (SANS)

1. Headward fluid shift

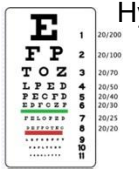


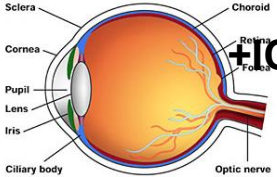
2. Increased ventricle volume



3. Elevated ICP transmitted to eye and optic nerve

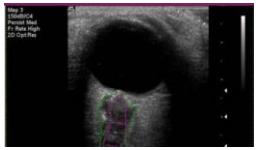
Hyperopic Shifts





+ICP

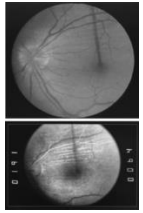
Increased Optic Nerve Sheath Diameter



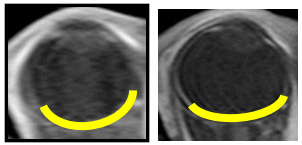
Scotoma

Altered Blood Flow

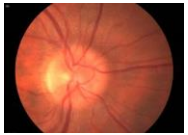
Choroidal Folds



Globe Flattening



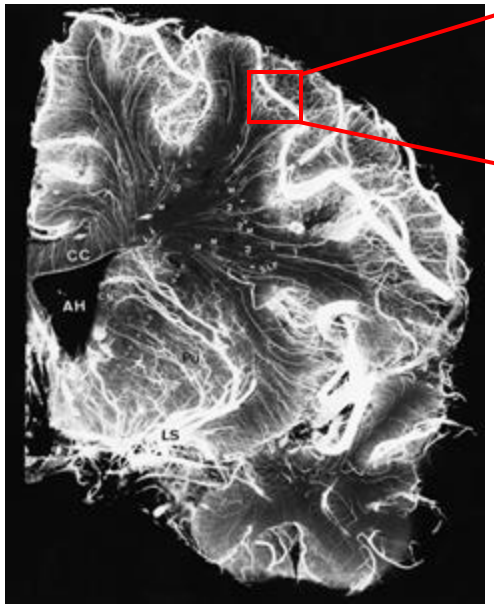
Optic Disc Edema



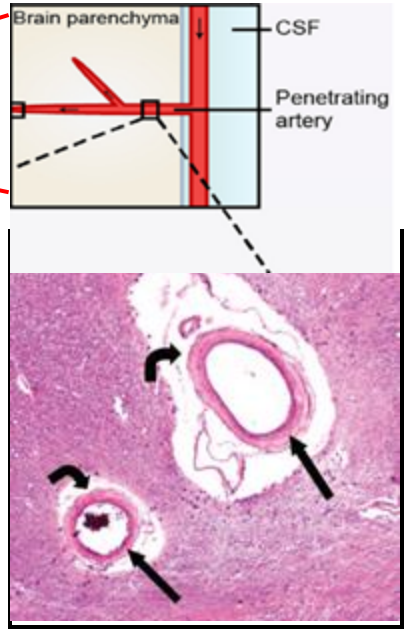
Courtesy Dr. Christian Otto and Mark Shelhamer

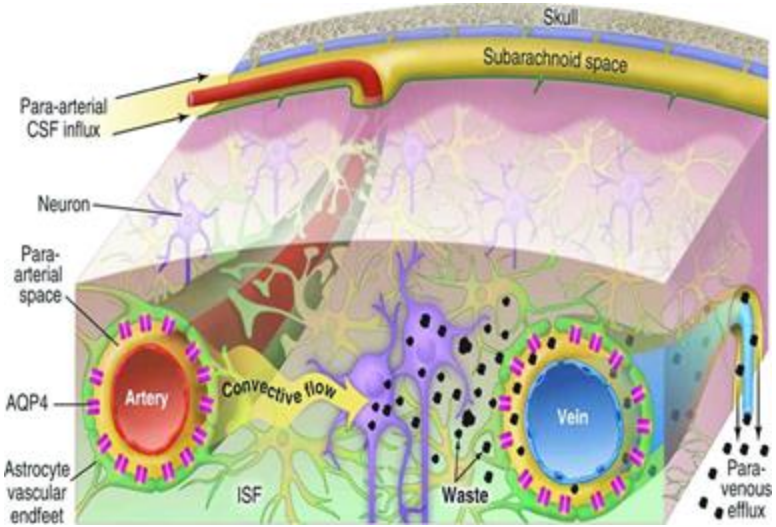
Perivascular spaces (PVS)

- Tubular fluid-filled structure around the blood vessels penetrating the brain parenchyma
- Clearance of waste products from the brain: the **glymphatic system**



Okudera et al, *Neuropathology,* 1999.

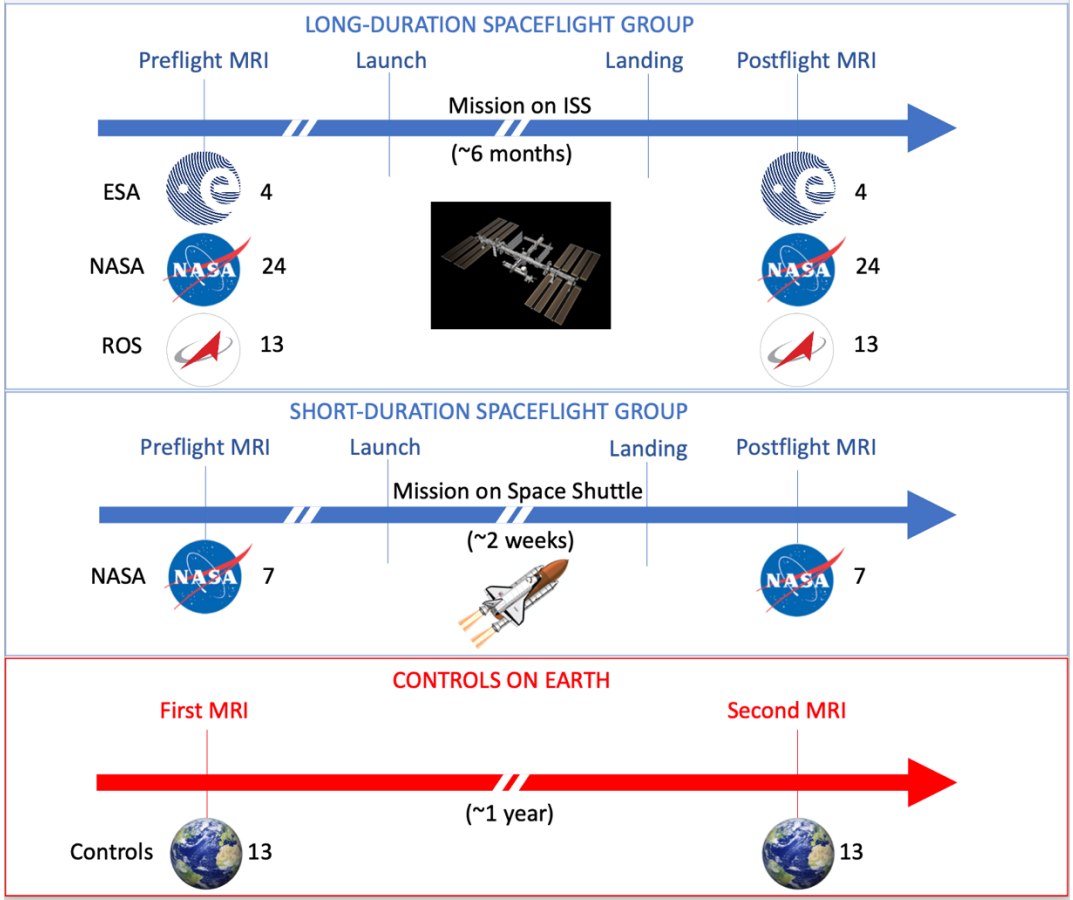




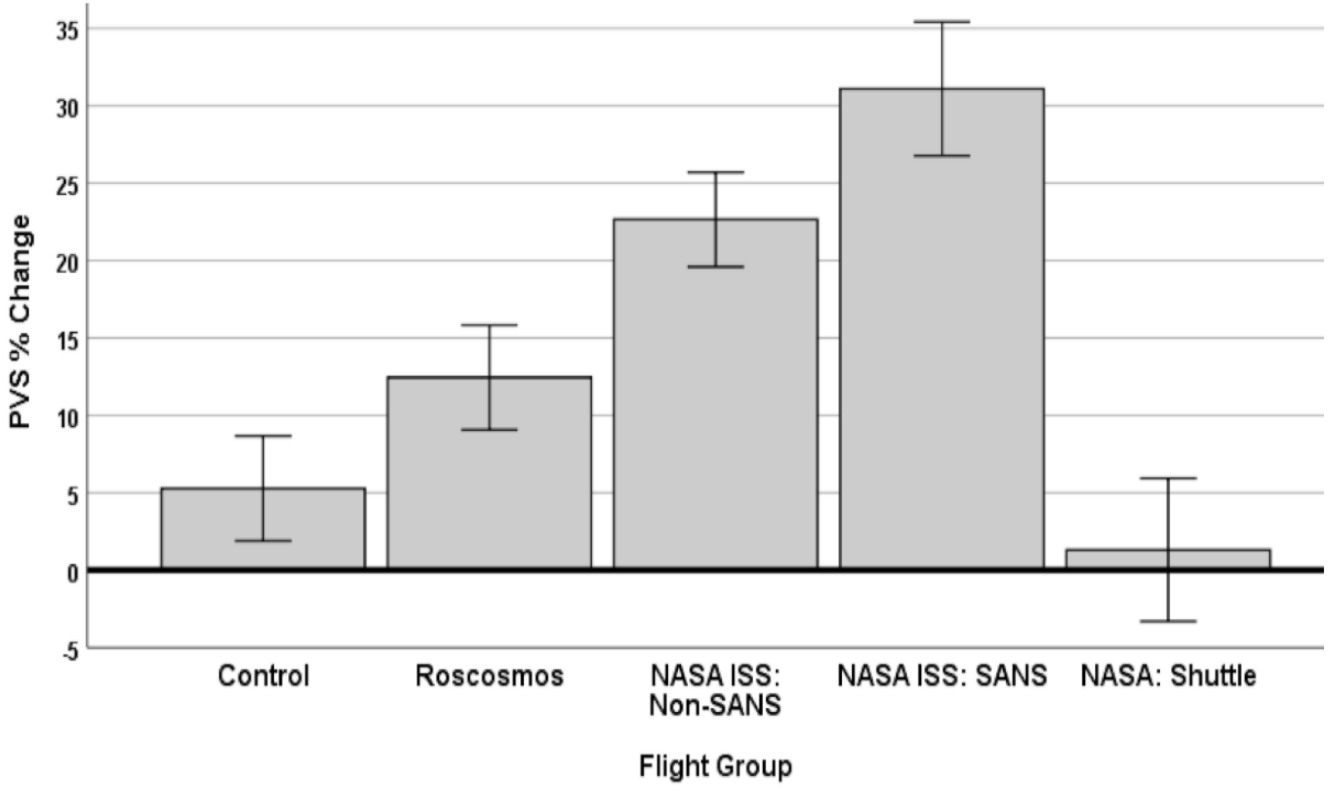
Mestre et al, *Clin Sci*, 2017

Study Design

- 3D T1-weighted MRI data (1mm isotropic resolution)
  - 41 long-duration spaceflight on ISS
  - 7 short-duration spaceflight on Space Shuttle
  - 13 age-matched controls on Earth

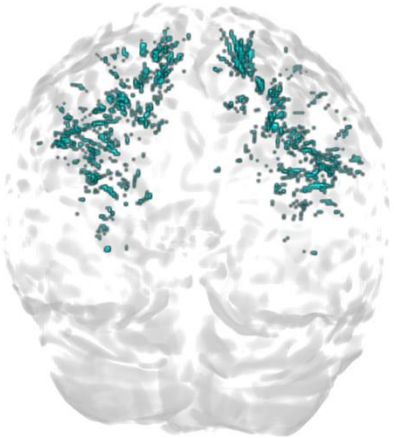


Results

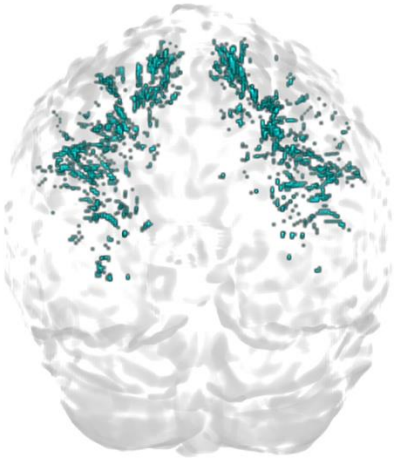


PVS volume changes are higher in NASA ISS astronauts compared with Roscosmos cosmonauts

White matter PVS

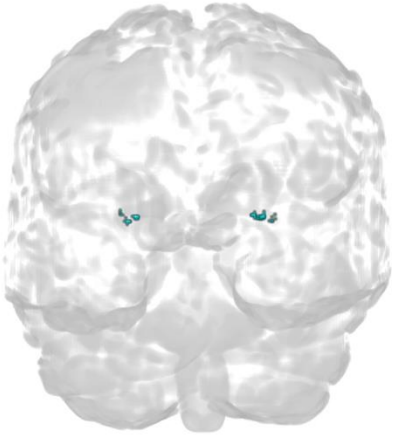


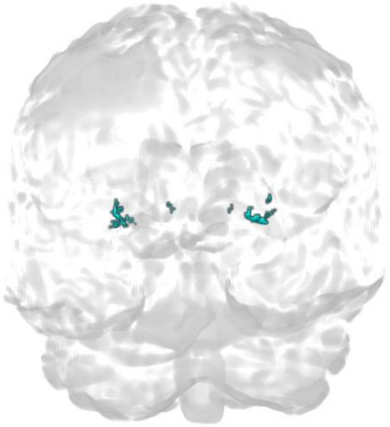
Before
long-duration spaceflight



After
long-duration spaceflight

Basal ganglia PVS



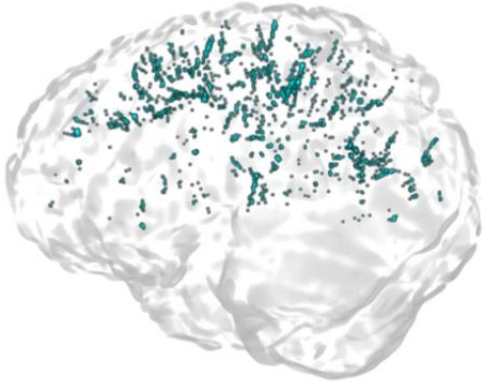


Before
long-duration spaceflight

After
long-duration spaceflight

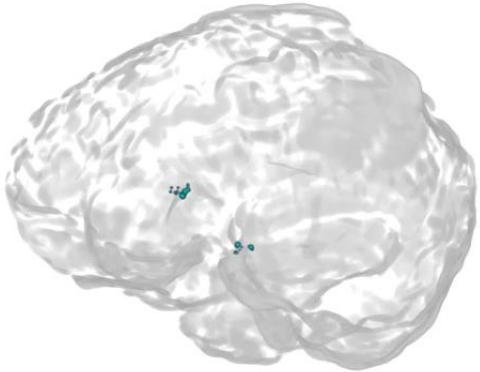
WM-PVS

Preflight MRI

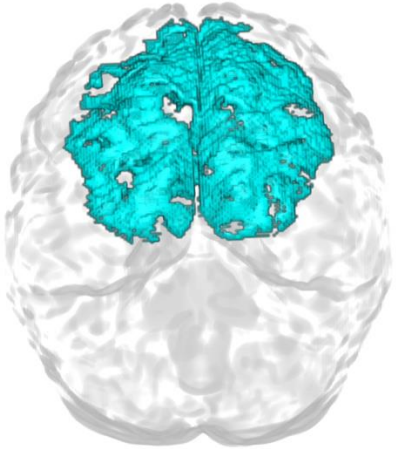


BG-PVS

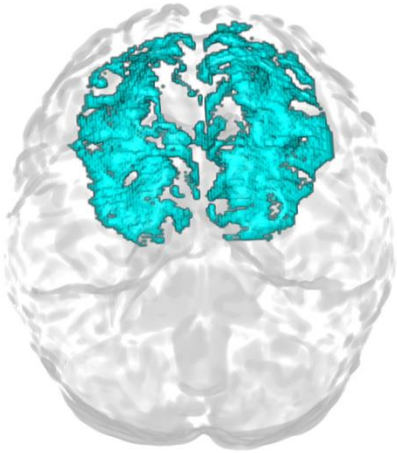
Preflight MRI



Subarachnoid space at the vertex (VSA)

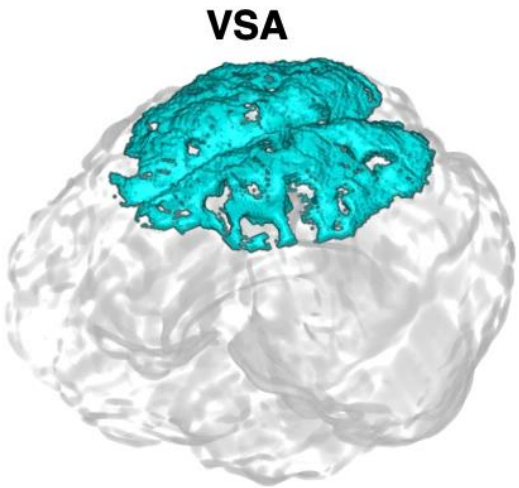


Before
long-duration spaceflight

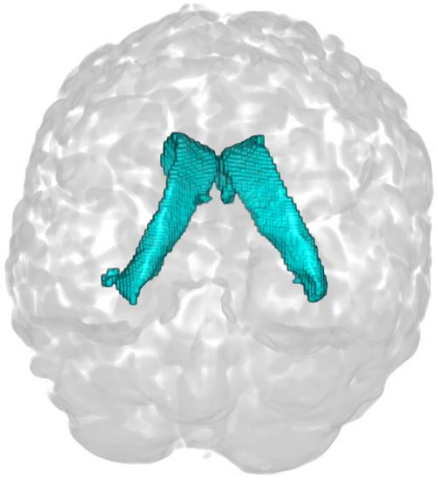


After
long-duration spaceflight

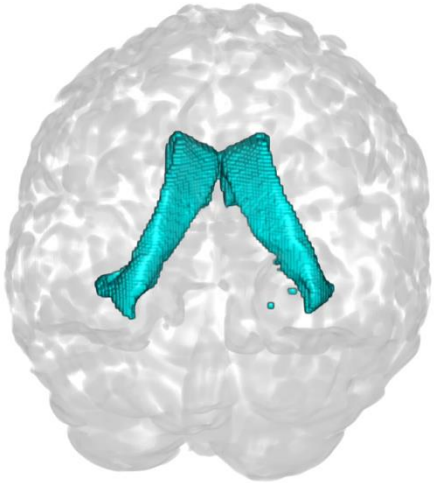
Preflight MRI



Lateral ventricles (LV)

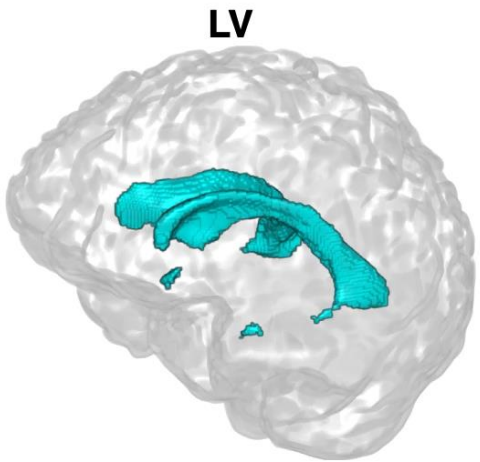


Before
long-duration spaceflight



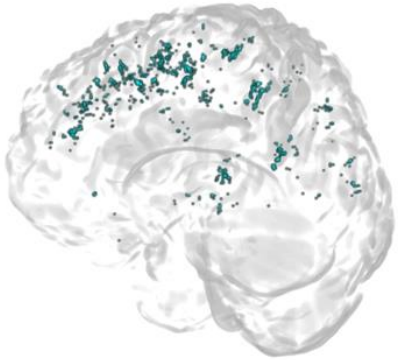
After
long-duration spaceflight

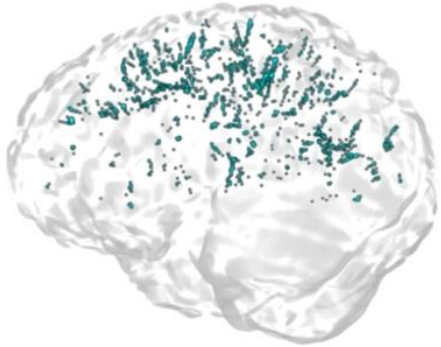
Preflight MRI

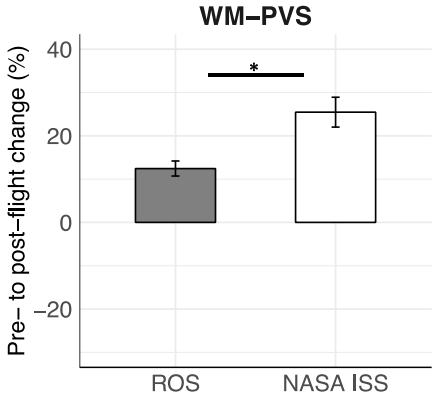


White matter PVS

Preflight MRI







What is the difference between NASA and Roscosmos crew?


esa
European Space Agency
Pesquet
Whitson
Novitsky
Kimbrough
Borisenko
Ryzhikov

LBNP - Chibis

ARED


SAHC ROOM
2022-12-08 12:01:37
Start
Stop Home
Clockwise
Counter Clockwise
Reset Timer
Motor Power Enable
Motor Power Disable
Clockwise
157
94
98
18
0.9
95
16

Take home messages

- Artificial gravity is essential for the health of space crew
- The level of AG however is not determined
- Dose response studie are needed to establish the needed AG
- Brain and ocular issues need to be solved

Acknowledgments: cosmonauts and astronauts taking part in BRAIN-DTI and GAZE-SPIN