



The
University
Of
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Unit of Academic Radiology

Synchronous acquisition of hyperpolarised ^3He and ^1H MR images of the lungs

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Motivation

- Hyperpolarised gas MRI (^3He and ^{129}Xe) & ^1H MRI complementary functional / anatomical information

12 yr old CF patient

Data acquisition requires separate breath-holds
- temporally/spatially mis-registered

^3He SPGR

^1H SSFP

Aims

- Develop methods for acquisition of ^3He & ^1H MRI in same breath-hold
- Spatial registration and temporally synchronised
- Explore role of **mutual information** :
 - prospective accelerated acquisition
 - multi-modality image **fusion**

Materials

^3He spin exchange polariser



1 litre gas bag: 300 ml ^3He @ 25% pol. + 700 ml N_2



Materials and Methods

MRI hardware

- Philips 3T Achieva scanner
(^1H 128 MHz, ^3He 97 MHz)
- MNS 4 kW RF amp (CPC)

RF coils

- ^1H Q Body coil T-R coil – detuned during ^3He T-R
- ^3He : Prototype 20 cm circular Helmholtz pair driven linearly
- Active detuning during ^1H T-R (collaboration with Pulseteq)

RF coils

^3He coil

^1H bo

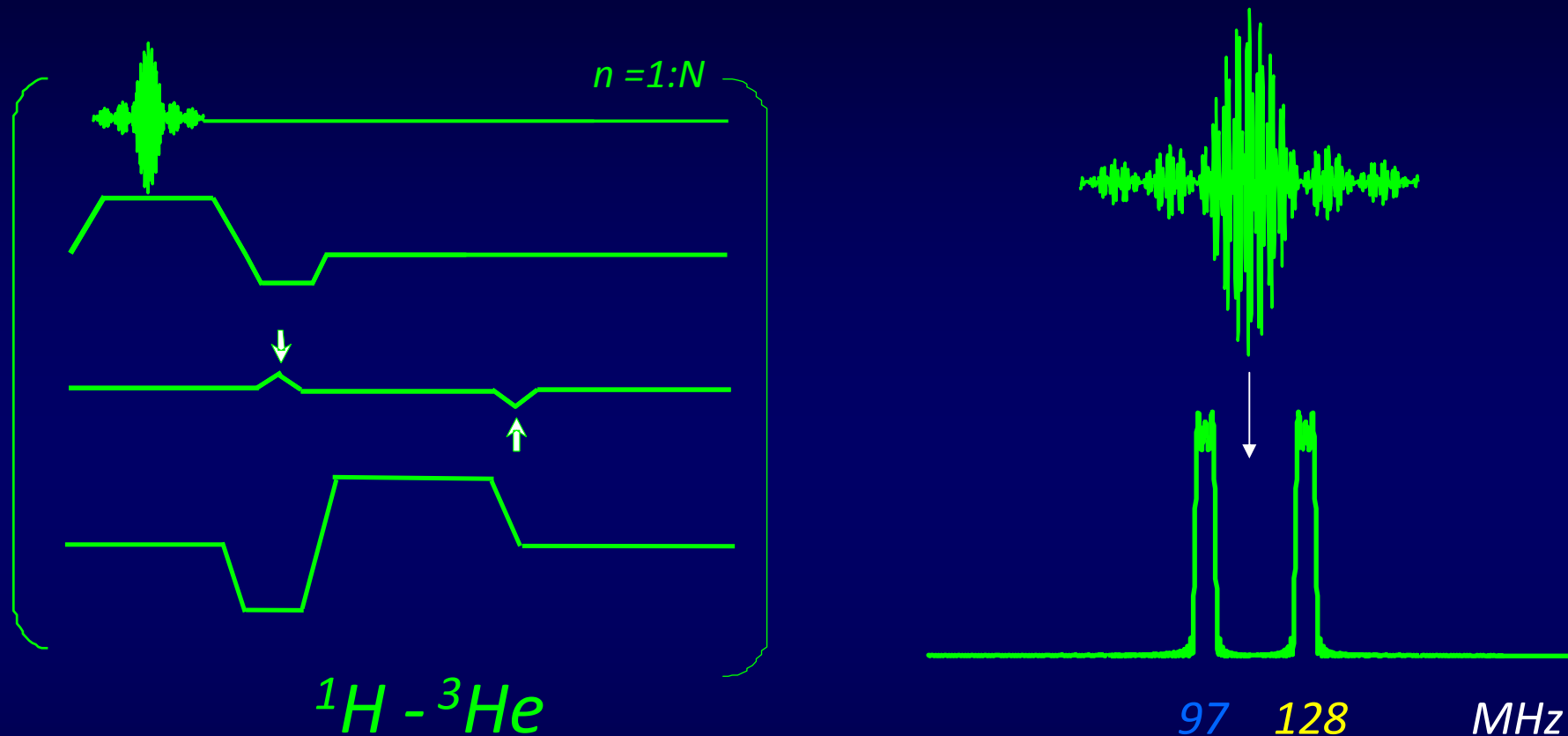


MRI Methods

pulse sequence

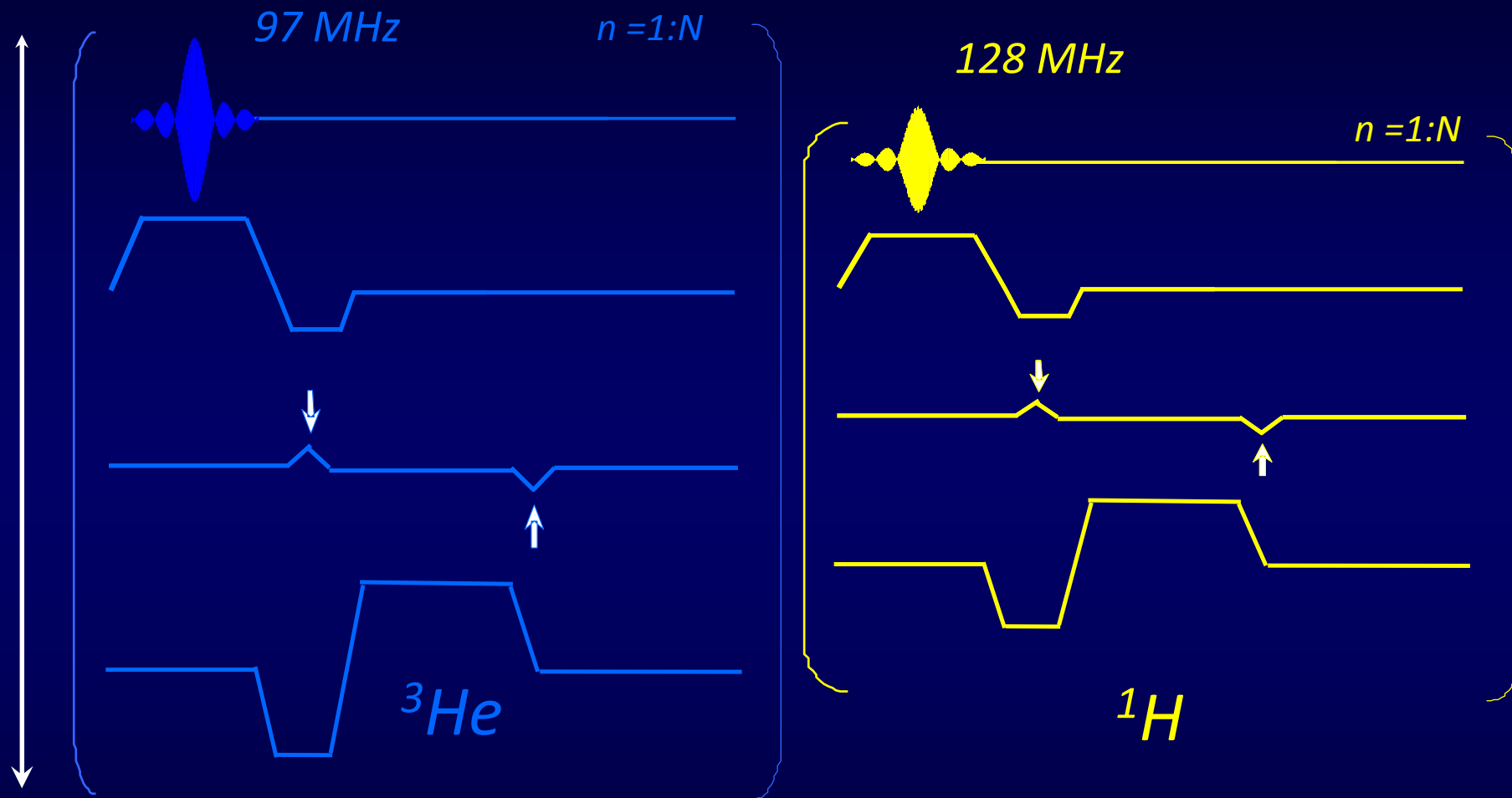
- 2D SPGR sequence – good trade-off for ^3He ventilation¹ and ^1H anatomy
- sequence parameters :
FA 8° , TE 1.3 ms, TR 5 ms, 5 x 15 mm slices, FOV 38 cm, 128 x 127 matrix, BW/pixel = 500 Hz
- Acquired in healthy volunteers and patients during 1 litre breath-hold from bag
- Acquisitions at separate breath-holds – registration checks

Method 1 - Parallel transmit receive ^1H slice – ^3He slice



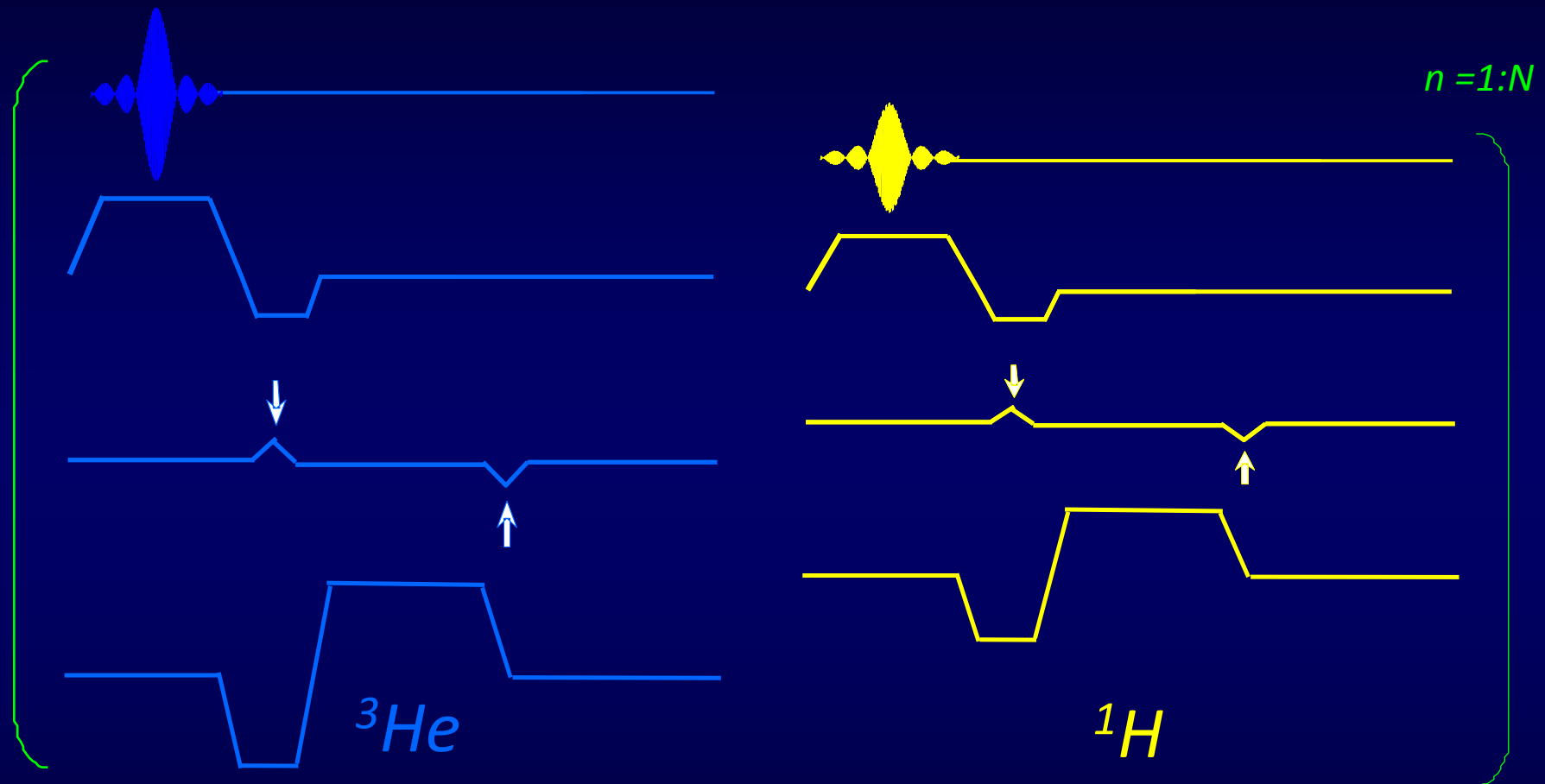
- Exactly synchronised
- Requires: dual excitation FM RF pulses, dual tuned coil, frequency multiplexing on synthesiser and receiver
- FOVs and slice thicknesses $1/\gamma$ dependent

Method 2 - sequential acquisition ^1H slice – ^3He slice



- B_1^+ and gradients scaled with $1/\gamma$
- Synchronised to $N \cdot \text{TR}$

Method 2 – interleaved sequential acquisition

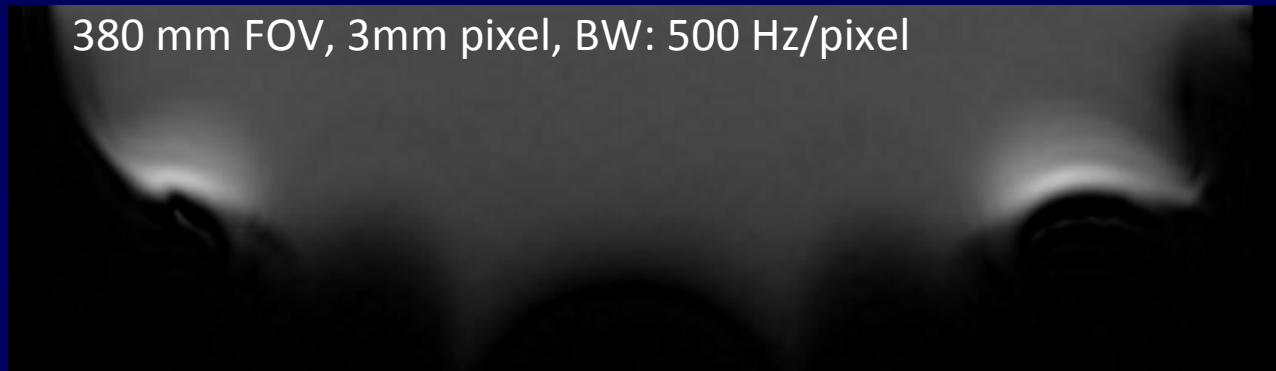


- interleaved acquisition ^1H p.e. – ^3He p.e.
- Synchronised to TR (5 ms)

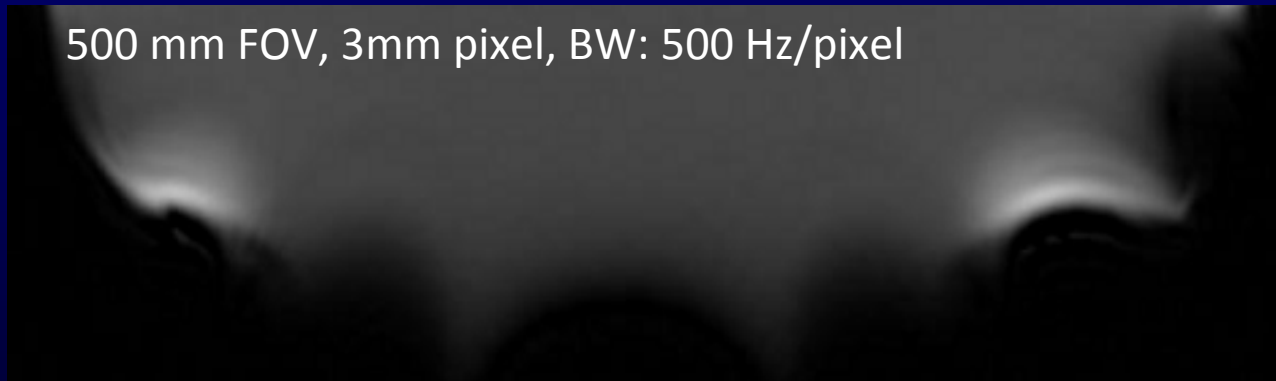
Spatial gradient linearity tests at different strength

^1H flood phantom imaged at two FOV's

380 mm FOV, 3mm pixel, BW: 500 Hz/pixel



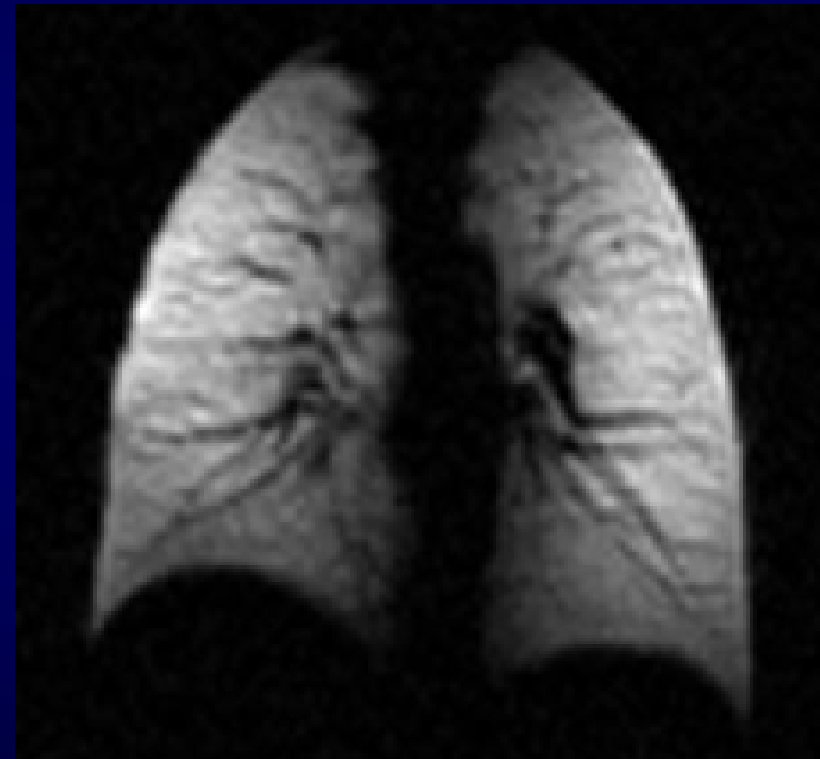
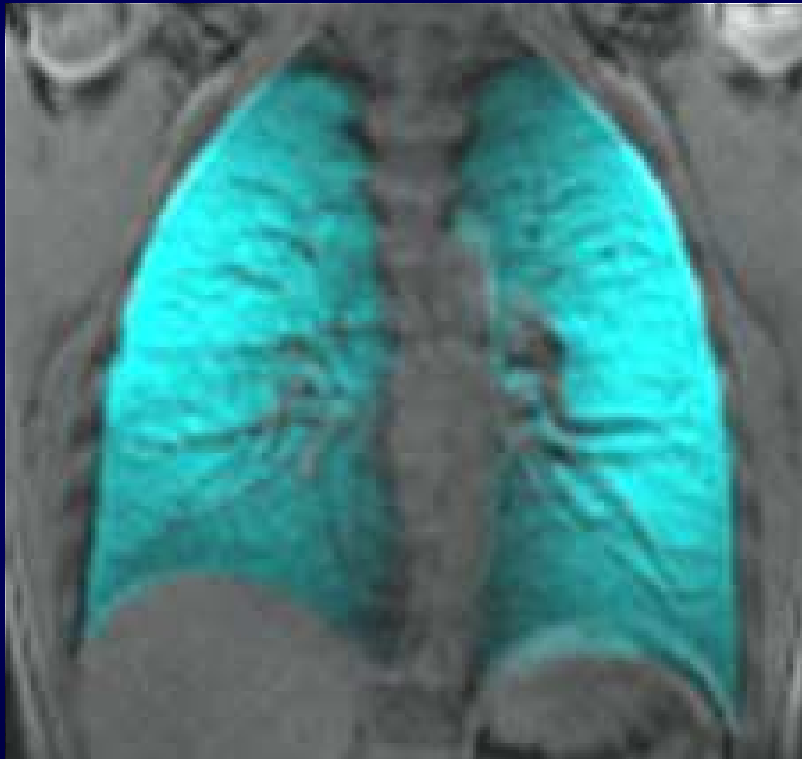
500 mm FOV, 3mm pixel, BW: 500 Hz/pixel



(Ratio FOV's : $\gamma_{^1\text{H}} / \gamma_{^3\text{He}} \sim 4/3$)

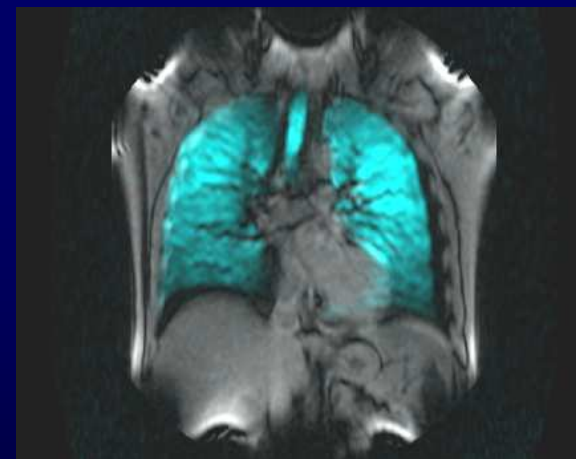
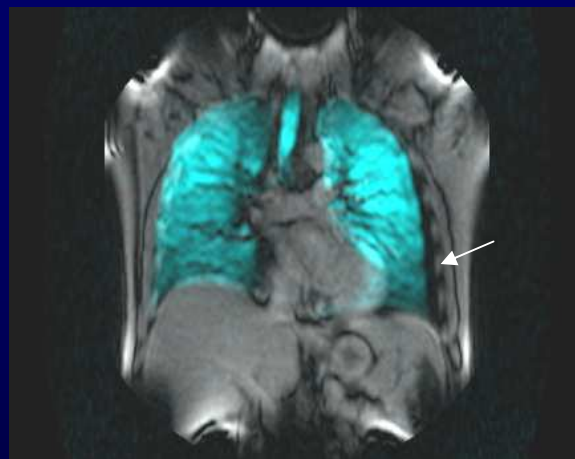
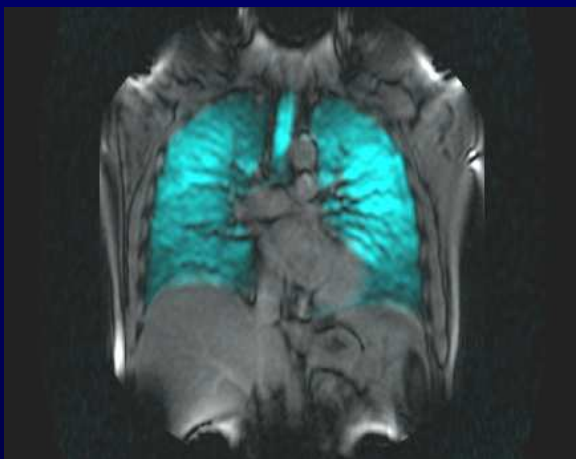
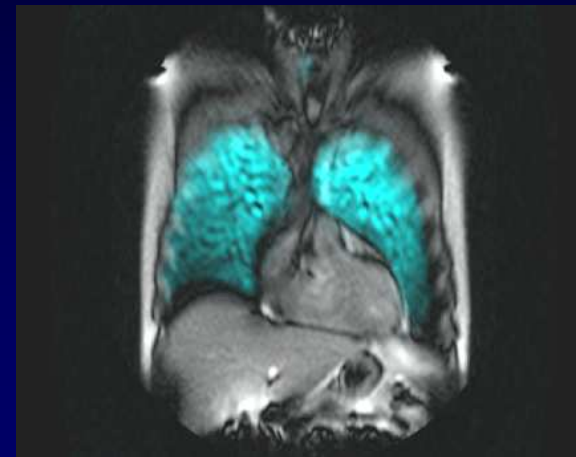
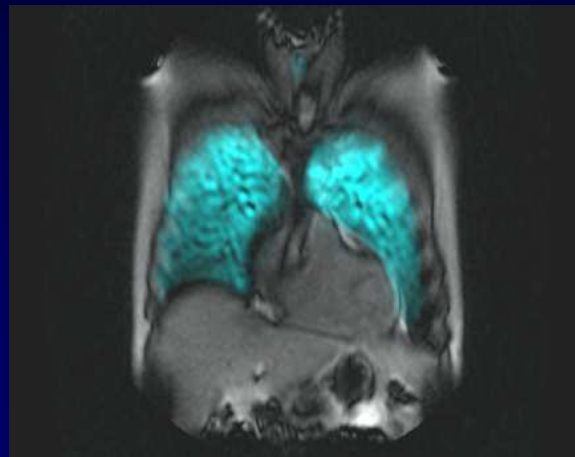
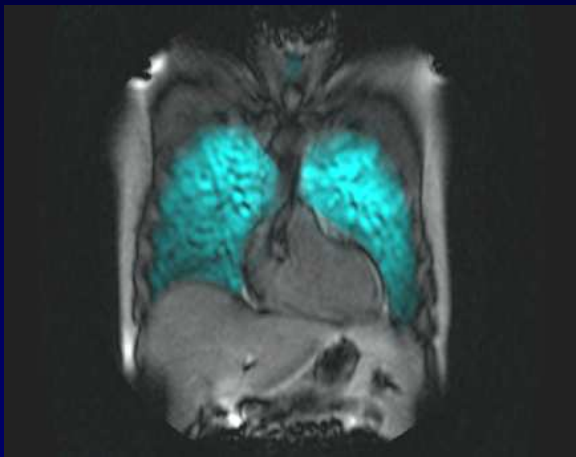
Volunteer results

– same ^1H and ^3He FOV



Registration

separate breath ^1H exams

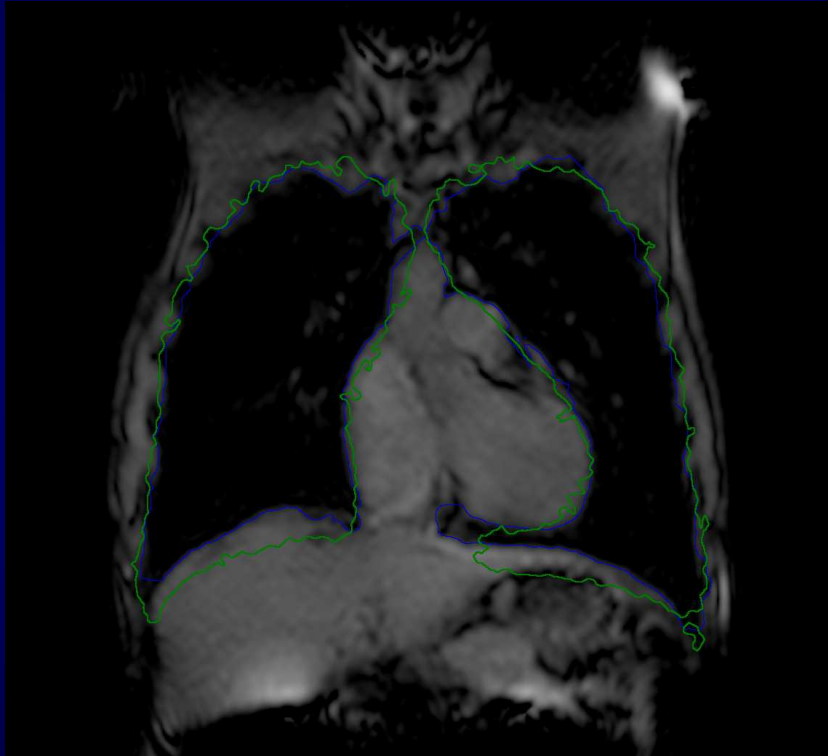


^3He - ^1H same breath

Repeat ^1H 1 litre breath

Full Inspiration

Registration overlap of separate breath ^1H exams

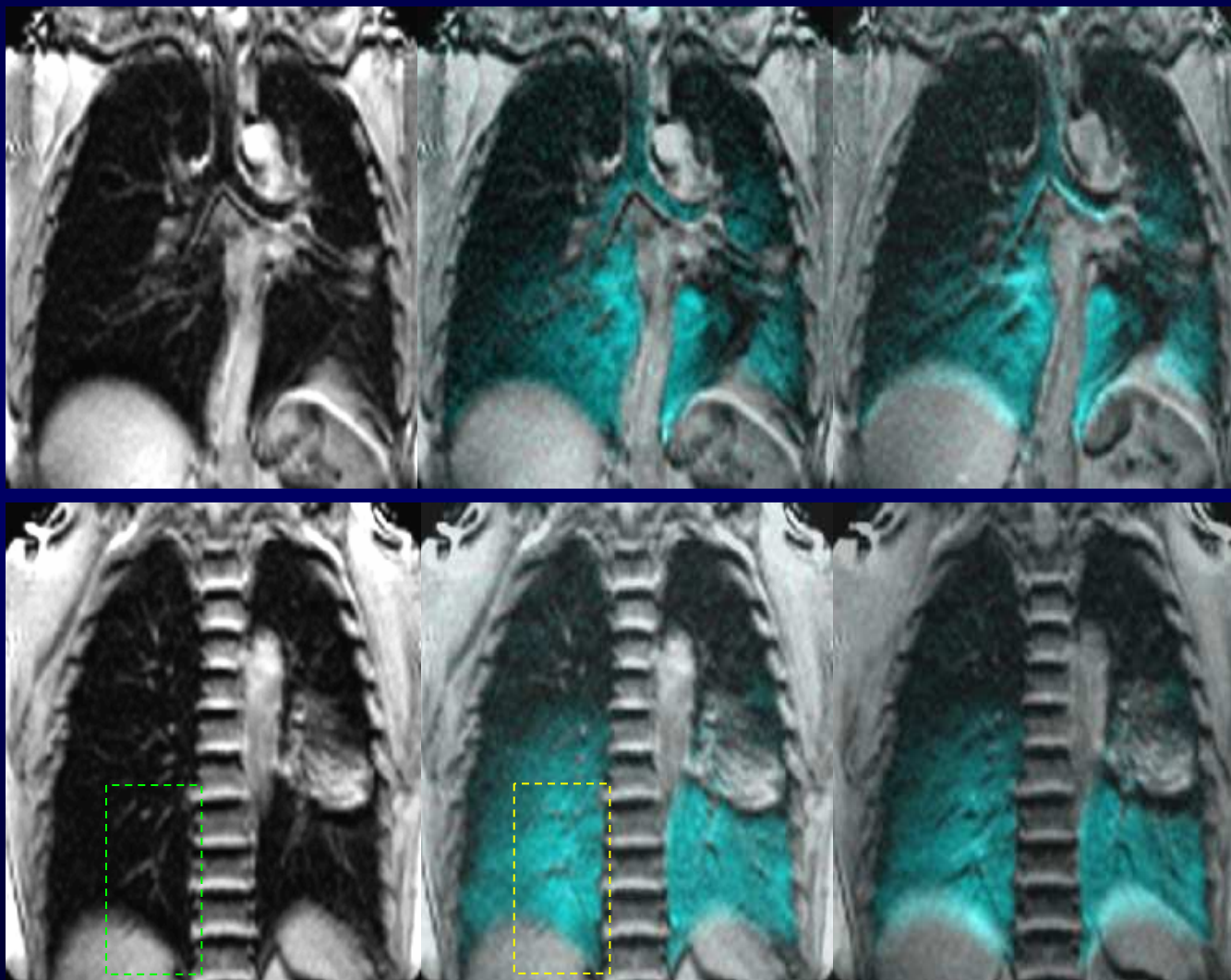


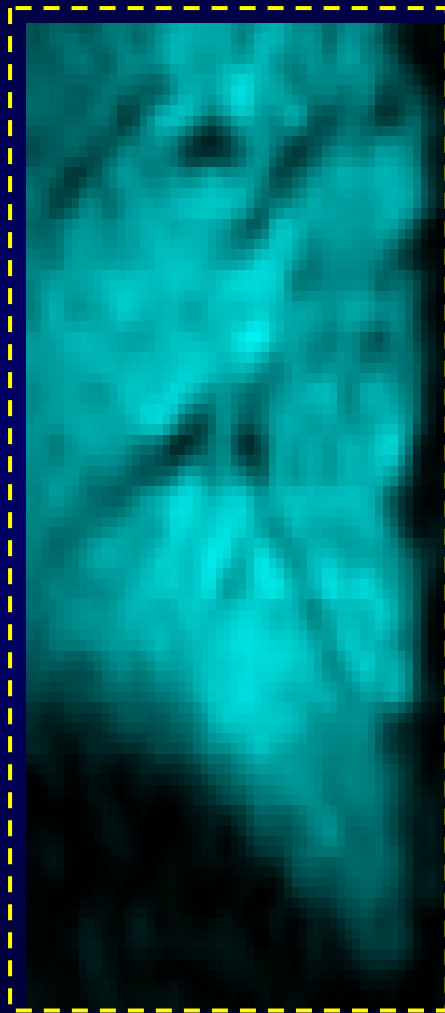
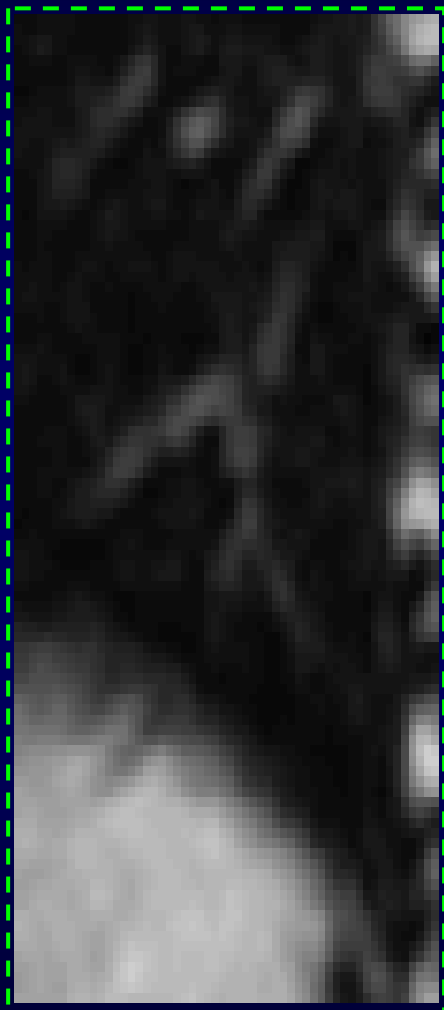
$$\text{Mean } ^1\text{H}_{\text{mri1}} \cap ^1\text{H}_{\text{mri2}} = 87\%$$

~ 1 cm deviations
between lung bases

Lung cancer patient

simultaneous ^3He - ^1H exams separate breath exams





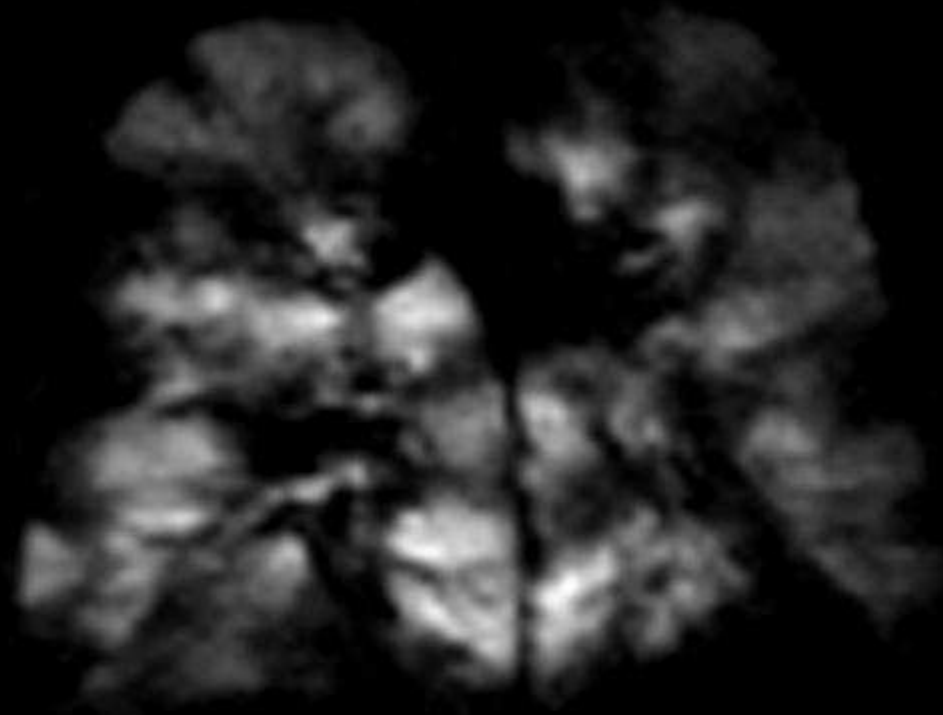
Cystic Fibrosis patient (13 yrs)

^1H MRI

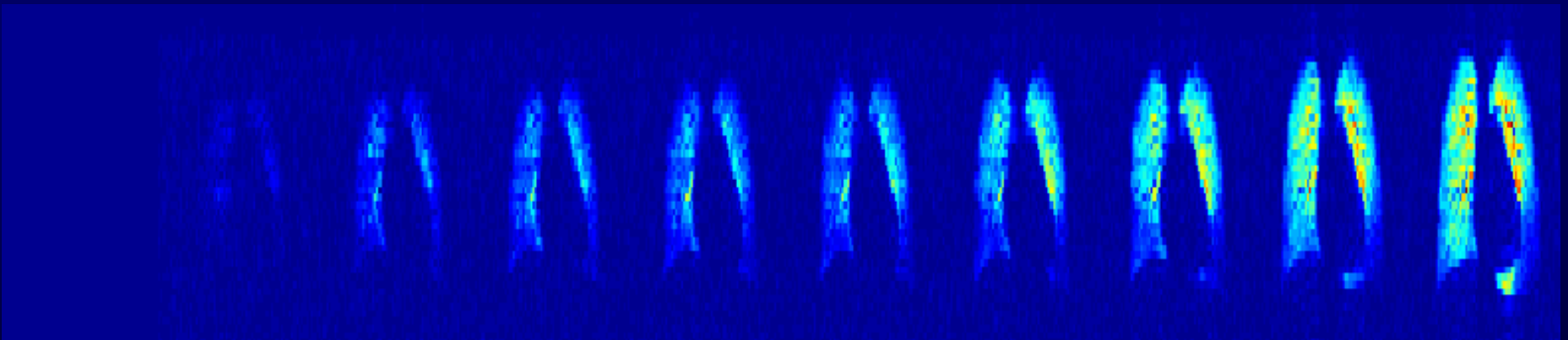
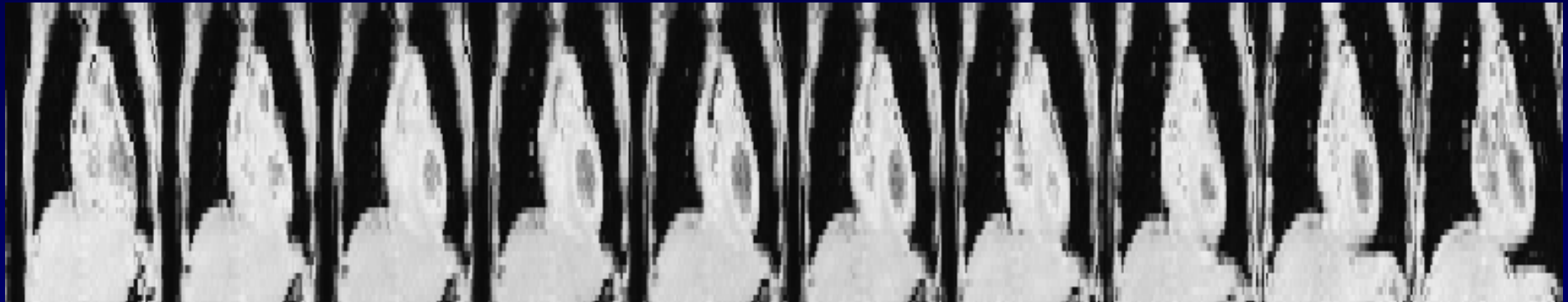


Cystic Fibrosis patient (13 yrs)

^3He MRI



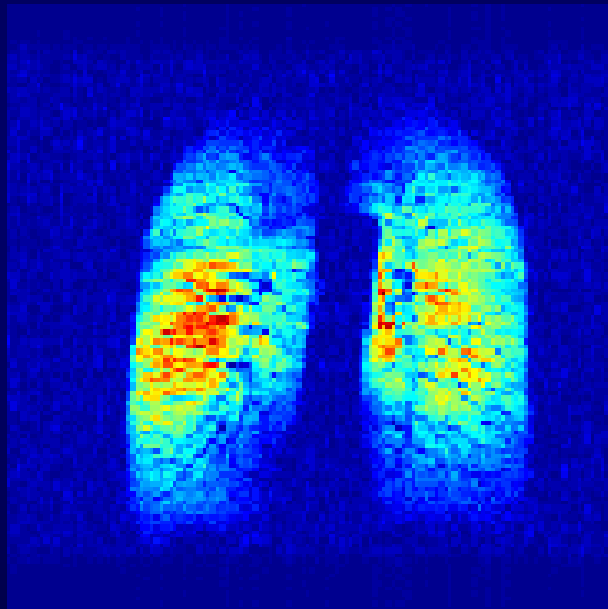
Synchronised dynamic imaging of ^3He and ^1H



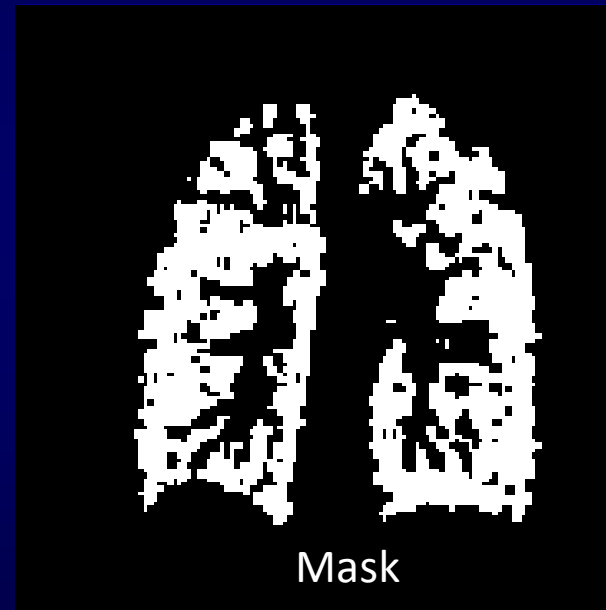
Compressed Sensing of ^3He

with prior knowledge ^1H MR mutual information

Original ^3He image

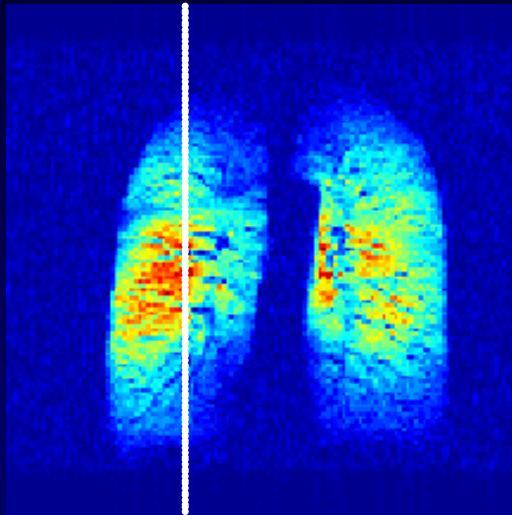


Inverted + filtered ^1H

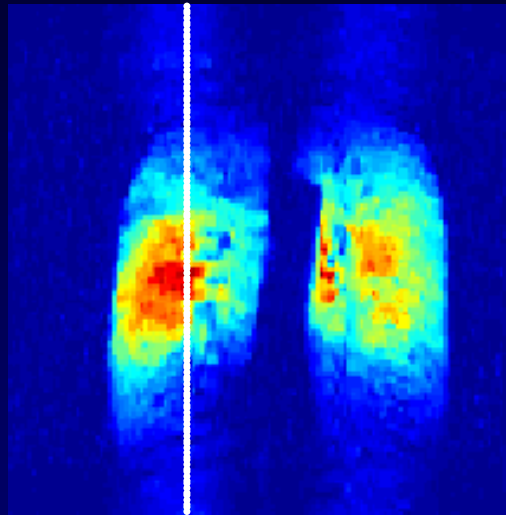


$$N_{pe} = 128$$

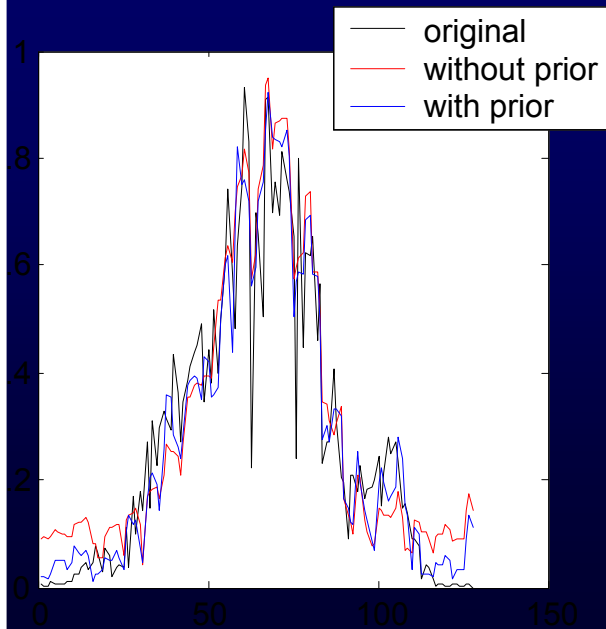
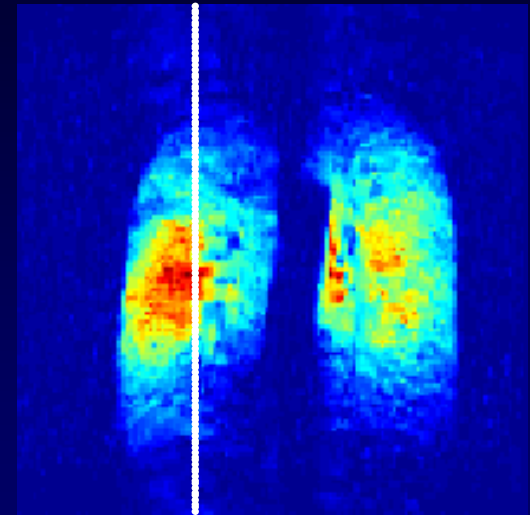
a. fully sampled 3He



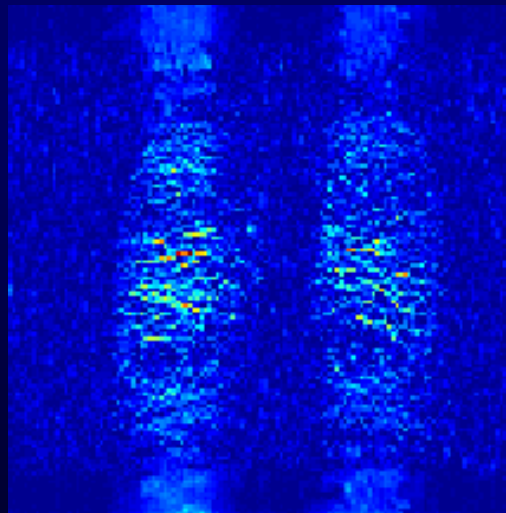
b. R=4 CS sampled 3He without MI



c. R=4 CS sampled 3He with 1H MI

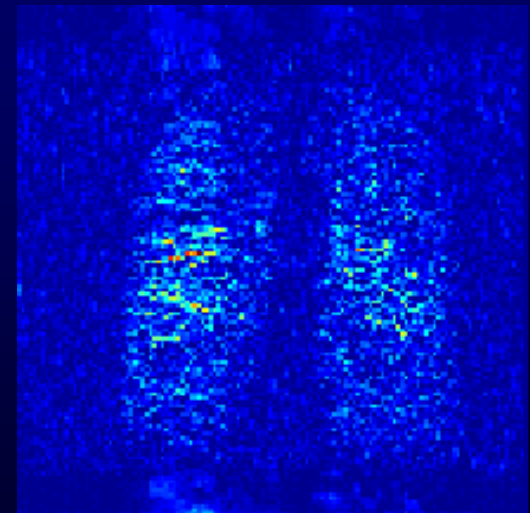


difference image b-a



RMS = 0.421

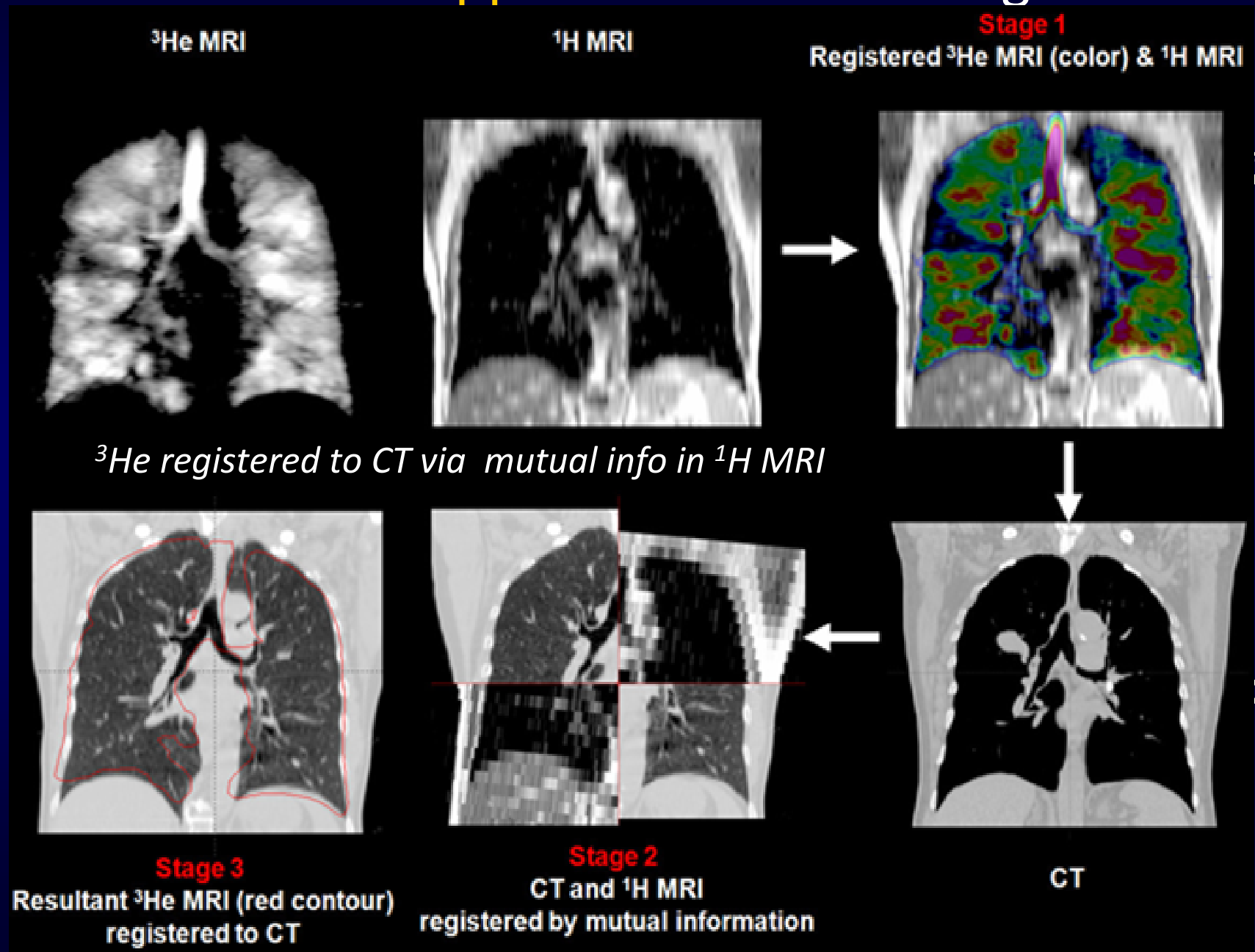
difference image c-a



RMS = 0.373

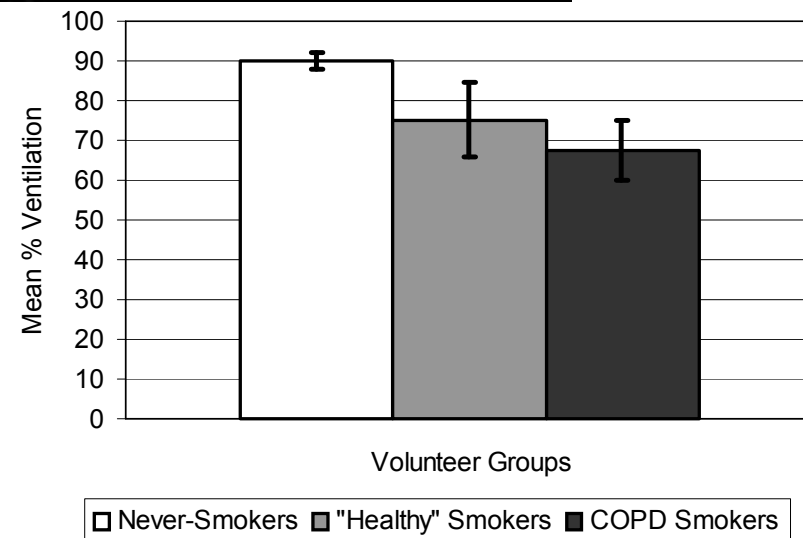
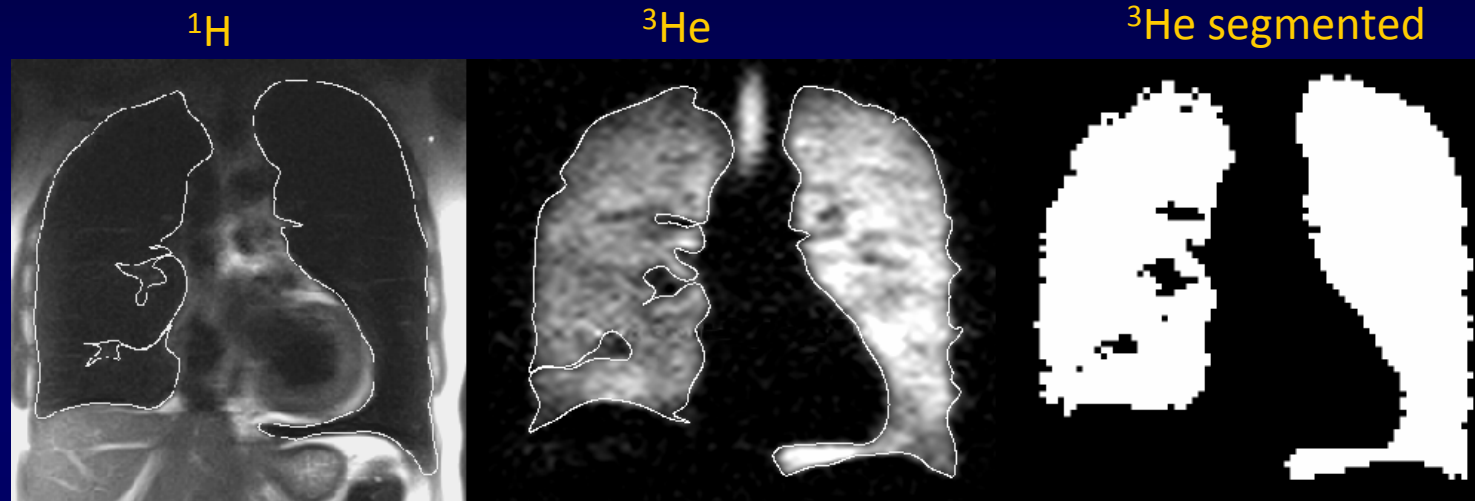
Potential clinical applications

Lung cancer



Applications of synchronised dual resonance MRI– quantitative ventilation volume measurement

Obstructive airway diseases – % obstruction from ventilated volumes



Woodhouse et al, JMRI. 2005 ;21:365-369.

Concluding remarks

- synchronised ^1H and ^3He MRI provides ^3He images of same quality as separate scans with spatial registration
- Q body coil images of ^1H are of acceptable quality for anatomical interpretation
- temporal resolution of interleaved sequence has an overhead of total imaging time
- parallel imaging / Compressed Sensing could be used to achieve volume coverage

Future work

- study ^1H and HP gas MRI side by side with anatomical information from CT
- dual tuned arrays
- synchronised ^1H - ^3He - ^{129}Xe

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