IVAN NMR Users Group

IVAN - Inspiring a Versatile and Agile NMR Community

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PureShift NMR: An Introduction

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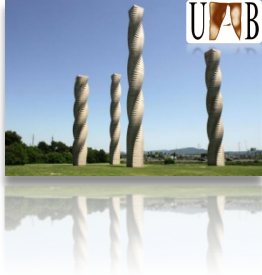
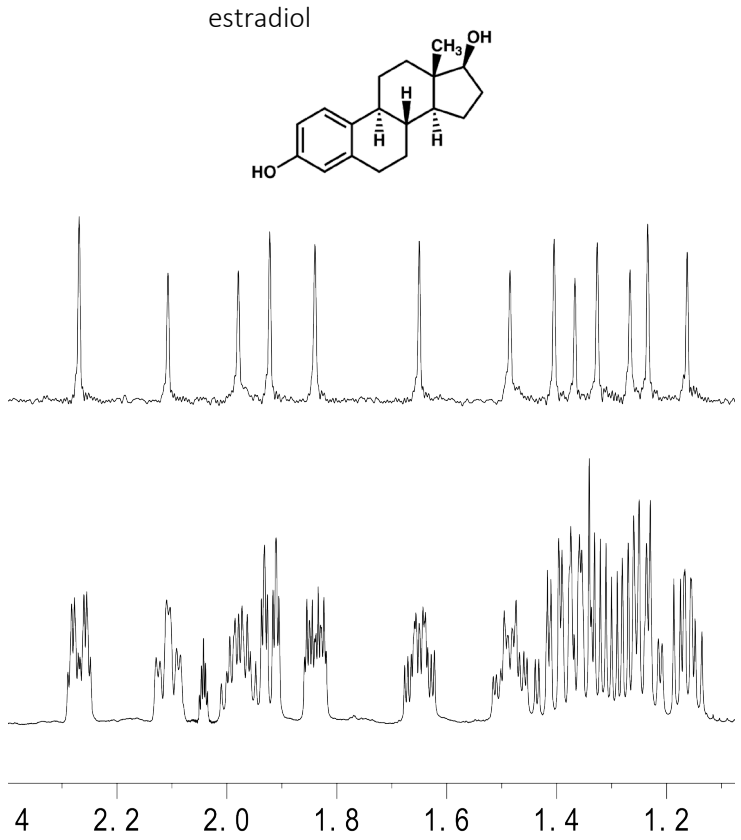
14th June 2021

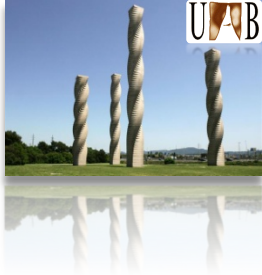


Pure Shift NMR: Basic Features

Broadband Homodecoupled ^{1}H NMR spectra

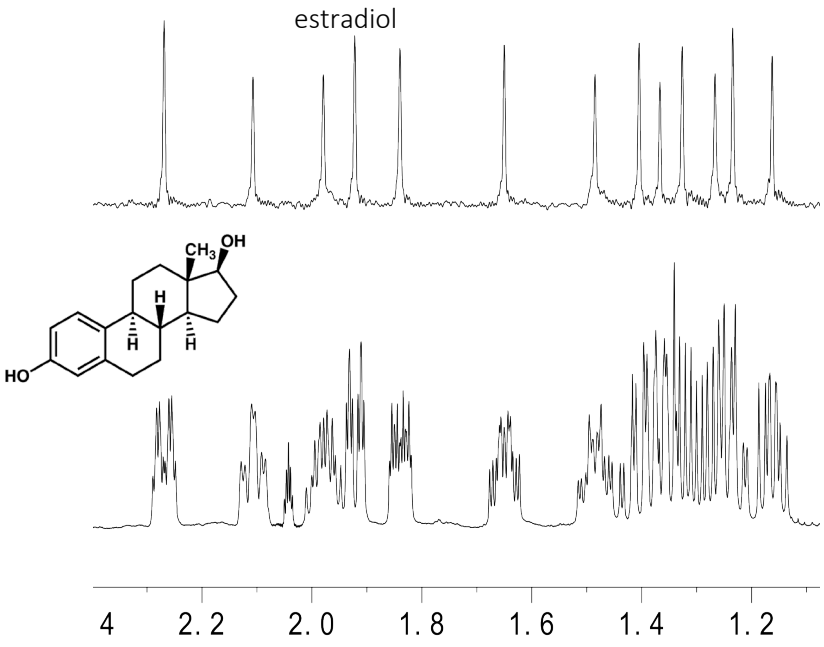


- ✓ Simplified multiplet J(HH) coupling patterns: **singlet signals**
- ✓ **Improved spectral resolution** and signal dispersion
- ✓ **Minimizing signal overlap** (No need for high magnetic fields??)
- ✓ Accurate determination of **small chemical shift differences**
- ✓ Easier and **simpler analysis**:
  - ✓ Identification of number of peaks in congested areas
  - ✓ Easy monitoring of signal intensities in array experiments



Pure Shift NMR: Basic Questions

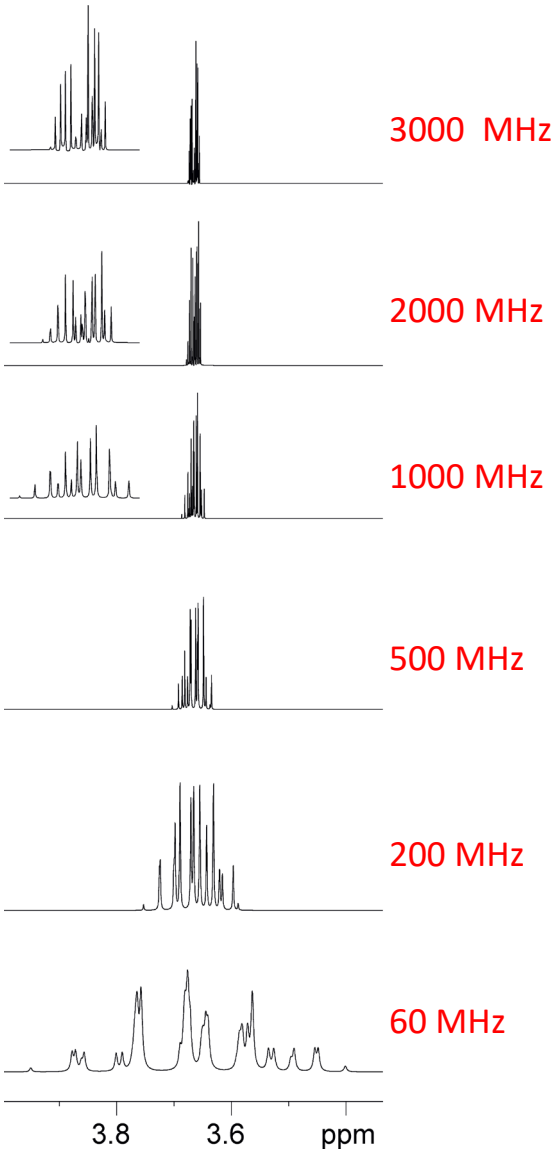
Broadband Homodecoupled ^{1}H NMR spectra

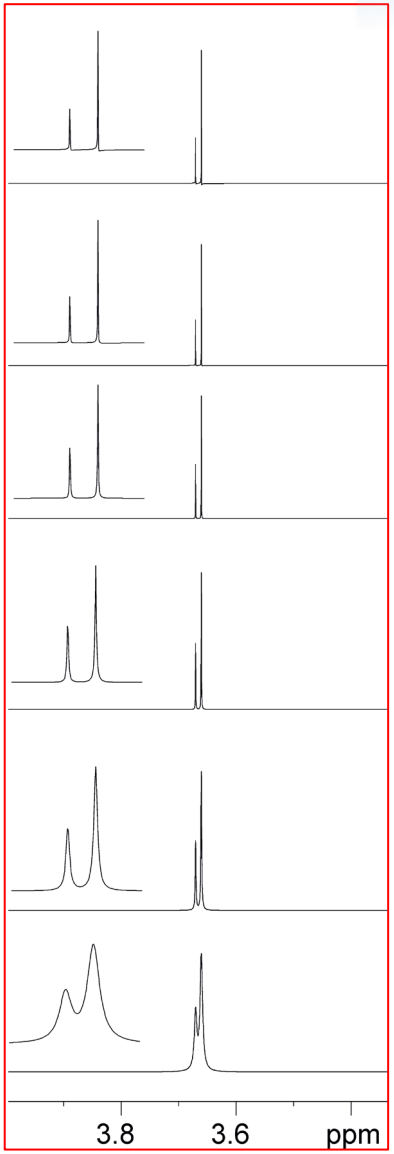


About practical aspects:

- ✓ Robust experiments?
- ✓ Easy set-up?
- ✓ General applicability?
- ✓ What about **sensitivity**?
- ✓ **Spectral quality**?: Linewidths, artefacts and unwanted sidebands, full homodecoupling for all signals, selectivity (strong coupling effects)….
- ✓ Practical implementation in other 1D/2D experiments?
- ✓ Quantification?
- ✓ Software & hardware requirements?

Pure Shift NMR: Spectral Resolution



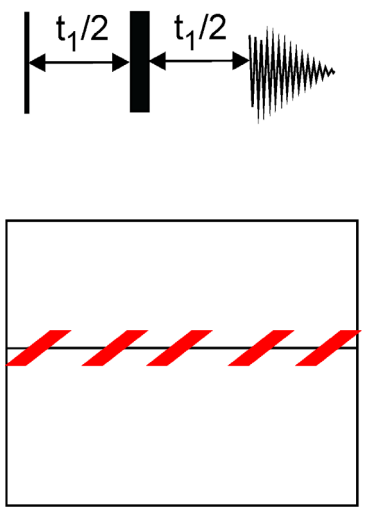


NMRSim

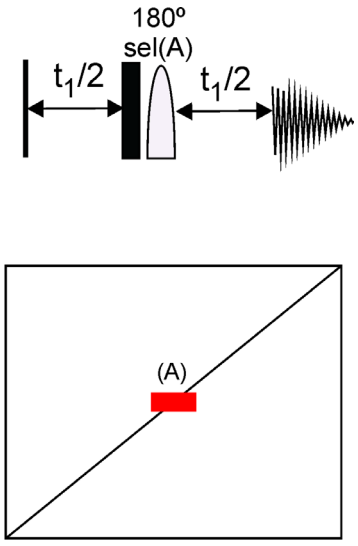
- Two ^{1}H signals separated by $\Delta\delta$=0.01 ppm
- $\Delta\nu$=1 Hz

Pure Shift NMR vs spin-echo

J-resolved

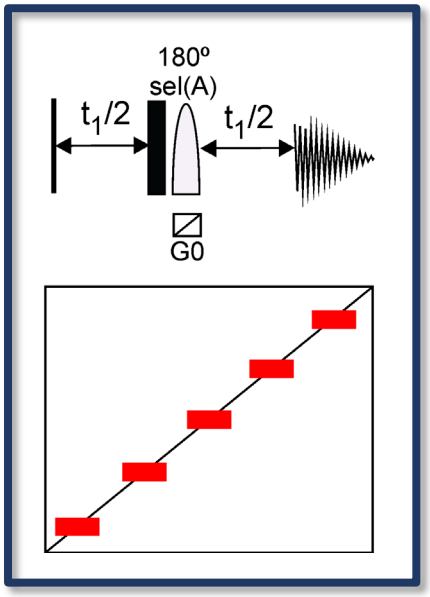


BASHD



+ slice selection

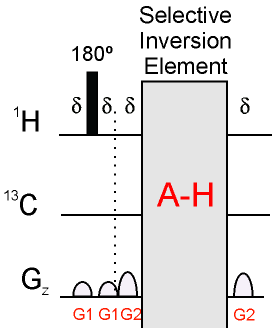
Original ZS



Active Spins (detected): 0º/360º
δ(Active): 360º

Passive Spins (homodecoupled): 180º
δ(Passive): 180º (dephased by gradients)
J(Active-Passive): 180º (homodecoupled)

Pure Shift NMR: Selective Refocusing Elements



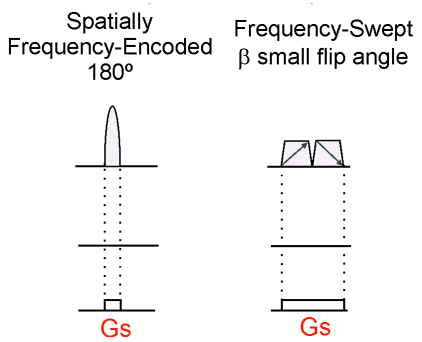
Pseudo-2D Zangger-Sterk

Real-time Homodecoupling

Spatial Encoding

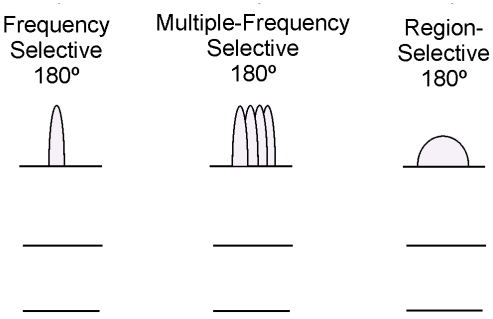
Frequency-Selective

Isotope-Editing



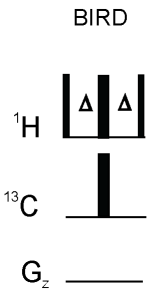
Protons located in different parts of the NMR tube

Slice-Selective NMR PSYCHE

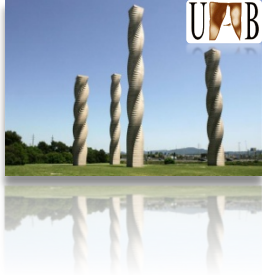


Protons located in different parts of the NMR spectrum

BASHD/HOBS

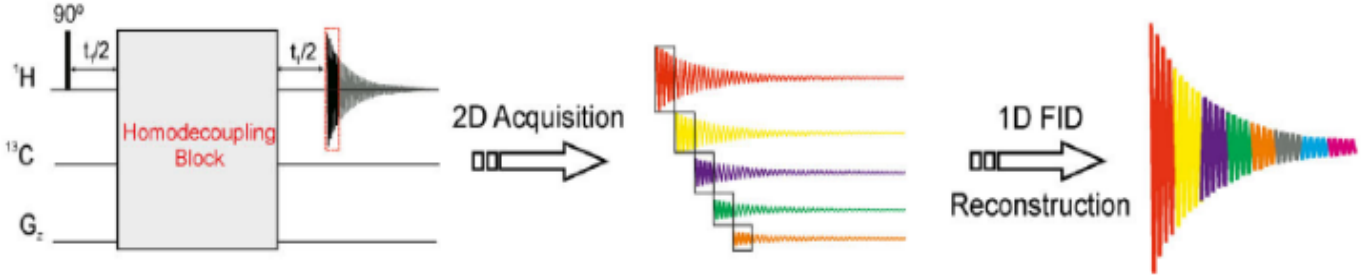


Distinction between ^{1}H-^{13}C from ^{1}H-^{12}C

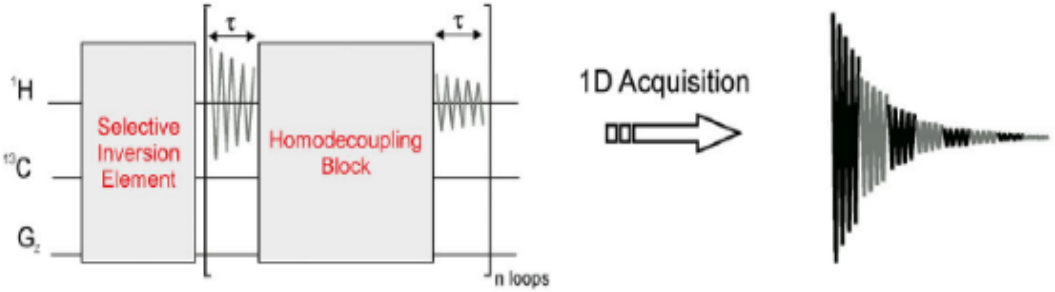


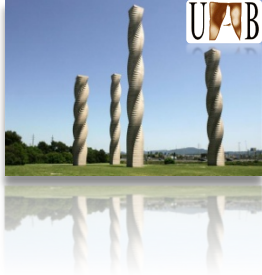
Pure Shift NMR: Acquisition Modes

A) Pseudo-2D ZS Experiment

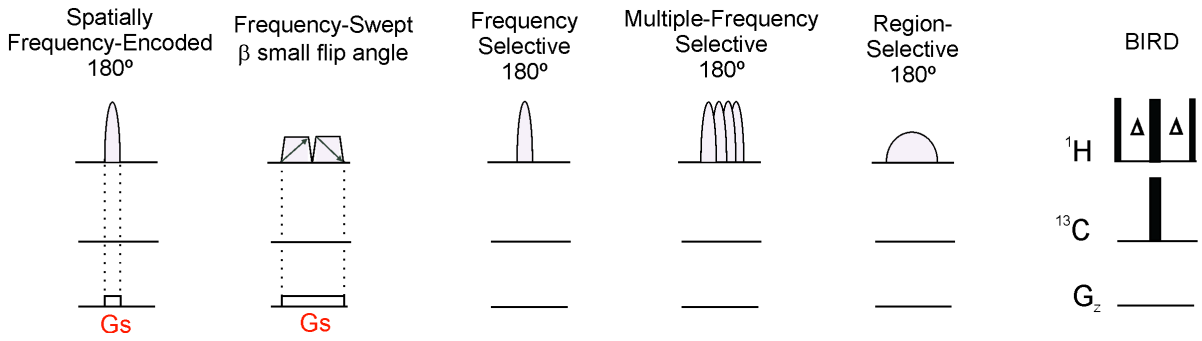


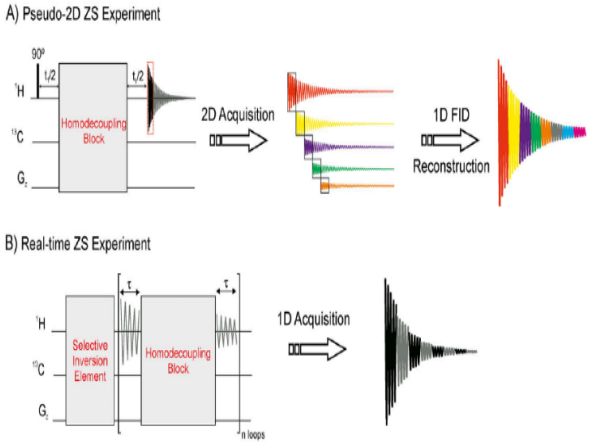
B) Real-time ZS Experiment





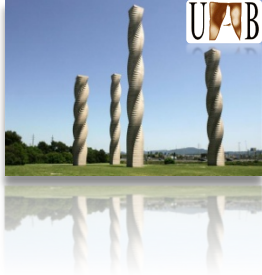
Pure Shift NMR: Practical Approaches





Pure Shift apps:
1H
COSY/TOCSY/NOESY/ROESY
Jres/Gserf
HSQC/HMBC...

HSQC
ADEQUATE



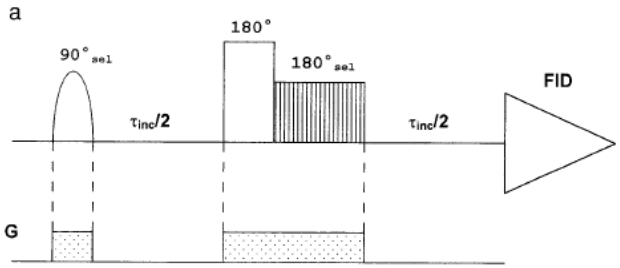
Pure Shift NMR: Original ZS Experiment

JOURNAL OF MAGNETIC RESONANCE **124**, 486–489 (1997)
ARTICLE NO. MN961063

Homonuclear Broadband-Decoupled NMR Spectra

KLAUS ZANGGER AND HEINZ STERK*

Institut für Organische Chemie, Karl-Franzens-Universität Graz, Heinrichstraße 28, 8010 Graz, Austria



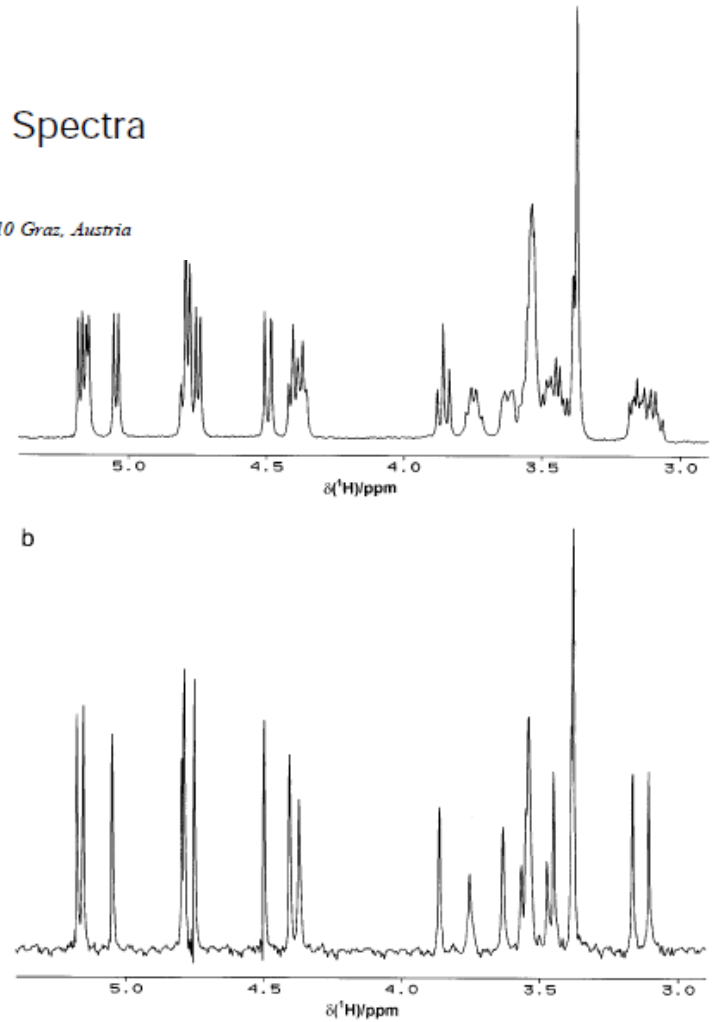
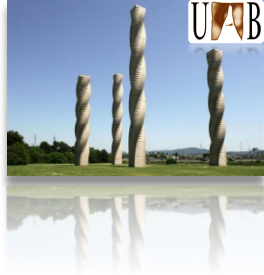
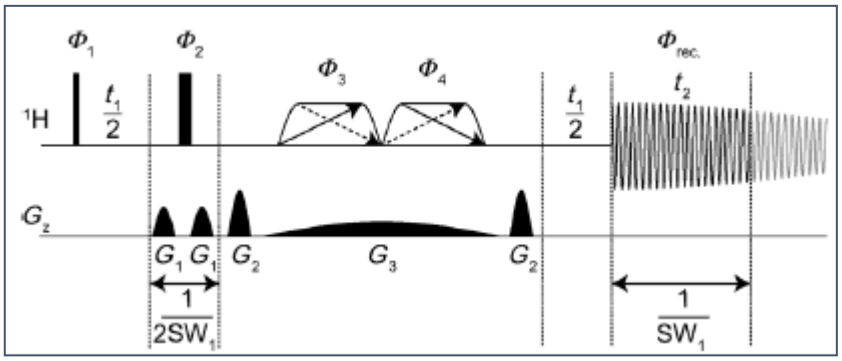


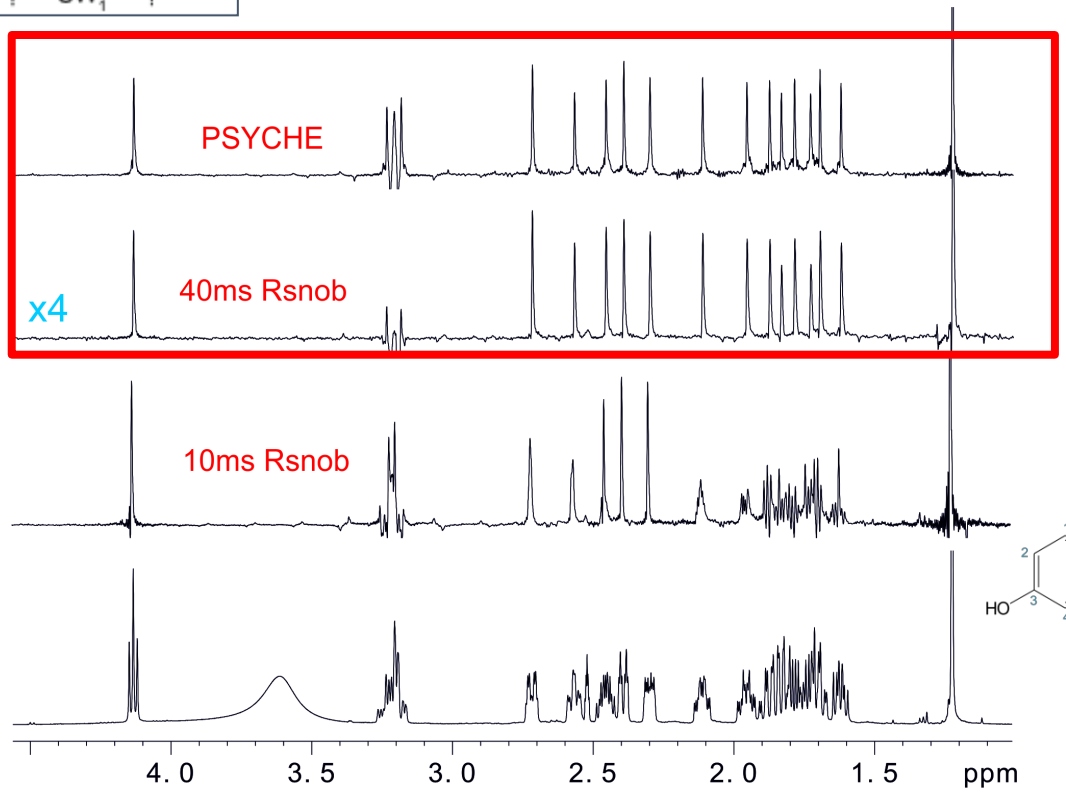
FIG. 2. (a) A 360 MHz ^{1}H NMR spectrum of sucrose in DMSO. Sixteen scans of 1024 complex data points were accumulated. (b) Spectrum of the same compound, obtained by the pulse sequence of Fig. 1a; 64 scans were accumulated for each of the 64 experiments; the time increment was 8 ms and the dwell time 250 μs. The first 32 complex data points of each FID were combined into a new FID consisting of 1024 complex data points, which after Fourier transformation led to the shown spectrum.

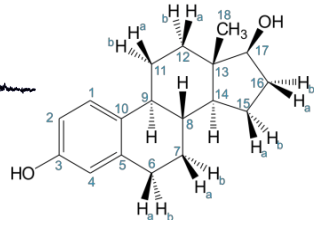


Pure Shift NMR: PSYCHE

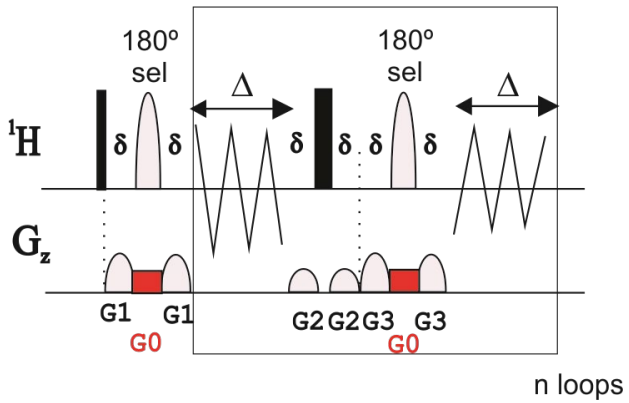


Pseudo-2D ZS
Using a pair of small flip-angle (≈15º) swept-frequency pulses





Pure Shift NMR: Real-Time Homodecoupling

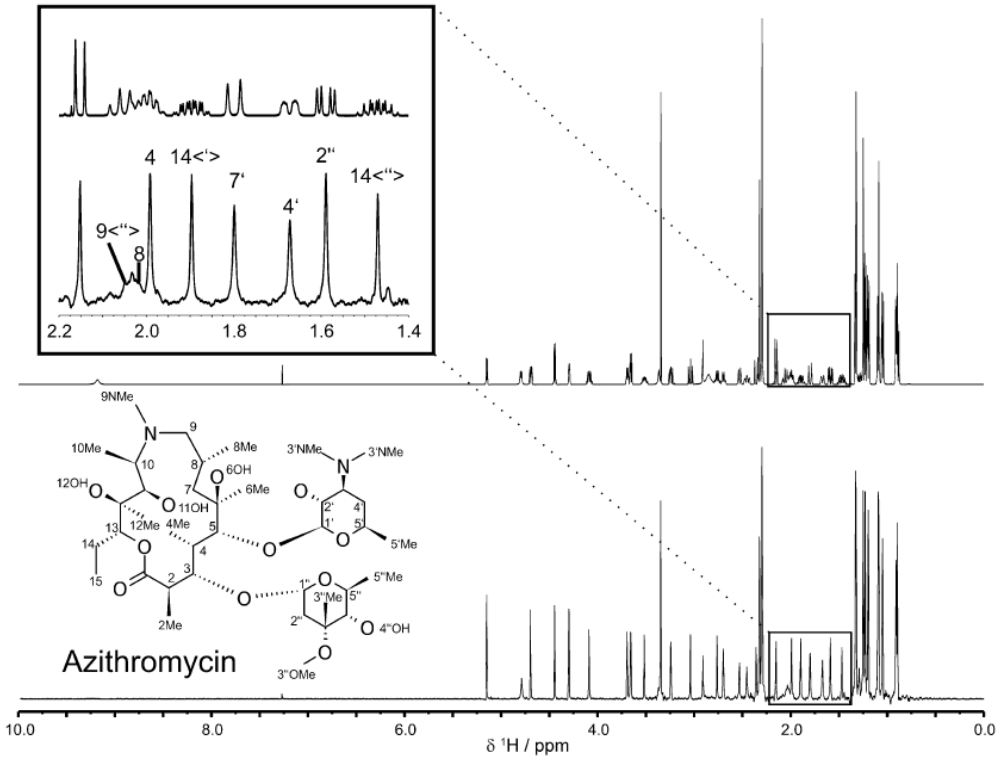


Advantages:

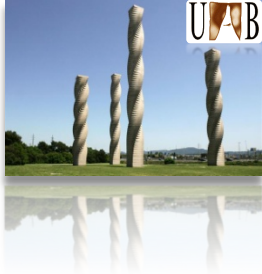
- Real-time 1D acquisition
- Faster than pseudo-2D ZS
- 1D homodecoupled ^{1}H spectrum
- Conventional Data Processing
- Easy implementation into 2D NMR

Limitations:

- Duration of selective 180º pulse (<10-15ms)
- Poor selectivity
- Severe sensitivity losses due to slice selection
- Wider lineshapes than original ZS
- Presence of undesired sidebands

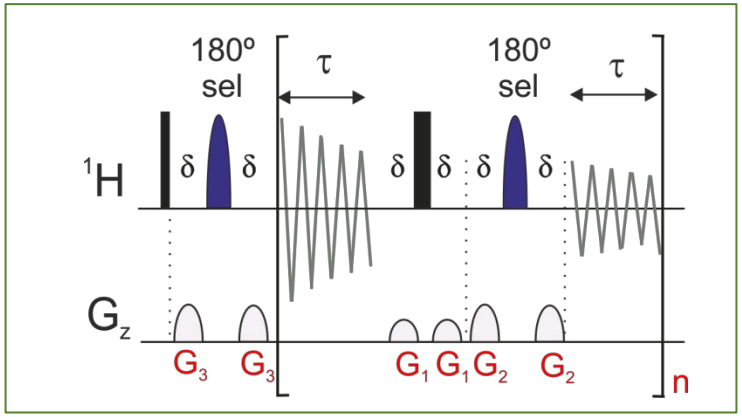


N.H. Meyer, K. Zangger, *Angew. Chem. Int. Ed.*, 52 (2013) 7143 .



Pure Shift NMR: Real-Time ZS with Full Sensitivity

HOmodecoupled Band-Selective (HOBS)

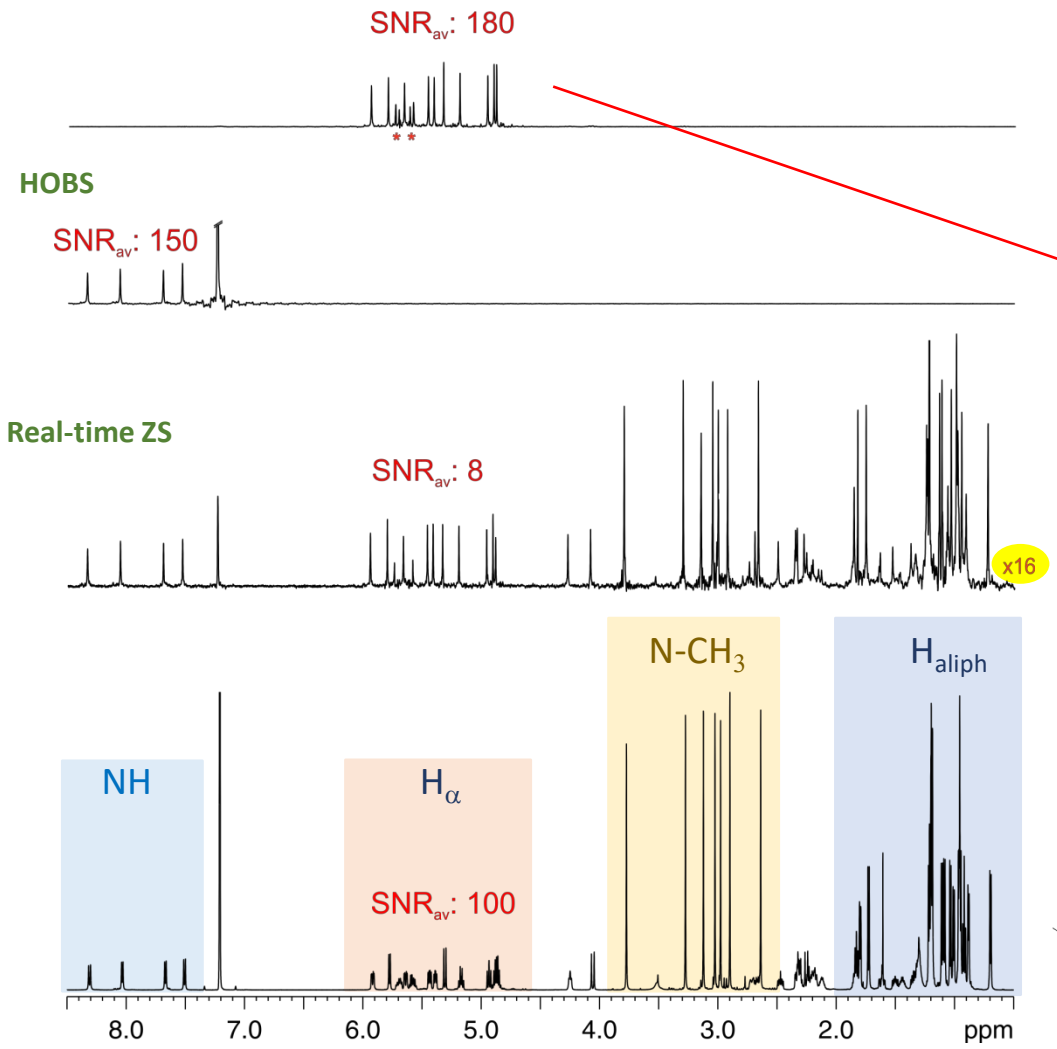


- ✓ Real-time 1D acquisition mode
- ✓ Conventional data processing
- ✓ Easy set-up
- ✓ **Full sensitivity (No Slice-selection)**
- ✓ Easy implementation into 2D

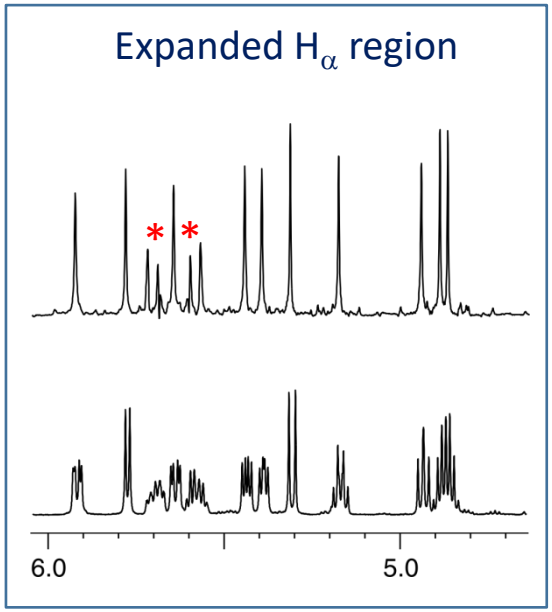
- ✗ Restricted selective 180º pulse (<10-15 ms)
- ✗ Frequency/Band selective, not broadband
- ✓✗ Wider linewidth

Pure Shift NMR: Real-Time ZS with Full Sensitivity

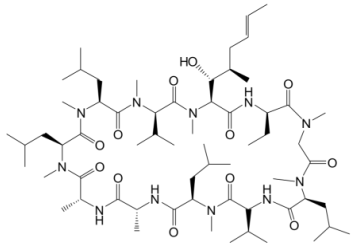
HOBS is useful when active and passive spins resonate within a separate band



Improved Sensitivity & Resolution than conventional ^{1}H !!!!

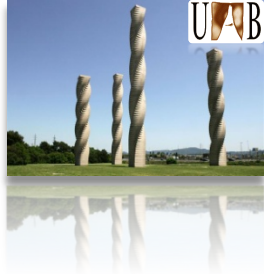


All spectra were acquired with **ns=1** and 5ms RE-BURP selective 180º ^{1}H pulse. **t_{exp}=1s**

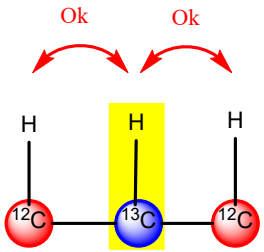


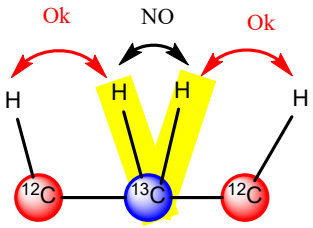
cyclosporine

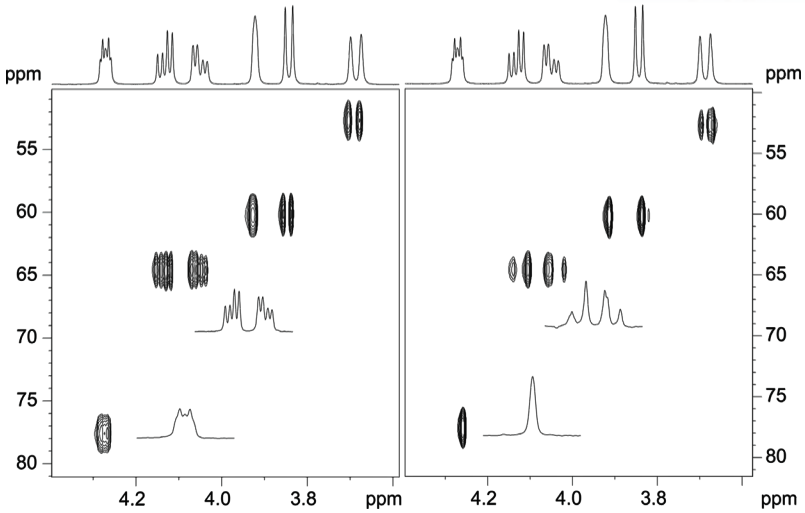
L. Castañar, P. Nolis, A. Virgili , T. Parella. *Chem. Eur. J.* **2013**, 19, 17283.

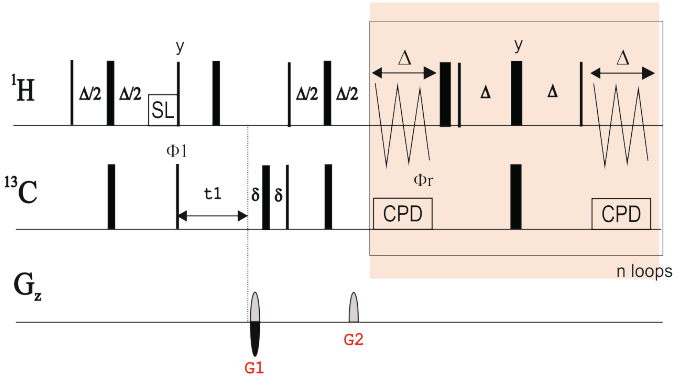


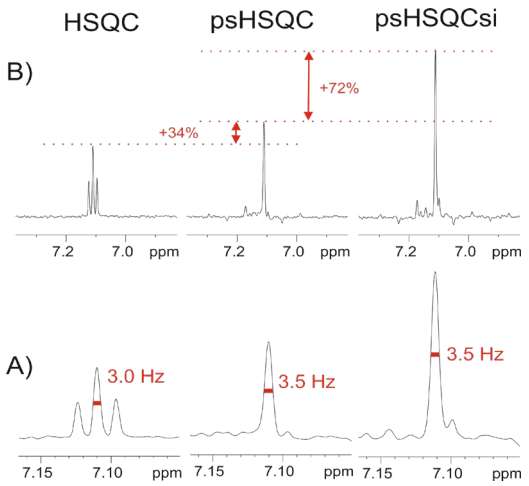
Homodecoupled HSQC



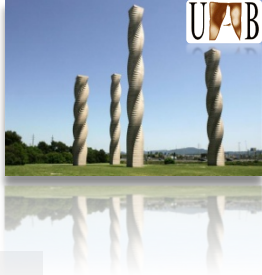








L. Paudel, R.W. Adams, P. Király, J.A. Aguilar, M. Foroozandeh, M.J. Cliff, M. Nilsson, P. Sándor, J.P. Waltho, G.A. Morris, *Angew. Chem. Int. Ed.* **2013**, 52, 11616.



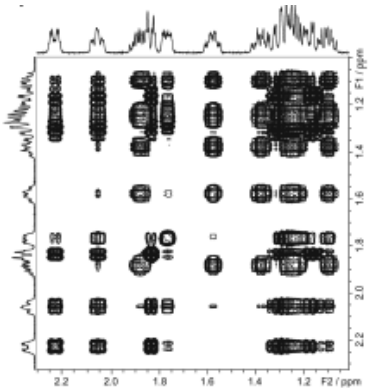
Pure Shift NMR: Complementary Tools

Combination of complementary resolution-enhanced NMR techniques in a single NMR experiment

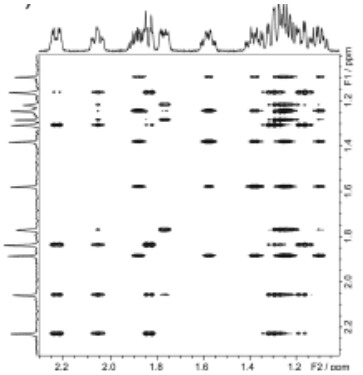
TOCSY

F1-homodecoupled TOCSY (PSYCHE-TOCSY)

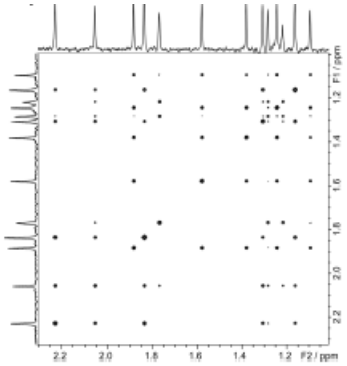
Pure-Shift TOCSY

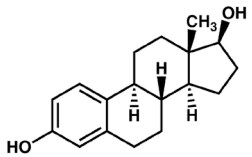


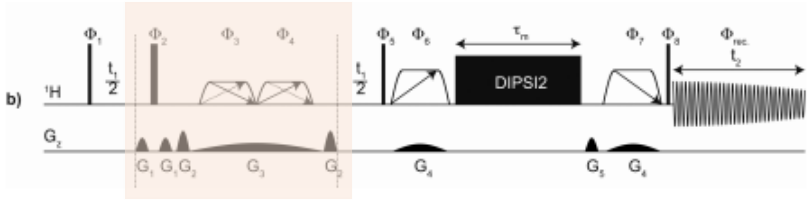
Homodecoupling in F1



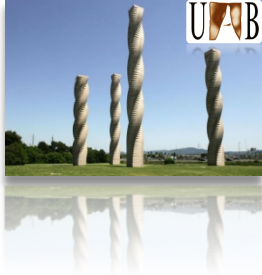
Indirect Covariance





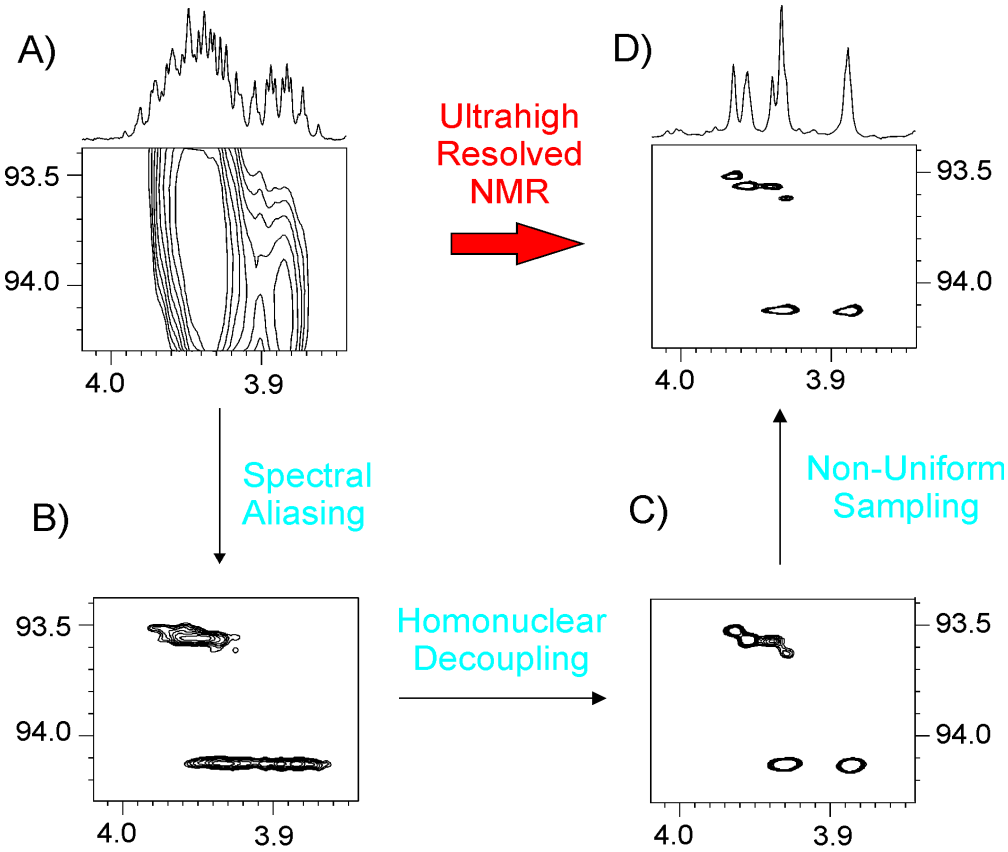


M. Foroozandeh et al., JACS **2014**, 136, 11867



Pure Shift NMR: Complementary Tools

SAPS-HSQC: Spectral Aliasing + Pure Shift



Better Peak identification
Automated peak-picking
Accurate Volume Integration

- ✓ **Improved Signal resolution in F2** by pure-shift NMR
- ✓ **Improved digital resolution in F1** by spectral aliasing and non-uniform sampling

Analysis of mixtures: L. Castañar, R. Roldán, P. Clapés, A. Virgili, T. Parella, *Chem. Eur. J.* **2015,** 244, 30.
NMR Enantiodifferentiation: M. Pérez-Trujillo, L. Castañar, E. Monteagudo, L. T. Kuhn, P. Nolis, A. Virgili, R. T. Williamson, T. Parella, *Chem. Commun.* **2014,** 50, 10214