Accelerator Mass Spectrometry

Technique, and its applications in climate research

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AMS Project

- AMS has been developed since the late 1970's
- Mass spectrometry rather than decay counting gains a sample mass reduction of ~10^3
- Isotopes of interest ^{14}C, ^{10}Be, ^{26}Al, ^{36}Cl, ^{41}Ca, ^{129}I

Brief description of the technique

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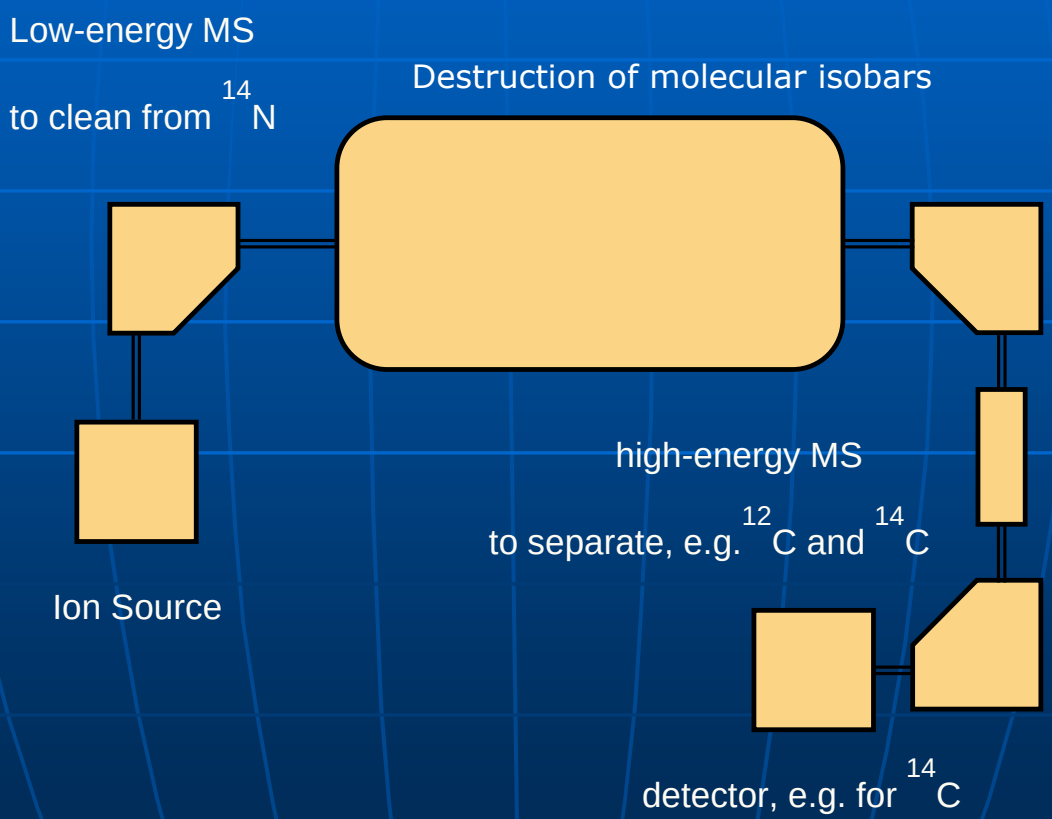
General layout AMS accelerator



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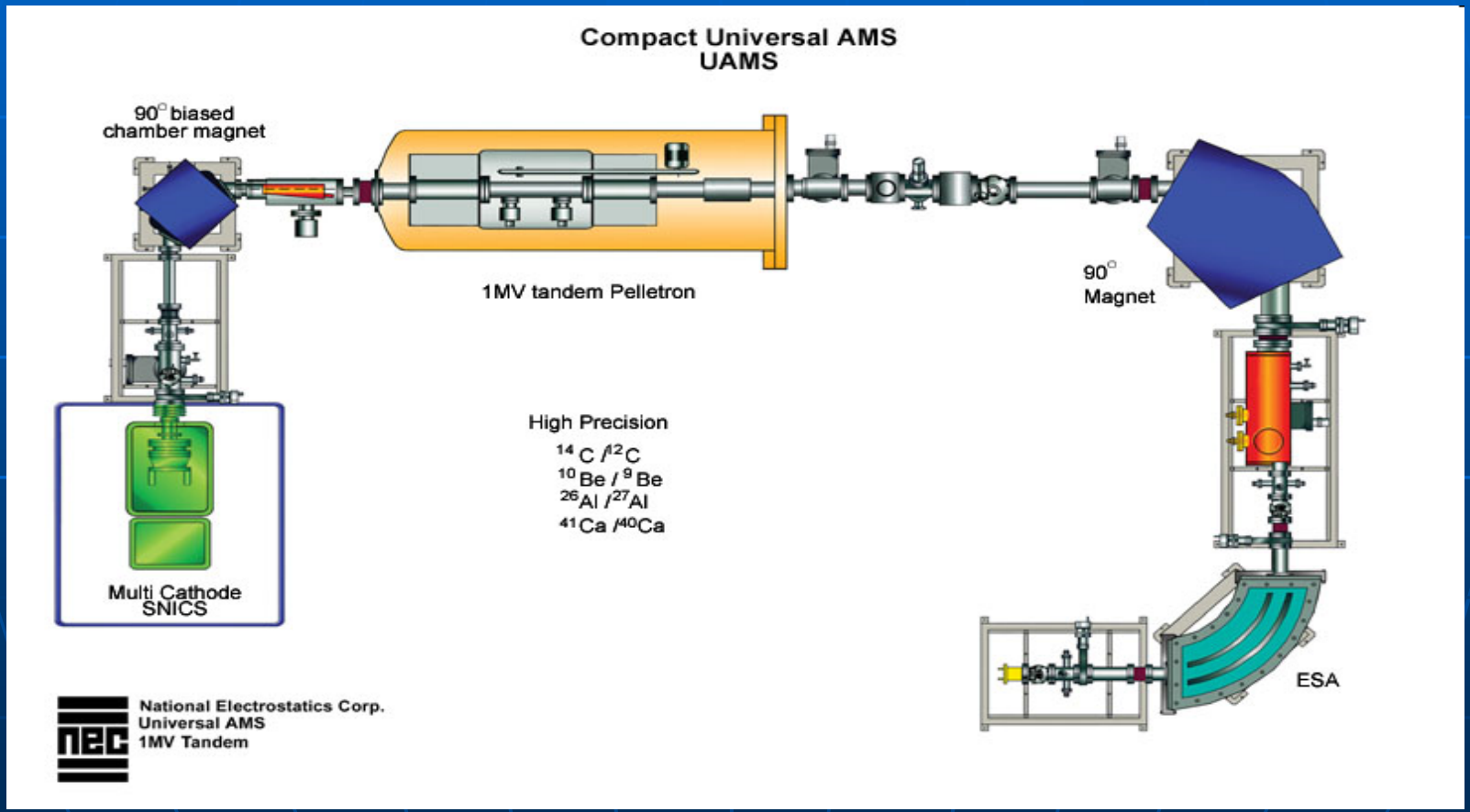
Compact Universal AMS
UAMS
90° biased
chamber magnet
1MV tandem Pelletron
90°
Magnet
High Precision
$^{14}C/^{12}C$
$^{10}Be/^{9}Be$
$^{26}Al/^{27}Al$
$^{41}Ca/^{40}Ca$
Multi Cathode
SNICS
ESA
National Electrostatics Corp.
Universal AMS
1MV Tandem

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From big systems (>6MV) to very small ones: 250kV

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- Measurements are expressed as ratios of the rare isotope (^{14}C in this case) against the more abundant isotope (^{13}C or ^{12}C in this case)

$$^{14}C / ^{13}C$$

- Samples are measured against a standard

Relative 14C content ("Fraction modern")

$$F = {}^{14}C/{}^{13}C_{sample} \; / \; {}^{14}C/{}^{13}C_{standard}$$

Needs correction for isotopic fractionation

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- Expression of ^{14}C content
- Scale for modern (contemporary) matter expressed as $\Delta^{14}C$ in ‰

- 0‰ is contemporary standard
- -1000‰ is radiocarbon “dead” = no measurable radiocarbon content

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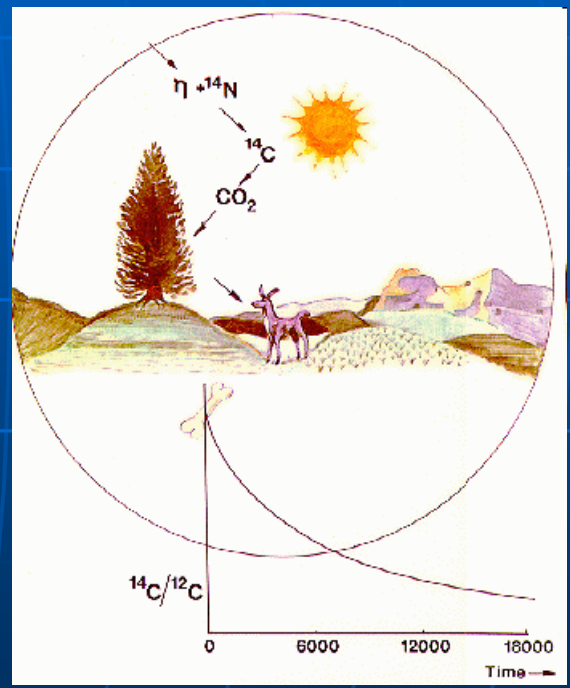
^{14}C and climate research

All living matter:
"Modern" level 10^{-12}

All organic matter >70KA:
"Dead" level 10^{-15}



Design REM Hedges, Oxford

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Carbon Sinks

- Atmosphere

- Ocean surface
- Deep ocean

- Biosphere
- Soil
- Rivers and lakes

- Fossil organic carbon
- Carbonates

- Different ^{14}C content based on residence time of carbon and rate of exchange

- Measurement of ^{14}C gives information about the dynamics of the system:

- Intake and uptake
- ^{14}C time series
- Combined with [CO_2], quantitative apportionment of fossil contributions to atmosphere

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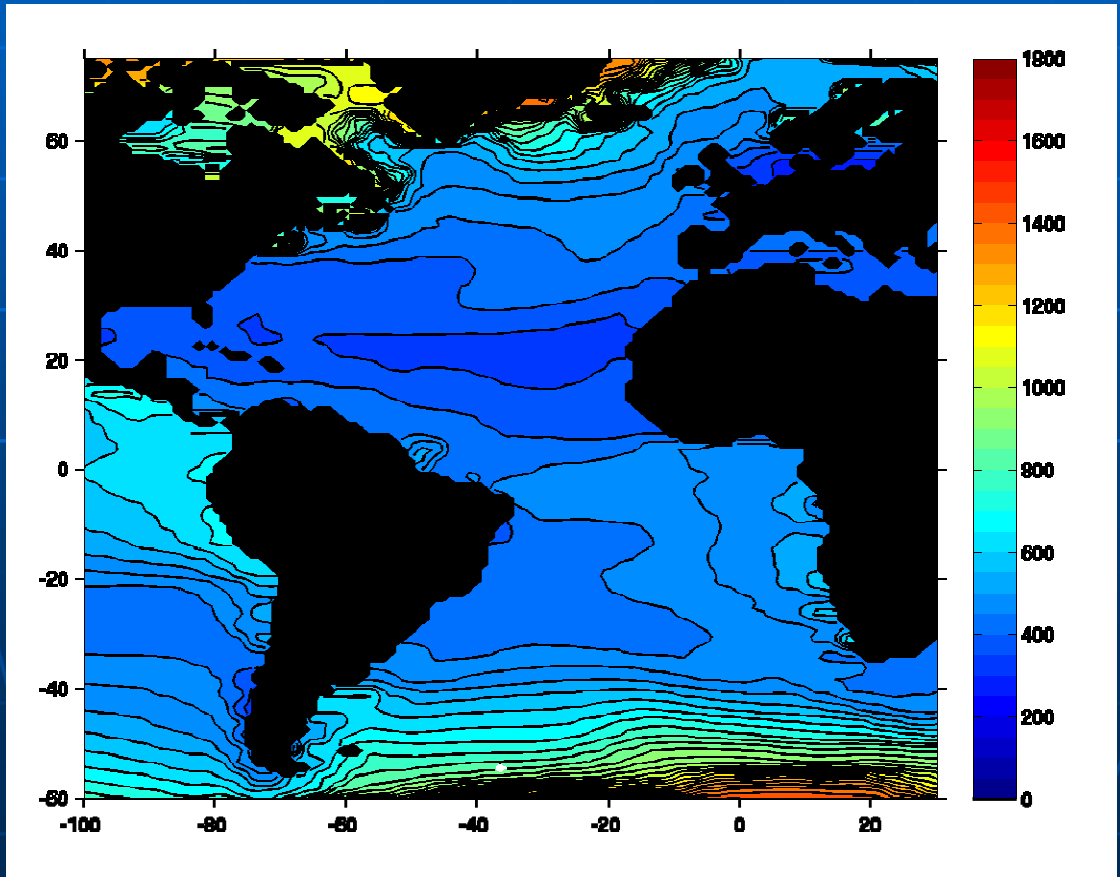
- Ocean radiocarbon reservoir: “apparent ^{14}C ages”



R.G.Fairbanks

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- ^{14}C concentration in the atmosphere has changed as a result of fossil fuel additions and of the nuclear bomb tests

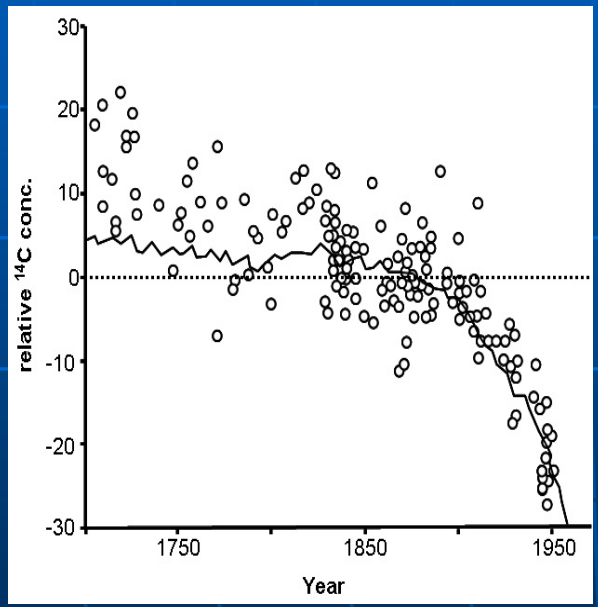
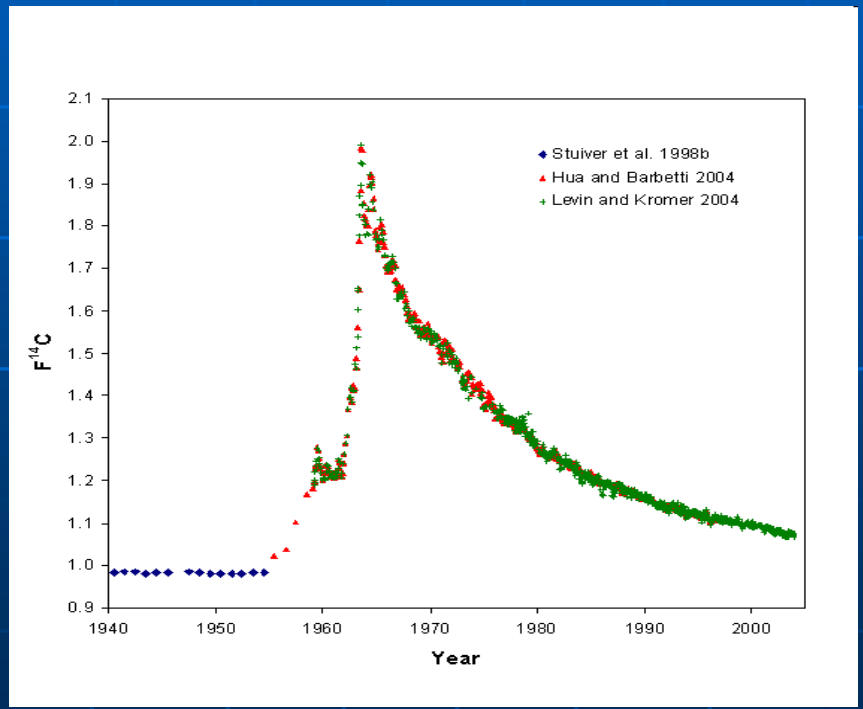


Figure 12.10: Relative concentration of 14C values of atmospheric CO2 derived from tree ring analysis. Trend line illustrates the dilution of 14C reflecting the burning of fossil fuels associated with world industrial activity known as the Suess Effect. From Molles (1992).



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- This means we can source, or apportion the contributions of biogenic and fossil fuel-derived matter
- Because of relatively small sample size, we can measure specific extracts or specific components from larger molecules

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Mandalakis et al.

Data comparing Sweden, Croatia, Greece

TABLE 1. Yield, Purity, and Isotopic Composition of PAHs Isolated from Four Aerosol Samples

sampling site[a]	yield (µg)	purity (%)[b]	NOSAMS accession no.[c]	$\delta^{13}C$ (‰)[d]	$\Delta^{14}C$ (‰)[e]	$F_{Biomass}$ (%)[f]
Aspvreten, Sweden (1995-1997)	14.1	95.4	OS-41865		-381	51
Aspvreten, Sweden (1998-2001)	35.7	96.1	OS-41862	-27.7	-388	50
Zadar & Velebit, Croatia (2003)	68.0	89.2	OS-43143	-29.2	-888	9
Finokalia, Greece (2003)	36.1	93.5	OS-43150	-29.0	-914	7

[a] The numbers in parentheses indicate the time period of aerosol sampling. [b] This purity was assessed prior to shipment from Stockholm University, and the subsequent additional cleanup at WHOI may have further increased these purities. [c] AMS accession numbers for each ^{14}C analysis. [d] Standard deviation for all ä^{13}C measurements is (0.1‰, based on replicate analysis of standards. [e] The relative standard error for these ^{14}C data is 1-3%. [f] $F_{Biomass}$ is the percentage contribution of biomass burning to atmospheric PAHs calculated by an isotopic mass balance approach

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- Extraction of specific PAHs from dust PM10 Aerosols using preparative capillary gas chromatography
- Comparison of urban areas in Tokyo

- Seasonal variability, and differences between fractions for the importance of biomass burning: More important than expected

- Kumata et al: Compound specific 14C analysis of Polycyclic Aromatic Hydrocarbons associated with PM10 and PM1.1 Aerosols from Residential Areas of Suburban Tokyo. 2006

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- AMS is a powerful, and thus essential tool to study anthropogenic climatic influences
- South-eastern Europe can expect more erratic climatic change than Northern Europe, so we need to develop a regional research infrastructure