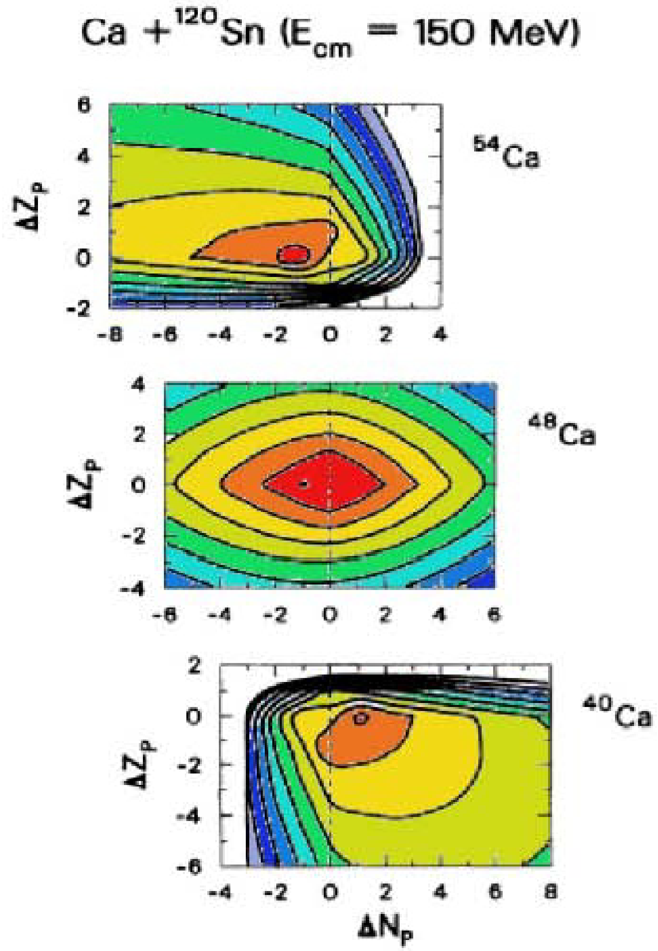
Pair Transfer

Heavy ion transfer reactions



C.H.Dasso, G. Pollarolo, A. Winther
Phys. Rev. Lett. 73, 1907 (1994)

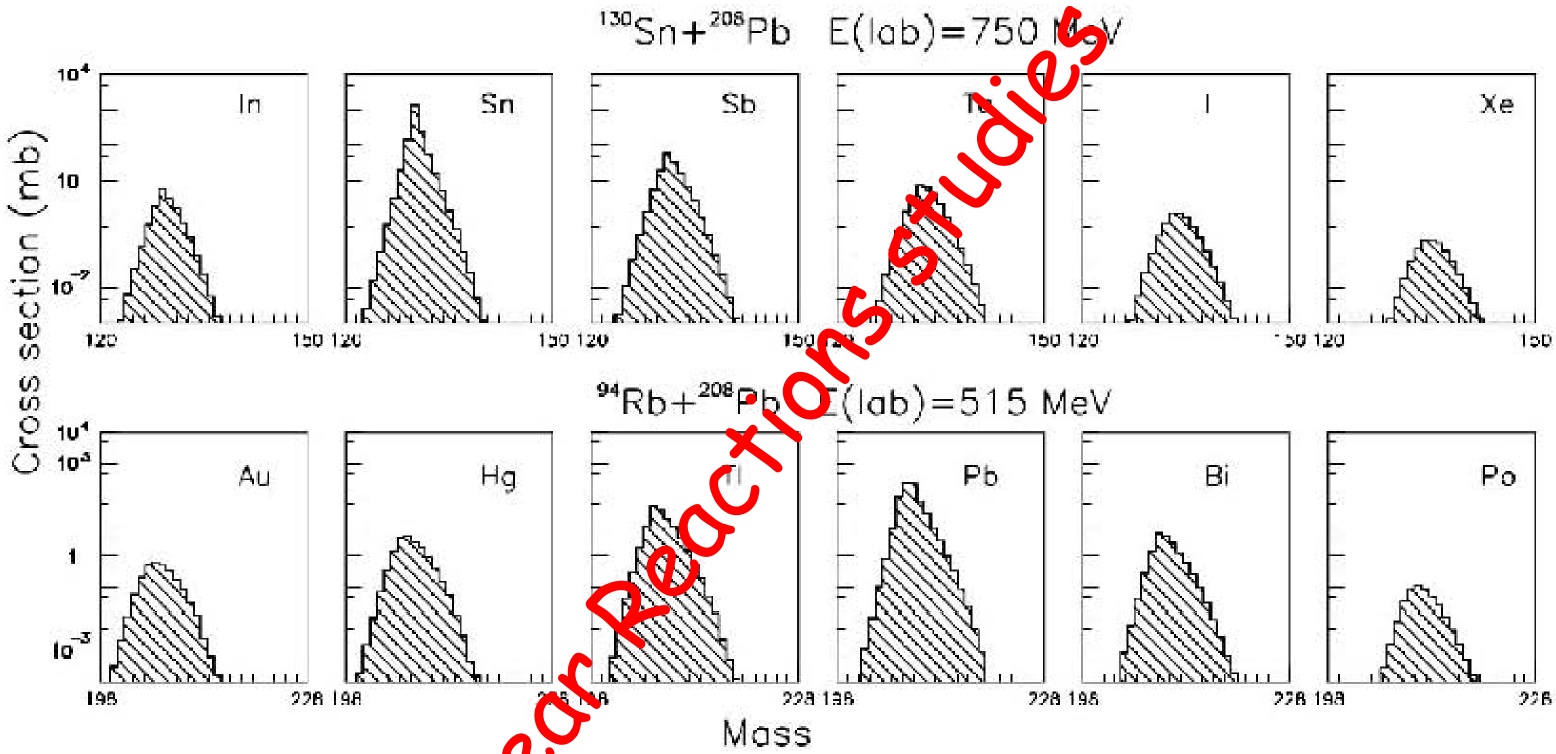
with neutron rich beams

- neutron stripping and proton pick-up
- **Heavy** partner to the **(neutron-rich side)** of the stability valley

with stable beams

- neutron pick-up and proton stripping
- **Heavy** partner to the **"left"** of the stability valley

Neutron-rich heavy nuclei explored via multinucleon transfers: Uni. Zagreb, IRES Strasbourg

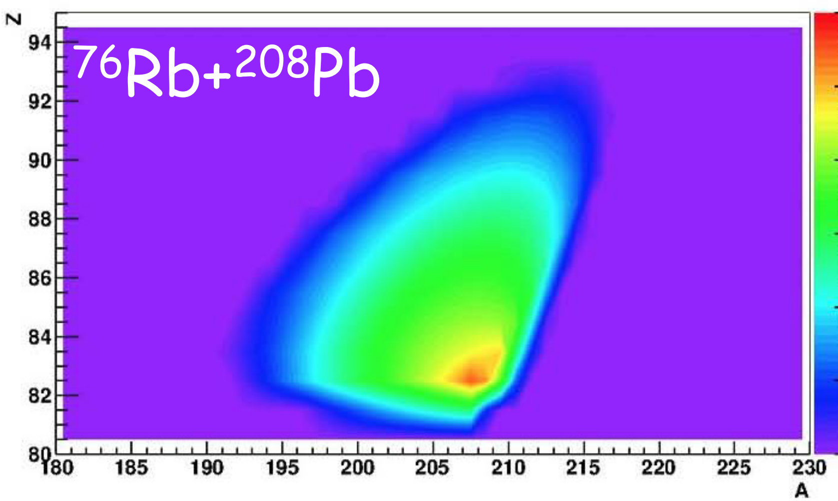


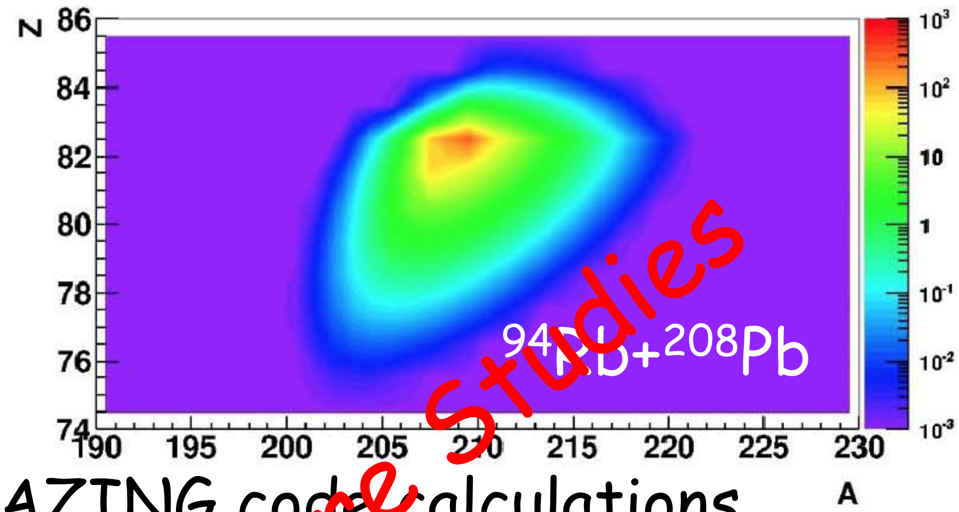
Calculation performed with GRAZING code: cross section

projectile-like reaction products in ^{130}Sn+^{208}Pb

target-like reaction products in ^{94}Rb+^{208}Pb

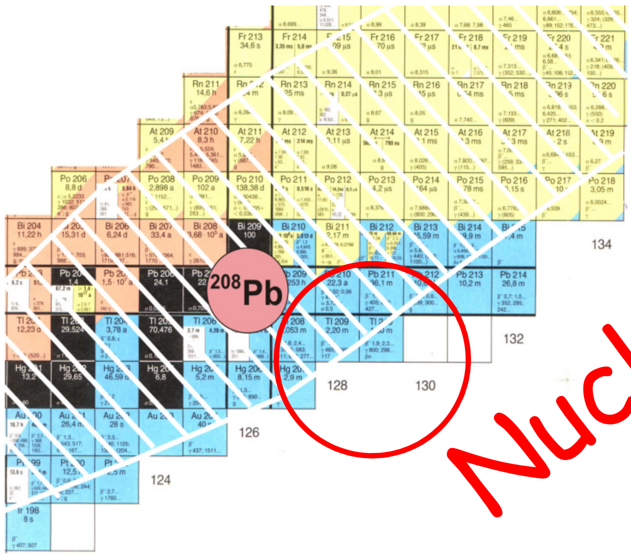
Deep Inelastic and Multinucleon Transfer Reactions with RIBS

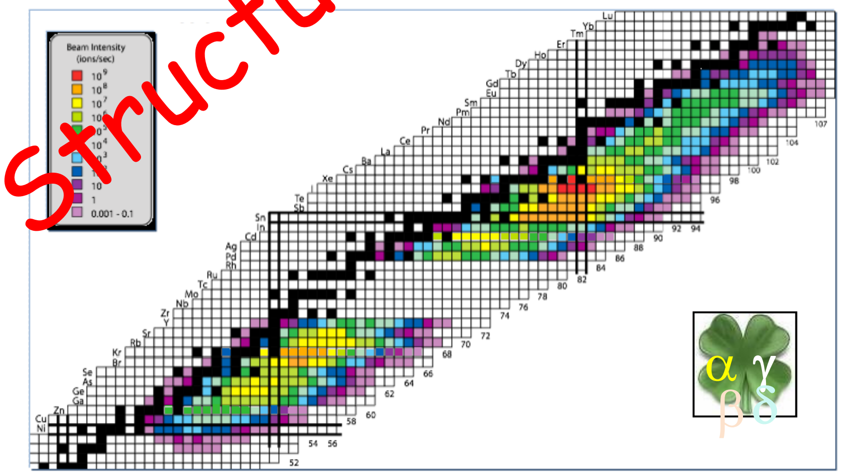




GRAZING code calculations

Nuclear Structure Studies





Super Heavy Elements

The search of double magic superheavy nucleus in the region of neutron shell at N=184

We propose to perform the measurements of the cross sections for the production of new neutron rich nuclei located along the closed neutron shell N=184 using the beam **of ^{140}Xe** providing by SPES facility in collisions with **^{248}Cm** target by the two-arm detection system **PRISMA or PRISMA+CORSET.**

Structure: New magic number at Z=120,126

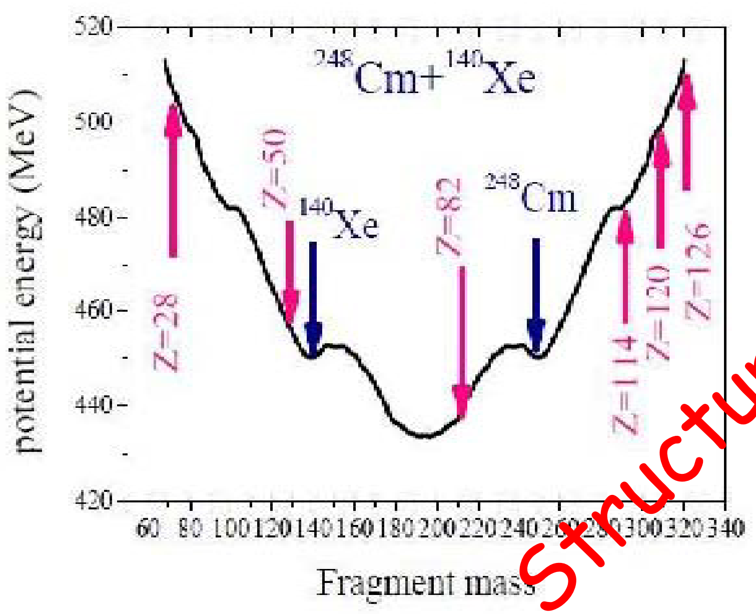


Figure 4. Potential energy at scission point as a function of the primary fragment mass in the reaction ^{248}Cm+^{140}Xe. The arrows indicate the positions of proton shells.

LOI LNL, Dubna (Ru)

Nuclear Astrophysics

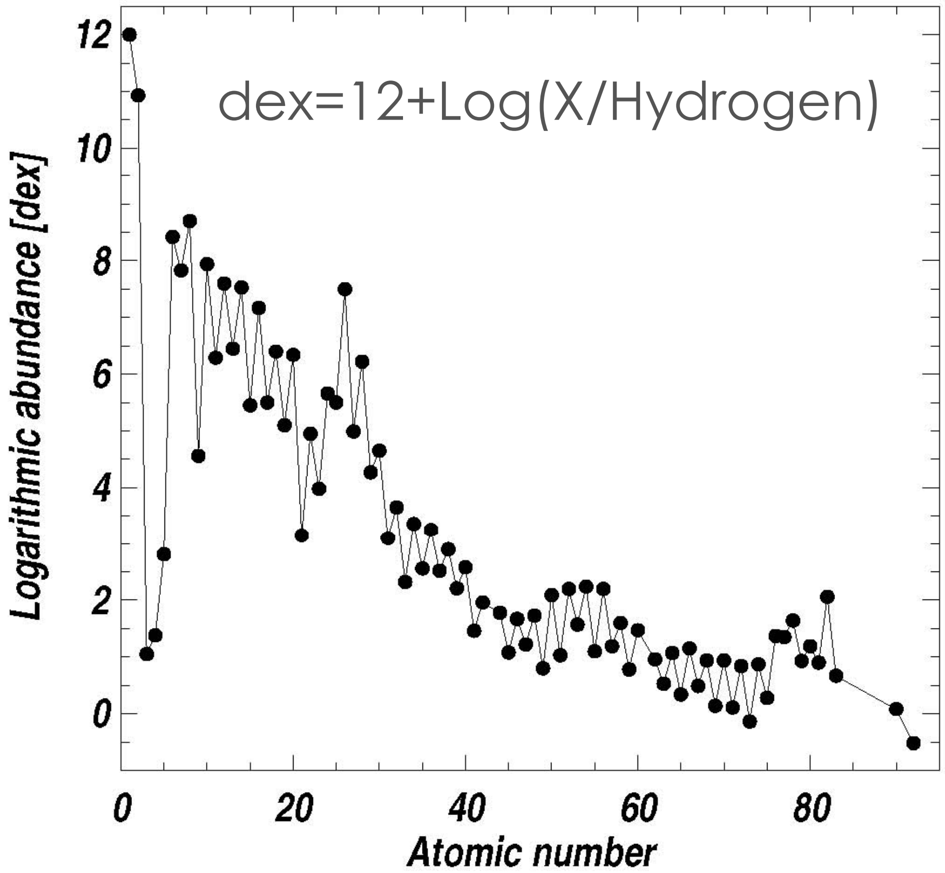
One of the challenges: Origin of the elemental abundances in the solar system

Stars are mostly made of hydrogen and helium, but each has a fairly unique pattern of other elements

The abundance of elements tells us about the hystory of events prior to the formation of our Sun

The plot shows the composition of the Sun Photosphere

How are these elements created prior to the formation of the Sun?



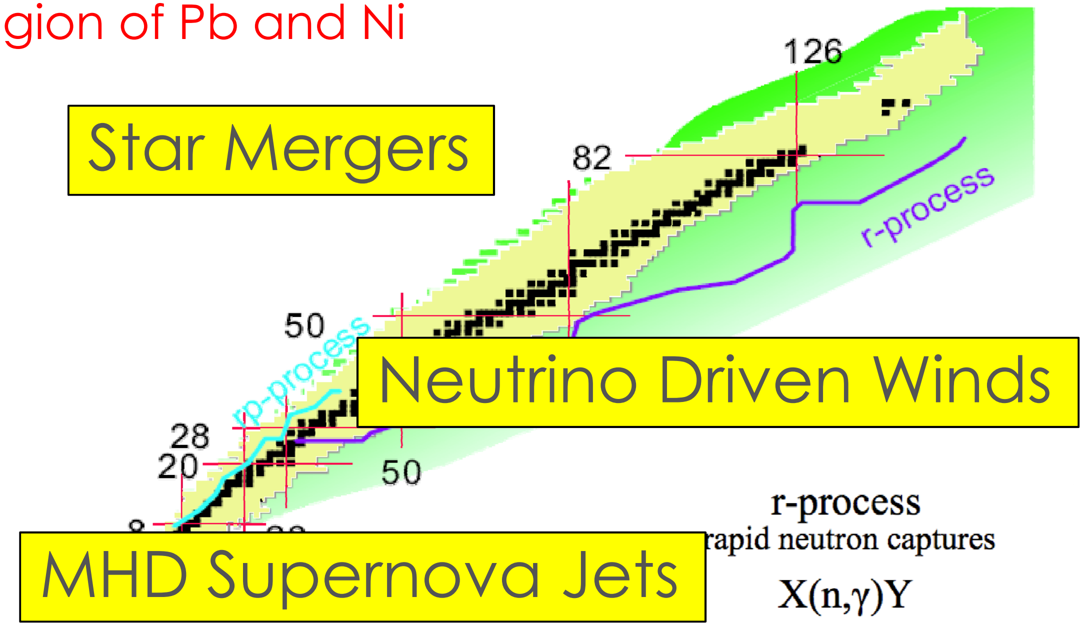
Asplund M. et al.
Ann. Rev. Astr. 47, 481 (2009)

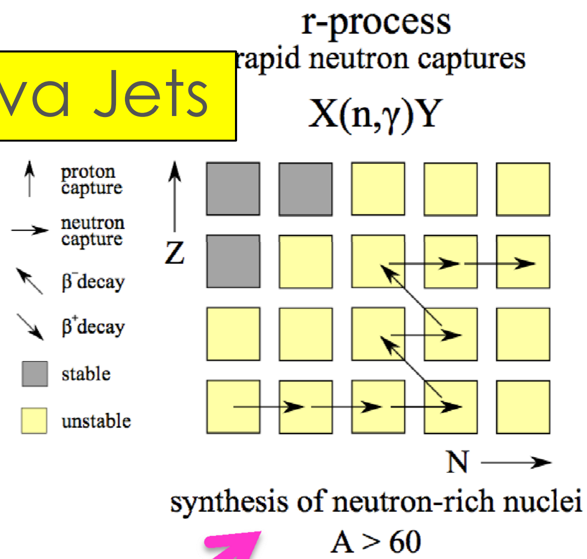
n-rich region of Pb and Ni

- β-decay half-lives
- neutron emission probabilities

different in **DEFORMED** and **SPHERICAL** nuclei

$$\tau_{\beta\,SPH} \sim 10 \times \tau_{\beta DEF}$$
$$P_{nSPH} \sim 0.5 \times P_{nDEF}$$



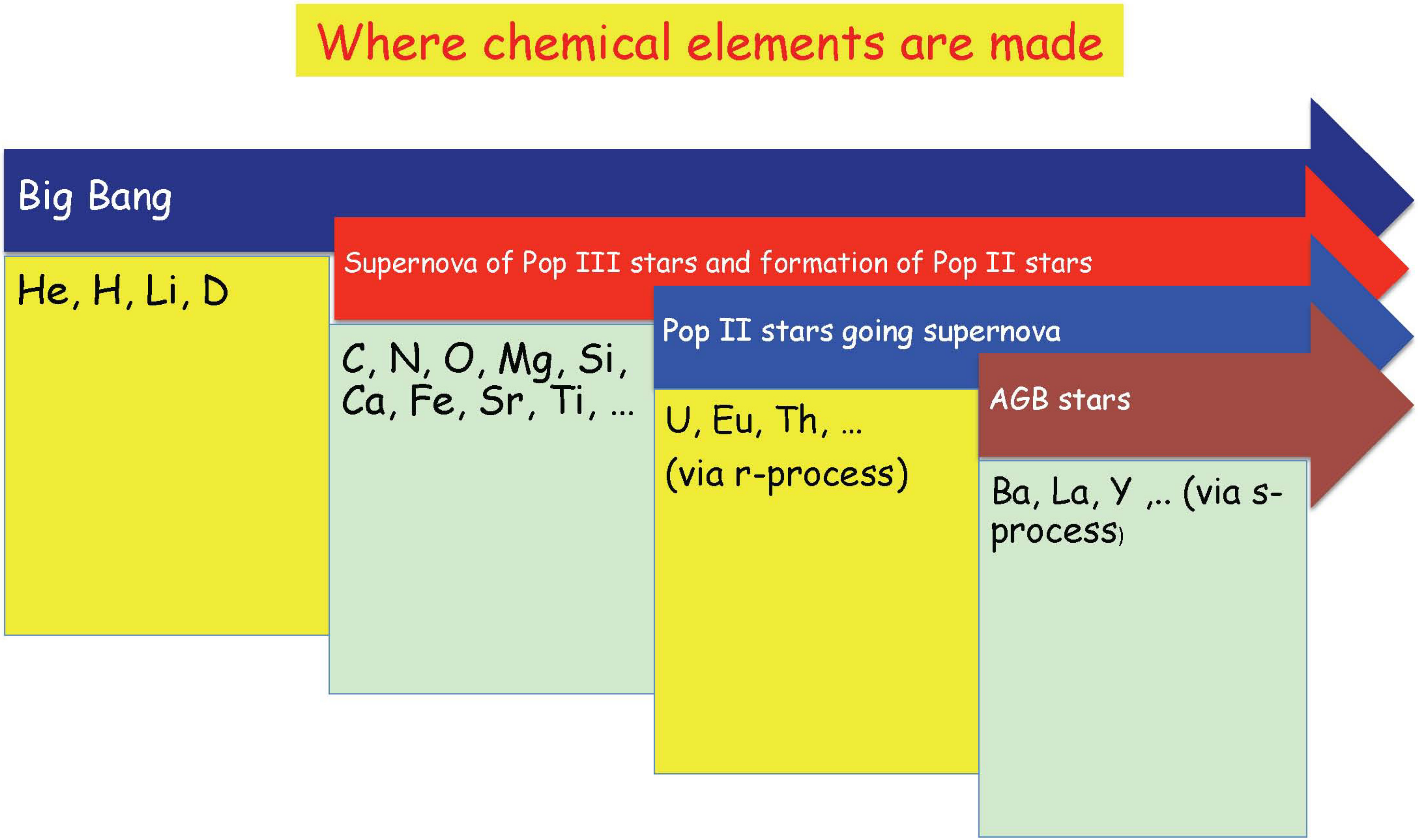


→ Large uncertainty in r-process location
→ difficulty to extrapolate to more exotic regions

Importance of Nuclear Structure studies in the vicinity/towards r-process path:

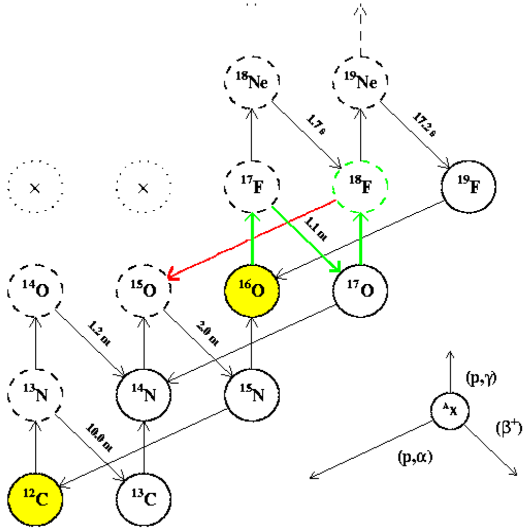
… first excited states
... Isomeric states
... β decay lifetimes

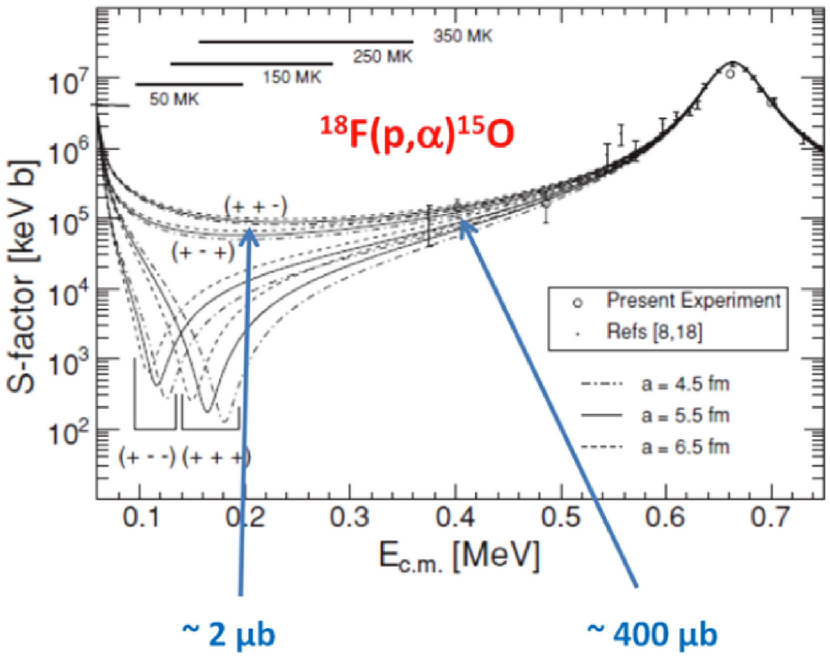
LOI SPES D. Mengoni (Uni. Pd)

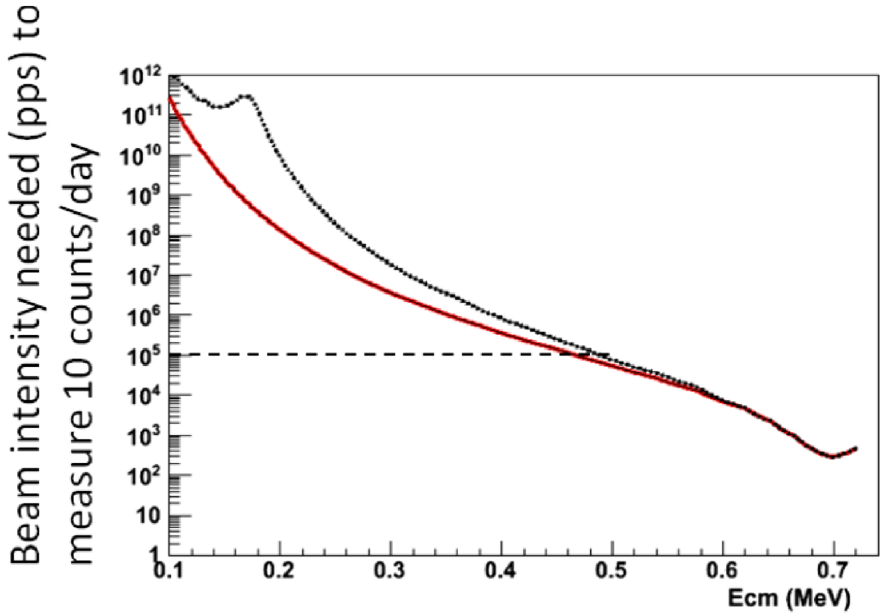


Neutrinos play a crucial role in many nucleosynthesis scenarios.

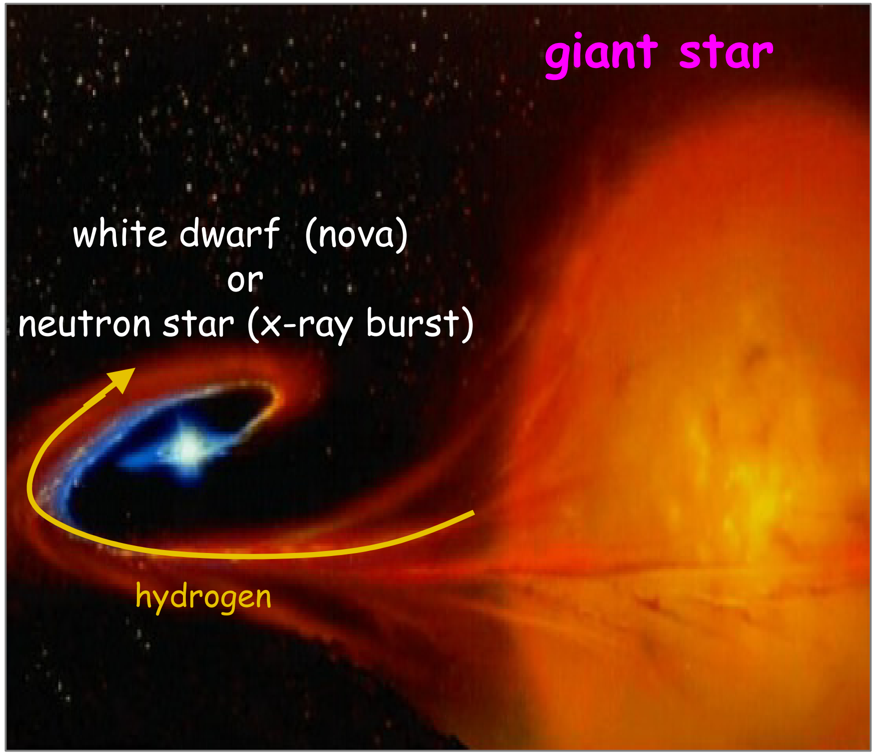
Direct reaction in Novae $^{18}F(p,\alpha)^{15}O$, $^{30}P(p,\gamma)^{31}S$, and $^{25}Al(p,\gamma)^{26}Si$,

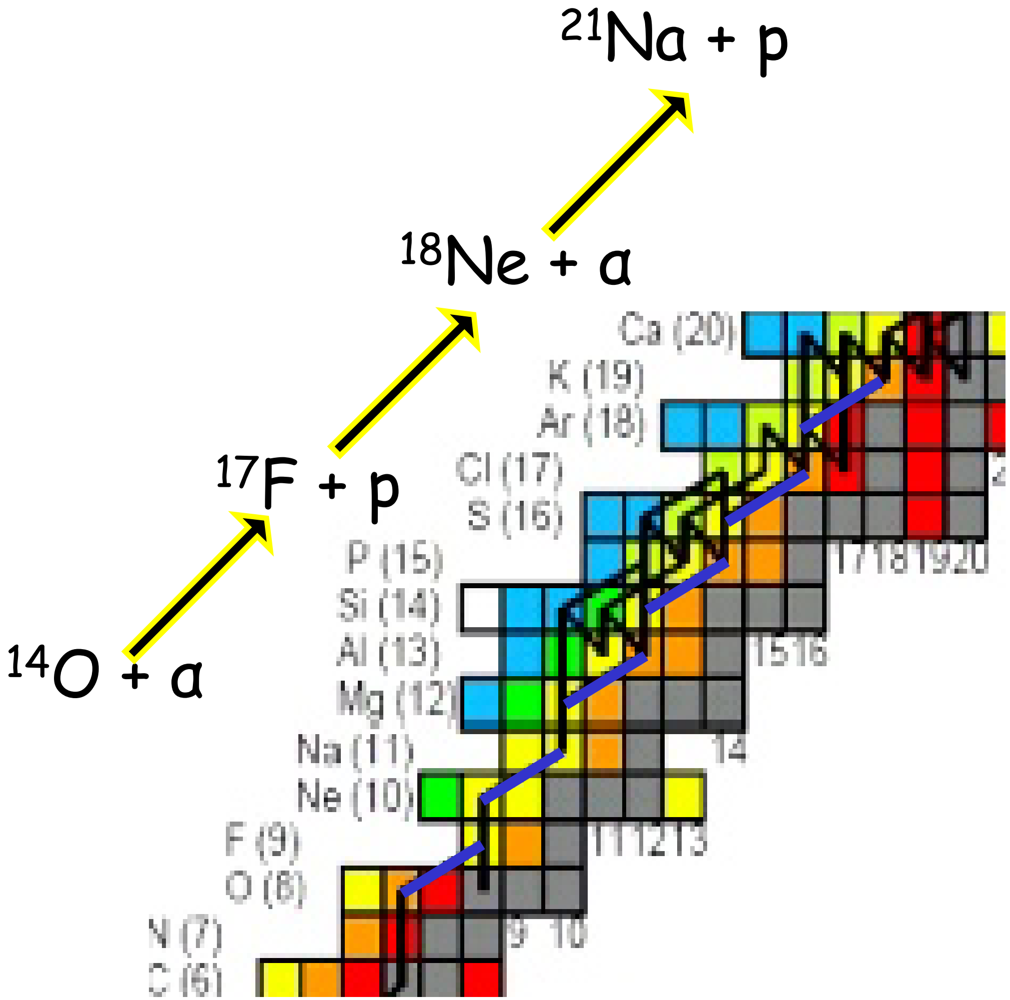






Direct reactions in x-ray bursts

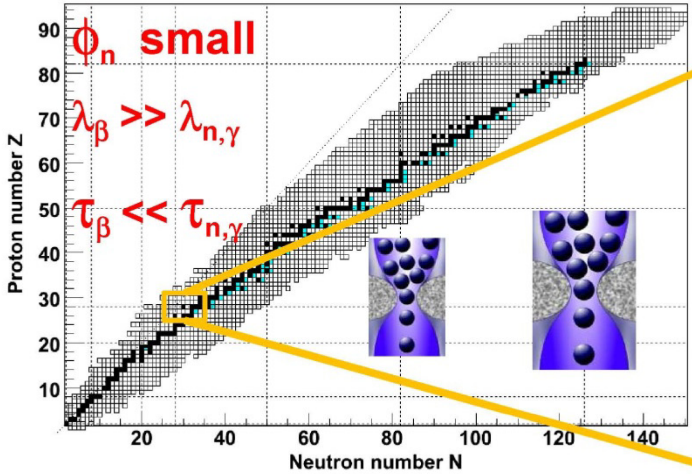




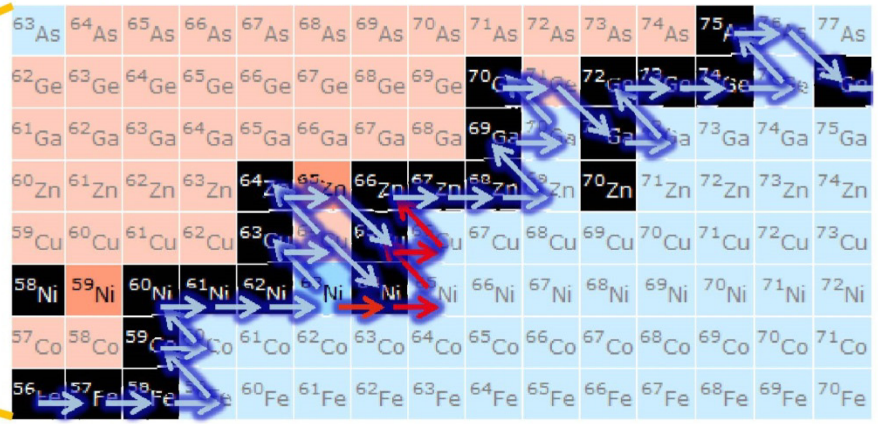
$^{14}O(\alpha,p)^{17}F$, $^{18}Ne(\alpha,p)^{21}Na$, and $^{30}S(\alpha,p)^{33}Cl$

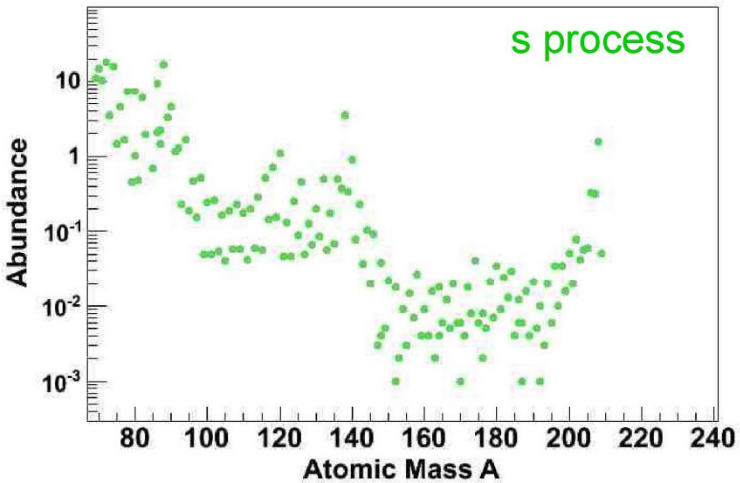
s-process nucleosynthesis and stellar n-flux

Stellar nucleosynthesis: the **s process**



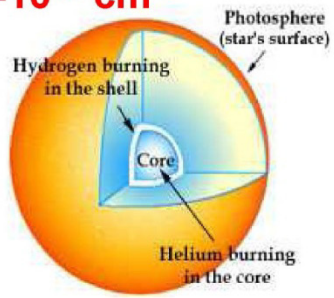
s process in AGB (Red Giant) Stars





core He-burning	shell C-burning
$3\text{-}3.5\cdot10^8$ K	$\sim1\cdot10^9$ K
kT=25 keV	kT=90 keV
10^6 cm^{-3}	**10^{11}-10^{12} cm^{-3}**

$^{22}Ne(\alpha,n)$



Arlandini et al. , Ap. J. 525 (1999)
Gallino et al., Ap. J. 497 (1998)
Raiteri et al. , Ap. J. 419 (1993)

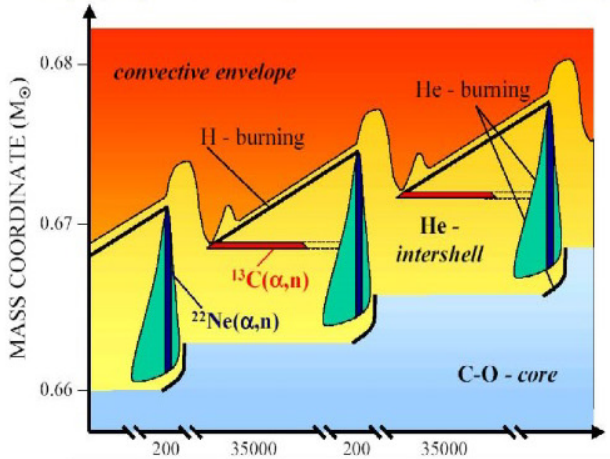
s-process nucleosynthesis and stellar n-flux

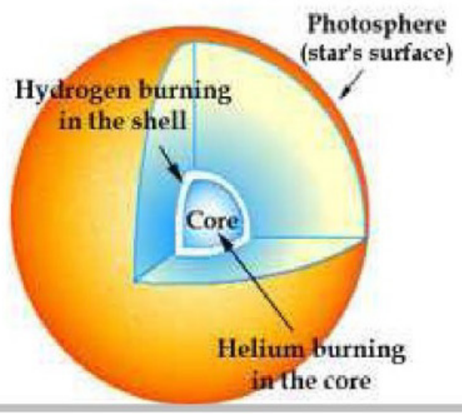
AGB- and Massive Stars: the neutron source of the S-PROCESS

s-process sites

Two components were identified and connected to stellar sites:

Main s-process 90<A<210		Weak s-process A<90	
TP-AGB stars 1-3 $M_\odot$		massive stars > 8 $M_\odot$	
shell H-burning	He-flash	core He-burning	shell C-burning
$0.9\cdot10^8$ K	$3\text{-}3.5\cdot10^8$ K	$3\text{-}3.5\cdot10^8$ K	$\sim1\cdot10^9$ K
kT=8 keV	kT=25 keV	kT=25 keV	kT=90 keV
$10^7\text{-}10^8$ cm^{-3}	$10^{10}\text{-}10^{11}$ cm^{-3}	10^6 cm^{-3}	$10^{11}\text{-}10^{12}$ cm^{-3}
$^{13}C(\alpha,n)^{16}O$	$^{22}Ne(\alpha,n)^{25}Mg$	**$^{22}Ne(\alpha,n)\,^{25}Mg$**	

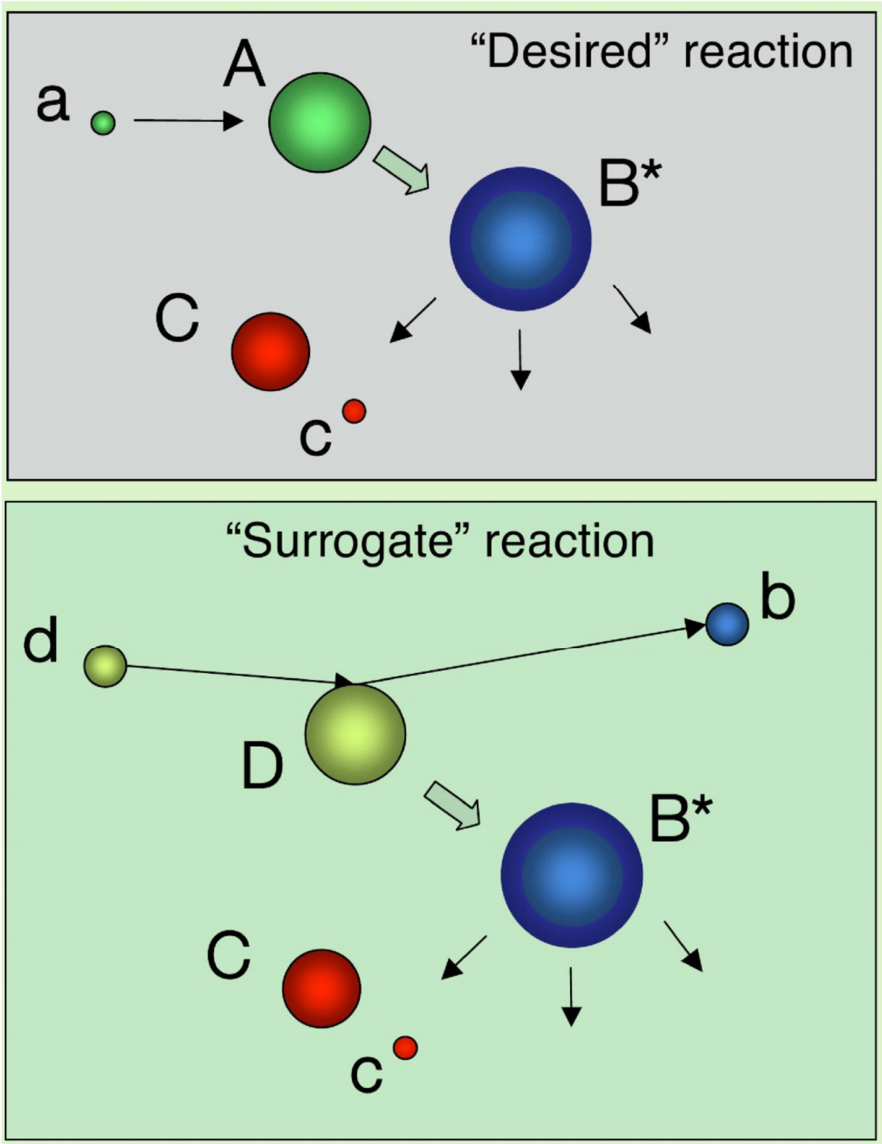




SPES LOI: The $^{79}Se(n,\gamma)$ capture cross section via the surrogate ^{79}Se (d,p) ^{80}Se reaction IFIC Spain

s-process nucleosynthesis and stellar n-flux

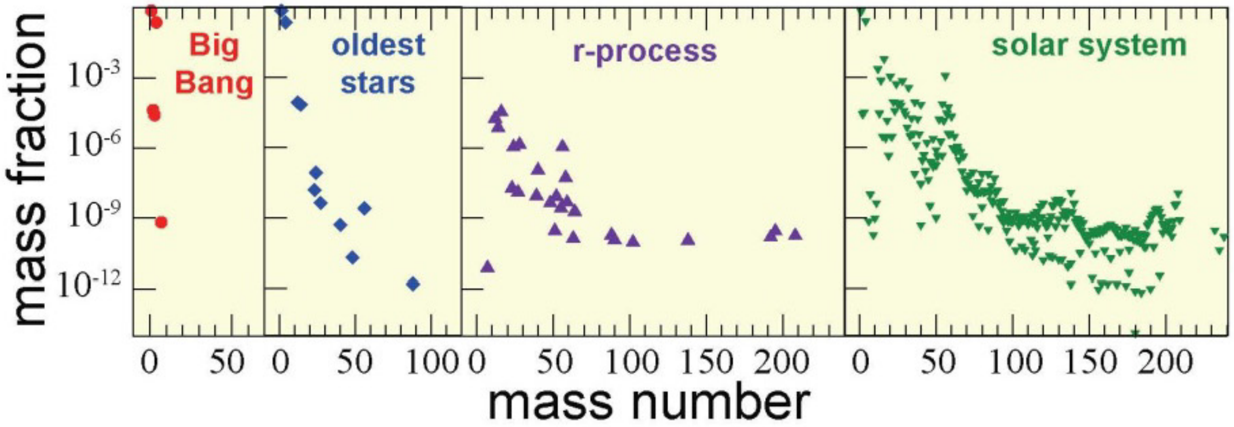
Indirect Determination of Cross Sections

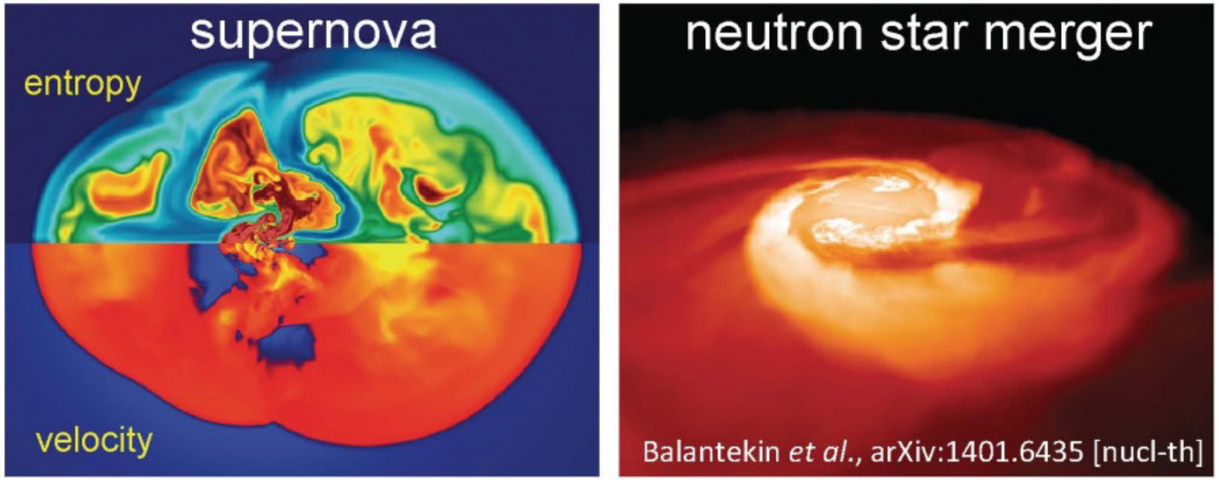


The Surrogate Nuclear Reactions approach is an indirect method for determining XS of CN reactions difficult to measure directly.

r-process nucleosynthesis

The origin of elements



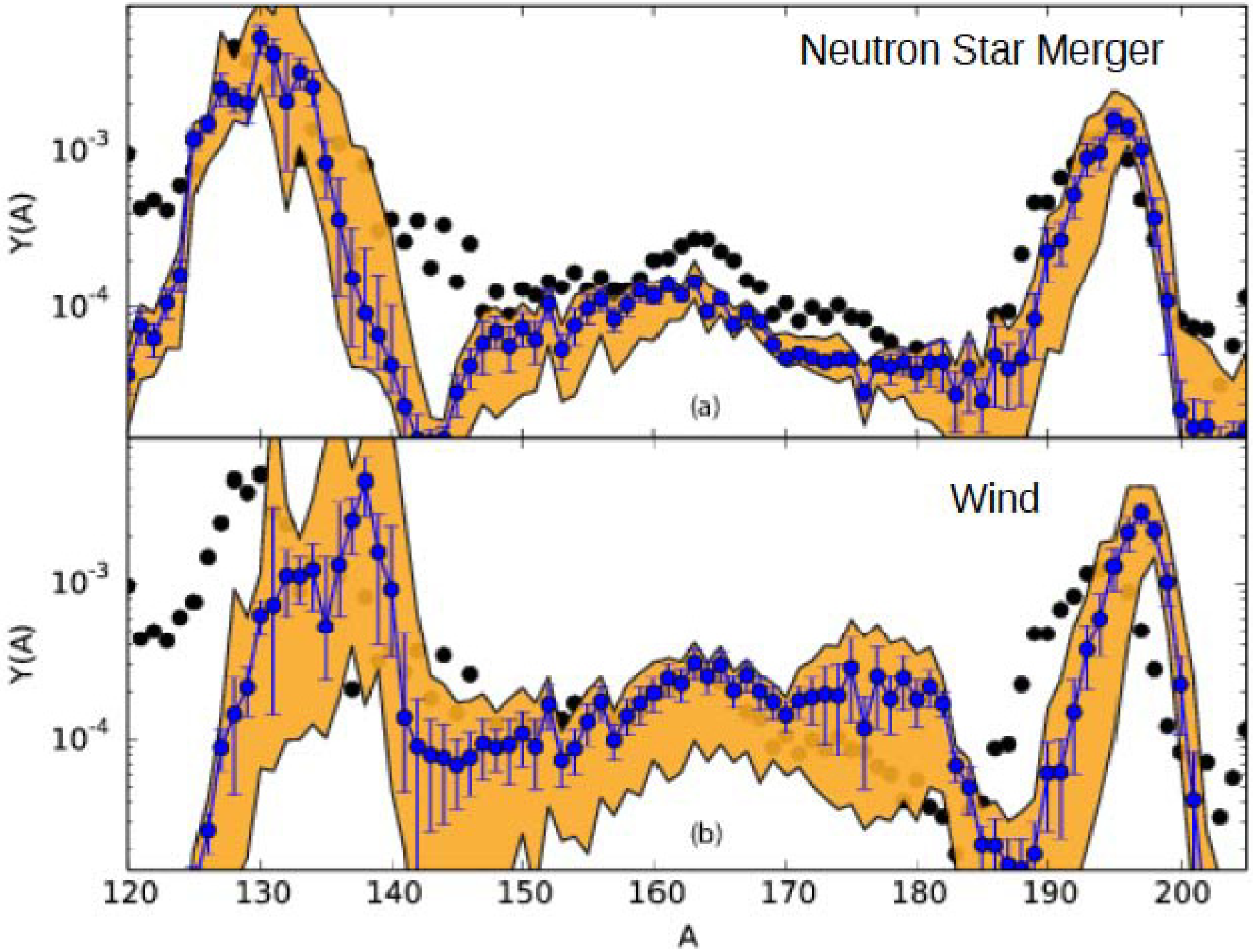


Possible sites for the r-process

Neutrinos not only play a crucial role in the dynamics of these sites, but they also control the value of the electron fraction, the parameter determining the yields of the r-process.

r-process nucleosynthesis

Estimated Final Abundances With Uncertainties

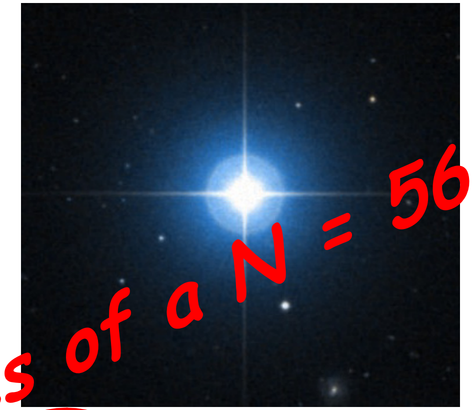


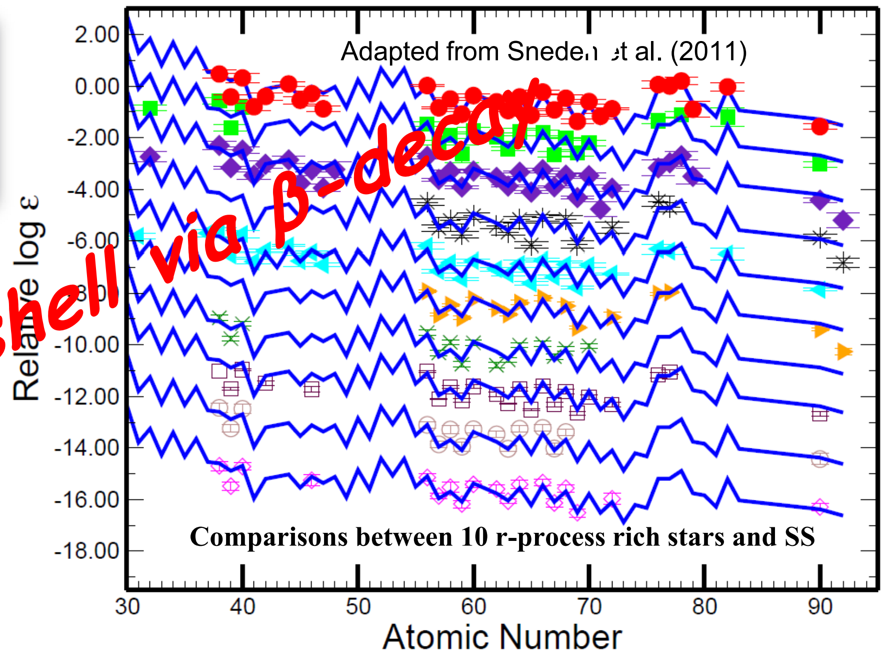
Variations in masses of N~82 and N~126 nuclei of +/- 1 MeV

Mumpower et al. (in prep)

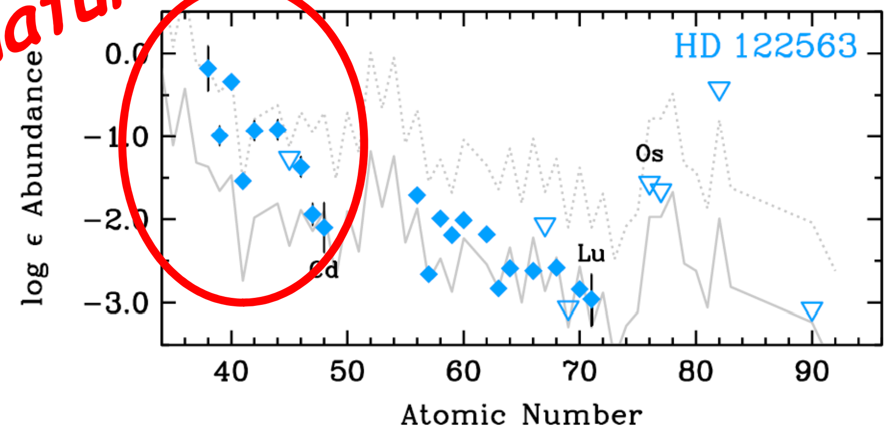
UMP giants stars provide crucial constraints to the stellar nucleosynthesis.

Its elemental abundances are consistent with the solar r-process elemental distribution.





Signatures of a N = 56 subshell via β-decay

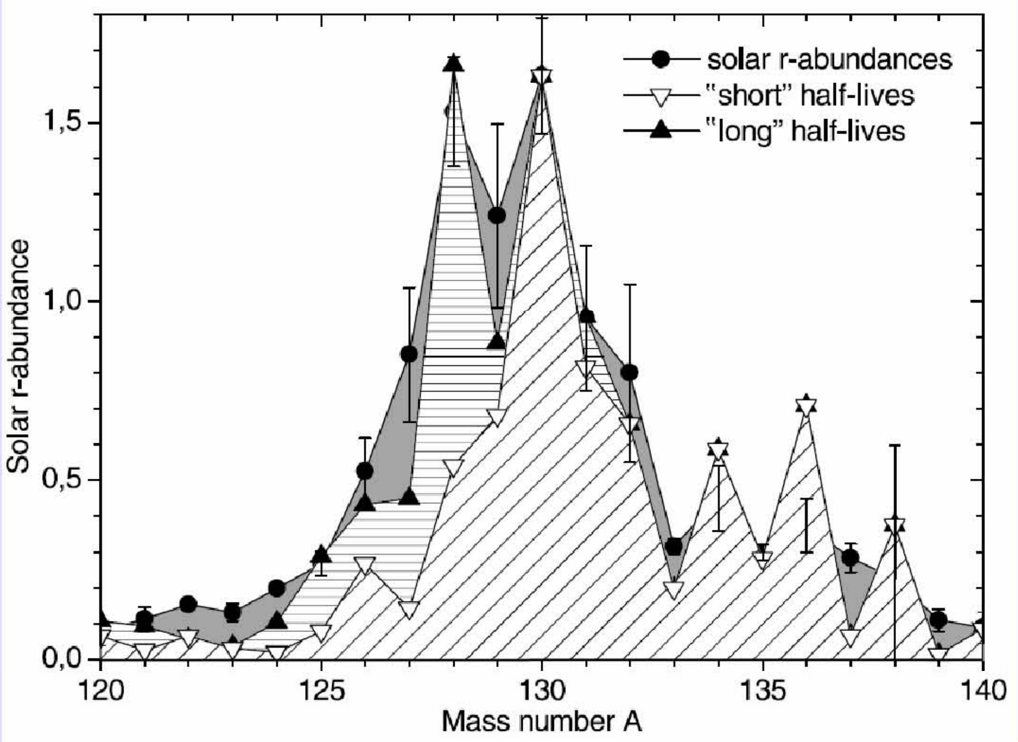


Overproduction of stable Sr, Y, and Zr isotopes in some UMP, compared to the SS r-process pattern.

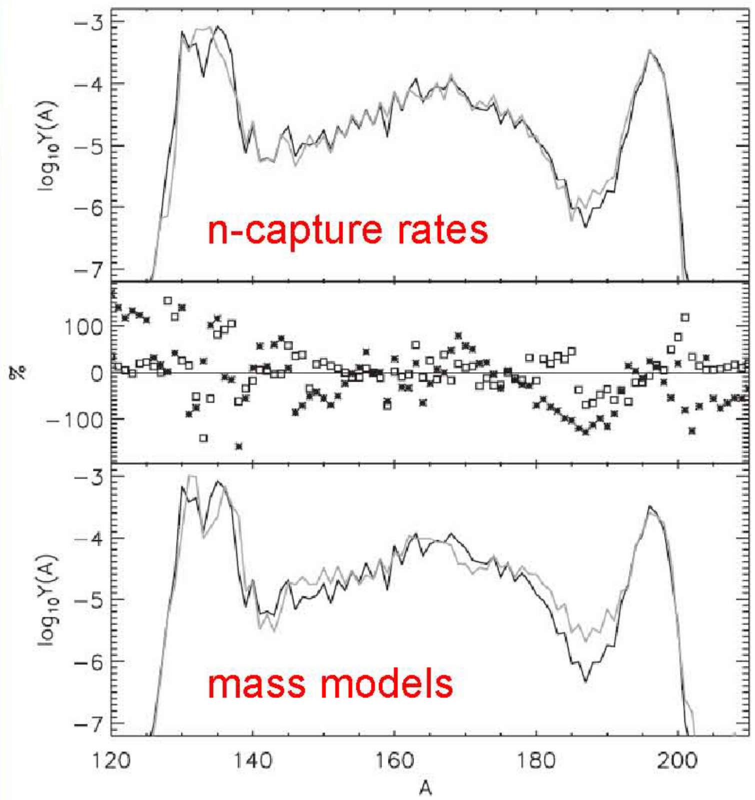
LOI ORNL (USA) r-process sensitivities

Sensitivities to global structure, and to individual n-capture rates

Adjustment of TBME to reproduce 1+ state in ^{130}In



I. Dillman *et al.*, *Phys. Rev. Lett.* **91**, 162503 (2003)



Z										
52	^{130}Te	^{131}Te	^{132}Te	^{133}Te	^{134}Te	^{135}Te	^{136}Te	^{137}Te	^{138}Te	^{139}Te
51	^{129}Sb	^{130}Sb	^{131}Sb	^{132}Sb	^{133}Sb	^{134}Sb	^{135}Sb	^{136}Sb	^{137}Sb	^{138}Sb
50	^{128}Sn	^{129}Sn	^{130}Sn	^{131}Sn	^{132}Sn	^{133}Sn	^{134}Sn	^{135}Sn	^{136}Sn	^{137}Sn
49	^{127}In	^{128}In	^{129}In	^{130}In	^{131}In	^{132}In	^{133}In	^{134}In	^{135}In	^{136}In
						^{131}Cd	^{132}Cd	^{133}Cd	^{134}Cd	^{135}Cd
N						83	84	85	86	87

R. Surman, J. Beun, G.

Ph

Transfer reactions to constrain Capture cross sections

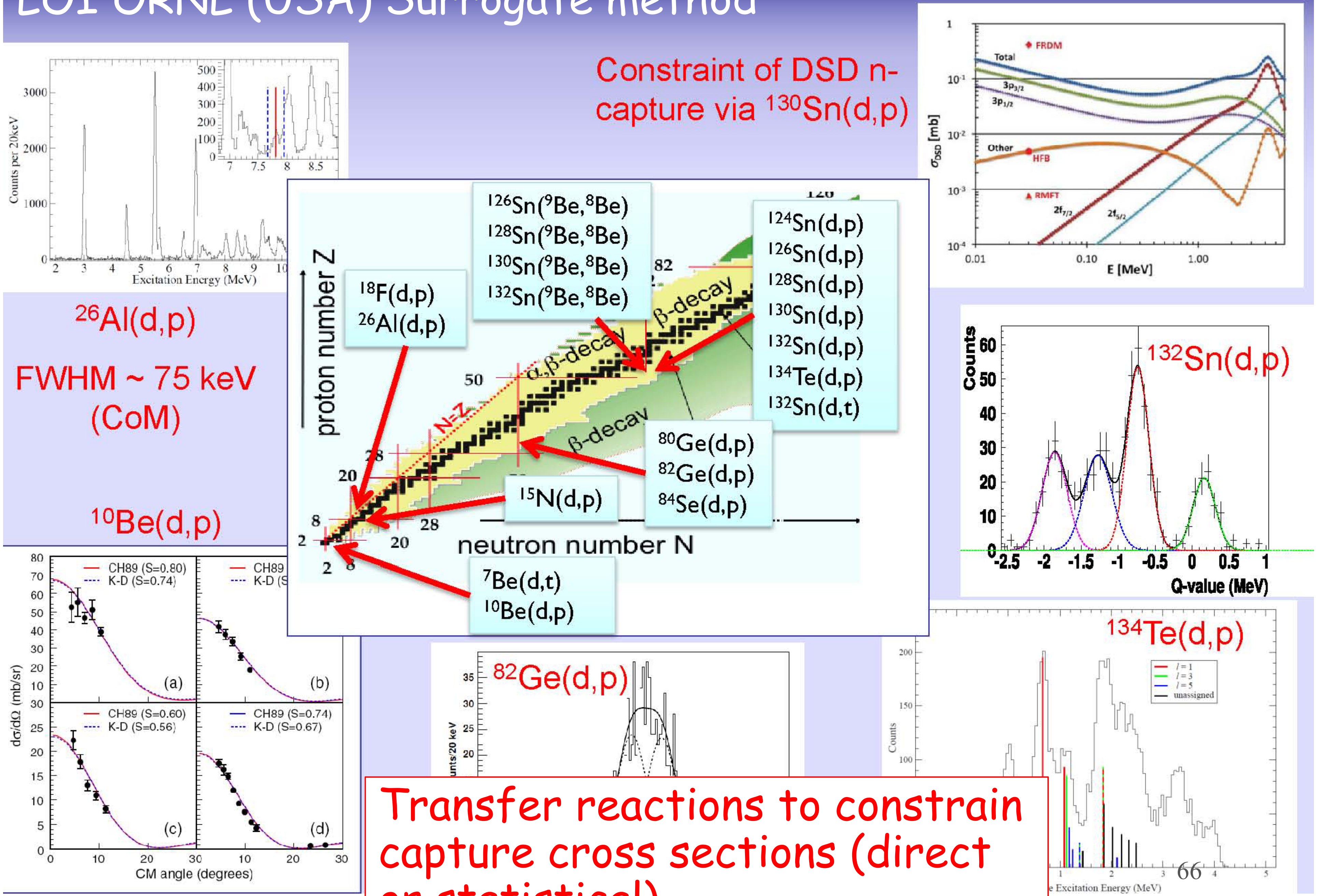
LOI ORNL (USA) Surrogate method

Constraint of DSD n-capture via ^{130}Sn(d,p)

^{26}Al(d,p)

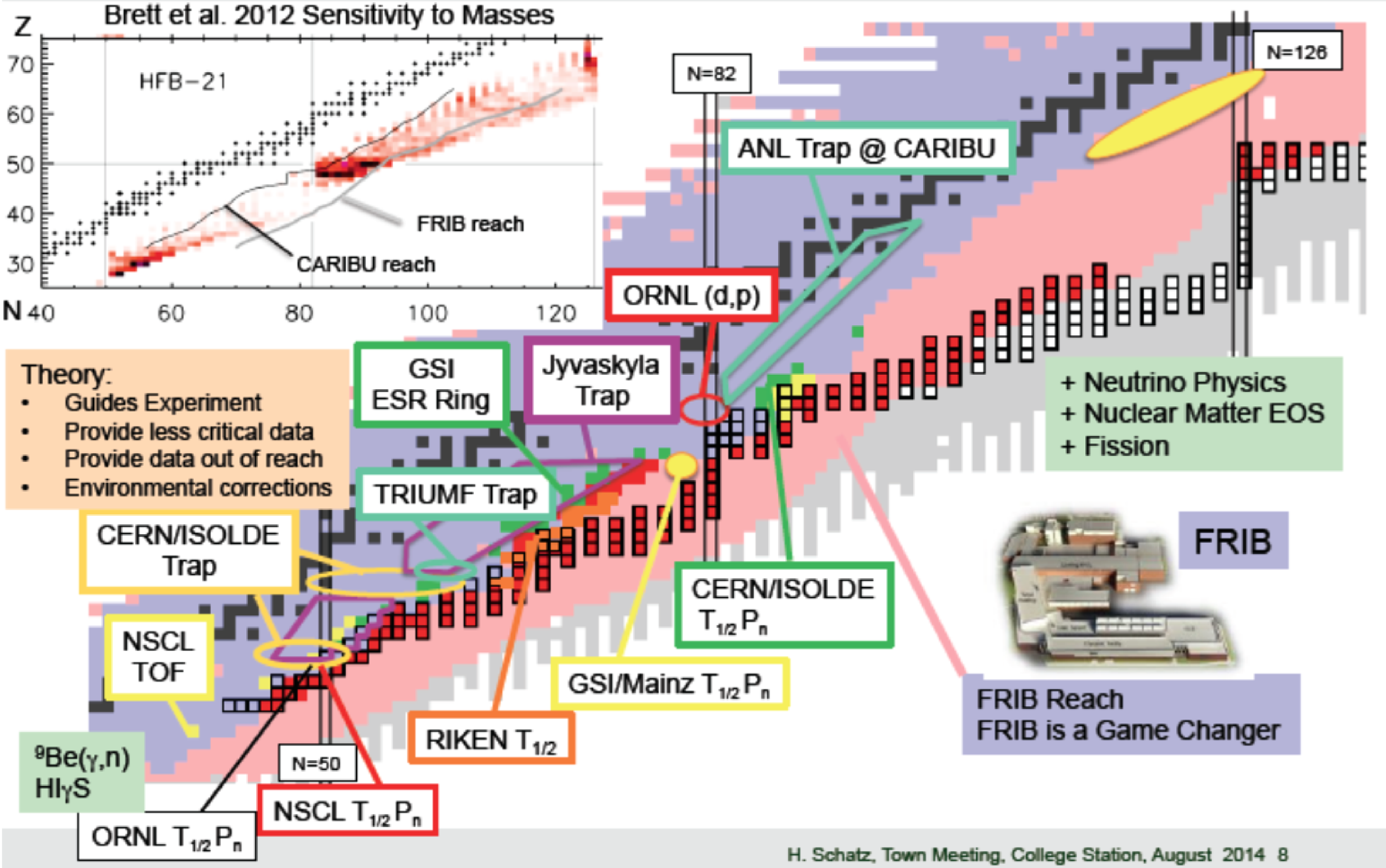
FWHM ~ 75 keV (CoM)

^{10}Be(d,p)

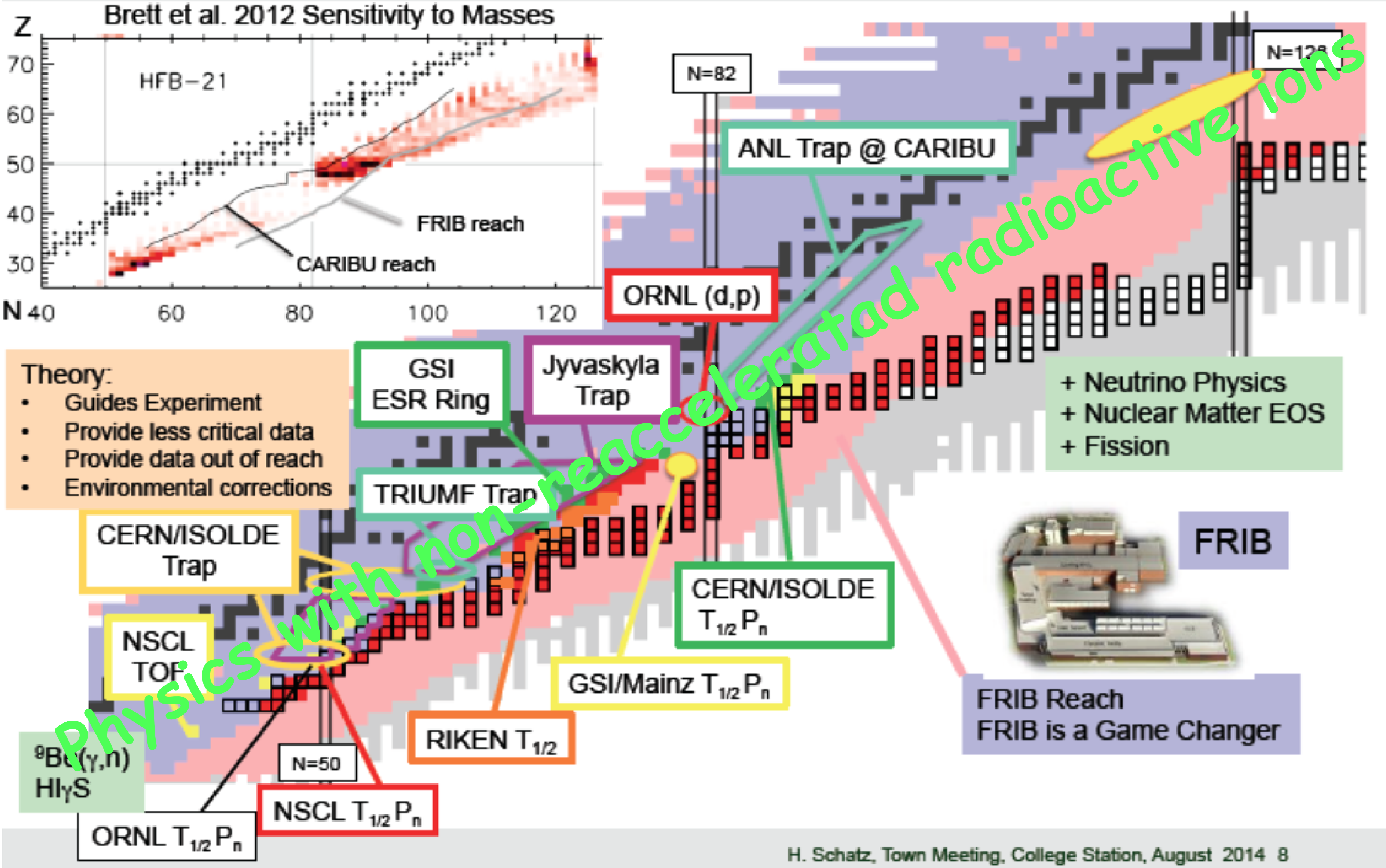


Transfer reactions to constrain capture cross sections (direct or statistical)

The Quest for r-process Nuclear Physics



The Quest for r-process Nuclear Physics



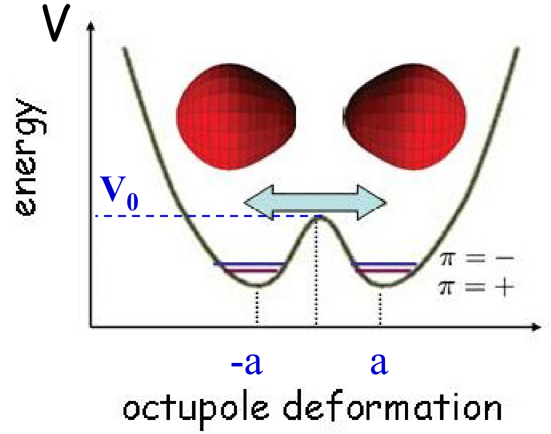
Fundamental Symmetries

ONE OF THE CHALLENGES: REFLECTION ASYMMETRIC NUCLEI AND STATIC ELECTRIC DIPOLE MOMENT

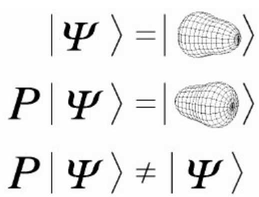
The lopsided nuclei, described today (May 8) in the journal Nature, *could be good candidates for researchers looking for new types of physics beyond the reigning explanation for the bits of matter that make up the universe* (called the Standard Model), said study author Peter Butler, a physicist at the University of Liverpool in the United Kingdom.

The findings could help scientists search for physics beyond the Standard model, said Witold Nazarewicz. *An electric dipole moment would provide a way to test extension theories to the Standard Model, such as supersymmetry, which could help explain why there is more matter than antimatter in the universe.*

The double oscillator

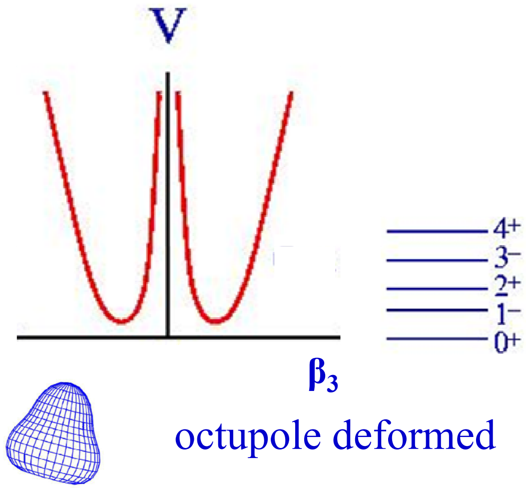


$$H\cdot\psi = -\frac{\hbar^2}{2\cdot B}\frac{\partial^2\psi}{\partial\beta_3^2} + \frac{V_0}{a^2}\cdot\left(|\beta_3| - a\right)^2\cdot\psi = E\cdot\psi$$

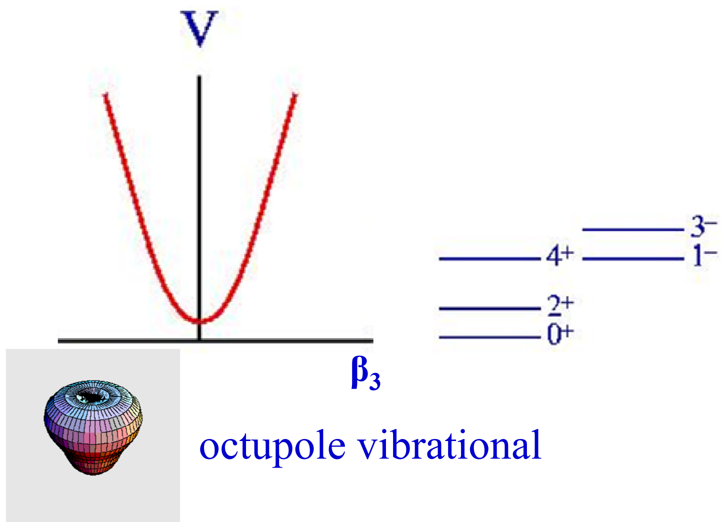


$$E_{even} = \hbar\omega\cdot\left(\nu_{even} + \frac{1}{2}\right) = \hbar\omega\cdot\left(\frac{1}{2} - \sqrt{\frac{2\cdot V_0}{\hbar\omega\cdot\pi}}\cdot e^{-\frac{2V_0}{\hbar\omega}}\right)$$

$$E_{odd} = \hbar\omega\cdot\left(\nu_{odd} + \frac{1}{2}\right) = \hbar\omega\cdot\left(\frac{1}{2} + \sqrt{\frac{2\cdot V_0}{\hbar\omega\cdot\pi}}\cdot e^{-\frac{2V_0}{\hbar\omega}}\right)$$



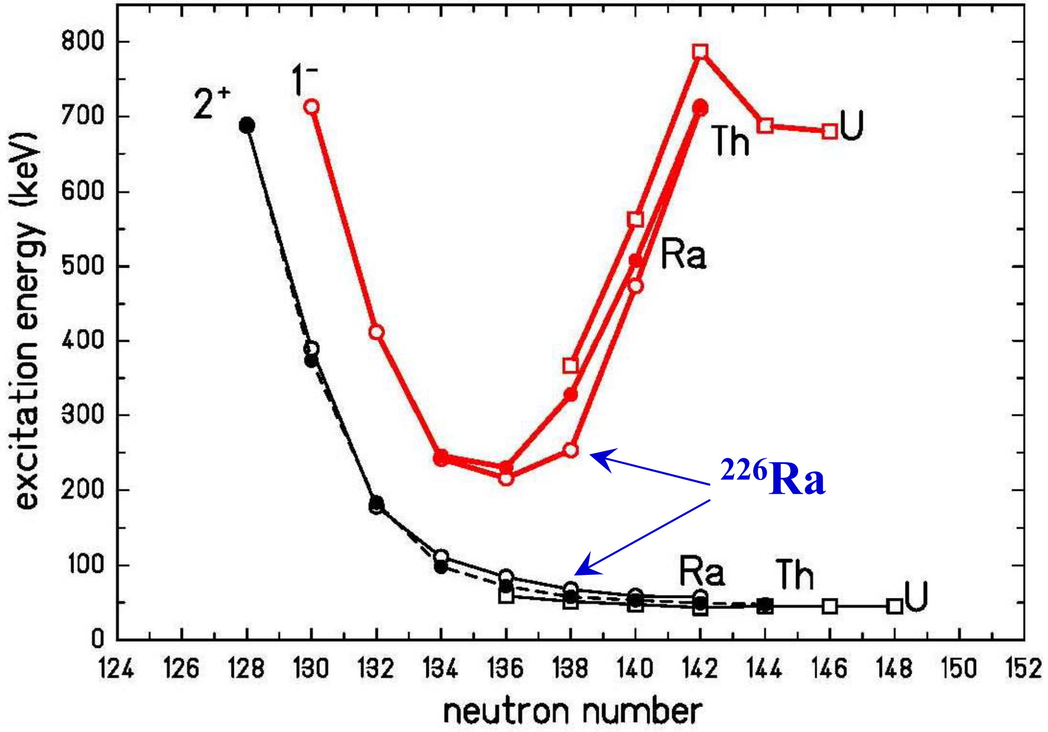
octupole deformed

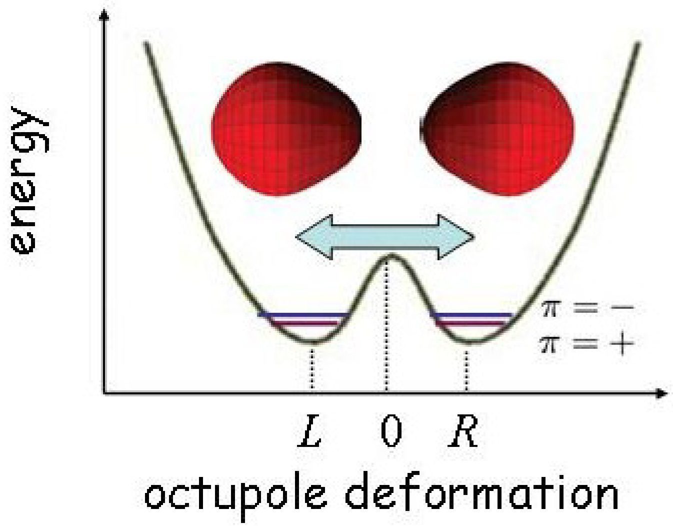


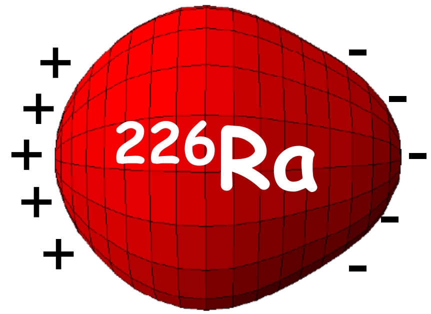
octupole vibrational

Merzbacher 'Quantum Mechanics'

Octupole collectivity







In an **octupole** deformed nucleus the center of mass and center of charge tend to separate, creating a non-zero **electric dipole moment**.

ONE OF THE CHALLENGES: REFLECTION ASYMMETRIC NUCLEI AND STATIC ELECTRIC DIPOLE MOMENT

V Spevak, N Auerbach, and VV Flambaum
PR C **56** (1997) 1357

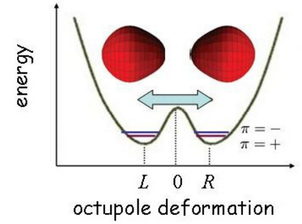
related to Q_3

P,T-violating n-n interaction

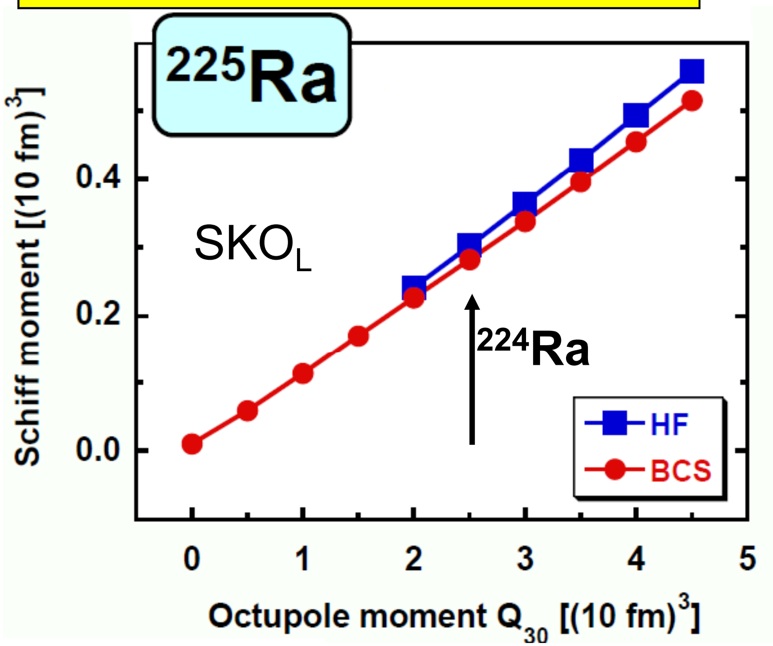
Schiff moment:

$$S = -2\frac{J}{J+1}\frac{<\hat{S}_z><\hat{V}_{PT}>}{\Delta E}$$

energy splitting of parity doublet

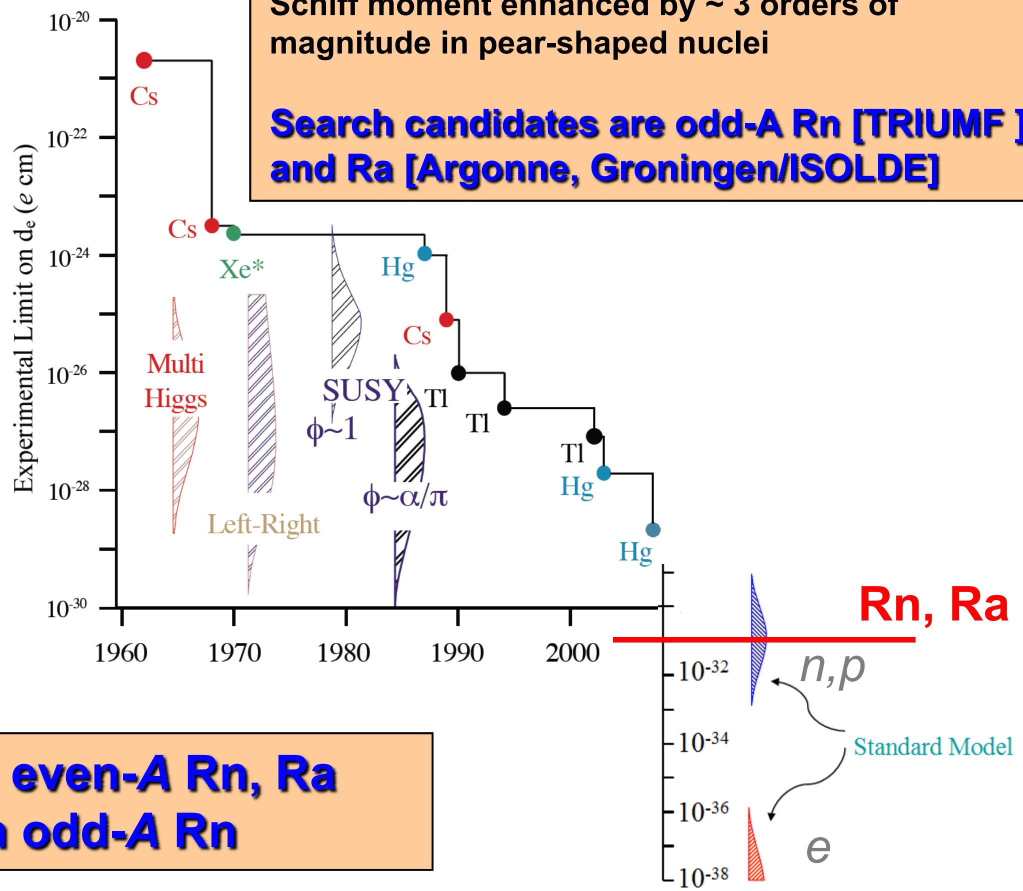


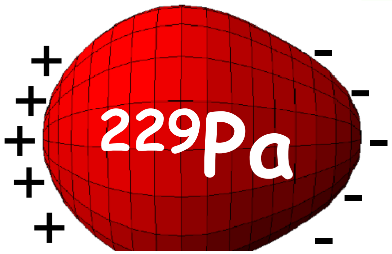
J Dobaczewski (Trento, 2010)



Schiff moment enhanced by ~ 3 orders of magnitude in pear-shaped nuclei

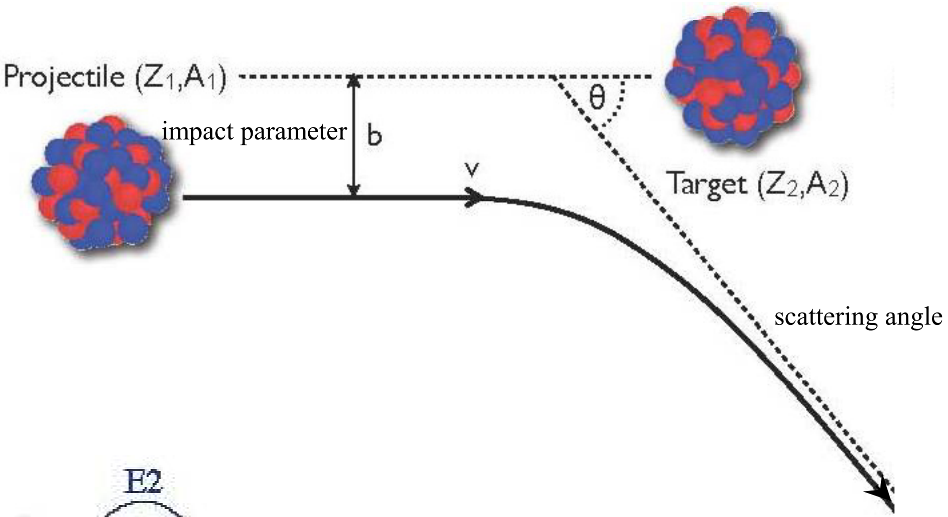
Search candidates are odd-A Rn [TRIUMF] and Ra [Argonne, Groningen/ISOLDE]

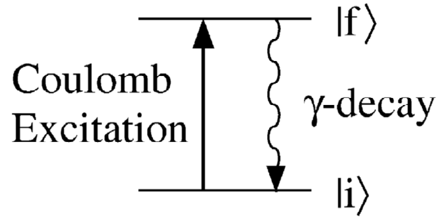




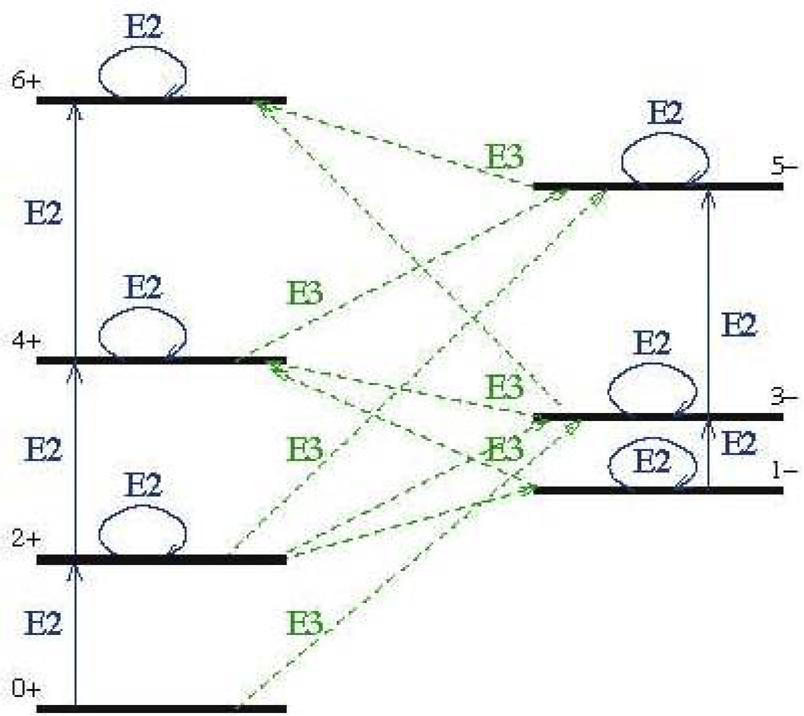
Measure: Q_3 in even-*A* Rn, Ra
ΔE in odd-*A* Rn

Coulomb excitation





$$\frac{d\sigma_{i\to f}}{d\Omega_{cm}} = P_{i\to f}\cdot\frac{d\sigma_{Ruth}}{d\Omega_{cm}}$$



$$d\sigma_{E2} \cong 4.819\cdot\left(1+\frac{A_1}{A_2}\right)^{-2}\cdot\frac{A_1}{Z_2^2}\cdot E_{MeV}\cdot B(E2;I_i\to I_f)\cdot df_{E2}(\eta,\xi)\ [b]$$

Goal: Octupole deformation in ^{229}Pa

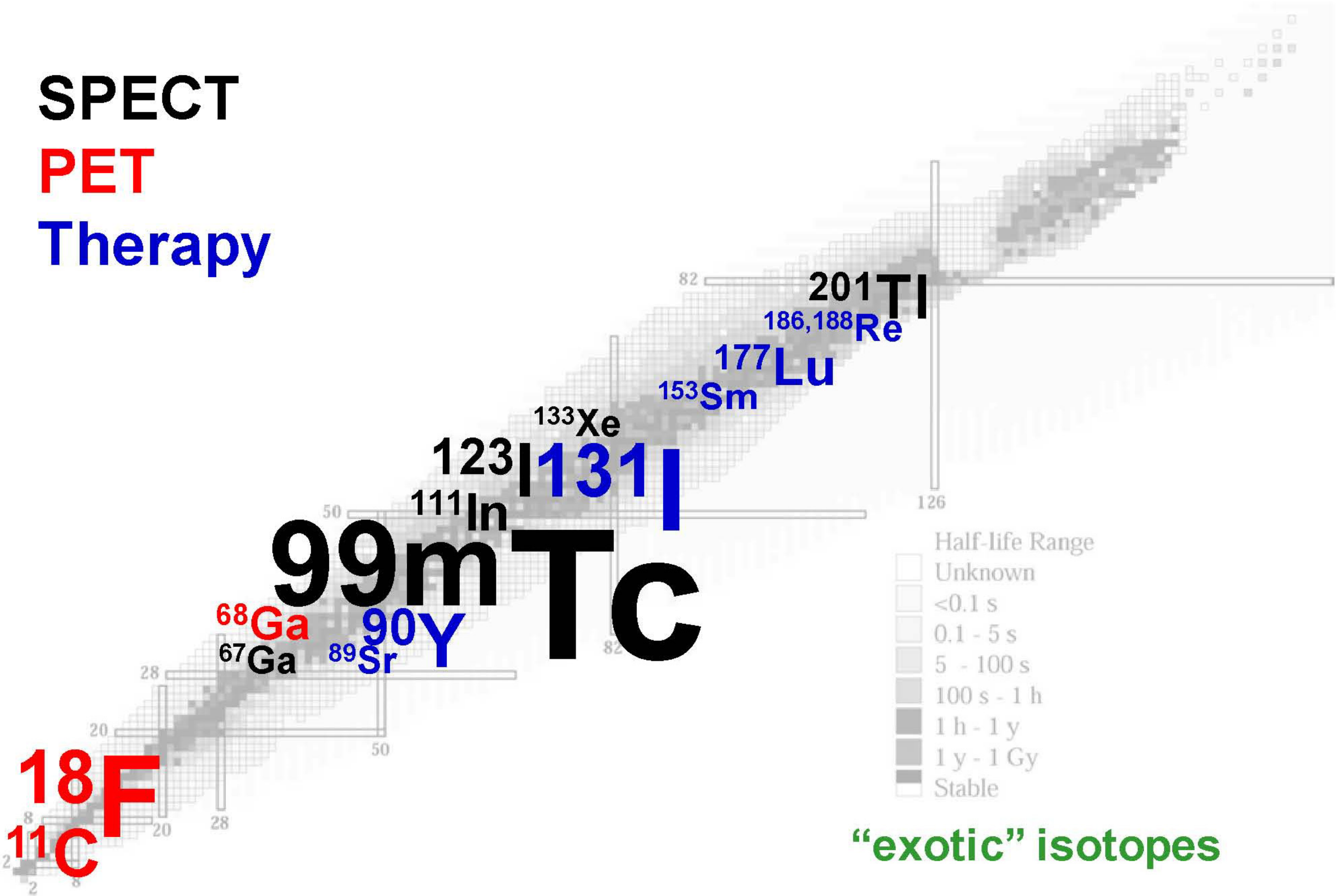
^{229}Pa by 232Thh(p,4n) reaction
Octupole strength measured via Coulex

Application of Isotopic Beams

ONE OF THE CHALLENGES: RADIONUCLEI FOR MEDICINE

The chart of nuclides – nuclear medicine perspective

SPECT
PET
Therapy



"exotic" isotopes

http://www.noaanews.noaa.gov

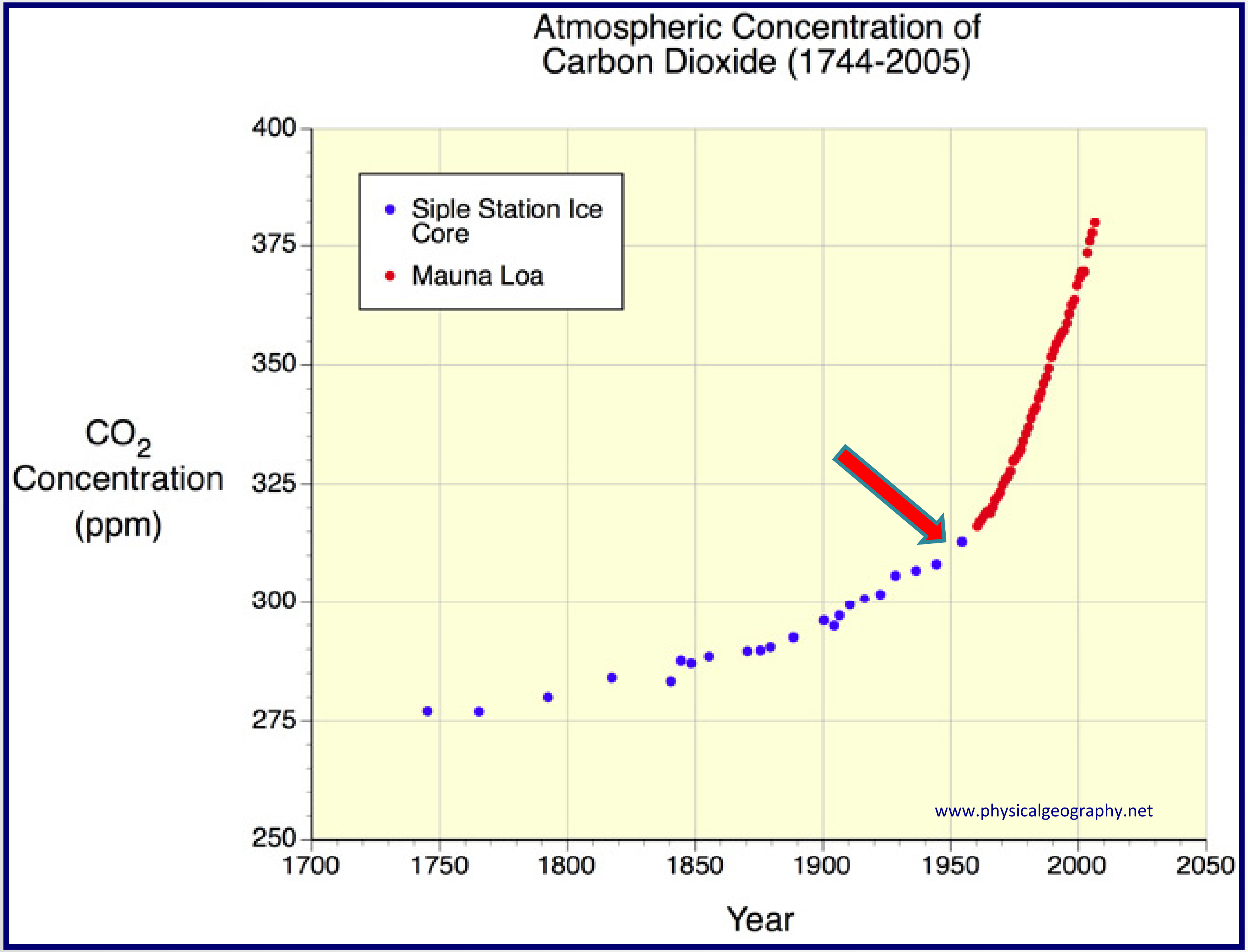
Ocean Acidification

Will the reef survive?

The burning of fossil fuels releases

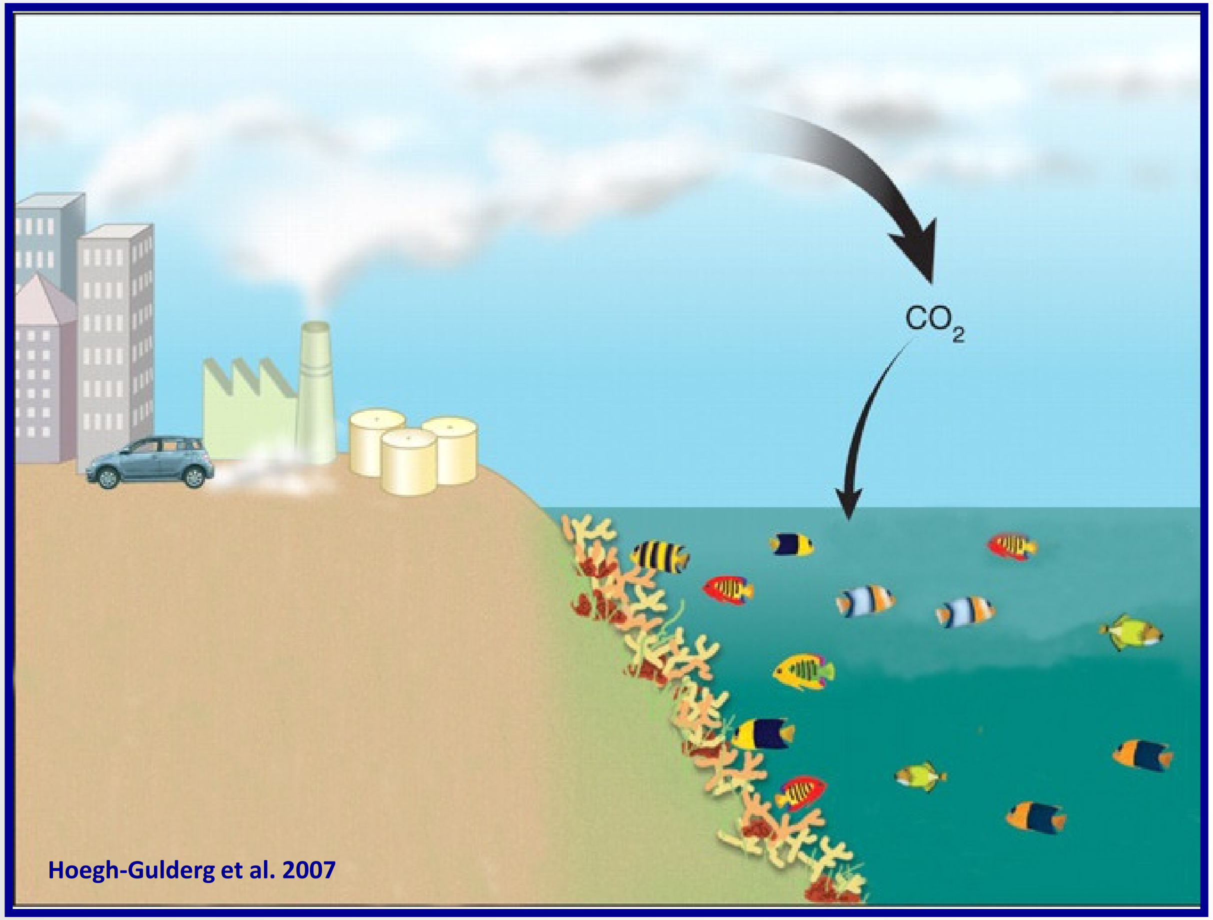
11 BILLION TONS

of carbon dioxide into the atmosphere every year.



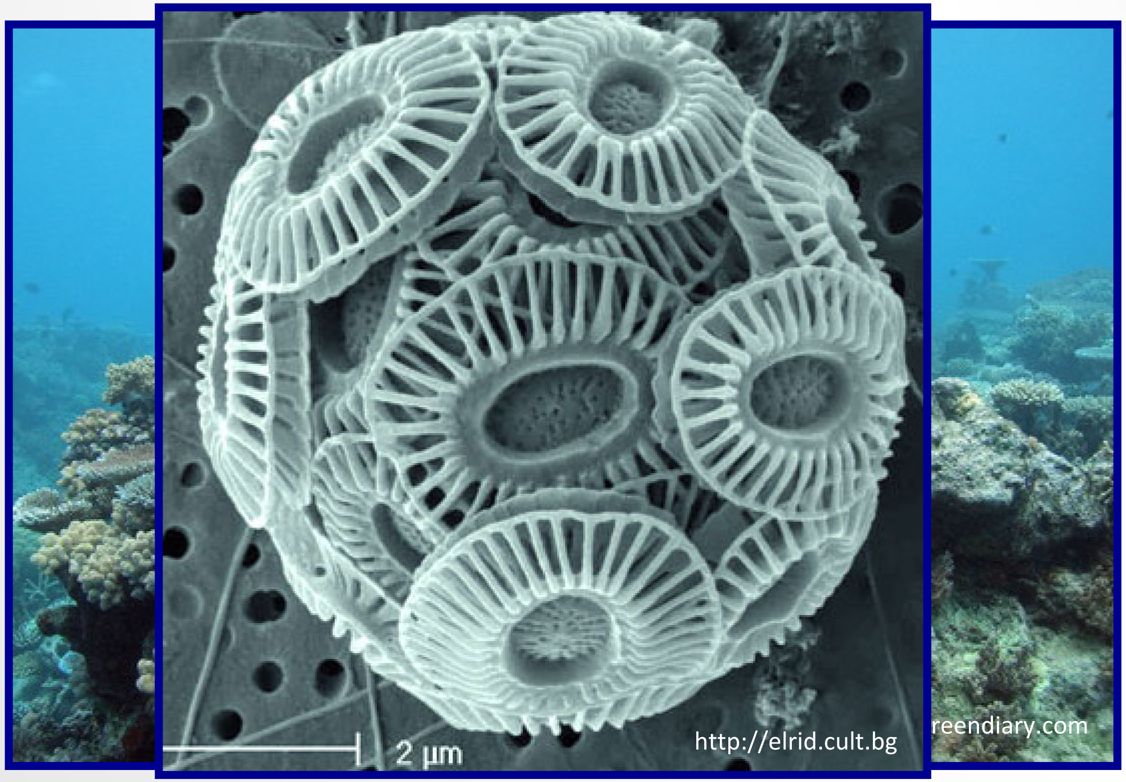
Atmospheric Concentration of
Carbon Dioxide (1744-2005)
CO_2 Concentration (ppm)
400
375
350
325
300
275
250
Siple Station Ice Core
Mauna Loa
www.physicalgeography.net
1700
1750
1800
1850
1900
1950
2000
2050
Year

Carbon dioxide dissolves in the ocean, where it causes a potentially more serious problem → ocean acidification.



Hoegh-Gulderg et al. 2007

Ocean acidification poses a threat to shell-forming organisms like corals and calcifying plankton.



Ocean acidification - numbers

- Ocean/atmosphere exchanges of CO_2 are very important
- Net uptake by oceans of 25-30% of man-made CO_2 emissions: ***24 million tons*** CO_2 per day!
- Key defence (buffer) against global warming, but drawback: causing an increase in acidity (decrease in pH).
- Acidity of the oceans has increased by ***30%*** since the onset of the industrial revolution.
- If CO_2 emissions continue at the current rate, acidity will increase by ***150%*** by 2100 (highest acidity experienced by marine ecosystems since at least ***800 000 years***).
- The current rate of pH change is unprecedented for ***300 millions years***.

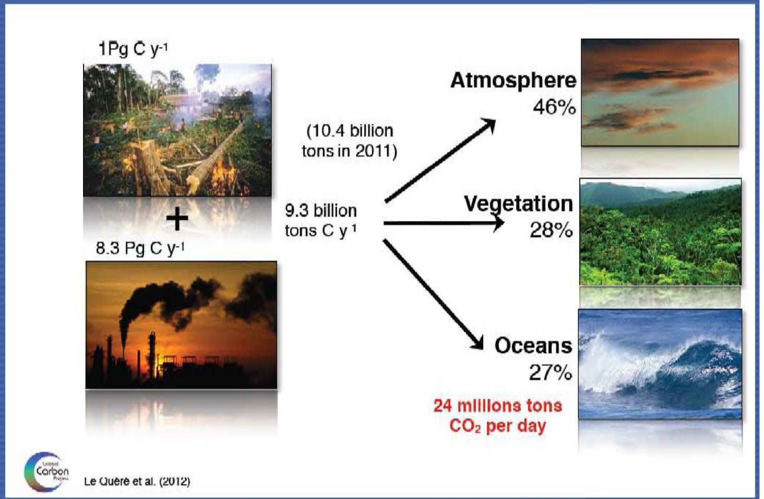


*Image courtesy of **J.-P. Gattuso***

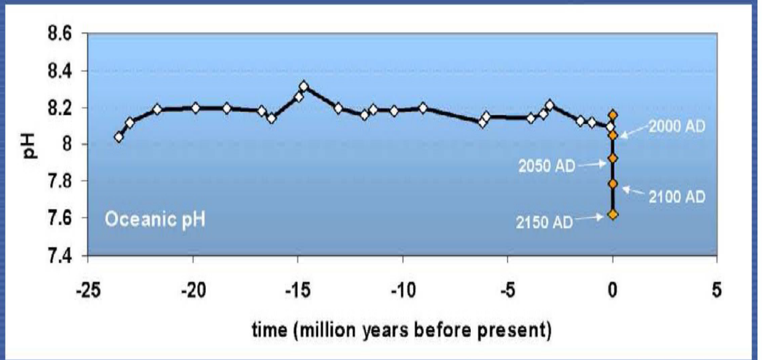


*Image courtesy of **C. Turley***

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The pH Scale

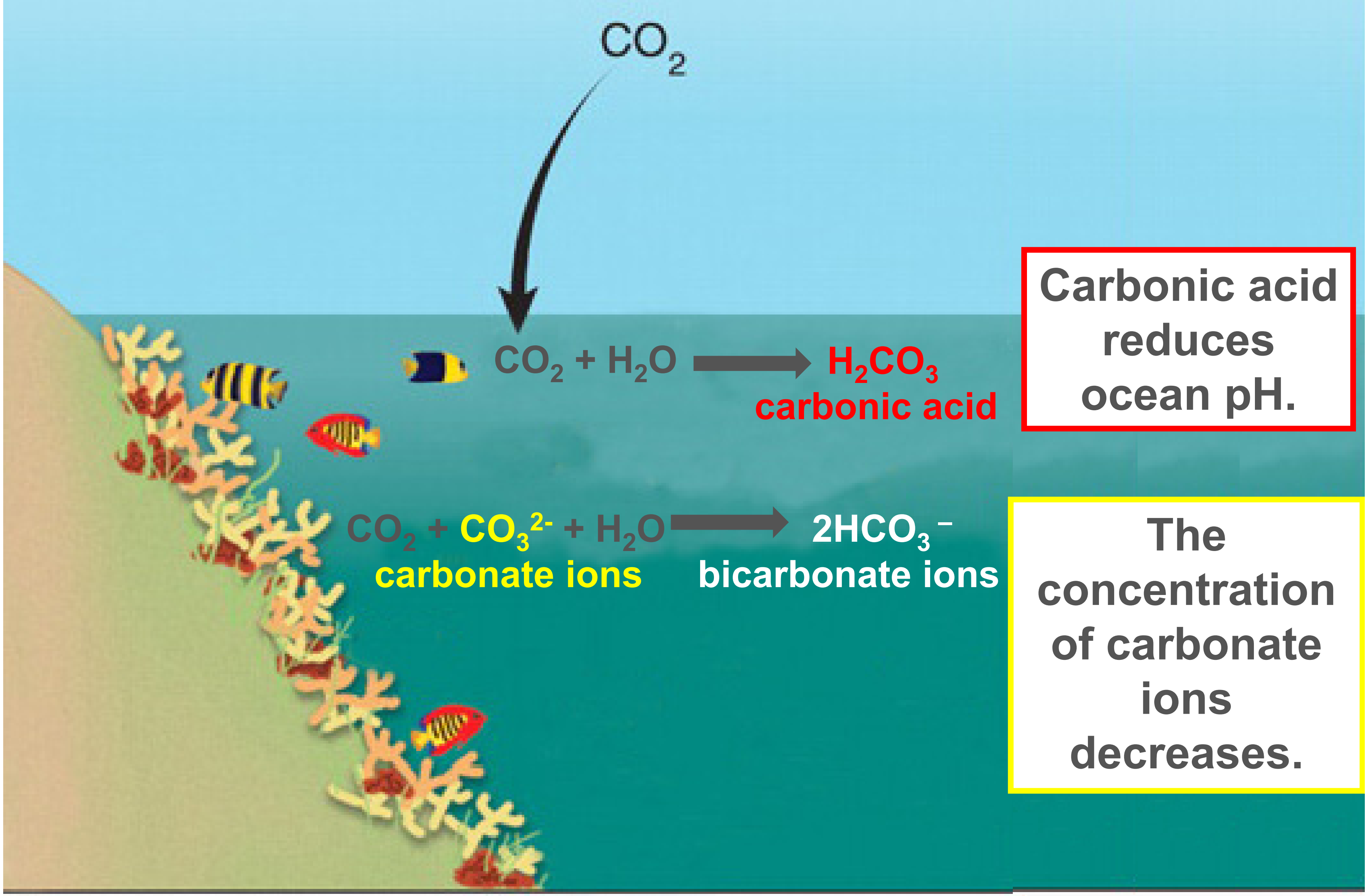
ACIDS

BASES

Concentration of Hydrogen ions compared to distilled water		Examples
10,000,000	pH 0	Battery acid
1,000,000	pH 1	Hydrochloric acid
100,000	pH 2	Lemon juice, vinegar
10,000	pH 3	Grapefruit, soft drink
1,000	pH 4	Tomato juice, acid rain
100	pH 5	Black coffee
10	pH 6	Urine, saliva
1	pH 7	"Pure" water
1/10	pH 8	Sea water
1/100	pH 9	Baking soda,
1/1,000	pH 10	Great Salt Lake
1/10,000	pH 11	Ammonia solution
1/100,000	pH 12	Soapy water
1/1,000,000	pH 13	Bleach
1/10,000,000	pH 14	Liquid drain cleaner

www.thegardenersresource.com

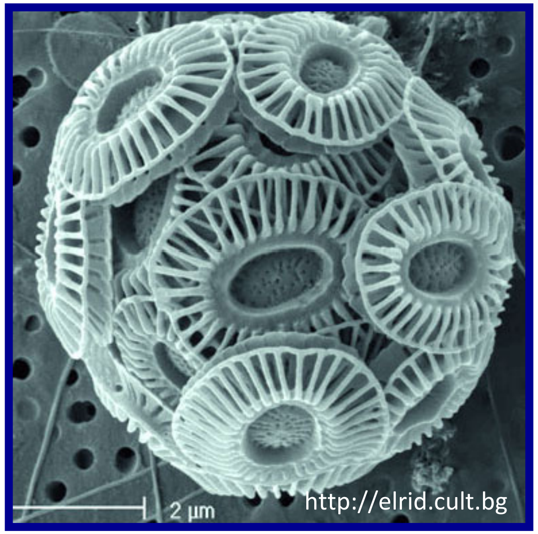
A small change in pH is equal to a LARGE change in acidity.


CO_2
$CO_2 + H_2O$ → H_2CO_3
carbonic acid
Carbonic acid reduces ocean pH.
$CO_2 + CO_3^{2-} + H_2O$ → $2HCO_3^-$
carbonate ions
bicarbonate ions
The concentration of carbonate ions decreases.

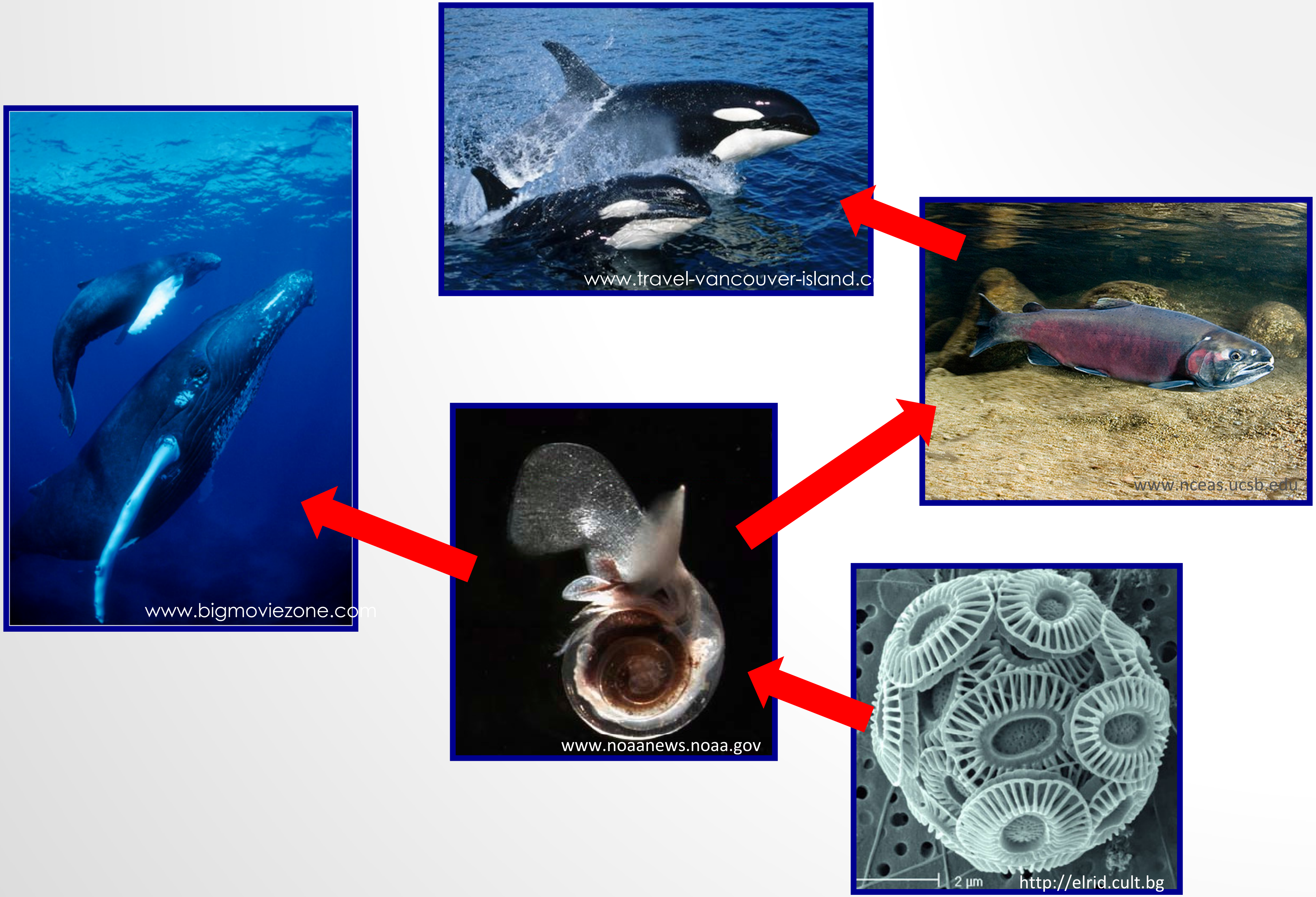
As the ocean acidifies, organisms such as corals, snails, and calcifying plankton will not be able to make their shells and grow.

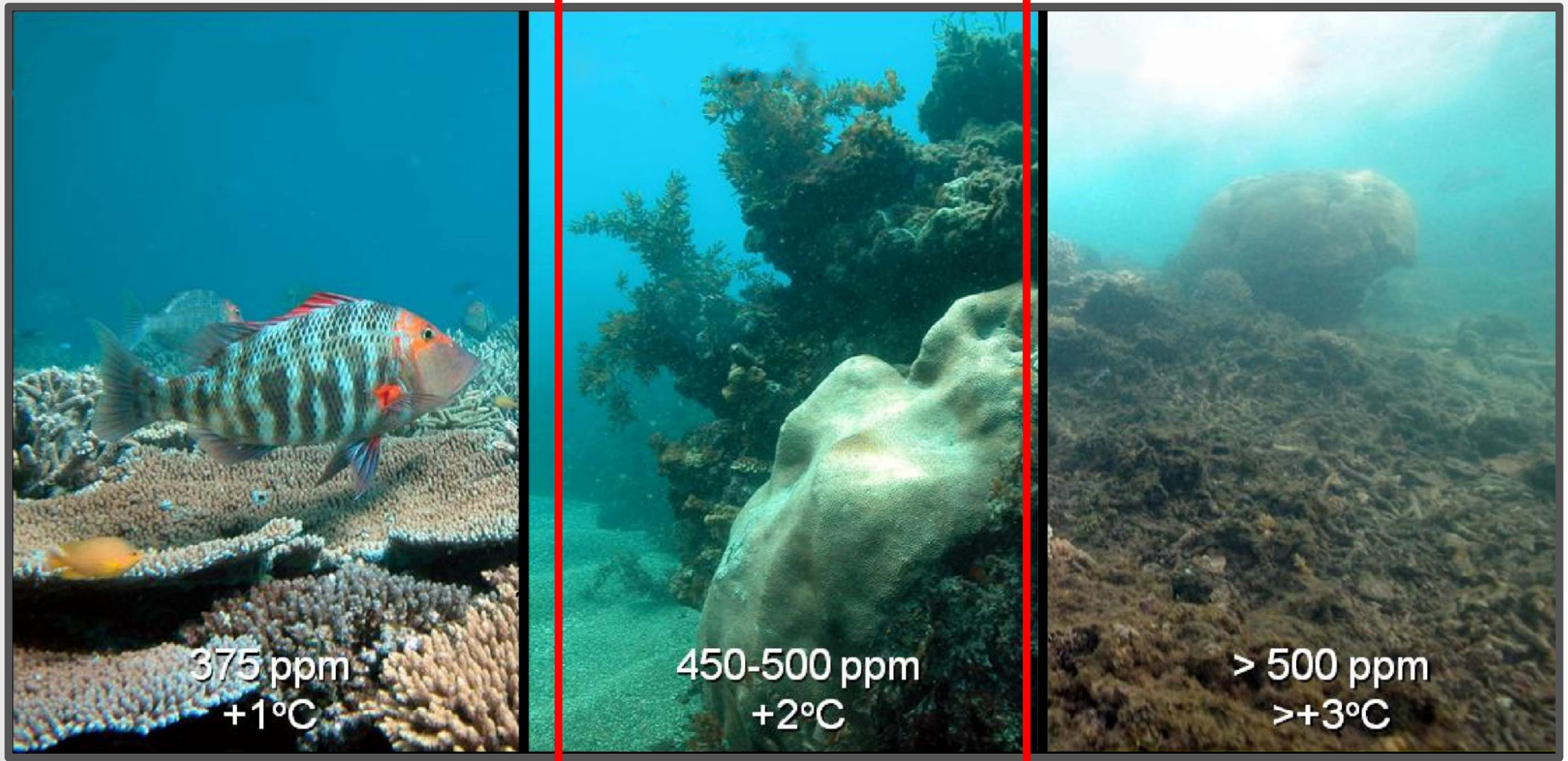
Zooplankton
(Pteropod)

Coral



Phytoplankton
(Coccolithophore)

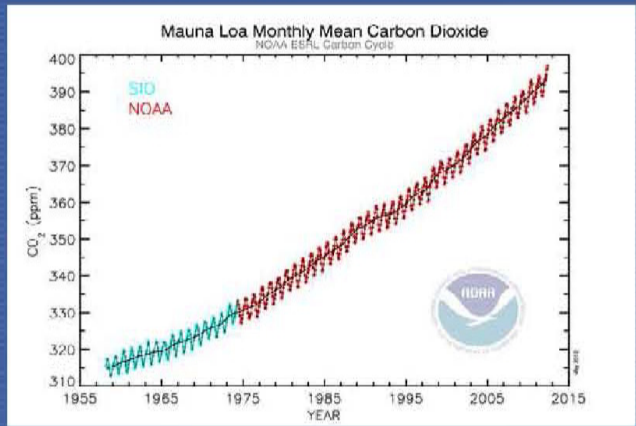

www.travel-vancouver-island.c
www.bigmoviezone.com
www.nceas.ucsb.edu
www.noaanews.noaa.gov
2 µm
http://elrid.cult.bg



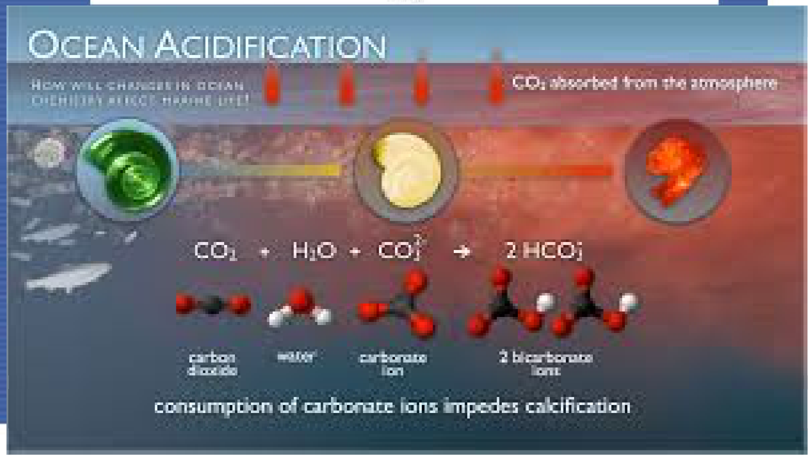
http://www.noaanews.noaa.gov

Ocean acidification

Ocean Acidification is a major, global environmental pressure due to increasing atmospheric CO_2 concentration in surface marine water.



It is predicted to have **major impact** on key marine ecosystems, including on biodiversity, safety and security of seafood resources and ecosystems services, especially in fragile ecosystems such as tropical coral reefs and polar regions.



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Ocean acidification – Nuclear and isotopic applications

Unique tools to assess biological effects under projected pCO_2 scenarios, identify vulnerable organisms, evaluate potential coastal economic impacts (fisheries, aquaculture, ecosystem services), e.g.:

- Use of Ca-45 to assess growth and calcification rates
- Use of C-14 to assess primary production of marine phytoplankton
- Use of radio-tracers to assess change in pollutant availability

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