Karl-Ludwig Kratz

23 April 1941 – 23 March 2025

during a PhD examination in Torino

Karl-Ludwig (or usually called KL) has been a nuclear chemist, who later turned towards nuclear astrophysics.

He studied chemistry at the Johannes Gutenberg University in Mainz, got his doctorate in 1972 under Günter Herrmann at the Institute of Nuclear Chemistry, founded by Fritz Strassmann. The thesis topic was related to the properties of neutron-rich halogen isotopes, using fast and highly selective radiochemical separation processes for very short-lived, neutron-rich nuclei from the fission of ^{235}U, with thermal neutrons, obtained from the Institute's TRIGA MARK/II reactor as a research neutron source.

His specialty became the topic of delayed neutrons: He developed methods to measure the energy of delayed neutrons. Together with spectroscopy of the emitted characteristic gamma radiation the nuclear structure of short-lived fission products could be determined. These data were early on used in reactor technology (in particular, the data on delayed neutrons were important for reactor control).

One of his early achievements was the ***Kratz-Hermann formula for beta-delayed neutron emission probabilities P_n*** (1973). P_n determination were continued with many experiments in Mainz, at OSTIS/ILL Grenoble, CERN/ ISOLDE, GANIL ....

On his boat at the Lake Constance

The "Kratz-Herrmann Formula"

$$P_n = a[(Q_\beta - B_n)/(Q_\beta - C)]^b$$

$$T_{1/2} = c[1/(Q_\beta - C)]^d$$

Another Topic: Neutron activation analysis

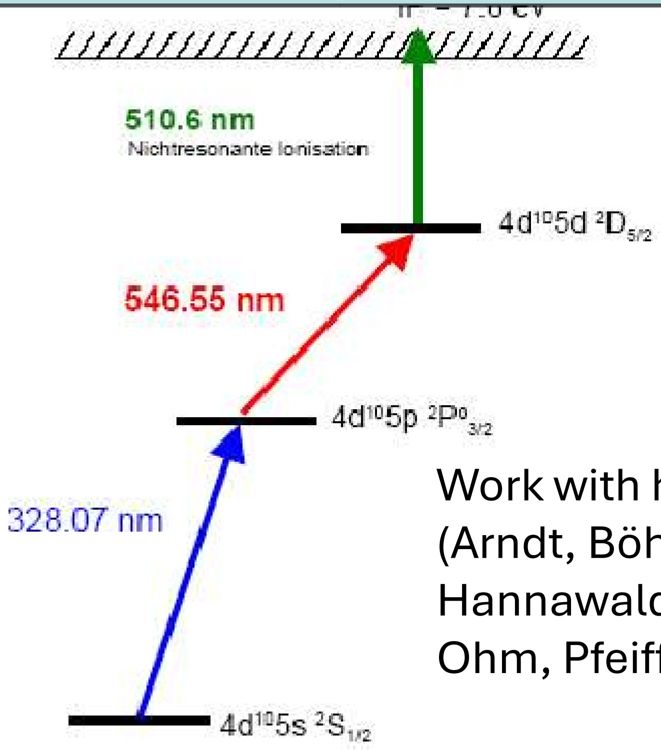
Knowing the characteristic gamma radiation of excited states in neutron-rich nuclei also made it possible to determine the content of (trace) elements in samples using neutron activation analysis. He and his research group extended this work to open challenges in environmental and geochemical studies, including the dispersion behavior of metals such as uranium in former mining areas. The same technique was also used to analyze samples for the incorporation monitoring of employees at nuclear facilities.

Although we know KL from astrophysics, his most cited publication has actually a chemical background: Hirsch et al. 1999, in Science of the Environment, Occurrence of Antibiotics in the aquatic environment (1067 citations).

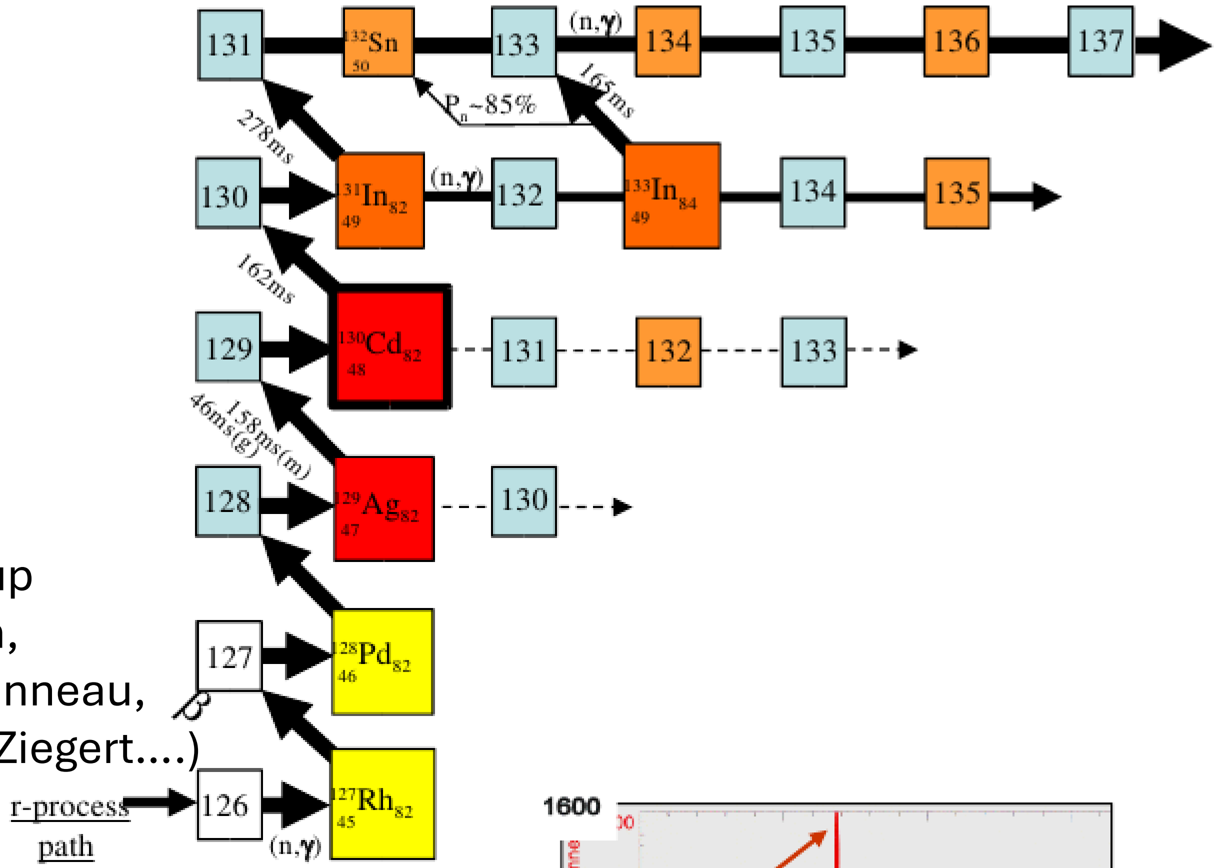
The turn to astrophysics

In 1982 a workshop in Burr Oak (Ohio) was attended by Claus Rolfs, Wolfgang Hillebrandt and Karl-Ludwig Kratz, among others. For him it was very impressive how much fun these nuclear astrophysicists seemed to have. A bottle of whisky that Wolfgang Hillebrandt had smuggled into this dry county seemed to have contributed to this.
In 1982, Wolfgang Hillebrandt and Hans-Volker Klapdor received the DPG Physics Prize for their work on the astrophysical r-Process: Hans-Volker Klapdor for his contributions to the theory of half-lives (Tamm-Damkoff calculations) and Wolfgang Hillebrandt for the astrophysical calculations. ***Looking back, one should mention that KL had previously verified Klapdor's theoretical results with measured beta-strength functions. This made him aware how important his research was for astrophysical applications.***
Just during this period of collaborations between KL and Klapdor on beta-strength functions, I started as a young postdoc in Klapdor's group (as a former student of Wolfgang Hillebrandt), after returning from a one-year stay in the US. This way I got to know KL, which started a collaboration and also continued after my return to Garching.

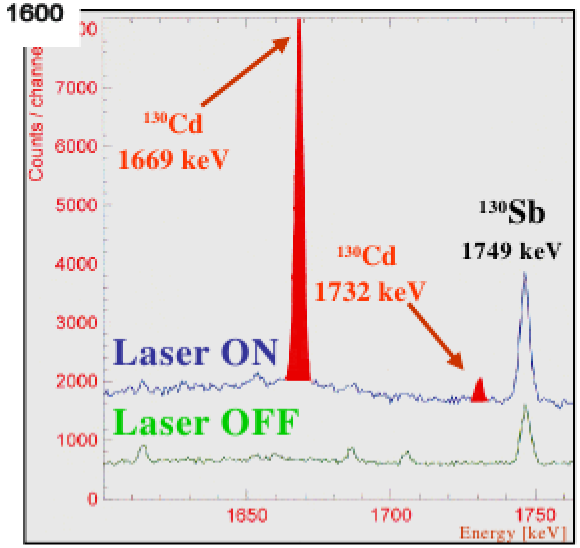
Laser ion-source (RILIS)



Work with his extended group (Arndt, Böhmer, Gabelmann, Hannawald, Harms, Lhersonneau, Ohm, Pfeiffer, Sorlin, Wöhr, Ziegert....)



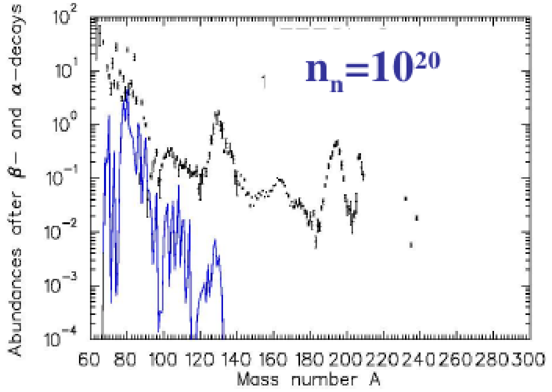
Chemically selective, three-step laser ionisation of Ag into continuum

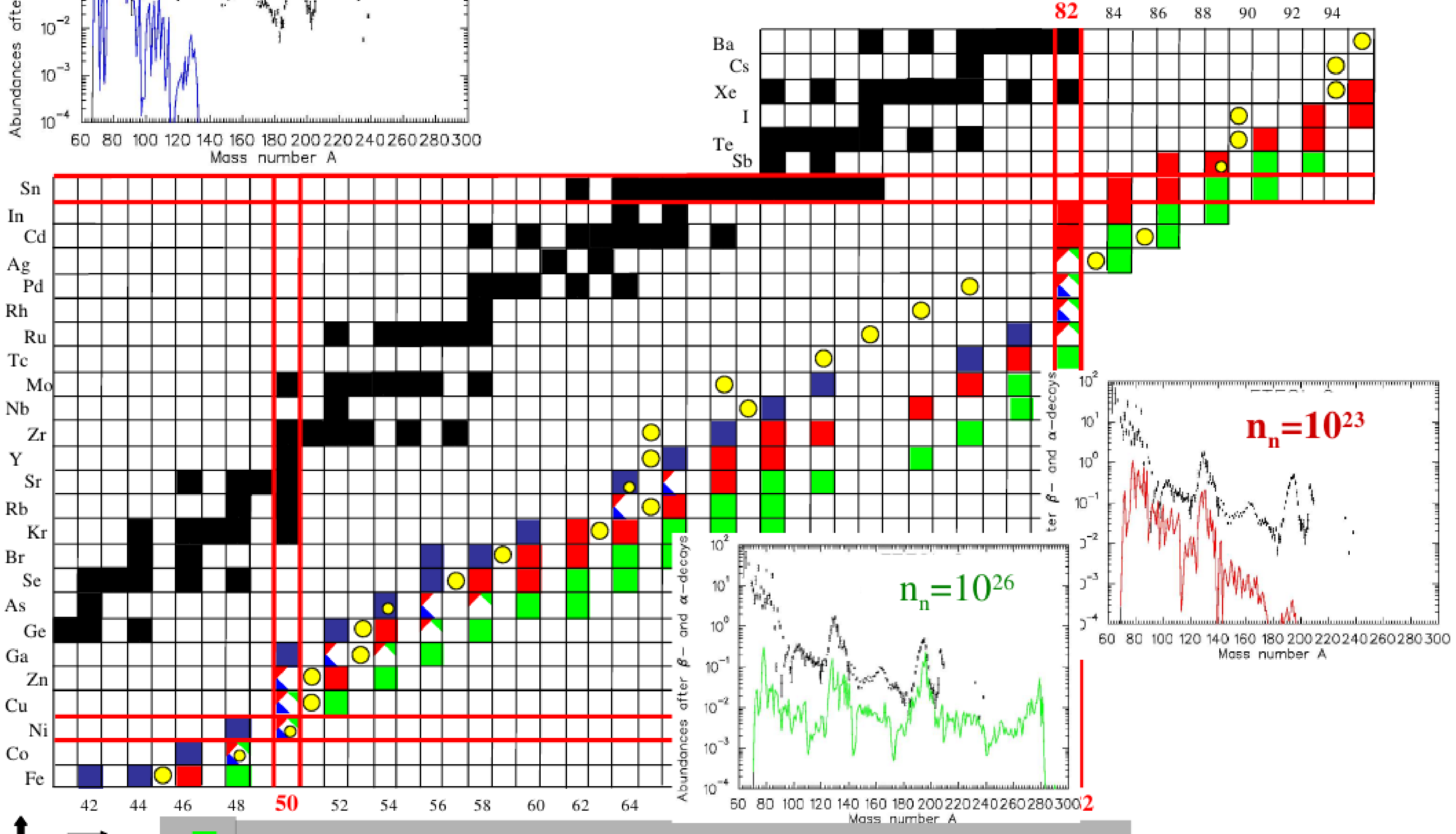


Selective laser ionization of very neutron-rich isotopes in the r-process path, e.g. ***^{130}Cd (measuring the first "waiting point half-life" for N=82!)***, In and Sn isotopes, ^{78}Ni, ^{80}Zn etc.

This very strong experimental program started at CERN/ISOLDE, already in the early 80s, **driven by KL!**

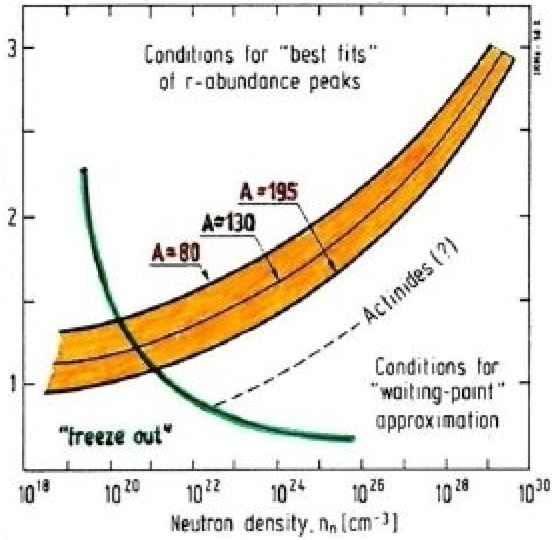
r-Process paths for $n_n=10^{20}$, 10^{23} and 10^{26}



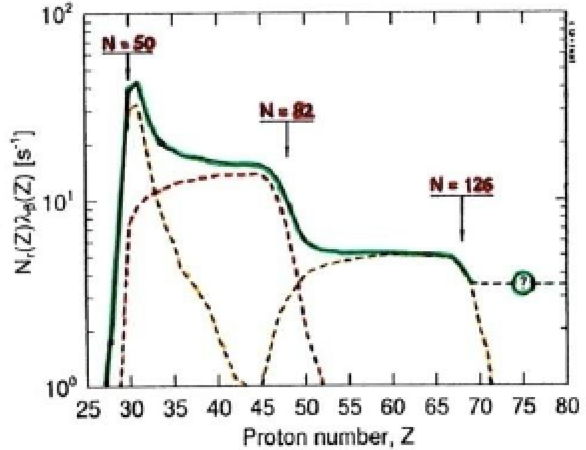


Z N

■ „waiting-point" isotopes at $n_n=10^{26}$ freeze-out
($T_{1/2}$ exp. : $_{28}$Ni, $_{29}$Cu, $_{47}$Ag – $_{50}$Sn)

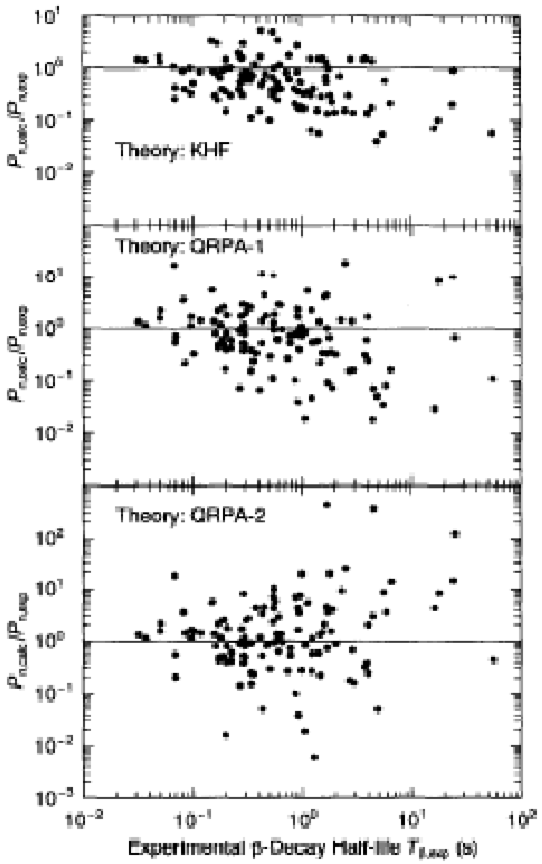


Three conditions lead to a beta-flow equilibrium between magic numbers, and their superposition results in a good overall fit, but what is the astrophysical environment??



In order to obtain a good fit for the overall solar r-process abundances within the traditional n,γ-γ,n equilibrium approach, ***it seemed that three different paths are required***, e.g. Kratz et al. (1983,1988, 1993, 1997), Pfeiffer et al. (1998), Freiburghaus et al. (1999)…

How to perform such calculations with the best nuclear input?

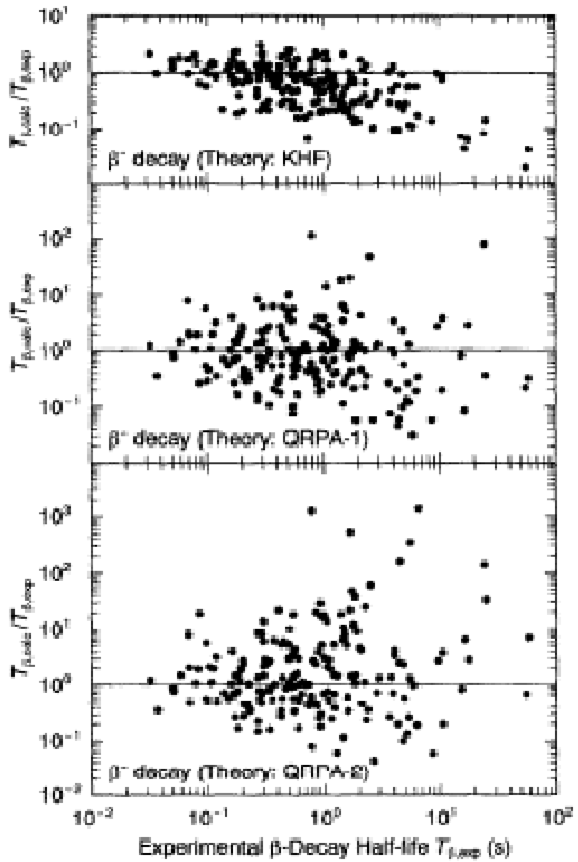


σ_{rms}^2

2.8

4.1

5.6

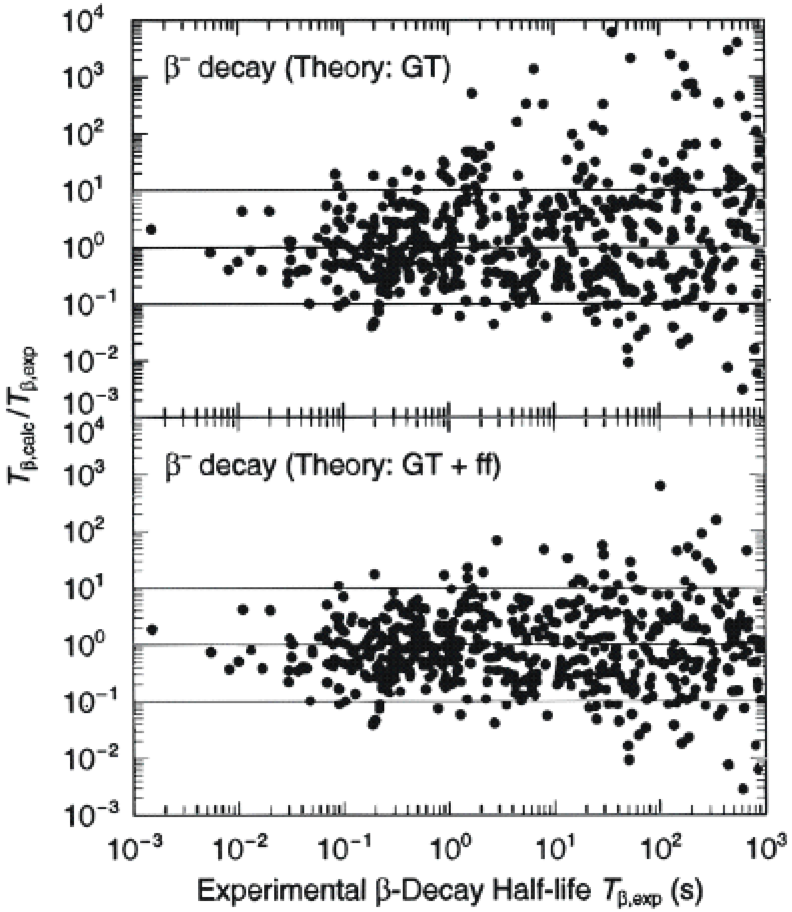


σ_{rms}^2

2.6

3.9

5.8

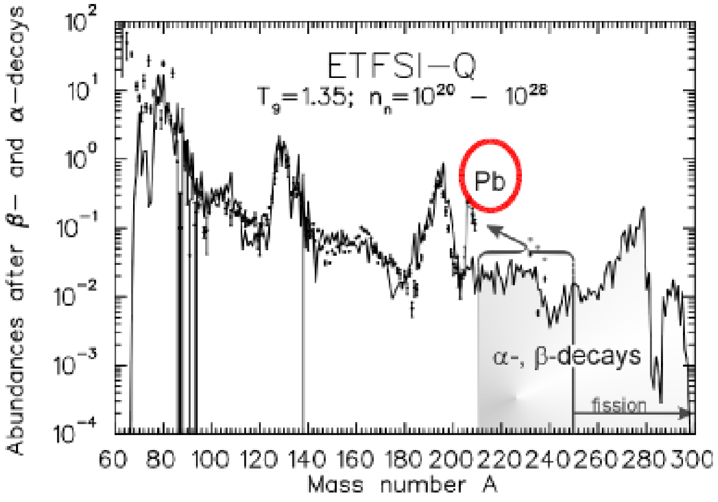


Ratios of calculated to experimental P_n (left) and $T_{1/2}$ (right):
upper part: Kratz - Herrmann **Formula** (KHF)
lower parts: QRPA(GT); Pfeiffer – Kratz – Möller **Model** (MPK)
Initially slightly disappointing results when comparing the old predictions by the Kratz-Herrmann formula with those of Peter Möller's FRDM/QRPA Gamow-Teller calculations

But improvements were obtained when adding first-forbidden transitions!
KL's most cited paper in Nuclear Astrophysics: Möller, Nix, Kratz (1997), 1052 citations, but see also Möller, Pfeiffer, Kratz (1993). ***Special attention to nuclear structure near shell closures and effects in vicinity of r-process peaks (Chen et al. 1995).***

r-Process calculations vs. observations

Reproduce total
isotopic $N_{r,solar}$
distribution
(lsq-fits; A > 80, 120)

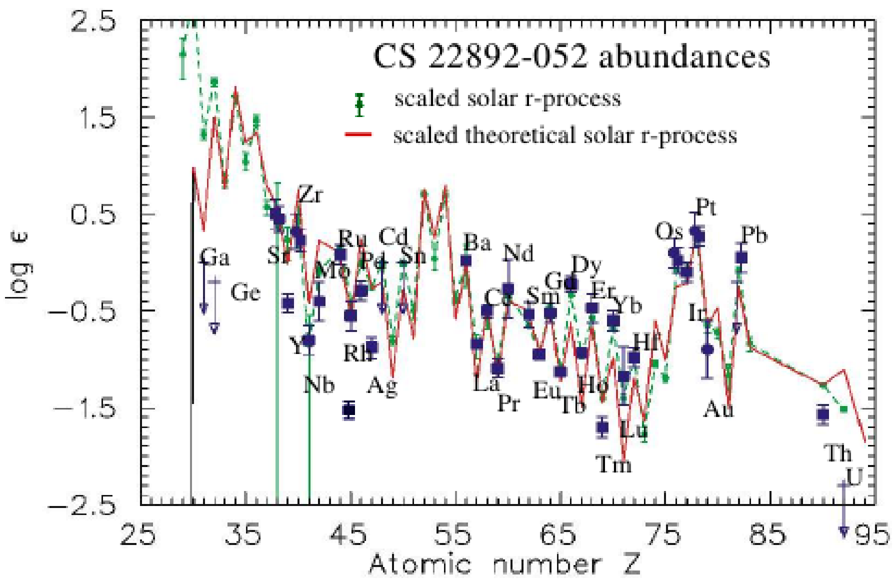


Pb abundances as reliability criterion for Th,U region!

Convert to elemental $N_{r,A}$ curve (—) and scale to halo abundance ( )

Comparison to $N_{r,solar}(Z)$

After predicting overall r-process abundances with an excellent fit, ***the Th/U predictions (in comparison with stellar abundances) can be utilized to determine the time when the star was polluted/born (-> age),*** but be aware of non-solar actinide boost stars!



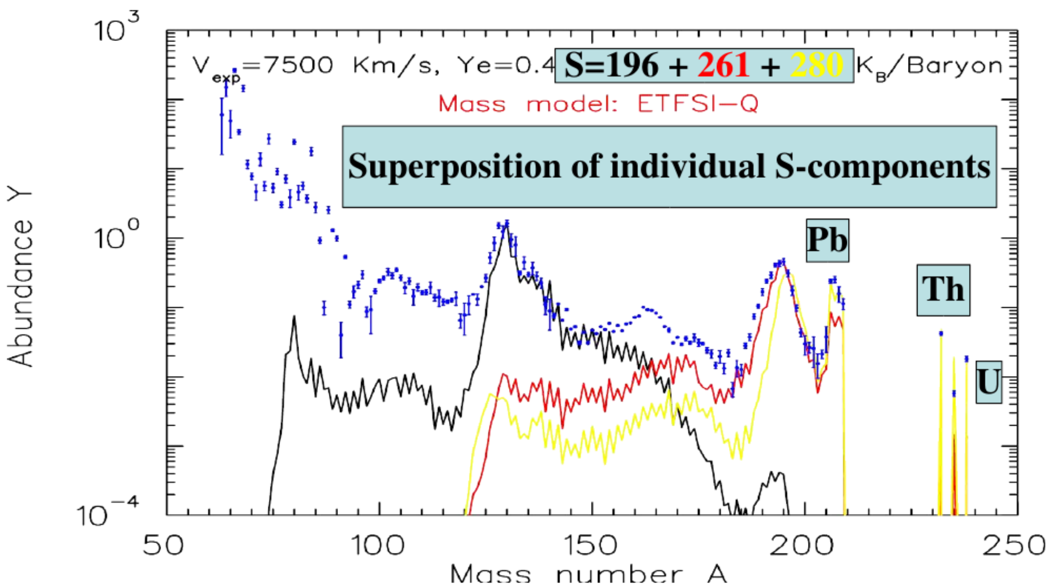
⇒ Excellent agreement above Ba

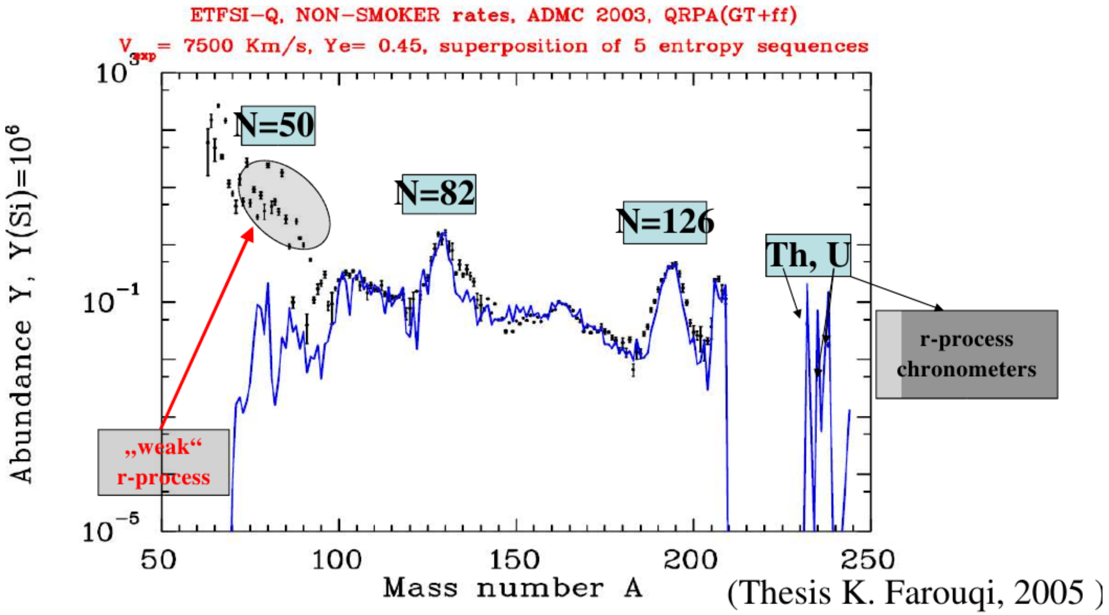
=> Th/U used for cosmochronometry

utilized in Hannawald+ (1997), Cowan+ (1999), Kratz+ (2000), Schatz+ (2005) ... also further comparison to metal-poor stars Montes+ (2001), Hill+ (2002), Sneden+ (2003), Christlieb+ (2005), Farouqi, Kratz+ (2006) Roederer+ (2007), Cowan+ (2011)

Synthesizing selected mass region

Superposition of 5 S-sequences to reproduce the $N_{r,\odot}$ pattern (100<A<240)





(Thesis K. Farouqi, 2005)

Basis for detailed astrophysical parameter studies

Dependent on **«fashions of the time»** other approaches to explain solar r-abundances were taken, i.e. the so-called ***high entropy bubble***, where the abundances could be explained with superpositions of entropies (Farouqi et al. 2005, 2010), but presently the same discussion can be found in ***Ye superpositions of compact binary mergers***.

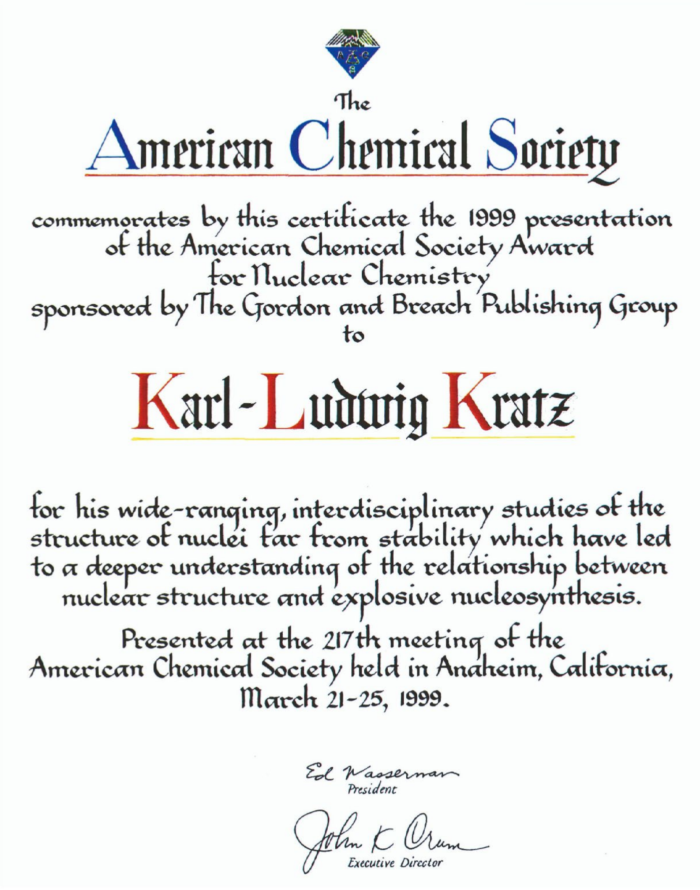
The question remains whether these have to be superpositions of different astrophysical sites or come from different regions in one site.

Statistical analysis of low-metallicity stars with limited-r, r-I, and r-II patterns gives clues that actually three different sites are needed (Farouqi et al. 2022, 2025)!

Apologies! Here I focused mainly on r-process related activities, but ***KL has been quite active as well in other topics, like meteoritic inclusions, dust grains etc. (***with U. Ott, W. Akram, O. Hallmann..)

As a pioneer in the physics of neutron-rich nuclei, KL was the first to systematically apply spectroscopy to astro-physical questions of the r-process—despite considerable opposition. He impressed with his ability to work tirelessly on evaluations until he arrived at the best interpretation of the results. Researching nuclei far from stability is presently one of the most important goals of nuclear physics worldwide. ***All these achievements (431 publications) led to awards!!***

Awards: ACS Nuclear Chemistry Award, APS Hans A. Bethe Prize


The American Chemical Society

commemorates by this certificate the 1999 presentation of the American Chemical Society Award for Nuclear Chemistry sponsored by The Gordon and Breach Publishing Group to

Karl-Ludwig Kratz

for his wide-ranging, interdisciplinary studies of the structure of nuclei far from stability which have led to a deeper understanding of the relationship between nuclear structure and explosive nucleosynthesis.

Presented at the 217th meeting of the American Chemical Society held in Anaheim, California, March 21-25, 1999.

Ed Wasserman
President

John K Crum
Executive Director

with Gerhart Friedlander, Bill Walters

"For his ground-breaking and visionary work towards developing a cohesive picture of the r-process by employing novel experimental techniques to study the decay of nuclei far from stability, working with observations of astronomers, models of astrophysicists and nuclear theorists, and the geochemical analyses of meteorites."

KL loved skiing– especially in Russbach, his beloved second home. As part of the Helmholtz VISTARS Virtual Institute (which he directed), he founded the internationally renowned "Russbach School on Nuclear Astrophysics," which still takes place there every year.

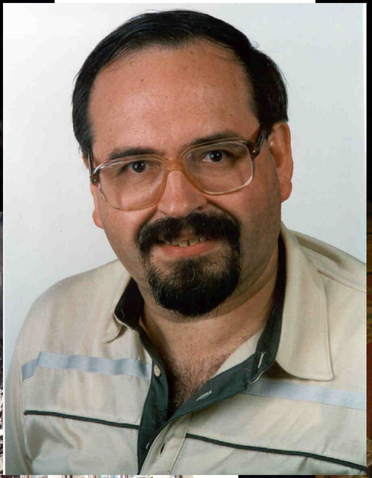
The Russbach Meetings (some personal impressions)





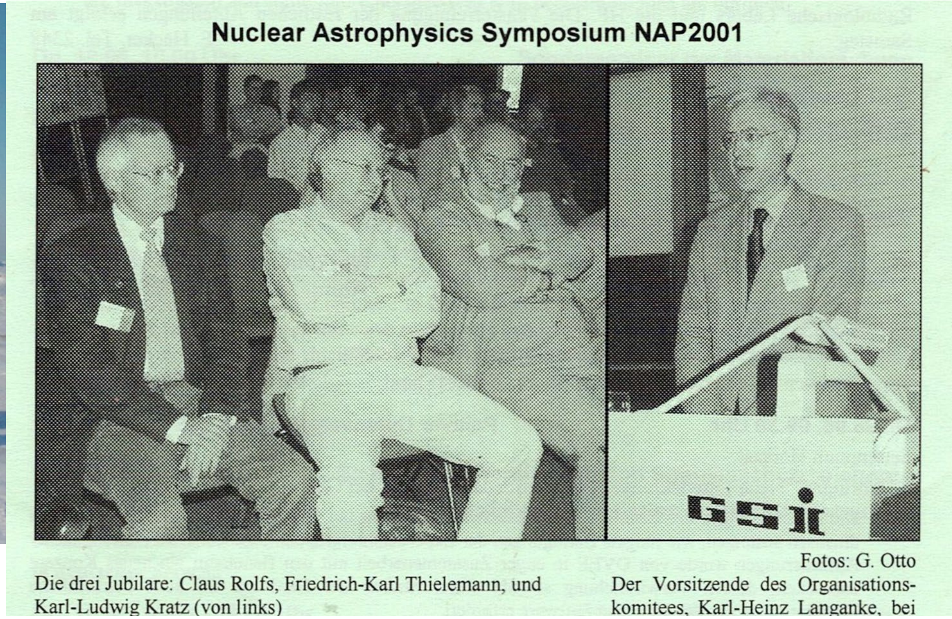


(some) Scientific Collaborators



and I missed many others and other topics KL has worked on:
e.g. the entire Isolde Collaboration (including Bill Walters), nuclear reaction measurements, s, rp-process with M. Wiescher, level densities and direct capture reactions of neutron-rich nuclei with T. Rauscher ...

And we always had fun after hard and long working days, whether at NIC 0 in Crete (1988), in Munich or South Bend bars at night, on frozen lake Michigan, in Basel, Boston, GSI, Mainz, Odessa, Ringberg, Sedona meetings etc.



Nuclear Astrophysics Symposium NAP2001

Fotos: G. Otto

Die drei Jubilare: Claus Rolfs, Friedrich-Karl Thielemann, und Karl-Ludwig Kratz (von links)

Der Vorsitzende des Organisations-komitees, Karl-Heinz Langanke, bei

Let's have a toast on KL!
and although he was not always easy to take and had his quarrels, in his last paper (Kratz 2023, EPJA 59,99) he described his life work and actually thanked also almost all of his enemies.

Nachruf auf Karl-Ludwig Kratz

Karl-Ludwig Kratz (geb. 23. April 1941 in Jena) verstarb am 23. März dieses Jahres. Er war der älteste Sohn des Chemikers Ludwig Kratz, der 1945 als einer der „41 Glasmacher“ von Schott/Jena nach Westdeutschland übersiedelt wurde. Karl-Ludwig Kratz studierte Chemie an der Johannes Gutenberg-Universität Mainz und promovierte am Institut für Kernchemie mit Arbeiten am Mainzer TRIGA-Reaktor. Er entwickelte ein Trennverfahren für Nuklide, die bei der Kernspaltung entstehen. Danach forschte er weltweit, insbesondere am Online-Massenseparator OSTIS des ILL in Grenoble und am ISOLDE-Massenseparator des CERN. Wegen der Bedeutung der verzögerten Neutronenemission von Spaltprodukten in der Reaktorkontrolltechnik wandte er sich zunächst diesem Thema zu. Zu seinen bedeutenden Beiträgen gehört die Entwicklung der empirischen „Kratz-Hermann“-Formel zur Berechnung von beta-verzögerten Neutronenemissionsstärken. Mit der Neutronen- und Gammaspektroskopie bestimmte er detailliert die Kernstruktur kurzlebiger Spaltprodukte.

Mit seiner Arbeitsgruppe erarbeitete Kratz die Systematik und Signaturen für Beta-Stärkefunktionen neutronenreicher Isotope. Die charakteristische Gammastrahlung angeregter Zustände neutronenreicher Kerne zu kennen, ermöglichte es auch, den Gehalt an (Spuren-)Elementen in Proben mittels Neutronenaktivierungsanalyse zu bestimmen. Diese Arbeit weitete er mit seiner Forschungsgruppe auf offene Herausforderungen in Umwelt- und geochemischen Studien aus, unter anderem beim Ausbreitungsverhalten von Metallen wie Uran in ehemaligen Bergbaugebieten. Die gleiche Technik diente auch der Analyse von Proben für die Inkorporationsüberwachung von Mitarbeitenden kerntechnischer Betriebe. Einnahmen aus dieser amtlich anerkannten Messstelle halfen Karl-Ludwig Kratz dabei, Promotionsstellen zu finanzieren.

Karl-Ludwig Kratz auf seinem Segelboot

Kratz' Arbeiten ermöglichten es, theoretische Vorhersagen für Zerfälle neutronenreicher Kerne zu überprüfen. Ein Workshop in Burr Oak (Ohio) inspirierte ihn 1982, seinen Forschungsschwerpunkt auf die Astrophysik zu verlagern. Die dort geknüpften Kontakte führten zu jahrzehntelanger intensiver Zusammenarbeit, die erstmals die experimentelle Verifizierung eines stationären Flusses im r-Prozesspfad bei der Massenzahl $A = 130$ ermöglichte und zeigte, wie sich mit beta-verzögerter Neutronenemission der umgekehrte Neutroneneinfang berechnen lässt.

Gemeinsam mit Bill Walters nutzte er die Entwicklung von isotopen- und isomeren-selektiven Laserionisationstechniken, um neutronenreiche Kerne in der Nähe des r-Prozesspfads an ISOLDE zu untersuchen. Seine Zusammenarbeit mit Peter Möller machte das Finite-Range Droplet Model (FRDM) zu einem der zuverlässigsten theoretischen Massenmodelle. Kratz zeigte auch, dass die solaren r-Prozess-Häufigkeiten aus mindestens drei Komponenten bestehen. Im Zuge dieser Arbeiten kam er in engen Kontakt mit Astronomen und deren Beobachtungen sehr metallarmer Sterne aus der Frühgeschichte von Galaxien. Der Vergleich mit den vorhergesagten Häufigkeiten von Uran und Thorium erlaubte es, das Alter der beobachteten Sterne und damit eine Untergrenze für das Alter der Galaxie zu bestimmen. Zuletzt arbeitete Kratz daran, die Isotopenhäufigkeiten von Staubkörnern aus Meteoriten zu nutzen, um auf die Eigenschaften astrophysikalischer Ereignisse zu schließen, in denen die Staubkörner entstanden.

Die wissenschaftlichen Ergebnisse seiner breit gefächerten Forschung von der Kernchemie über die Kernphysik bis zur Astrophysik bescherten Karl-Ludwig Kratz bedeutende Auszeichnungen, darunter der Glenn T. Seaborg Award for Nuclear Chemistry der American Chemical Society (1999), der GENCO Award der GSI Exotic Nuclei Community (2004) und der Hans A. Bethe-Preis der American Physical Society (2014). Neben seiner Professur in Mainz war er auch als Adjunct Professor für Physik an der University of Notre Dame (Indiana), als Mitglied der JINA Collaboration und als Direktor des Virtuellen Helmholtz-Instituts VISTARS tätig.

Karl-Ludwig Kratz liebte das Skifahren – speziell in Russbach, seiner zweiten Heimat. Im Rahmen der VISTARS-Kollaboration rief er dort die bis heute jährlich stattfindende, international renommierte „Russbach School on Nuclear Astrophysics“ ins Leben. Mit seinem Segelboot auf dem Bodensee genoss er entspannte Momente. Als ein Pionier der Physik neutronenreicher Kerne wendete er als Erster deren Spektroskopie systematisch auf astrophysikalische Fragen des r-Prozesses an – auch gegen viele Widerstände. Dabei beeindruckte seine Fähigkeit, unermüdlich an Auswertungen zu arbeiten bis zur besten Interpretation der Ergebnisse. Kerne weitab der Stabilität zu erforschen, gehört heute zu den wichtigsten Zielen der Kernphysik weltweit.

*

Diesen Nachruf haben die Unterzeichnenden in aktiver Zusammenarbeit mit 22 Personen der ehemaligen Arbeitsgruppe Kratz erstellt.

A. Aprahamian, K. Farouqi, O. Hallmann, U. Ott, B. Pfeiffer, T. Rauscher, H. Schatz, F.-K. Thielemann, M. Wiescher und A. Wöhr

Appeared in this month's issue of the Physik Journal of the German Physical Society (similar to Physics Today)

We were limited to 10 authors, but *in total about 22 former group members participated actively!*