SUMMARY REMARKS: THE FULL-COURT PRESS

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It was evident that the best developed theme at this workshop was that of the astronomy of gamma-ray lines from radioactivity. That is to be expected, since MPE is the host institute and the organizing committee was largely astronomers of radioactivity (Diehl, Leising, Hartmann and Prantzos). Both the results to date (Knödlseder, Oberlack, Iyudin, Milne) and the technological hopes for the future (von Ballmoos, Kurfess, Aprile) were brilliantly detailed. But if we think about it we quickly realize that the disciplines involving isotopes in presolar STARDUST and isotopes in the cosmic rays have comparable hopes and dreams insofar as the next generation of instruments are concerned. We must hope for their funding and their success, and not be competitive with them, for the future of our isotopic astronomy will require the dedicated and sympathetic support of all of us who care about the history of the isotopes, radioactive or not. We rejoice that ACE is even now measuring cosmic-ray isotopic composition with unprecedented precision, and that teams at Washington University (St. Louis) and MPI fuer Chemie (Mainz) await the delivery of their new nanoSIMS sputtering mass spectrometers, which will set new standards for isotopic measurements in presolar grains. Insofar as next generation gamma-ray-line instruments are concerned, I detected a serious conviction, expressed ably by many, that it is necaessary to press forward on several technological fronts simultaneously, so that when the new opportunity emerges we will choose from the best and most dependable technology for our gamma-ray-line future.

We need to continuously stress in our scientific lives the great science benefits that will follow precise measurements of a gamma-ray-line flux. I call this the "acceleration principle', borrowing a term from the science of economics. How many scientific publications will follow a precise measurement? How many science disciplines will be excited over and impacted by a precise measurement of any gamma-line flux? I allege that the number is large. As example imagine the detection of the 1.275 MeV line from ^{22}Na in novae, and suppose that it has been measured with a precision of 10%. It astonishes to think of the number of studies that would subsequently be carried out by scientists of many types, nova astronomers, prenova astronomers, hydrodynamicists, stellar evolution and nucleosynthesis experts. We heard some here (Hernanz, Truran, Woosley), but how much more would follow the actual measurement! Our discussion of SN1991T shows that it is hard to do followup science with a few-σ measurement; but qualitatively different consequences for SNIa would flow from a 100σ measurement! Not only the nature of the burning (deflagration, detonation, mixed bag), but the non-spherical nature of that burning as illustrated so brilliantly by Wolfgang Hillebrandt's movies shown here. A 1% fixing of the 847 flux would not only measure the ^{56}Ni mass to 1%, but its light curve will yield the structure of the burning and the precursor. Type Ia supernovae in Virgo will be seen at 50-100σ overall, implying 10-20σ per day! This should, without doubt, be adequate to provide some detailed understanding of the event. And at 10^{-7}cm^{-2}s^{-1}, many such events are assured. Conceivably the ^{56}Ni mass will become well understood and predictable and a 1% measurement may even give 0.5% evidence for the distance to the host galaxy! We can not say; but we can be sure of the inevitable action of this acceleration principle on accurate measurements of gamma line fluxes.

We will not achieve these 10% measurements, requiring as they do line sensitivity near 10^{-7}cm^{-2}s^{-1} unless we are able to convince the highly competitive science world that it needs to know. It will not suffice to sing to the choir. We must sing to every discipline that will feel the impact of those newer fainter 10% measurements. We basketball pundits on the OSSE team (Kurfess, Leising, Clayton) might call this the need for a "full-court press". By a full-court press a team hopes to change the outcome of the game, to alter its routine evolution by exerting perpetual diligence. We in gamma ray astronomy can alter the routine evolution of science competition only by a full-court press. We must stress without abatement the science returns from the 1-10% accuracy for workers in stellar evolution, in presolar grains, in cosmic rays, in origins of solar systems, in ISM physics. We must make them want to have the 10% knowledge not for our amusement but because they need to know. They all need to have some information of new nuclei to enable their own disciplines to advance faster. If not we may feel the brunt of Hillebrandt's warning that the golden age of space astronomy may be even now passing by.

To aid this full-court press I invite you to imagine with me a subsequent "Press Release Conference" following the launch of a mission accurate to line flux of $10^{-7}cm^{-2}s^{-1}$. Each speaker in this science session invents his own follow-on to a measurement at the $10^{-7}cm^{-2}s^{-1}$ level of a radioactive line, each choosing a different object, a different isotope, and even a different discipline. Each reports the measurement using some equally fictitious but not improbable astronomical event. The audience is not told in advance what these new detections are, but must await each 10-minute presentation. Given the level of scholarship that we have witnessed in this workshop, we could expect a series of exciting discovery papers with intriguing consequences and questions for the future of science. I for one would as soon attend this imagined session as many sessions of "real science" that occur routinely at scientific meetings. I urge you to consider this and share your understandings of what it might achieve. This in any case would be the "full-court press" when repeated with emphasis toward differing disciplines until each wants our mission, each needing to know its answers.

Wasn't it great to see Reuven Ramaty using his speech synthesizer to participate so effectively in this workshop! We are reminded that courage is required for more issues than that of the next gamma-ray mission. It was almost exactly twenty years ago (on April 3, 1979) when Reuven and I met with Frank McDonald for dinner at his apartment in Greenbelt MD to discuss a plan to drum up scientific support for Gamma Ray Observatory (as it was then called). With Frank's advice, we mounted a writing plan to request letters of support from leading scientists to NASA and to Congress urging that GRO be approved. The exciting results discussed at this workshop show that our optimism for astronomy with radioactivities was well justifed. The scientists had responded in good number and with enthusiasm to our argument. Since that time Reuven has challenged almost everything that I have speculated about extinct radioactivities in Orion, guided from the first CGRO data, and taught me that there is no substitute for careful computation. But there is a good side. Don Ellison quipped at dinner, "I find Reuven easier to talk to now." After the laughter subsided, we agreed that the barrage of words and calculations that peppered Reuven's speech did not always allow easy exchange. I told this story to Reuven at this meeting, whereupon he pulled out his pad and wrote, "That's a good story! Every cloud has a silver lining." So thanks to Reuven, and thanks for Reuven, who continues to teach us much.

Throughout this workshop I saw and heard of the rewarding mix of topics and speakers, for which the organizers deserve credit. Almost all sat through every talk. Like you, I found that my attention refocussed with each new speaker, in large part because they were talking of different aspects of the astronomy of radioactivity. I suggest that it is the common culture of nuclear astrophysics rather than that of gamma astronomy that unified the program and endowed each new topic with high interest to all. Indeed, for the narrower goal of the full-court press for a new gamma-ray-line mission we see that it is the entire community of nuclear astrophysics, with its observational derivatives in stellar evolution, cosmic radiation, isotopic anomalies within presolar dust and within solar system rocks (and even deep ocean rocks!) that must be engaged in support of that goal. Our mission is one mission, nothing less than the isotopic history and distribution of matter.

Brad Meyer presented an especially stimulating message, ten radioactive isotopes that have been found to have observable abundances within the early solar system. At least three of these are now and have always been among the prime targets for gamma-line astronomy of the ISM today. Meyer presented what I think to be the most promising current picture of the relationships of these ten in the solar molecular cloud to those expected on average in today's ISM. He divided these ten into three groups: those anticipated to be continuously mixed into molecular clouds generally from SNIa explosions; those from core collapse r-process events which were for specific historic reasons deficient in the solar cloud by an order of magnitude; and those admixed into the presolar cloud hydrodynamically from its core-collapse " SN trigger", from only its shells lying outside of (approximately) its inner 7 solar masses, matter which was not itself admixed for physical reasons. Particularly novel was Meyer's demonstration that live ^{182}Hf owes its existence in this picture to s-process acting in the C-burning shell of that supernova trigger, rather than to the galactic r-process events which are reponsible for the bulk ISM budget of its daughter, ^{182}W. It is a very stimulating canvas, offering for the first time a self-consistent picture. No doubt it will prove wrong in details; but perhaps correct in its methodology. Guenter Lugmair presented evidence that one of these (^{53}Mn) was inhomogeneously distributed in the accretion disk that grew the solar planets. Because ^{53}Mn in not injected from the SN trigger in Meyer's picture, but is instead present in all average molecular clouds at its observed level, the reason for the decline in ^{53}Mn concentration with distance from the sun (Earth, Mars, Vesta) at the time of planetary accumulation must be sought in cosmic chemical memory of ^{53}Mn vis-a-vis ^{55}Mn, its stable (and much older) counterpart. Lugmair also used his observations of live ^{60}Fe in meteorites along with radiogenic Pb from U decay to set the most accurate chronology ever established for planetary accumulation. Guenter Korschinek presented evidence of live ^{60}Fe today in matter, probably dust grains from a recent supernova, that drift into the Earth's atmosphere and deposit in the manganese crust of the ocean beds! A supernova that occurred a few million years ago, and which must have been alarming to our tree-dwelling ancestors, has probably created the hot low density bubble that has made astronomy from Earth so rich visually. Whatever the eventual implications, it cannot escape the attention of gamma-line astronomers that ^{60}Fe has been since 1971 a prime target of searches and that ^{53}Mn would be even gamma-ray brighter than ^{26}Al if only it emitted a gamma ray!

Presolar grains are solid fossils that formed before the solar system existed. Traditionally it has been held as unlikely that mankind would ever hold such fossils in his hand and examine them with high-resolution instruments in his laboratories, but that is what Sachiko Amari and Peter Hoppe have reported in their talks. Indeed the presolar grains that they and others have identified to date might better be called STARDUST, because the anomalous isotopic composition of the elements from which they grew are so anomalous that there seems no chance that such grains could have grown in any interstellar situation. The "mainstream SiC grains" descibed by Hoppe contain 10^{12} Si atoms and C atoms, so they surely represent the bulk composition of the gases from which they condensed rather than a fluctuation. The ratio ^{12}C/^{13}C near 50 rather than 89 seems to identify carbon stars as their origin, condensing in the winds as they depart from the stellar surfaces. For non-radioactive environments the C abundance must exceed that of O in order that SiC condense, and carbon stars not only provide that but also the observed ^{12}C/^{13}C ratios near 50.

If that is not convincing enough, the ^{22}Ne purity of the neon implanted in them and the pure-s-process nature of the xenon implanted within them shouts "C-star atmosphere!". Such discoveries move nucleosynthesis theory to higher dimensions. They demonstrate that the s-process, for instance, did indeed occur distinctly from other processes, and that the solar abundances do indeed represent a mixture of these distinct processes, as we have believed for four decades. This is a major step in natural philosophy. For radioactivity astronomy, Hoppe reported ^{26}Al/^{27}Al initial ratios within the mainstream grains near 10^{-3}, a value that is compatible with dredgeup of matter to the C-star surface prior to its condensation in the cooling wind. I have calculated that that ratio is not sufficiently large to provide a significant portion of the interstellar ^{26}Al budget, provided that the mainstream SiC grains are assumed to sample all AGB star ejecta. Radioactive ^{22}Na, which we seek both in novae and supernovae by its gamma ray line at 1.275 MeV, does not seem to be the source of the ^{22}Ne-rich neon in these mainstream grains, however; Hoppe attributes that to the ^{22}Ne-rich dredgeup along with the new carbon created in the shell flashes. That ^{22}Ne follows from two alpha captures on ^{14}N during early He burning.

Amari discussed specifically the extinct radioactivities in the presolar STARDUST. These are most dramatic in the SUperNOva CONdensates (SUNOCONs), a specie of STARDUST from condensation within the supernova interior. The SUNOCONs are much richer in initial radioactivities, as is the supernova itself. Of those that seem identified (^{22}Na, ^{26}Al, ^{41}Ca, ^{44}Ti) in SUNOCONs, three are traditional gamma-ray-line targets for astronomy. Clearly then, we need to not only understand but also utilize the STARDUST of all types for the ISM budget that we hope to understand. I like to claim that each STARDUST particle is an astronomical observation. The observation was made long before the Earth existed, and it is our task to develop the film. Whereas gamma-ray lines measure the bulk yield from individual exploding objects, STARDUST particles record many stars. SUNOCONs described by Amari probably were inherited from ISM dust from many different supernovae - or indeed, even from different shells of the same supernovae! Let me be specific. The observed ^{44}Ti/^{48}Ti initial ratios in the SUNOCONs (both graphite particles and SiC particles of type X) mostly range between about 0.001 and 1.0. These sample respectively the ejecta of silicon burning and of the α-rich freezeout of strongly shocked Si in SNII. But how shall we interpret their many discreet values? Do they represent discreet burning shells, as I seem to suggest, or different admixtures of the burning shells, as I also suggest? This was a lively question at this workshop, and I sensed that the vigorous discussion of it following these presentations could have gone on much, much longer had not the chair sensed the need to move on. The challenge is not only to explain what we have, but to explain why others are missing! The discrete shells do not have isotopic compositions that match the grains, so what type of mixing has produced their condensation? Uniform molecular mixing within two years seems out of the question. So where are the grains from the pure shells? I suggested that the answer is to be found in the chemical kinetics of grain growth, kinetics that project out of the bulk compositions those that are favored chemically to grow to large size. Bear in mind that the studied particles are very large, microns in size, so that we must seek the conditions that favor growth to large size. The pure shells lack that condition, perhaps a chemical catalyst. My own presentation on graphite growth revealed that this is a tricky problem with several counterintuitive aspects. But the key lies in chemical kinetics. We seek chemical catalysis along the mixing interfaces of plumes in velocity that cause the grains to grow to largest size there.

We listened to thorough updates of thermonuclear production of radioisotopes (Meynet, Gallino, Mowlawi, Hernanz, Thielemann, Woosley, Kifonidis) and to discussions (Hartmann, Plüschke, The) of interesting aspects of how star-formation history presents astrophysical manifestations of interstellar radioactivity. These lay within the context of gamma-line astronomy; but they are relevant for considerations of STARDUST and SUNOCONs. It is stimulating in this regard to briefly consider the precisions of measurements. We hope with a future gamma-line mission to record line fluxes with sensitivity near $10^{-7}cm^{-2}s^{-1}$. Not only will this enable many new detections, but will provide 10% accuracy to the measured radioactive masses in many cases that are too faint to even be detected by CGRO. In SN87A we might have recorded $^{57}Ni/^{56}Ni$ production ratio to 1%! In CasA we will measure the ^{44}Ti mass to 1%! All with much secondary science of high significance. Optical astronomy in general cannot do so well, and optical isotopic measurements are good if accurate to 25%. Cosmic-ray missions like ACE now measure some isotopic CR ratios to 1%, enabling new science. But in STARDUST the astronomical measurements contain isotope ratios to 0.1% from SIMS counting; and even better may be possible (though not necesssarily desireable since 0.1 % is already accuracy of heroic proportions that does not require destruction of the grain). Realize that these provide stellar production ratios to an accuracy of 0.1%, far more accurate than they can be calculated with known nuclear and stellar knowledge! And with thermal ionization mass spectrometry of larger samples accuracies of 10^{-5} are achieved in isotope ratios! We realize that these differences in sensitivity do not reflect corresponding scientific significances, because each sample studied (exploding stars, cosmic rays at Earth today, STARDUST records of nucleosynthesis and mixing and chemical kinetics in specific stars, and planetary bodies) needs its own level of precision to be able to draw significant consequences.

The scientific "full-court press" called for embraces the study of cosmic rays. Duvernois, Bykov, Ellison and Ramaty made clear that the scientific goals of these studies overlap those of gamma-ray astronomy and of STARDUST to a degree not anticipated a decade ago. A mission to record narrow-line fluxes with sensitivity near $10^{-7}cm^{-2}s^{-1}$ will detect the broader-lined "Orion phenomenon", even if COMPTEL's first suggestions in this regard have been heard to be more ambiguous than realized at first. We will see cosmic-ray caused gamma-ray lines with such a mission; but for broad diffuse lines, such as cosmic-ray produced ^{16}O and ^{12}C, the improvement over CGRO will not be so dramatic. Good enough to see them, however, and make galactic maps in lots of lines. Bykov outlined the role of superbubbles in the acceleration of the CR, and we hope to see this in gamma-lines and hard X rays. Ramaty reminded us that the origin of LiBeB and their cosmic abundance evolution are tied to the nuclear interactions of low-energy cosmic rays, ones that we can not measure in our heliosphere and which may be locally quite different than in our heliosphere. And Ellison even went so far as to convince us that the CR source lies in accelerated dust. He argued that the enhancements of refractory elements are well reproduced by requiring modest grain acceleration as a first stage "injector"; and his calculations show that it works. If so, the CR composition is not independent of the chemistry and isotopes of dust, including ambient STARDUST.

No clear distinctions separate the science of gamma-line astronomy from those of presolar STARDUST, of extinct radioactivity in the solar system and how it formed, of cosmic ray isotopes and their origin and propagation, of stellar evolution and nucleosynthesis. To even hope for the future gamma-line mission to record line fluxes with sensitivity near $10^{-7}cm^{-2}s^{-1}$, we must persuade each community with strong science grounds that its goals are best served by that mission. Then we may escape Wolfgang Hillebrandt's stern warning that the golden age of gamma-line astronomy is drawing to a close.

These are the conclusions that I draw from this most enjoyable Ringberg Workshop, "Astronomy with Radioactivities".

Whether you agree with me or not, you surely join me in thanking Roland Diehl and the other organizers (Hartmann, Leising, Prantzos) for inviting our participation and thank the Max Planck Society for maintaining such a thoroughly stimulating setting as Schloss Ringberg.

When I was a boy we enjoyed a popular radio program called "Queen for a Day". Nancy joins me in thanking the organization for allowing us to be "Herzog und Herzogin der Woche" !