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Tanguy Altherr: a physicist and a friend*

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Tanguy Altherr was born thirty-one years ago in Brittany, a region to which he had remained very much attached. He grew up near Rennes and graduated from the University there in June 1984 with a BS in physics. In fall 1984, he moved to Grenoble where he enrolled in the MS program in the Science University. Tanguy did not come to Grenoble by chance: he knew that there he would find a large and famous Science University. Tanguy's wife, Hlne, also told me recently that, in fact, he had been attracted also by the Alps which he had discovered as a child during a skiing vacation with his parents.

In 1986, after his MS, Tanguy enrolled in a Ph. D. program. In France, the first year is devoted to a rather heavy set of lectures and courses and is followed by two or three years of research. In those days, the students specializing in particle physics would come to LAPP where they would attend the lectures. There were about four or five students and in Tanguy's year they were a particularly quiet set. I was talking on Quantum Electrodynamics and Quantum Chromodynamics, one-loop renormalization, ... and not a single question was asked during or after the lectures. Checking with my colleagues who also taught at that time, I realized that it was exactly the same for all of us. That year, they were really a very silent bunch! I was giving homework which the students did very conscientiously (unlike what happens now). There was, in particular, a problem nobody could solve in the years before or after, except for Tanguy who came up with a three-line solution whilst my solution was more like three pages! So, despite his being very silent, Tanguy really had something to say in Physics. When later, he asked me for a research topic for his thesis, naturally we began to talk more.

One should realize that it was not an easy situation for Tanguy who had chosen to go through the University system rather than to follow the selective channel of "Grandes Ecoles" which would have been the normal way for someone intending to study theoretical physics. In short and to be somewhat caricatural, in the mind of many theoretical colleagues and friends, students who follow the University cursus may be good enough to become experimentalists in particle physics but not theoreticians! Fortunately, there *are* exceptions and Tanguy was undoubtedly one of them. Tanguy knew that it would not be easy and that he really had to prove his worth. But he was optimistic and persevering, and also he was confident so he decided to give it a try.

He was supposed to start his research in October 1987, right after his military service which he spent running enormous Monte-Carlo programs to study the shielding of satellites against radiations (it was in the days of the SDI!). We had agreed to work on Finite Temperature Field Theory. This was a topic I was not very familiar with, since I had just started to work on it with my friend J. Lindfors from Helsinki, who

was spending a sabbatical year in 1986/1987 at LAPP. I decided to take an early start and did some computations on this topic during the summer: as a “thesis adviser”, I thought it would be appropriate to give the impression that I knew a bit more than the student did. My head-start turned out not to be very useful and did not last very long since by November 1987 Tanguy was already ahead of me in the calculations. He was really working very fast, making quite a few mistakes on the way, but, in the end, he would come up with the right results.

The problem we studied was dilepton production in a quark-gluon plasma ¹⁻⁵. This process was then thought to be interesting as a clear-cut signal for the formation of a quark-gluon plasma in heavy ion collisions at ultra-relativistic energies.

Fig. 1. Some of the diagrams of lepton pair production in a quark-gluon plasma.

This was before the rather pessimistic conclusions of Vesa Ruuskanen as presented in these proceedings. At that time, we were not so much interested in the phenomenological aspects but rather in the theoretical aspects concerning the validity of the perturbative series for this process. At finite temperature, some of the diagrams to be studied are shown in the above figure.

We looked at $R(Q)$, the rate of production of virtual photons γ^* , assuming the quarks and the gluons to be in equilibrium in the hot plasma. The set of diagrams

to be studied is very similar to the set needed for the production of virtual photons in usual field theory (at zero temperature). In that case, as is well known, one has to follow a special procedure to get rid of singularities: when integrating over the phase space of final state partons one encounters infinities which arise when the final state partons are collinear to the initial ones. These divergences are absorbed in the structure functions which describe the distribution of quarks and gluons in the initial hadrons. In other words, the confinement of the q, G in the hadron shields these singularities. In the plasma at finite temperature the quarks and the gluons are not confined and there are no hadronic structure functions to play with. The question was: what happens to these singularities? The net result, at least at the two-loop level at which the calculation was performed, is that all divergences cancel and that the perturbative series is well behaved (in the first two orders). This happens:

- partly, because the phase space is larger than at $T = 0$ (one has to integrate over the phase space of initial particles as well as final particles).

- partly, because of a “miraculous” relation between Bose-Einstein and Fermi-Dirac statistical factors. Tanguy was using this word rather as a provocation as he was not a believer and he thought that there was no room for miracles in Physics.

It was not trivial to get this result and it took several months during which we went through periods of “highs” and “lows”: whenever one of us found cancellations the other one had not and vice versa. So it took us a long time before both our results thermalized towards a full cancellation of infra-red as well as mass singularities.

It is amusing to remark that there were four different groups working more or less independently on similar problems at that time:

- J. Cleymans, I. Dadić (Cape Town/Zagreb): they considered the kinematically much more complicated case of deep-inelastic lepton scattering on a plasma.
- R. Baier, B. Pire, D. Schiff (Bielefeld/Ecole Polytechnique/Orsay): they considered lepton-pair production but used different regularization techniques (masses to quarks and gluons).
- T. Grandon, M. Le Bellac, J.L. Meunier (Nice): they worked with $\lambda\phi^3$ theory in six dimensions: despite the geographical proximity we had no contacts with Nice at that time!
- T. Altherr, P. Aurenche, T. Becherawy (Annecy); we used dimensional regularization.

All these groups, calling upon different theories/techniques, found cancellation of divergences. It is perhaps worthwhile mentioning that, since then, three other groups have considered the problem and found no cancellation! I do not believe in those latter results which are probably due to a wrong set of approximations.

Since the perturbative series appeared to be well behaved, we went on to calculate the finite terms: this was not too difficult in the context of the dimensional regularization approach. In the interesting case where the virtual photon mass, Q , is much smaller than the temperature, we found ⁶:

$$R(Q) = R^{(0)}(Q) \left(1 \oplus g^2 \frac{T^2}{Q^2} \ln \frac{T^2}{Q^2} + \dots \right). \quad (1)$$

The quantity $R^{(0)}(Q)$ is the one-loop result and the T^2 factor appearing in the correction term reflects the phase space available to thermal particles. This result shows that the domain of validity of our calculation is given by $gT < Q$, but when $gT \geq Q$ the result cannot be trusted as the correction term becomes as big as the lowest order one.

In the meantime, Braaten and Pisarski as well as Frenkel and Taylor had developed a very general method to handle the perturbative series in the case $Q \sim gT$ ($g \ll 1$). This is now known under the name of the Braaten-Pisarski, or effective theory, and Tanguy later on spent much time applying the effective theory to several processes and extending its applicability to the case of systems with chemical potential ⁷.

What I have just described is part of the work that Tanguy submitted for his Ph. D. thesis which he submitted in December 1989, *i.e.* barely two years after starting his research ⁸. In fact, during these years we overlapped for eight or nine months only as I was away on a long sabbatical leave. At the beginning I felt very bad about it as I feared that Tanguy might not have enough experience to work by himself. In fact, he turned this into an advantage and he spent a lot of time going through the literature, finding books and articles which would trigger his interest on a variety of topics. By the time he took his Ph. D. he had several research projects of his own which he did not include in his thesis. His curiosity for different fields and his eagerness to learn was quite remarkable and very refreshing.

Before continuing with Tanguy's work, I would like to talk about his activities as a mountaineer, a rock guitarist, an Italian sport-cars fan, ...

In fact, whenever the weather permitted and even when it did not (he once passed the top of Mont-Blanc without realizing it because the weather was so bad!) he would go by himself wherever he could find a slope at 45° or more. His preferred activity was to climb to the top of a mountain and then to ski down a steep "goulet" (gully) as fast as he could. Occasionally, on Monday mornings, he would arrive at the laboratory all bruised but that did not stop him from continuing all by himself. In fact, at the beginning of his stay at LAPP, he had joined the mountain club, but it became clear, after some time, that he was no longer going with the group anymore. When I asked him why, he replied in his usual direct and rather abrupt manner that

“there was no fun in going skiing with pre-retired people!”

When the “pre-retired” people were asked about their point of view, they said that Tanguy’s ways were rather careless to say the least! Later on, he became wiser and joined a mountain club in Annecy, where he met his wife-to-be, Hélène, and the more experienced he was, the more careful he became. At some point Hélène and Tanguy considered celebrating their wedding in a mountain hut were it not for the objections of parents and grand-parents who would not have been able to attend the ceremony.

About Tanguy’s activity as a rock guitarist, I know very little except that one day he said that he felt like a very old man compared to the young people in his band. I guess he must have felt something similar to what I have always felt when talking to him. Tanguy was extremely fast. This was also obvious from his interest in sporty Italian cars, a taste he shared with his friend T. Grandou.

I would like to come back to Tanguy as a physicist. A few days after his thesis, Tanguy moved to Helsinki where he had a one-year fellowship. There, he also found a snowy environment like in Annecy, but no mountains. Nevertheless, he enjoyed his stay very much as he found that skiing on frozen lakes was as exciting as going down steep slopes. Despite the fact that he liked Finland very much, he did not stay there quite a year and he left when he realized that in August, one finds more Finnish physicists abroad than in Finland. From the scientific point of view, his stay in Helsinki was very fruitful as he started collaborating with K. Kainulainen on topics in astrophysics and with V. Ruuskanen on the phenomenology of lepton pair production in a hot plasma. He came back to LAPP in late Summer 1990 and joined the CNRS in October of that year. He was awarded a CERN fellowship in January 1993. During these few years he went on several trips in Europe and the United States during which he met many physicists with whom he started collaborations.

Tanguy’s activity as a researcher is quite impressive: his first paper was written in 1988 and by 1994 he had thirty-three publications and conference reports! He has had no less than thirteen different collaborators, so I guess many people appreciated his qualities as a physicist as well as his personality. In fact it was quite pleasant to work with him: he would never get personally aggressive as it is too often the case in our field. He would always be calm, keeping an enigmatic smile on his face. He gave the impression that Physics was a game, a very challenging game, but still: a game. I do not know many people like him.

Except for the (for me) “exotic” and fashionable topic which Joao Seixas discusses in his contribution, Tanguy’s work dealt with many aspects of Field Theory at finite temperature and density and their applications. I will now try to regroup his works by themes.

A) Infra-red and mass singularities in the perturbative expansion

This problem was always at the back of his mind and he tried several approaches to better understand the situation ^{9,10}. Clearly, he was not satisfied with his having proven the absence of singularities at the two-loop order: there was a deeper reason and he wanted to make it more explicit. He considered the problem in different theories ($\lambda\phi^4$, $\lambda\phi^3$) and he combined perturbation theory and dispersion relations to prove the cancellation of certain classes of singularities. Also, with T. Grandou, he considered systems which do not obey the usual statistics and studied q -deformed statistics (see T.G.'s contribution in these proceedings) ¹¹. This is a rather mystical paper in which they conclude that, even in this extended statistics, the compensation of singularities occurs and that it is a direct consequence of the detailed balance principle, i.e.

The Lee-Kinoshita-Nauenberg theorem still appears to hold at finite temperature.

In the category of infra-red problems in Finite Temperature Field Theory one can include the problem of the fast fermion damping rate which Tanguy studied with Teresa del Río and E. Petitgirard ^{12,13}. The object to be calculated is the imaginary part of the two-point function:

The problem is that, because of the absence of a magnetic mass in perturbation theory, the transverse gluon contribution to this diagram leads to infra-red divergences when the external fermion leg goes on shell. There are no less than four or five different points of view to solve this problem and this led to quite lively discussions in the literature or at conferences. Tanguy and his friends heroically joined in the fight. I do not want to say more about this since most of the experts on this topic are in the

audience, almost each one with a different point of view (R. Baier, R. Pisarski, A. Rebhan, T. del Río Gaztelurrutia, D. Schiff), and I refer you to them for details.

Although not directly related to the problem of singularities, I should mention at this point his work with T. Grandou and R. Pisarski on perturbative instabilities at finite temperature ¹⁴: considering a ϕ^3 model in six dimensions with the parameters chosen such that the theory is perturbatively stable at zero-temperature, it is shown that there exists a critical temperature above which the perturbative stability is lost (this is to be contrasted with ϕ^4 models where thermal corrections can restore the stability).

B) Signals for the quark-gluon plasma

He considered with Vesa Ruuskanen the production of low mass dileptons at high momenta ¹⁵. Despite large corrections from higher order terms, the signal seems to be washed out by background from meson decays (see V. R.'s talk). This point is deeply connected with A) since dilepton rates were the playground for studying the singularity structure.

Later on, together with D. Seibert who was visiting CERN in 1992/1993, he considered the production of both heavy and light quarks from a pure gluon plasma ¹⁶⁻¹⁸. One of the interesting consequences of their work is that the rate is rather small and therefore it is unlikely that quarks would be in chemical equilibrium in high energy heavy ion collisions.

C) Physics in dense media and applications

While in Helsinki, Tanguy got interested in astrophysical problems, such as the question of energy loss in dense and hot stars (via scalar or pseudoscalar particles) ¹⁹⁻²¹, or the properties of neutrinos in dense and hot stars (with K. Kainulainen) ²². So, naturally, he looked at the problem of resummation in thermal system with a large chemical potential. He did this with U. Kraemmer, who was a post-doc at LAPP in 1991/1992 and they found that the resummed theory is rather simple for dense media since in QED, e.g., only the photon line has to be resummed, the fermion being always hard, on the Fermi surface ($E_F \sim \mu$) ²³.

These techniques were applied to several problems:

1. axion emission from dense stars, with Teresa de Río Gaztelurrutia and E. Petitgirard ²⁴.

2. photon propagation in dense media, with the same collaborators as above, providing a unified treatment of the various limits (relativistic vs. non-relativistic) ²⁵.
3. the electric charge of neutrino and plasmon decay, a problem which, again, he considered with P. Salati ^{26,27}.

D) Systems out of equilibrium

In his last two papers, Tanguy was interested in systems out of thermal equilibrium. Some of the work was done in collaboration with D. Seibert ^{28,29}. There are Feynman rules for such systems: the Keldysh rules or the Thermo Field Dynamics rules of Umezawa. Tanguy and D. Seibert found inconsistencies in the perturbative expansion constructed from such rules. For example, in the two-point function, the self-energy diagram causes problems since it generates ill-defined terms containing products of δ -functions

$$\equiv \int d^n K (\delta(K^2 - M^2))^2$$

This occurs at two loops in $\lambda\phi^3$, three loops in $\lambda\phi^4$. The coefficient in front of the ill-defined term can be represented as:

which vanishes when the system is in equilibrium (also the condition for the vanishing of collinear and infra-red singularities). Tanguy also found that, after properly regularizing these terms, they can be resummed and that the resummation provides a natural regularization. The order of these terms in the $g^n T$ expansion depends, of course, on how far from equilibrium the system is.

Clearly these were not Tanguy's final thoughts on this problem and he had also started further work about this with his student F. Gélis.

E) Neural networks and track recognitions

This is a completely different topic and it is discussed by J. Seixas in his talk ^{30–33}.

I have just sketched very superficially what Tanguy had been interested in during his much-too-brief career. His interests were very wide ranging as is apparent from this book which is devoted to some of the topics to which he made contributions. He was truly a representative of the new generation of physicists to whom international collaborations are an essential aspect of the work: indeed, some of his friends from six different countries contributed to these proceedings. It is a tragedy for all of us that his life was interrupted so early, and in particular it is a tragedy for the French community of theoretical physics where too few young people of his caliber are interested in particle physics and phenomenology.

I would like to express my admiration to Hélène, who has gone through this tragic summer with so much strength and courage setting an example for all of us.

Publications by T. Altherr

1. T. Altherr, *Radiative Corrections to Drell-Yan Production in a Quark-Gluon Plasma*, 19th Symposium on Multiparticle Dynamics, Arles, France, June 1988.
2. T. Altherr, *Perturbative QCD at Finite Temperature*, 24th Rencontres de Moriond: Electroweak Interactions and Unified Theories, Les Arcs, France, March 1989.
3. T. Altherr, P. Aurenche and T. Becherrawy, *On Infrared and Mass Singularities of Perturbative QCD in a Quark-Gluon Plasma*, Nuc. Phys. **B315** (1989) 436.
4. T. Altherr and T. Becherrawy, *Cancellation of Infrared and Mass Singularities in the Thermal Dilepton Rate* Nuc. Phys. **B330** (1990) 174.
5. T. Altherr and P. Aurenche, *Fermion Self-Energy Corrections in Perturbative Theory at Finite Temperature*, Phys. Rev. **D40** (1989) 4171.
6. T. Altherr and P. Aurenche, *Finite Temperature QCD Corrections to Lepton Pair Formation in a Quark-Gluon Plasma* Zeit. für Phys. **C45** (1989) 99.
7. T. Altherr, *Introduction to Thermal Field Theory*, Int. Jour. of Mod. Phys. **A32** (1993) 5605.

8. T. Altherr, *Etude Perturbative en Théorie Quantique des Champs à Température Finie. Application à l'Emission de Paires de Leptons par un Plasma de Quarks et de Gluons*, Thèse, Université de Savoie, déc 1989 (unpublished).
9. T. Altherr, *Infrared Problem in $g\phi^4$ Theory at Finite Temperature*, Phys. Lett. **B238** (1990) 360.
10. T. Altherr, *Infrared Singularities Cancellation in Reaction Rates at Finite Temperature* Phys. Lett. **B262** (1991) 314.
11. T. Altherr and T. Grandou *Thermal Field Theory and Infinite Statistics*, Nucl. Phys. **B402** (1993) 395.
12. T. Altherr, E. Petitgirard and T. del Río Gaztelurrutia, *Damping Rate of a Moving Fermion*, Phys. Rev. **D47** (1993) 703.
13. T. Altherr, *Plasmon Decay: from QED to QCD*, 3rd Workshop on Thermal Field Theories and their Applications, Banff, Canada, Aug. 1993.
14. T. Altherr, T. Grandou and R. D. Pisarski, *Thermal Instability in $(\phi^3)_6$* , Phys. Lett. **B271** (1991) 183.
15. T. Altherr and P. V. Ruuskanen, *Low-Mass Dileptons at High Momenta in Ultra-Relativistic Heavy Ion Collisions*, Nucl. Phys. **B380** (1992) 377.
16. D. Seibert and T. Altherr, *Pre-equilibrium Dileptons Look Thermal*, Phys. Rev. **D48** (1993) 3386.
17. T. Altherr and D. Seibert, *Thermal Quark Production in Pure Glue and Quark-Gluon Plasmas*, Phys. Lett. **B313** (1993) 149.
18. T. Altherr and D. Seibert, *Thermal Quark Production in Ultra-Relativistic Nuclear Collisions*, Phys. Rev. **C49** (1994) 1684.
19. T. Altherr, *Axion Emission from a Hot Plasma*, Zeit. für Phys. **C47** (1990) 559.
20. T. Altherr, *Plasmon Effects in Light Scalar and Pseudo-Scalar Emission from a Supernova*, Annals of Physics **207** (1991) 374.
21. T. Altherr, *Axions, Plasmons and Supernovae*, 26th Rencontres de Moriond, Les Arcs, France, Jan. 1991.
22. T. Altherr and K. Kainulainen, *Electromagnetic Interactions and Chirality Flip of Neutrinos in a Thermal Background*, Phys. Lett. **B262** (1991) 79.
23. T. Altherr and U. Kraemmer, *Gauge Field Theory Methods for Ultra-Degenerate and Ultra-Relativistic Plasmas*, Astrop. Phys. **1** (1992) 133.
24. T. Altherr, E. Petitgirard and T. del Río Gaztelurrutia, *Axion Emission from Red Giants and White Dwarfs*, Astrop. Phys. **2** (1994) 175.
25. T. Altherr, E. Petitgirard and T. del Río Gaztelurrutia, *Photon Propagation in Dense Media*, Astrop. Phys. **1** (1993) 289.
26. T. Altherr, P. Chardonnet and P. Salati, *The 17 keV Neutrino in the Light of Astrophysics and Cosmology*, Phys. Lett. **B265** (1991) 251.
27. T. Altherr and P. Salati, *The Electric Charge of Neutrinos and Plasmon Decay*,

- Nucl. Phys. **B421** (1994) 662.
28. T. Altherr and D. Seibert, *Problems of Perturbation Series in Non-equilibrium Quantum Field Theories*, Phys. Lett. **B333** (1994) 149.
 29. T. Altherr, *Resummation of Perturbation Series in Non-equilibrium Scalar Field Theory*, Phys. Lett. **B341** (1995) 325.
 30. T. Altherr and J. C. Seixas, *Neural Networks and Calorimeter Cluster Recognition*, International Workshop on Software Engineering, Artificial Intelligence and Expert Systems for High-Energy and Nuclear Physics, Lyon, France, March 1990.
 31. T. Altherr and J. Seixas, *Cerenkov Ring Recognition Using a Non-Adaptable Network*, Nucl. Instrum. and Meth. **A317** (1992) 335.
 32. T. Altherr, *Cerenkov Ring Recognition Using Adaptable and Non-Adaptable Network*, 2nd International Workshop on Software Engineering, Artificial Intelligence and Expert Systems for High-Energy and Nuclear Physics, La Londe-les-Maures, France, Jan. 1992.
 33. T. Altherr, R. Vilela Mendes and J. Seixas, *A New Method for Fast Track Recognition at Present and Future Colliders*, Nucl. Instrum. and Meth. **A332** (1993) 283.