Thermodynamics

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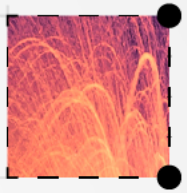

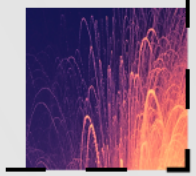

NB: I have tentatively used a template prepared by Gaia as a starting point for the graphic format discussion on Friday

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Rationale and Goals

We plan to cover material relevant for the study of strong interactions in extreme conditions of temperature and densities, with and without magnetic fields.

In this unit one would learn how to define the theory at finite temperature and densities, and how to study the relevant phase transitions.

What one needs to know before:

1) Essentials of Lattice Field Theory (in depth)
2) Critical phenomena and RG (in depth)
3) Numerical and Statistical analysis (elements)
4) Renormalisation and Improvement (elements)

Related units:

1)Algorithms: Real time, sign problem
2) BSM (conformal window, Large Nf)
3) Machine Learning (for phase transitions)
4) Tensor Networks and Quantum Computing
5) EFT methods (to be discussed)

Interactions with the outer world:

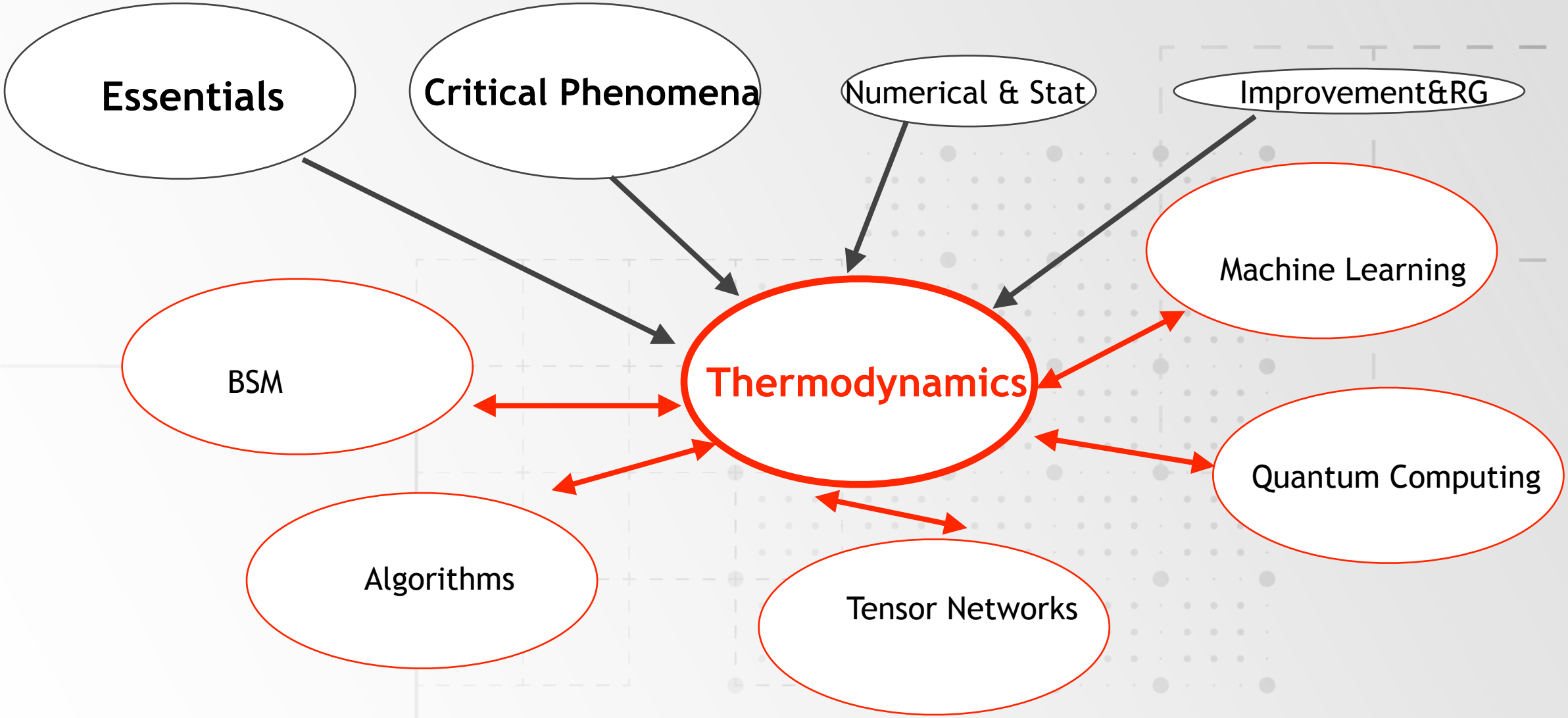
Nuclear Astro/Gravitational waves

Condensed Matter

Axion searches - Thermal axions

Heavy Ions Experiments

ML/QC

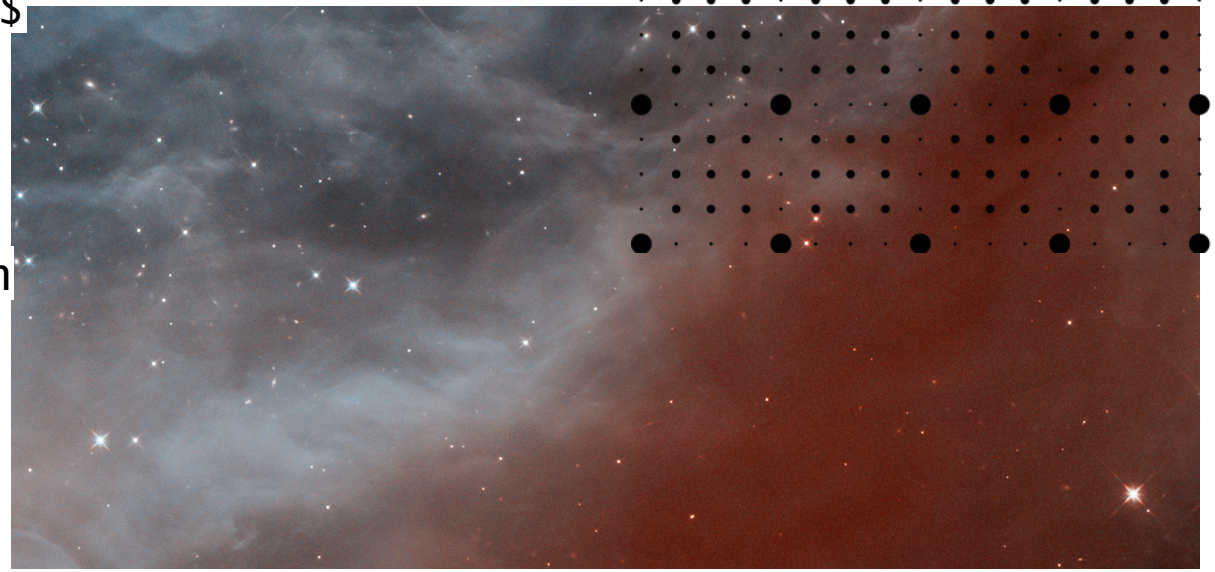

Essentials
Critical Phenomena
Numerical & Stat
Improvement&RG
Machine Learning
BSM
Thermodynamics
Quantum Computing
Algorithms
Tensor Networks

Topics:

--Topics not requiring the lattice per-se --
Basics of Finite Temperature Field Theory
Symmetries and phases of massless QCD
Phase diagram as function of quark masses
Phase diagram as a function of temperature and density

--Topics which use the lattice and are foundational --
Lattice bulk thermodynamics
Fluctuations
Quark chemical potentials, real and imaginary
Phase diagram for imaginary μ and for isospin-μ
Finite volume scaling

— Advanced topics —
Topology and axions
Transport and other quantities from analytical continuation
Heavy quark states and sequential melting
Classical-statistical Real-Time methods
Magnetic fields

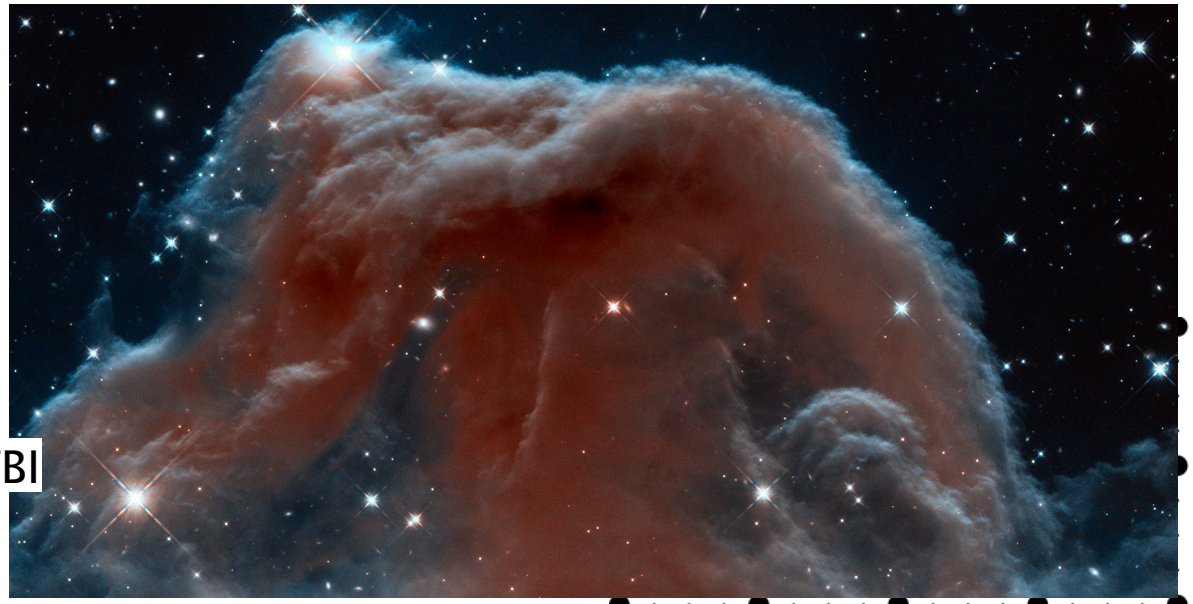


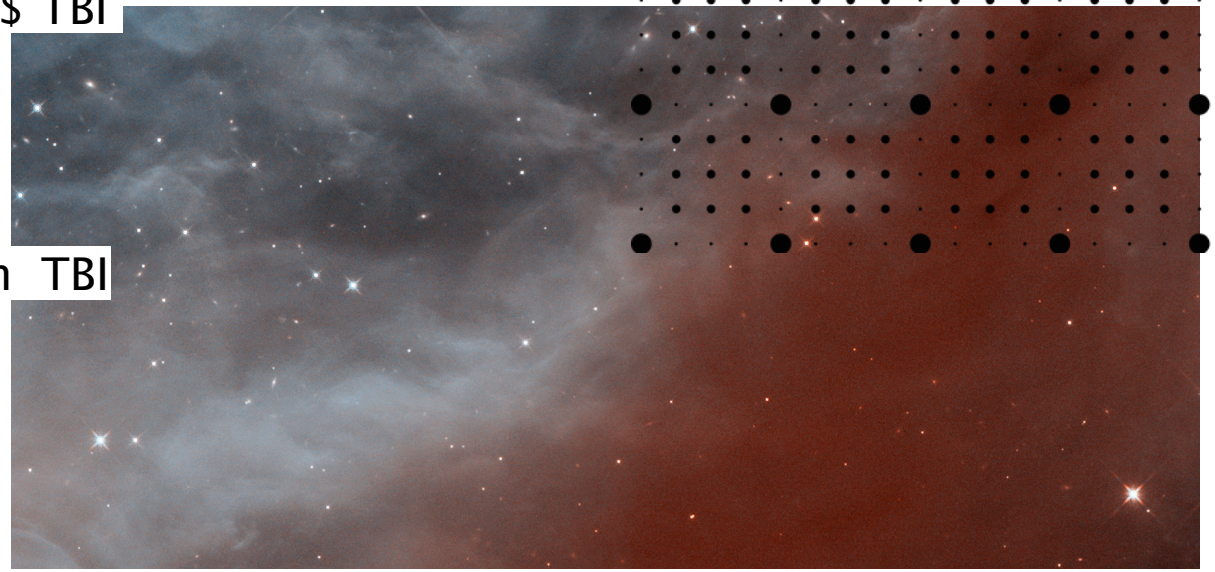
Topics and suggested lecturers

--Topics not requiring the lattice per-se --
Basics of Finite Temperature Field Theory - Guy / Frithjof
Symmetries and phases of massless QCD - Frithjof
Phase diagram as function of quark masses - TBI
Phase diagram as a function of temperature and density - TBI

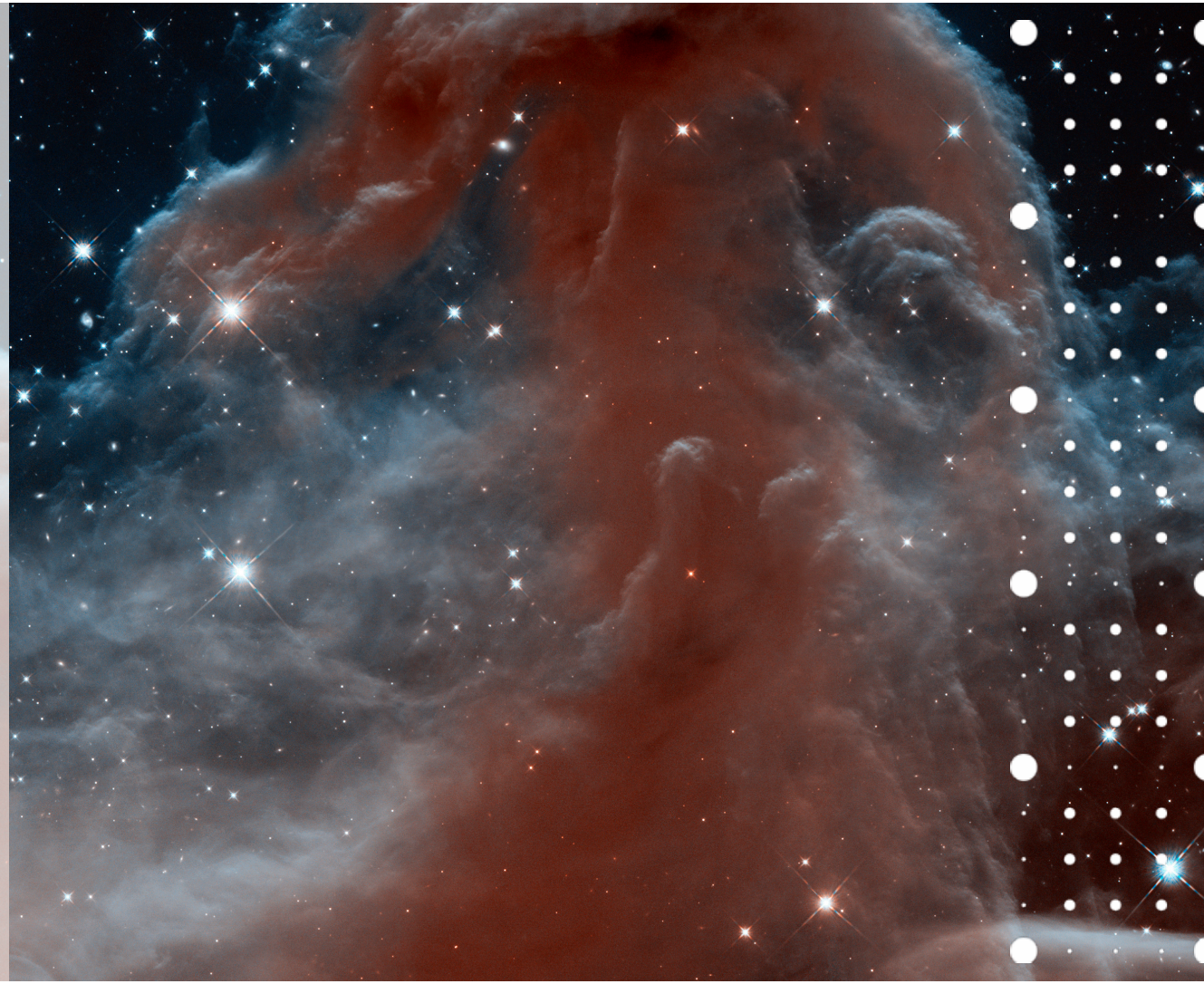
--Topics which use the lattice and are foundational --
Lattice bulk thermodynamics TBI
Fluctuations Christian
Quark chemical potentials, real and imaginary mu TBI
Phase diagram for imaginary μ and for isospin-μ TBI
Finite volume scaling Frithjof

— Advanced topics —
Topology at high temperature Claudio
Transport and other quantities from analytical continuation TBI
Heavy quark states and sequential melting TBI
Classical-statistical Real-Time methods Guy
Magnetic fields TBI



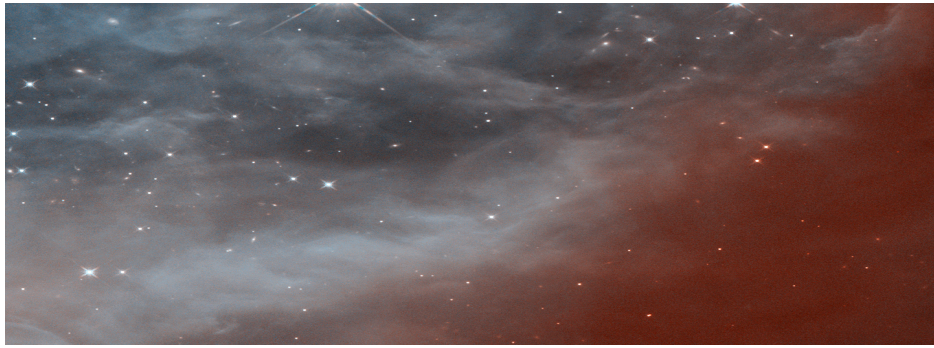


For each topic:
-a lecture;
-a set of notes which contains the details such as equations and explanations for each lecture
- (a bibliography for further reading and/ or original literature - for each topic or at the end?)




Existing material

Slides&Video Material



Owe Philipsen QCD Thermodynamics
https://www.ifsc.usp.br/~lattice/iipschool-philipsen/

Guy Moore Thermal Field Theory

https://www.youtube.com/watch?v=g1HYEteV5pY

Claudia Ratti Thermodynamics of the Quark Gluon Plasma I,II,III

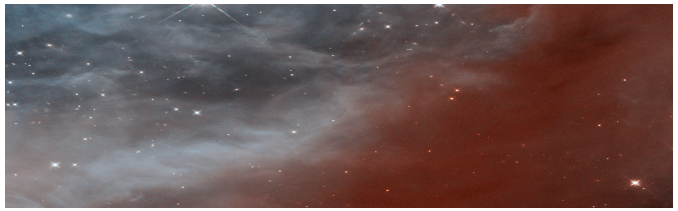
http://personalpages.to.infn.it/~nardi/QGPSchool/5th/Lectures/Ratti1.pdf
http://personalpages.to.infn.it/~nardi/QGPSchool/5th/Lectures/Ratti2.pdf
http://personalpages.to.infn.it/~nardi/QGPSchool/5th/Lectures/Ratti3.pdf

Gert Aarts Lattice QCD at nonzero baryon density

https://crunch.ikp.physik.tu-darmstadt.de/erice/2016/sec/talks/friday/aarts.pdf

Various Authors xQCD2022 PhD School
https://indico.uis.no/event/3/timetable/#20220722.detailed

Slides&Video Material (cont'd)



Frithjof Karsch Supercomputing the properties of strong interaction matter by Lattice QCD
https://www.youtube.com/watch?v=fXnUsoQZJz8

Peter Petreczky Studying thermal QCD matter on the Lattice
https://www.youtube.com/watch?v=5Pbv8ahjp2Y

Claudia Ratti QCD Phase Diagram
https://www.youtube.com/watch?v=G4o7l7WgQT4
https://www.youtube.com/watch?v=Os6fG5sZYn0
https://www.youtube.com/watch?v=aa4d2cQ-cmY

Francesca Cuteri Non Zero temperature and density
https://www.youtube.com/watch?v=MeBt-vnuK3A

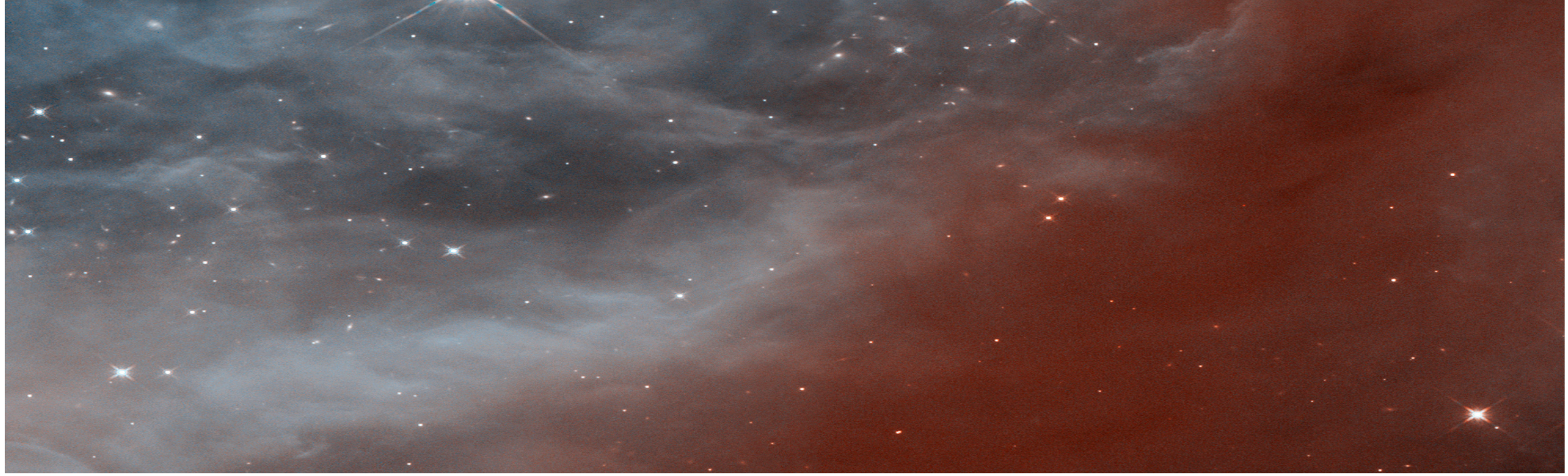
Massimo D'Elia Topology & Confinement @ Europlex School
https://europlex.unipr.it/network-events/europlex-online-school-2020/topology-confinement-video-of-the
by-massimo-delia/

….etc. etc.

Existing material :

Several excellent write-ups of lectures at Summer Schools.

- They will appear in the bibliography
- Authors may be invited to deliver and record them for the lava site



Proposed WEB page layout:

Title

1) Rationale and Goals
2) Prerequisites (Units)
3) List of topics and lecturers /authors of the written material (if already known)
4) Links to material already available

Basic structure of the Thermodynamics WEB page

In this unit one would learn how to define the theory at finite temperature and densities, and how to study the relevant phase transitions.

Prerequistes include Essentials and Critical Phenomena.

Topics:

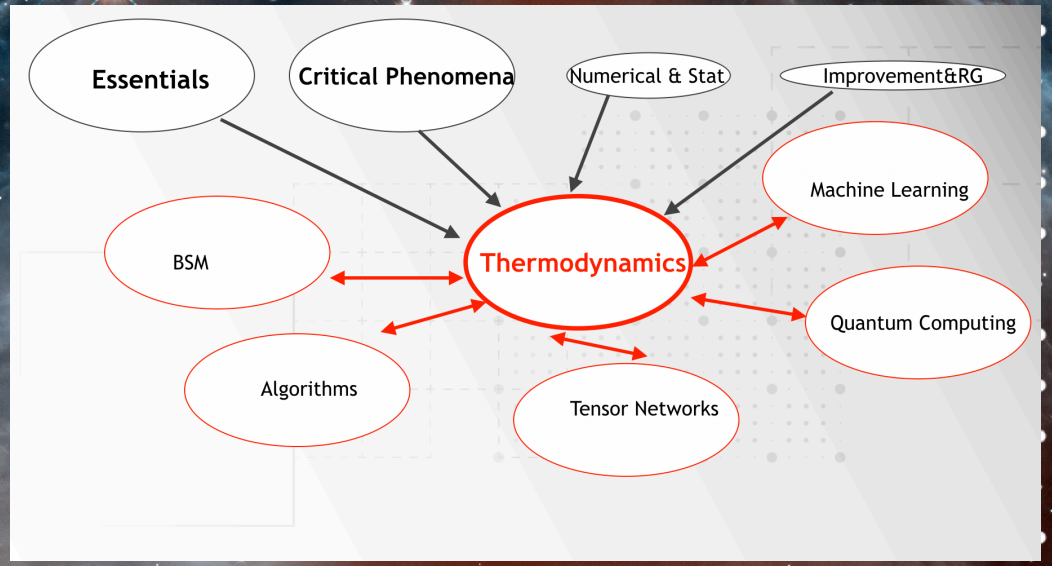
--Topics not requiring the lattice per-se --
Basics of Finite Temperature Field Theory [video, text]
Symmetries and phases of massless QCD [video, text]
Phase diagram as function of quark masses [video, text]
Phase diagram as a function of temperature and density [etc. etc]

--Topics which use the lattice and are foundational --
Lattice bulk thermodynamics
Fluctuations
Quark chemical potentials, real and imaginary
Phase diagram for imaginary μ and for isospin-μ
Finite volume scaling

— Advanced topics —
Topology and axions
Transport and other quantities from analytical continuation
Heavy quark states and sequential melting
Classical-statistical Real-Time methods
Magnetic fields

Study time about 12 hours

Further readings:
[Link to page with material, which may be edited by us]



Next steps

1. Selected videos by group
2. Invitation to colleagues to prepare videos based on their existing written lectures
3. Invitation ‘at large’ : anyone welcome to point out their lectures to be put on the ‘material’ page (mild refereeing); propose new dedicated ‘basic’ videos (to be filtered and approved)