Indirect Search for New Dynamics – like Odysseus' Conquest of Troy by Cunning

No better place to learn about history & cultures than Naples: Greeks settled here in the second millennium BC & continued for many centuries & taught culture to the Romans/Italians. Thus the organizers of this conference decided to give me the last talk: my first name is Greek & the last name is Italian.

ibi: "Odysseus conquering Troy"

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Also the place: Parthenope University of Naples:
the name of a `siren' (not `seer' !)

Siren Parthenope as founder of Naples

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Also Parthenope University of Naples:
the name of a `siren' (not `seer' !) who failed to `convince' Odysseus.

Siren Parthenope as founder of Naples

(Max Beckmann)

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History: Achaeans had besieged Troy for nine years without success and losing their hero -- Achilles.
They needed a new leader. The favored candidate was Ajax, clearly their strongest fighter,
but the Achaeans elected another hero as a leader -
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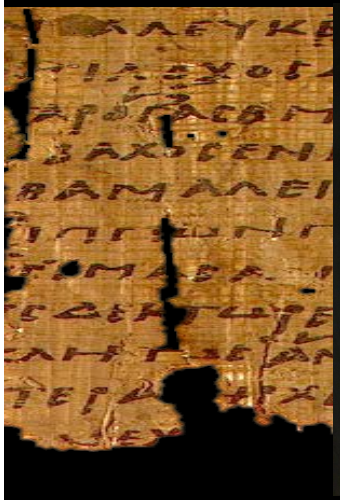
Odysseus = need force & lots of cunning of exp. & th.
LHCb (& Belle II later)!

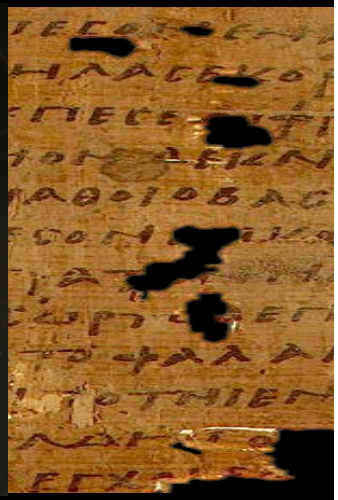
Achilles
= ATLAS

Aias
= CMS

WHEN GODS SPEAK IN RIDDLES:

TRAGIC ORACLES AND TRAGIC MISUNDERSTANDINGS



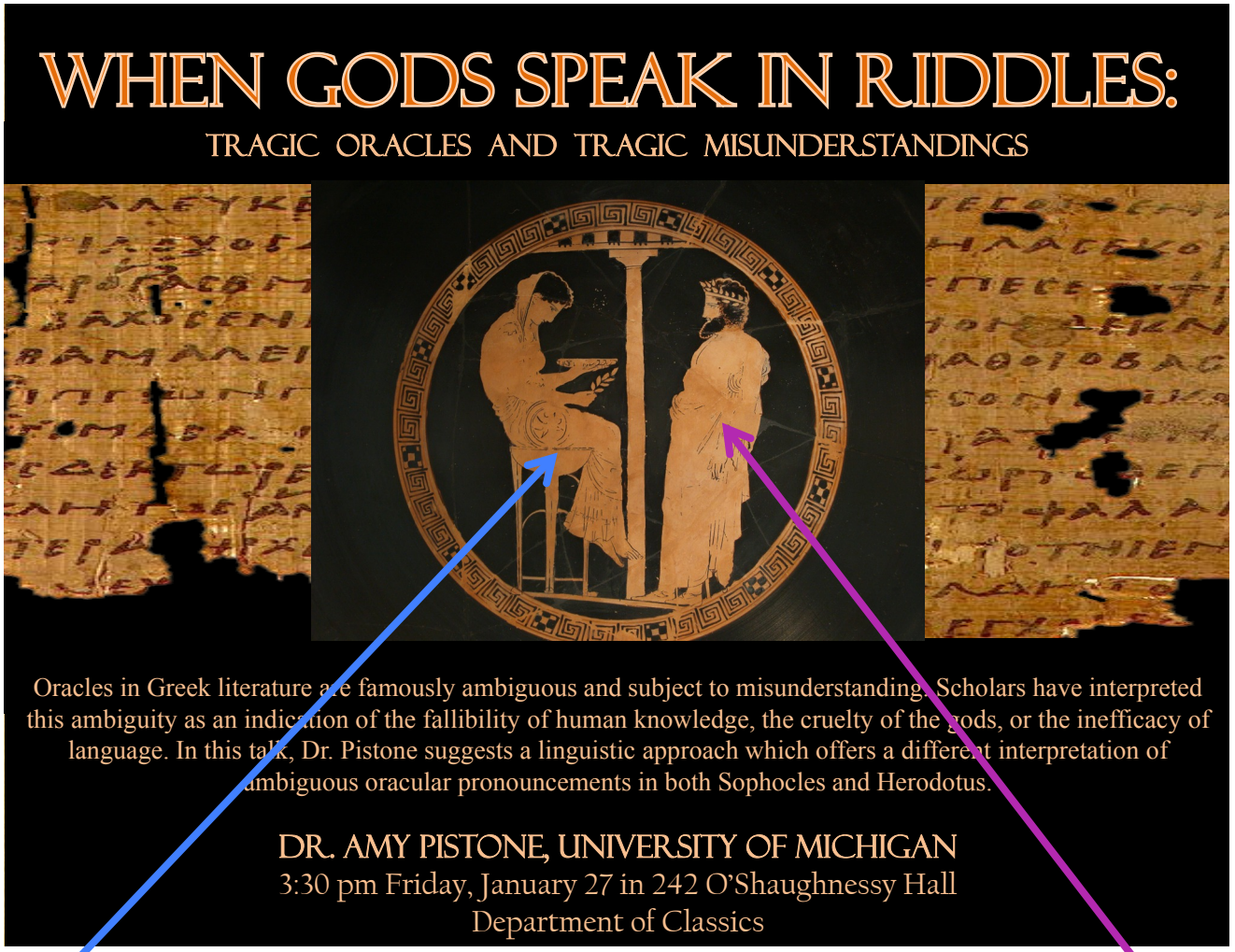


Oracles in Greek literature are famously ambiguous and subject to misunderstanding. Scholars have interpreted this ambiguity as an indication of the fallibility of human knowledge, the cruelty of the gods, or the inefficacy of language. In this talk, Dr. Pistone suggests a linguistic approach which offers a different interpretation of ambiguous oracular pronouncements in both Sophocles and Herodotus.

DR. AMY PISTONE, UNIVERSITY OF MICHIGAN

3:30 pm Friday, January 27 in 242 O'Shaughnessy Hall

Department of Classics



experimenters

theorists

ibi: "Odysseus conquering Troy"

my main point for the introduction:

"Fabula docet":

- to find the new dynamics (ND) there are two `roads'
  - -- study high p_T processes directly with novel states;
  - -- probe `low energies' with precision!

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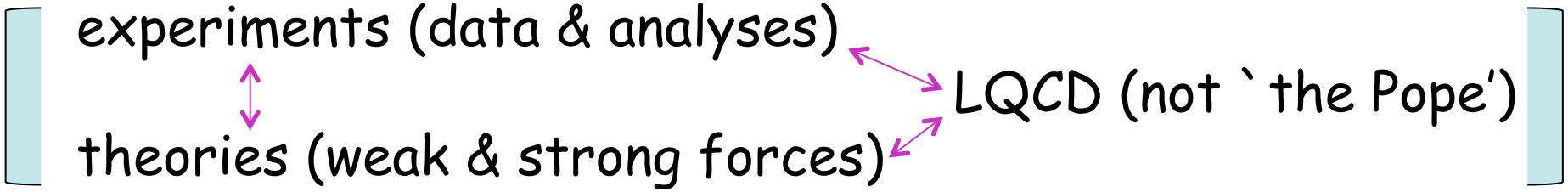

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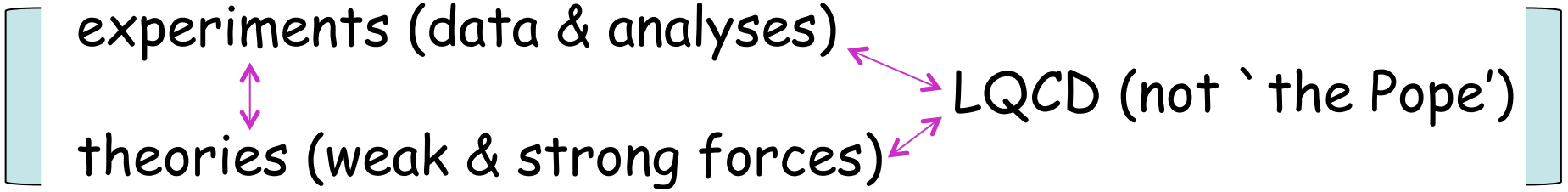

Of course, the data are the referees – in the end !

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experiments (data & analyses) ↔ LQCD (not `the Pope')

↕

theories (weak & strong forces) ↔ LQCD (not `the Pope')

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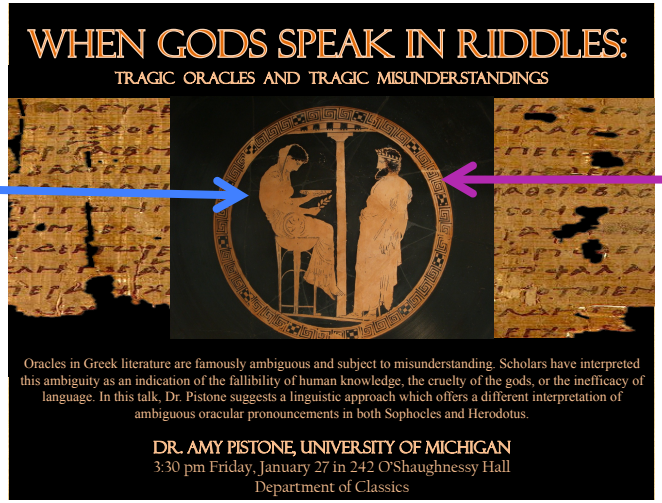
actually the situation is more complex



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experiments (data & analyses)

theories (weak & strong forces)

LQCD (not `the Pope')

Prof. Mannelli from Pisa once assured me that he does not entertain the illusion that theorists can speak the truth all the time -- speaking in good faith is all he expects from a theorist!

ibi: "Odysseus conquering Troy"

Of course, our colleague Mannelli from Pisa followed a long tradition/history that can sometimes happen, namely:

collaboration between experimentalists and theorists

"To be honest, I never would have invented the wheel if not for Urg's groundbreaking theoretical work with the circle."

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Outline

Prologue: The `Landscape' of Flavor Dynamics

I. Strong Production of Heavy Flavor Hadrons
II. List of `gaps'
III. Tools for Flavor Dynamics

IV. $\Delta S \neq 0$: Anomalies, challenges, candidates: SUSY …

V. ΔB [& ΔC] $\neq 0$: V_{cb}, V_{ub}, purely leptonic decays, CPV in Dalitz plots, CPV in Λ_b decays

VI. Lepton Dynamics somewhat in general

VII. EDMs for baryons & leptons including $(g-2)|_\mu$ & $(g-2)|_\tau$.

VIII. About the `Future'

ibi: "Odysseus conquering Troy"

Prologue: The `Landscape' of Flavor Dynamics

"Philosophy"

-- "known" matter ~ 4.5 %

- huge matter vs. anti-matter ??
- neutrino oscillations: ND !
- CP asymmetries in leptons ?
  Leading to matter vs. anti-matter ??
- `Higgs' is established; at least leading source is scalar; probe `Higgs' as pseudo-scalar?

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"dark" matter ~ 26.5 %

connection Known Matter with DM ?!?

ibi: "Odysseus conquering Troy"

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connection Known Matter with DM ?!?

`dark'/vacuum energy ~ 69 %: I am too old

ibi: "Odysseus conquering Troy"

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Competition/Combination

-- (Belle/BaBar) – LHCb – Belle 2
-- Sessions 1 – 4
-- List of speakers
before this conference .
Excellent lists of 4 sessions & 21(+1) speakers;

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my main point is: I will not just summarize the items of fundamental dynamics discussed here;
there are `gaps' where LHCb & Belle II can work on, but also beyond.
It is my privilege not to be fair all the time.
[Remember, I am a Bavarian despite my name.]

ibi: "Odysseus conquering Troy"

I. Strong Production of Heavy Flavor Hadrons

-- QCD is the only (local) QFT for strong forces

-- it is difficult to disagree with Michelangelo M. about QCD in general.

-- However:
how can you use the word `bottom', not "beauty"?

ibi: "Odysseus conquering Troy"

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-- compare $B\Lambda_b/\Lambda_b B$ [$\Lambda_b\Lambda_b$] vs. BB;the same for charm

-- multiple pairs

-- (semi-)direct impact of ND (including very heavy quarks like top quarks together with Higgs etc.).

ibi: "Odysseus conquering Troy"

II. List of `gaps'

-- it is crucial to probe 3- & 4-body final states in the weak decays of beauty & charm hadrons with accuracy, not only back-up information;

-- discuss inclusive vs. exclusive ones;

-- `duality' quarks vs. hadron worlds close to thresholds; special case: $B^- \to l^- \nu K^+ K^-$;

-- probe CPV in $J/\psi \to \bar{\Lambda}\Lambda$;

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-- $(g-2)_{\mu,\tau}$;

-- EDMs for leptons & baryons etc.; "axions"

ibi: "Odysseus conquering Troy"

III. Tools for information underlying Flavor Dynamics

III.1 Parameterization of CKM Matrix *through* $O(\lambda^6)$

(A) In smart Wolfenstein parameterization with
$\lambda \approx 0.225$ with A, η & ρ ~ O(1); $A \sim 0.81 = O(1)$
however:

- $\eta \approx 0.34$, $\rho \approx 0.13 \ll O(1)$ [there I disagree with Luca about tools]
- $V_{CKM,Wolf} = \ldots + O(\lambda^{4,5,6})$

Ibi: "Odysseus conquering Troy"

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(B) Needs *consistent* parameteriz. of CKM matrix with precision ! Y.H. Ahn, H-Y. Cheng, S. Oh (2011)

$$\begin{bmatrix} 1-\lambda^2/2-\lambda^4/8-\lambda^6/16 & \lambda & h\lambda^4\exp(-i\delta_{QM}) \\ -\lambda+\lambda^5 f^2/2 & 1-\lambda^2/2-\lambda^4/8(1+4f^2)-fh\lambda^5\exp(-i\delta_{QM})+\ldots & f\lambda^2+h\lambda^3\exp(-i\delta_{QM})+\ldots \\ f\lambda^3 & -f\lambda^2-h\lambda^3\exp(-i\delta_{QM})+\ldots & 1-\lambda^4/2\, f^2 - fh\lambda^5\exp(-i\delta_{QM})+\ldots \end{bmatrix}$$

with f ~ 0.75, h ~ 1.35, $\delta_{QM} \sim 90^o$

correlations, correlations, correlations

ĩbi: "Odysseus conquering Troy"

Tri. I.1: $V_{ud}V^*_{us}\,[O(\lambda)]+V_{cd}V^*_{cs}\,[O(\lambda)]+V_{td}V^*_{ts}\,[O(\lambda^{5\&6})]=0$

Tri. I.2: $V^*_{ud}V_{cd}\,[O(\lambda)]+V^*_{us}V_{cs}\,[O(\lambda)]+V^*_{ub}V_{cb}\,[O(\lambda^{6\&7})]=0$

Tri. II.1: $V_{us}V^*_{ub}\,[O(\lambda^5)]+V_{cs}V^*_{cb}\,[O(\lambda^{2\&3})]+V_{ts}V^*_{tb}\,[O(\lambda^2)]=0$

Tri. II.2: $V^*_{cd}V_{td}\,[O(\lambda^4)]+V^*_{cs}V_{ts}\,[O(\lambda^{2\&3})]+V^*_{cb}V_{tb}\,[O(\lambda^{2\&3})]=0$

Tri. III.1: $V_{ud}V^*_{ub}\,[O(\lambda^4)]+V_{cd}V^*_{cb}\,[O(\lambda^{3\&4})]+V_{td}V^*_{tb}\,[O(\lambda^3)]=0$

Tri. III.2: $V^*_{ud}V_{td}\,[O(\lambda^3)]+V^*_{us}V_{ts}\,[O(\lambda^{3\&4})]+V^*_{ub}V_{tb}\,[O(\lambda^4)]=0$

the pattern in flavor dynamics is less obvious for CPV

-- probe Tri. III.1 with precision in $B_{d,s}$ transitions

-- Tri. II.1 has sizable impact on B_s & connects with $B_{d,u}$ decays

-- Tri. I.2 produces CPV in *SCS* D decays & hardly for *DCS* one

-- Tri. I.1 can be probed in tiny K -> $\pi\nu\nu$ decays with small theoretical uncertainties

Again:

focus on correlations with several triangles with accuracy

ibi: "Odysseus conquering Troy"

III.2 Re-scattering & Impact of CPT Invariance

The goal is: measuring CP asymmetries probes existence & even features of New Dynamics (ND), since they can depend only an amplitude.

$$T(P \to a) = \exp(i\delta_a)\,[T_a + \sum_{aj\neq a} T_{aj}\, i\, T_{aj,a}^{resc}]$$

$$T(\overline{P} \to \overline{a}) = \exp(i\delta_a)\,[T^*_a + \sum_{aj\neq a} T^*_{aj}\, i\, T_{aj,a}^{resc}]$$

$$\Delta\gamma(a) = |T(P \to a)|^2 - |T(\overline{P} \to \overline{a})|^2 = 4\sum_{aj\neq a} T_{aj,a}^{resc}\, \mathrm{Im}\, T^*_a T_{aj}$$

With zero re-scattering direct CP asymmetries cannot happen, even if there are weak phases.

Misha & Misha & collab.; Wolfenstein

ibi: "Odysseus conquering Troy"

-- Do not know how to calculate FSI/re-scattering in general (& it is *not* the strength of LQCD);

-- I am so `mature' to assume CPT invariance.

-- Finding CP asymmetry in one channel one infers, which channels have to *compensate* asymmetries based on CPT invariance.

-- Finally analyzing those decays teach us at least important lessons about the inner working of QCD.

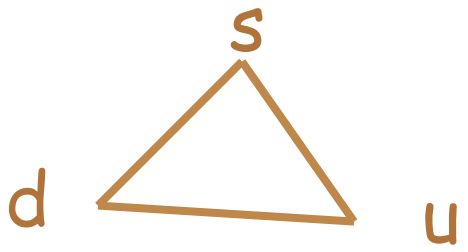
ibi: "Odysseus conquering Troy"

III.3 Connections between U- vs. V-spin symmetries

U- vs. V-spin symmetries were introduced to describe *spectroscopies* of hadrons as subgroups of global SU(3) (by Lipkin …), *before* quarks were seen as real physical states.

The situation changes much with weak transitions.

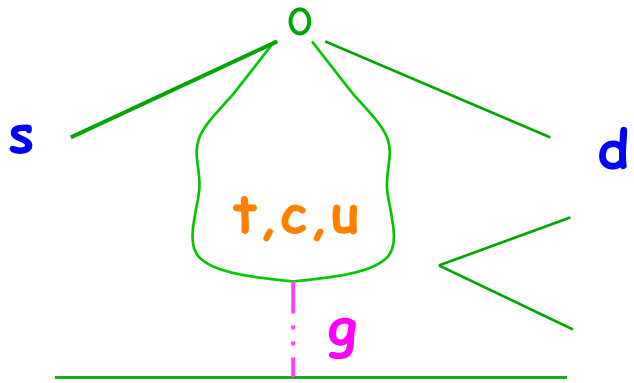
-- large impact of strong re-scattering
-- in particular about `fuzzy' difference between U-spin & V-spin symmetries.



ibi: "Odysseus conquering Troy"

-- Impact of `penguin'

- $\Delta S = 1$: *local* operator !



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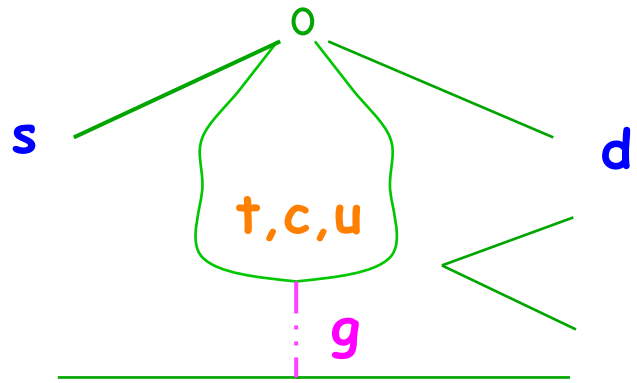
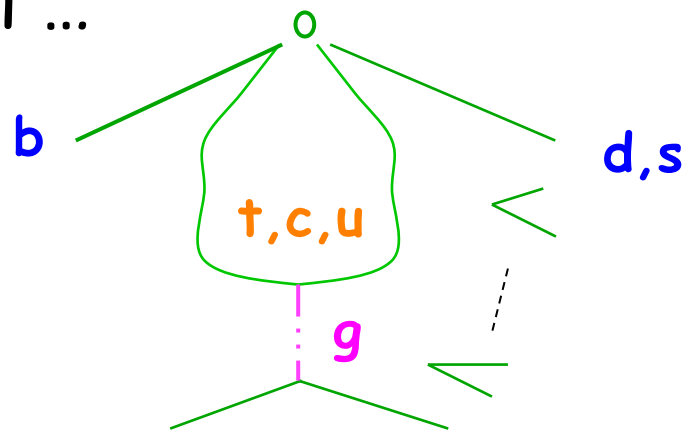


- $\Delta B = 1$: well ...



ibi: "Odysseus conquering Troy"

IV. $\Delta S \neq 0$: Anomalies, challenges, candidates: SUSY …

-- Measured $\varepsilon'/\varepsilon_K$ vs. $\varepsilon'/\varepsilon_K|_{SM}$

- Re $(\varepsilon'/\varepsilon_K)|_{exp.} = (1.66 +/- 0.23) \times 10^{-3}$;
- Re $(\varepsilon'/\varepsilon_K)|_{LQCD} = (0.138 +/- 0.515 +/- 0.443) \times 10^{-3}$;
- Re $(\varepsilon'/\varepsilon_K)|_{Buras\ team} = (0.86 +/- 0.32) \times 10^{-3}$;

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-- $K^+ \to \pi^+ \nu\nu$ vs. $K_L \to \pi^0 \nu\nu$:

Tri. I.1 described by

- its height connected with BR($K_L \to \pi^0\nu\nu$) &
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- BR($K^+ \to \pi^+\nu\nu$) = $(17 +/- 11) \times 10^{-11}$ vs. $\sim(8 +/- 1) \times 10^{-11}$

BR($K_L \to \pi^0\nu\nu$) < 2600×10^{-11}.

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$BR(K_L \to \pi^0 \nu\nu) < 2600 \times 10^{-11}$; KOTO by ~ 2019 ?

-- what about CP asymmetries in $J/\psi \to \overline{\Lambda}\,\Lambda$ etc. ?

- BESIII will probe CPV by 2018 with below 10^{-3}; what about LHCb for runs 2 & 3?

ibi: "Odysseus conquering Troy"

V. ΔB [& ΔC] $\neq$ 0: V_{cb}, V_{ub}, purely leptonic decays, CPV in Dalitz plots, CPV in Λ_b decays

V.1: V_{qb} with q=c,u – inclusive vs. exclusive transitions

The landscapes are different for V_{cb} & V_{ub} both on the experimental & theory side; we have to be subtle.

-- B -> lν D & B -> lν D* & … B -> lν D** ?

vs.

B -> lν X_c, Λ_b -> lν X^{bary}_c ;

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-- B -> lν π vs. B -> lν $\pi\pi$ vs. B -> lν π 's

-- duality !

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-- duality ? Probe B -> lν KK… close to thresholds due to experimental reasons

ibi: "Odysseus conquering Troy"

V.2: Purely leptonic decays

$l = e, \mu, \tau$

-- $B^0 \to l^+l^-$;

-- $B^0_s \to l^+l^-$

-- $D^0 \to l^+l^-$

ibi: "Odysseus conquering Troy"

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Of course, asymmetries of 3.3 σ often found;
However – in my view – is special for several reasons.

-- $A_{CP}(\Lambda_b \to p\pi^-\pi^+\pi^-)$ is 3.3 σ different from zero;
it is direct CPV;
looking at regional data it suggests ~ 20 % ?!

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-- with run 2 also probe $A_{CP}(\Lambda_b \to pK^-\pi^+\pi^-)$ & $A_{CP}(\Lambda_b \to pK^-K^+K^-)$;
probe impact of Penguin diagrams ?!

-- ...

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VI. Lepton Dynamics somewhat in general

`we' have failed to understand the
huge matter vs. anti-matter

-- maybe matter vs. anti-matter is not original; this is second effect; first effect: leptons vs. anti-leptons

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-- of course: it is crucial – but very subtle.
Therefore: LFV !

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VII. EDMs for baryons & leptons including $(g-2)|_{\mu}$ & $(g-2)|_{\tau}$.

-- 1st step: measure $(g-2)|_{\mu}$ with huge precision

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- one comments: $M_{\text{"H0"}} \sim M_{H0(SM)}$
  maybe sign of SUSY > few TeV
  best chance to find SUSY (even its features) indirectly
  rare decays & CP asymmetries

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VIII. About the `Future'

How can you think about working in this wonderful Naples ?

Actually it is easy for theorists; they can hardly think about hardware.

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S. Beckett: "Ever tried? Ever failed?
No matter.
Try again. Fail again. Fail better.

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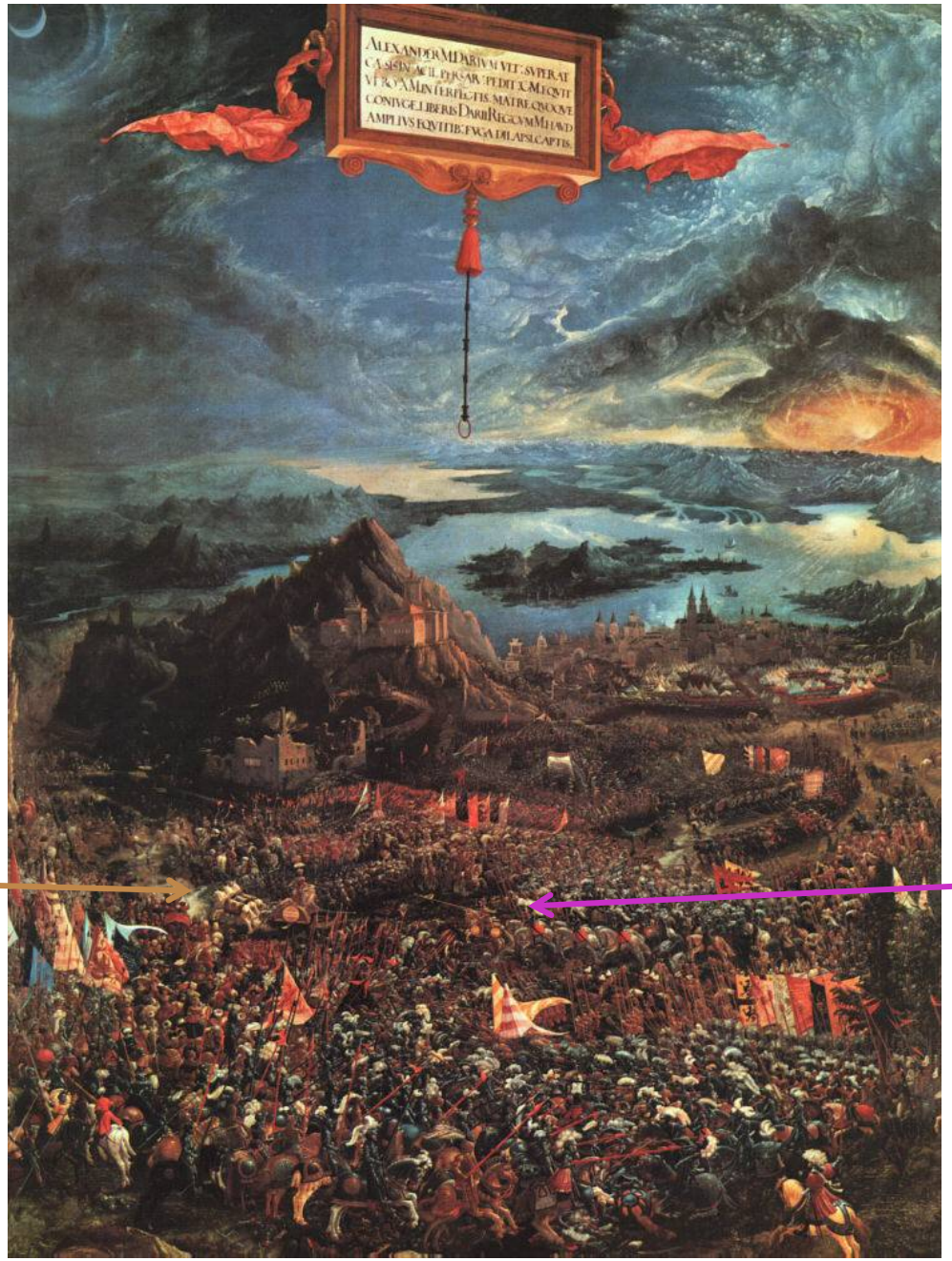

SM

ND

ibi: “Odysseus conquering Troy”

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Very recent, but crucial new information: he won it.

But he cannot relax at all!

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-- Marc Knecht is a person of culture:
"experimentalists don't live in the theoretician's paradise"

ibi: "Odysseus conquering Troy"

List of items & `gaps':

-- inclusive vs. exclusive rates of hadrons
-- need consistent CKM matrix parameterization through $O(\lambda^6)$
-- connection between U- & V-spin symmetries are crucial
-- crucial to probe 3- & 4-body FS in weak transitions of hadrons with accuracy, not back-up information
-- duality - & duality violation close to thresholds
-- CP asymmetries in $J/\psi \to \overline{\Lambda}\Lambda, \overline{\Sigma}\Sigma, \ldots$

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Ikaros Bigi: "Odysseus conquering Troy"

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- Book for up-dated strategy for LHCb runs 3 – 5:

  no response.

That is life.

Ikaros Bigi: "Odysseus conquering Troy"

The School of Athens
(at best we have a draft)

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More comments as back-up

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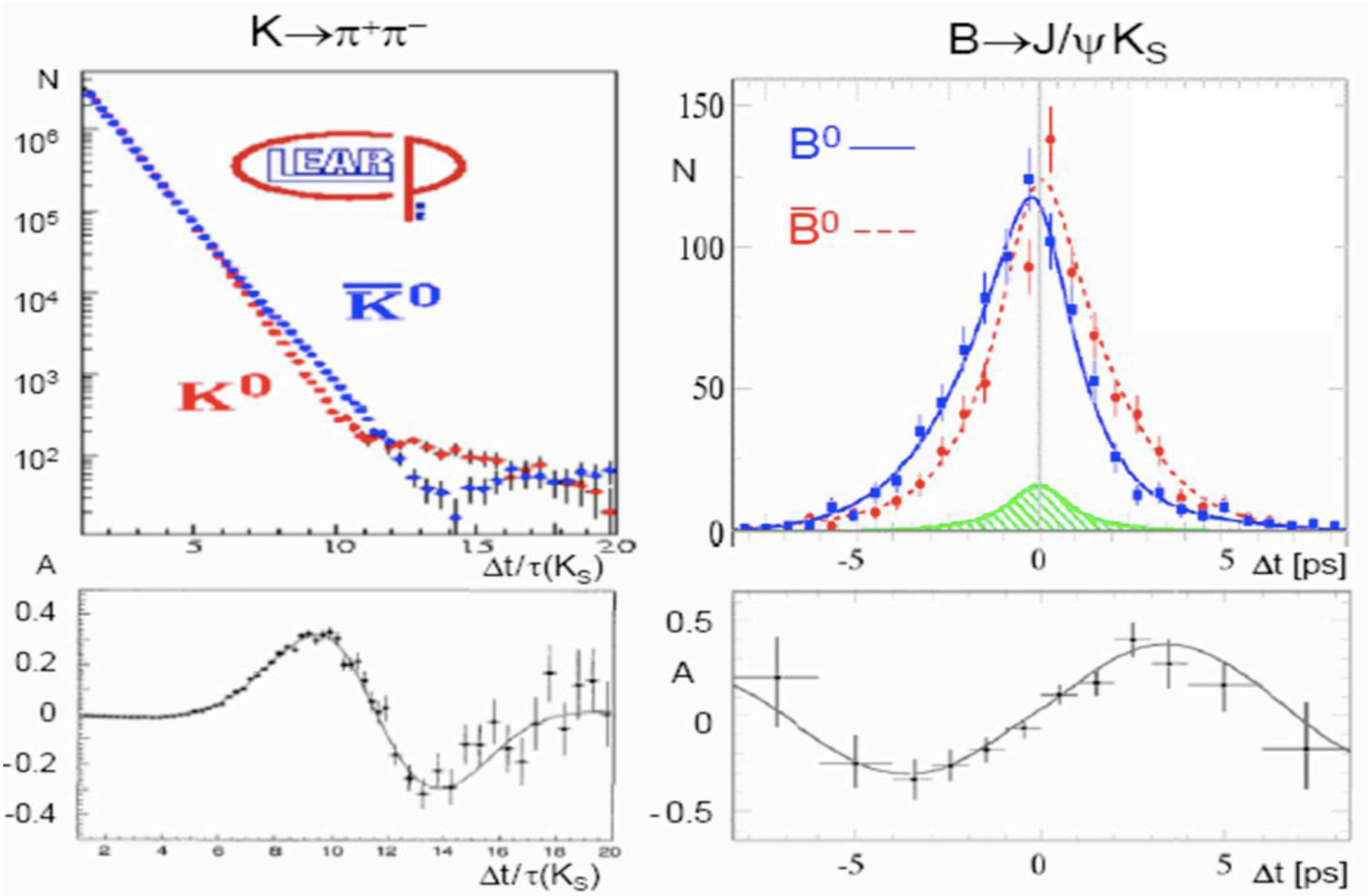


[courtesy of K. Schubert]

➥ statement `~~CP~~ in B decays is much larger than in K decays' is an empirically verified fact

Ikaros Bigi: "Odysseus conquering Troy"

(I.2) Seeing `Helen' on the Towers of Troy from faraway

Menelaos found out:
struck by Helen's beauty drops his sword --
only true beauty does it!

Ikaros Bigi: "Odysseus conquering Troy"

- The struggle for supremacy has been decided:
  The CKM paradigm has become a tested theory!
  - goal no longer to find alternatives to CKM
- `supremacy' ≠ `monopoly'
  - goal to identify corrections to CKM!
- `demystification of ~~CP~~':
  if dynamics can support ~~CP~~, it can be large!
  i.e., observable phases can be large!
- `demystification' completed
  if find ~~CP~~ anywhere in lepton sector

discovery of ~~P~~ in '57 a great shock –
theorists fast recovered with theor.`engineering' :
charged weak currents from $SU(2)_L$

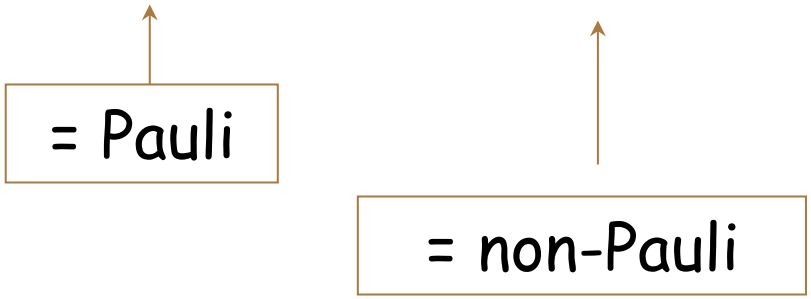
$\pi^- \to e_L^- \nu$ or $\pi^+ \to e_R^+ \nu$ $\Longleftrightarrow$ "L" = f ("-")

CP: $(\pi^- \to e_L^- \nu) \Longleftrightarrow (\pi^+ \to e_R^+ \nu)$

If CP √, "L" pure convention – like "the thumb is left on the right hand!"

$\mathcal{M}$...

`quod licet Jovi, non licet bovi'



Ikaros Bigi: "Odysseus conquering Troy"