"Bridge between Hadro-dynamics & HEP"
or
"Finding New Dynamics by Cunning"
or
"The School of Athens"

About the history of Austria:
The Romans had built many, many castles in many, many parts of our old world:

Ikaros Bigi (Notre Dame du Lac)

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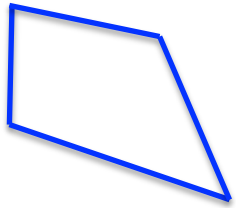
with one exception: scholars told us about Austria's castles



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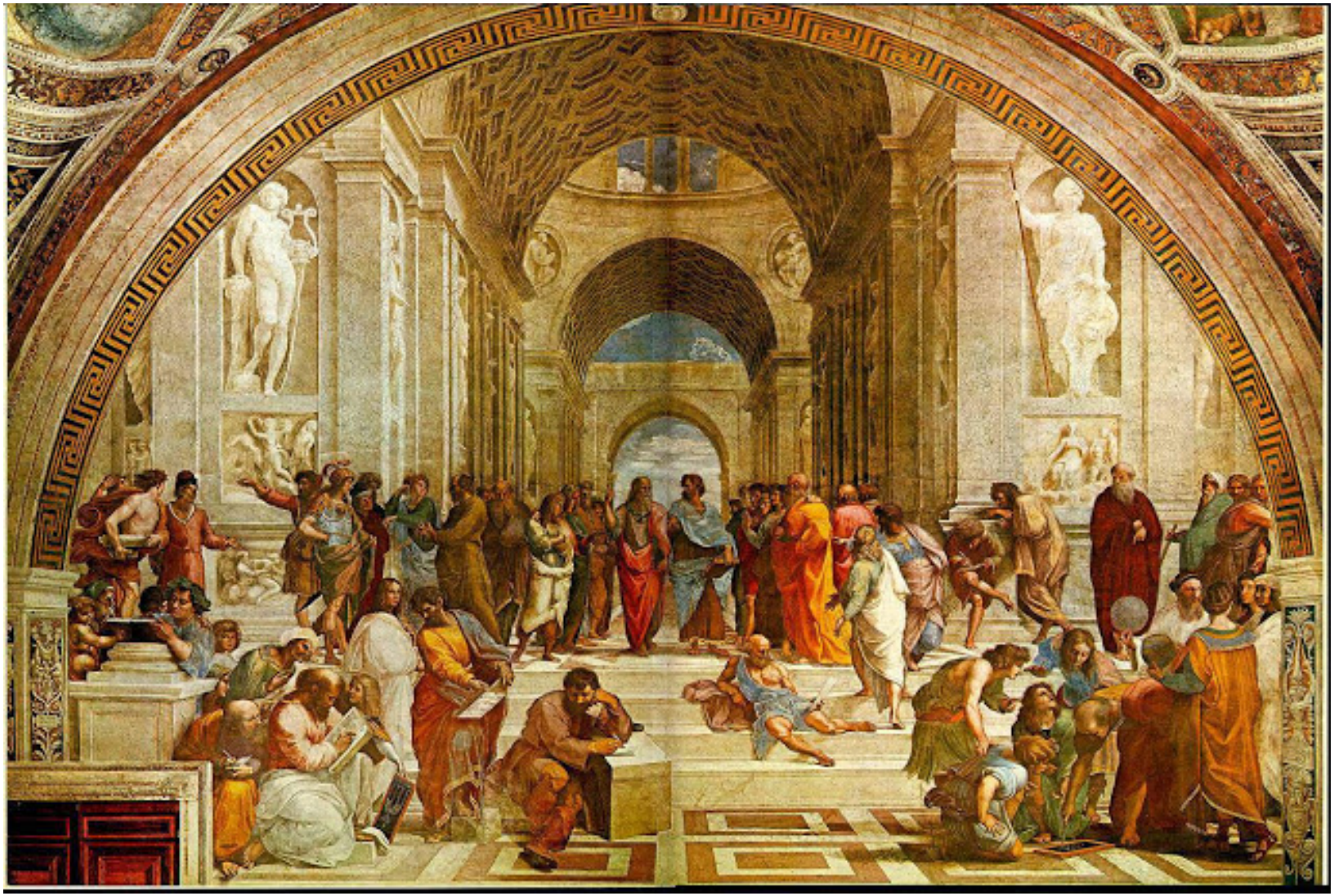

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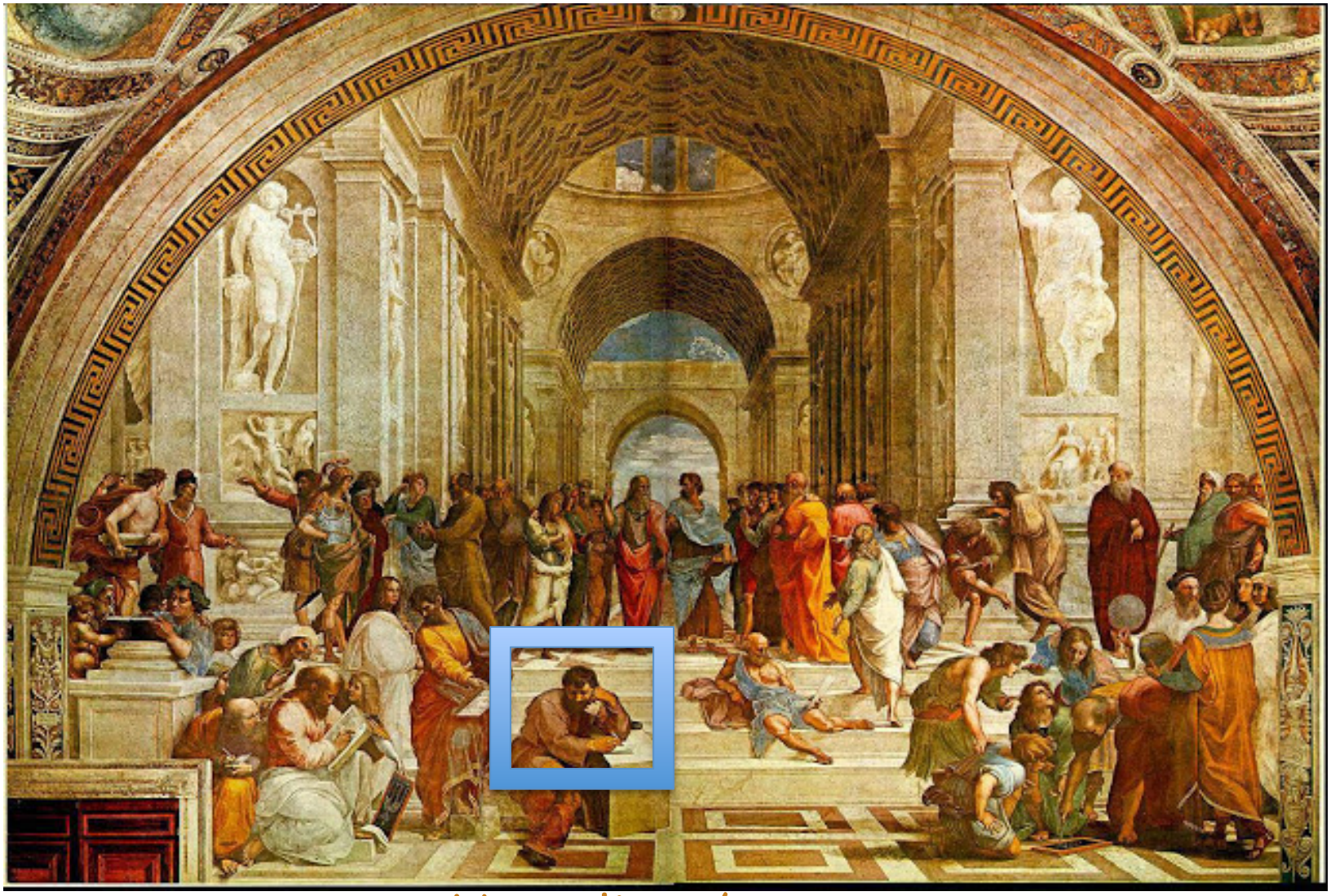

Heraclitus/
theorist

"ND by Cunning '17"

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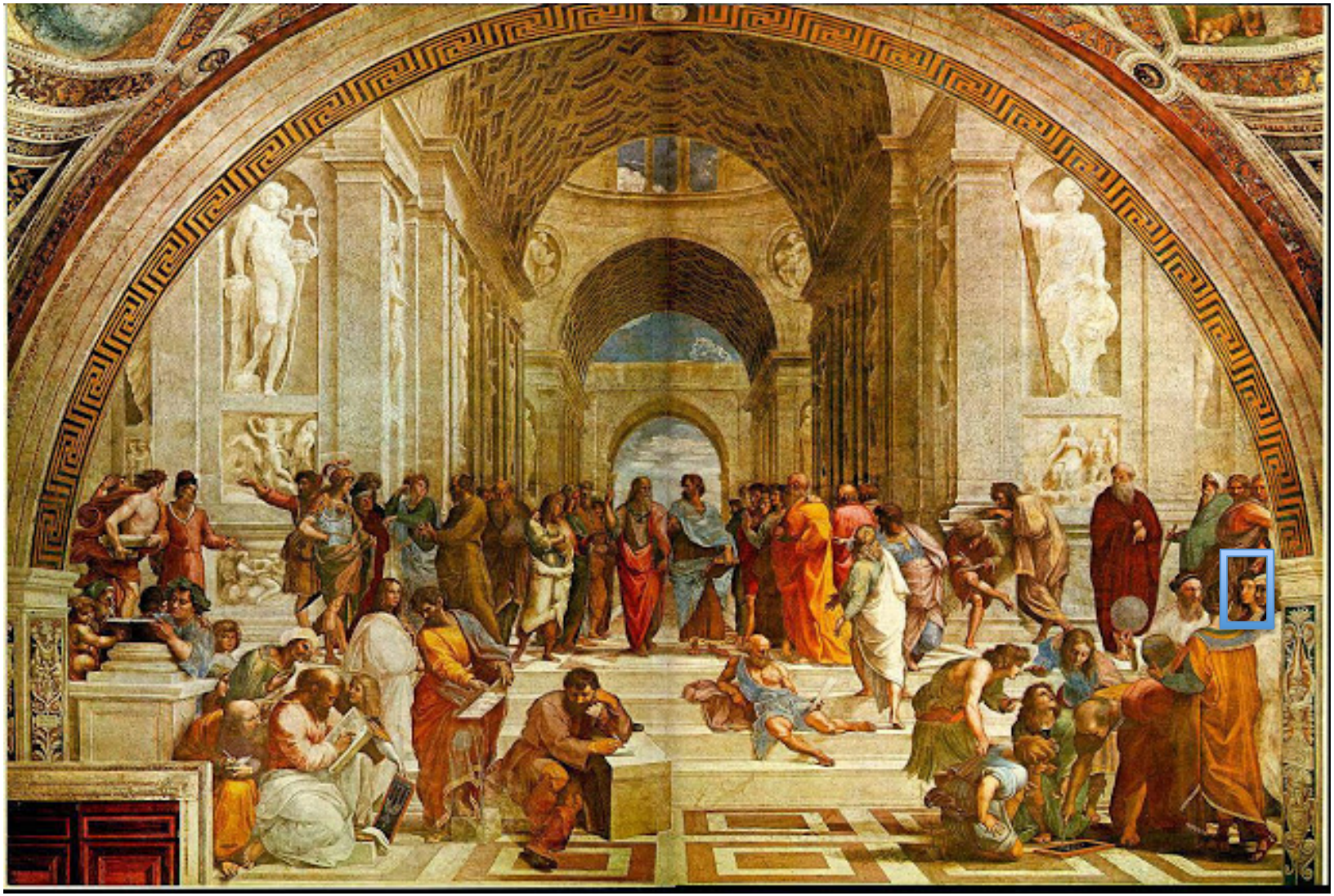

Raphael/SUSY

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We talk about New Dynamics (ND) – with perturb. QCD.
-- jet productions: many, many hadrons/quarks & gluons

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-- ?`Radiative Corrections'?
! `Applications of QFT to Phenomenology' !

"ND by Cunning '17"

My general items
-- history

"ND by Cunning '17"

My general items
-- history

→ NP → HEP

flavor dynamics

-- now

→ NP → Hadrodynamics → HEP

decays of strange/
beauty/charm hadrons
Dalitz plots
dispersion relations
accuracy/precision

jets,
Higgs, top quarks
direct SUSY

"ND by Cunning '17"

(I) CKM Matrix: consistent one

(II) Duality: exclusive vs. inclusive for V_{qb}, q = c,u

(III) 2- vs. 3- & 4-body Final States in non-leptonic decays for $\Delta B \neq 0 \neq \Delta C$ Hadrons

(IV) New Alliance between Hadrodynamics & HEP

"ND by Cunning '17"

(I) CKM Matrix: consistent one

In Wolfenstein parameterization it gets 3 classes; however:

- $\eta \approx 0.34, \rho \approx 0.13 \ll O(1)$
- PDG: $|V(ub)/V(cb)| \sim 0.085 - 0.10 < 0.225$

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Need consistent parameterization of CKM matrix with more precision !

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

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

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

Pattern is not so obvious as before,

- but not very different in qualitative ways,
- needs more accuracy &
- deeper insights in flavor dynamics & QCD impacts!

"ND by Cunning '17"

"Landscape of fundamental dynamics in our world"

CP asymmetry

- $S(B_d \to \psi K_S) \sim 0.69$ for $\delta_{QM} = 90^o$

  maximal $S(B_d \to \psi K_S) \sim 0.74$ for $\delta_{QM} = 100 - 120^o$

- $S(B_s \to \psi\varphi) = O(\lambda^2) \sim 0.03 - 0.05$

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lessons:

❖ CKM could produce ~~CP~~ in $B_d \to \psi K_S$ up to 0.74 at most

❖ $S(B_d \to \psi K_S) \sim 0.66 \pm 0.03$ does *not* establish that CKM truly generates that value of ~~CP~~ –

ND could `hide' there.

-- the SM gives ~ zero ~~CP~~ in doubly Cabibbo decays

❖ CP asymmetries are most sensitive for theoretical uncertainties – do not treat them like statistical errors!

"ND by Cunning '17"

Procedures in steps

1st step: models

2nd step:
model-insensitive (better than model-independent)

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Procedures in steps

1st step: models

2nd step:
model-insensitive (better than model-independent)

3rd step:
best fitted analyses often do *not* give us the best information about the underlying dynamics –
i.e., theorists should not be the slaves of the data
(there are several examples)

! *correlations* & judgments !

"ND by Cunning '17"

My goal is to measure CP asymmetries to probe existence & even features of New Dynamics (ND), since they can depend only one amplitude.

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

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

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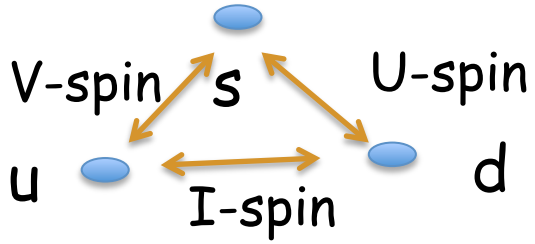

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-- in particular about `fuzzy' difference between U-spin & V-spin symmetries;

I disagree about our control of penguin diagrams in even semi-quantitatively in 2-body FS for $\Delta C \neq 0 \neq \Delta B$.

"ND by Cunning '17"

(II) Duality: exclusive vs. inclusive for V_{qb}, q = c,u

-- it seems the *difference* between exclusive vs. inclusive for V_{cb} is *smaller* now

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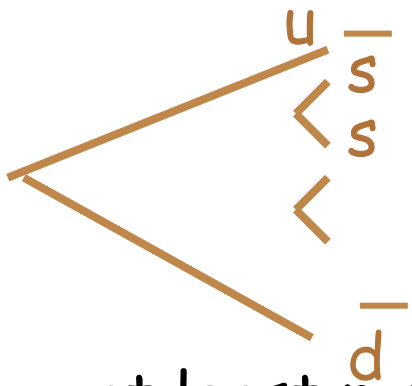
-- challenge for `duality' close to thresholds



at least novel lessons of non-perturb. QCD

"ND by Cunning '17"

(III) *2- vs. 3- & 4-body* Final States in non-leptonic decays for $\Delta B \neq 0 \neq \Delta C$ Hadrons

Probing final states with 2 hadrons (including narrow resonances) is not trivial to measure CPV;
on the other hand one gets `just' numbers.

However 3- & 4-body FS are described by two-& more dimensional plots.

☹ Price:
lots of work both for experimenters & theorists

☺ Prize:
find existence & *features* of New Dynamics (ND)!

"ND by Cunning '17"

(III.1) $B^{+/-} \to K^{+/-}\pi^+\pi^-$ vs. B+/- -> K+/-K+K-

Data about rates:

$BR(B^+ \to K^+\pi^+\pi^-) = (5.10 \pm 0.29) \times 10^{-5}$;

$BR(B^+ \to K^+K^+K^-) = (3.37 \pm 0.22) \times 10^{-5}$;

not surprising at all

averaged CP asymmetries

$\Delta A_{CP}(B^+ \to K^+\pi^+\pi^-) = + 0.032 \pm 0.008 \pm 0.004 \pm 0.007$;

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regional CP asymmetries

$\Delta A_{CP}(B^+ \to K^+\pi^+\pi^-)|_{regional} = + 0.678 \pm 0.078 \pm 0.032 \pm 0.007$;

$\Delta A_{CP}(B^+ \to K^+K^+K^-)|_{regional} = - 0.226 \pm 0.020 \pm 0.004 \pm 0.007$;

Very surprising for me due to two connected points:

-- the centers of the Dalitz plots are mostly empty

-- the differences are so huge!

"ND by Cunning '17"

(III.2) $B^{+/-} \to \pi^{+/-}\pi^+\pi^-$ vs. $B^{+/-} \to \pi^{+/-}K^+K^-$

Data about rates:

$BR(B^+ \to \pi^+\pi^+\pi^-) = (1.52 \pm 0.14) \times 10^{-5}$;

$BR(B^+ \to \pi^+K^+K^-) = (0.50 \pm 0.07) \times 10^{-5}$;

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$\Delta A_{CP}(B^+ \to \pi^+\pi^+\pi^-)|_{regional} = + 0.584 \pm 0.082 \pm 0.027 \pm 0.007$;

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"ND by Cunning '17"

(IV) New Alliance between Hadrodynamics & HEP

these connections are more subtle than looking at diagrams;
it connects two worlds of theorists with a different landscape
-- *HEP theorists* work with quarks.
-- *hadrodynamics theorists* work using pions, kaon exchanges
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Probing final states with 2 hadrons (including narrow resonances) is not trivial to measure CPV; on the other hand one gets `just' numbers.
3- & 4-body FS are described by 2-& more dimensional plots.
There is a prize to deal with much more data:
-- unitary
-- chiral symmetry: pions [+++], kaons [++/+],
-- dispersion relations …
-- fitting the data is the 2nd step, but not the final one!

! Correlations & Judgement !

"ND by Cunning '17"

Example:

LHCb Collab. PRL 110 (2013) 221601:

$A_{CP}(B_s \to K^-\pi^+)=0.27\pm0.04\pm0.01$, $A_{CP}(B_d \to K^+\pi^-)=-0.080\pm0.007\pm0.03$

$$\Delta_{LHCb} = -0.02 \pm 0.05 \pm 0.04$$

"These results allow a *stringent* test of the validity of the ..."

Look at the real eq.:

$\Delta = A_{CP}(B_d \to K^+\pi^-)/A_{CP}(B_s \to K^-\pi^+) + \Gamma(B_s \to K^-\pi^+)/\Gamma(B_d \to K^+\pi^-) = 0$

to get opposite signs in the SM is obvious; however

-- it is a test of the model of U-spin broken symmetry.

-- The job was done by probing 2-body FS ?

I disagree !

"ND by Cunning '17"

Quote of Marinus

(~468 AD student of Proklos, known Neoplatonist Philosopher):

" Only *being* good is one thing –

but good *doing* it is the other one! "

"Bridge between Hadrodynamics & HEP"
or
"Lot of Water still Passing under the Bridge"

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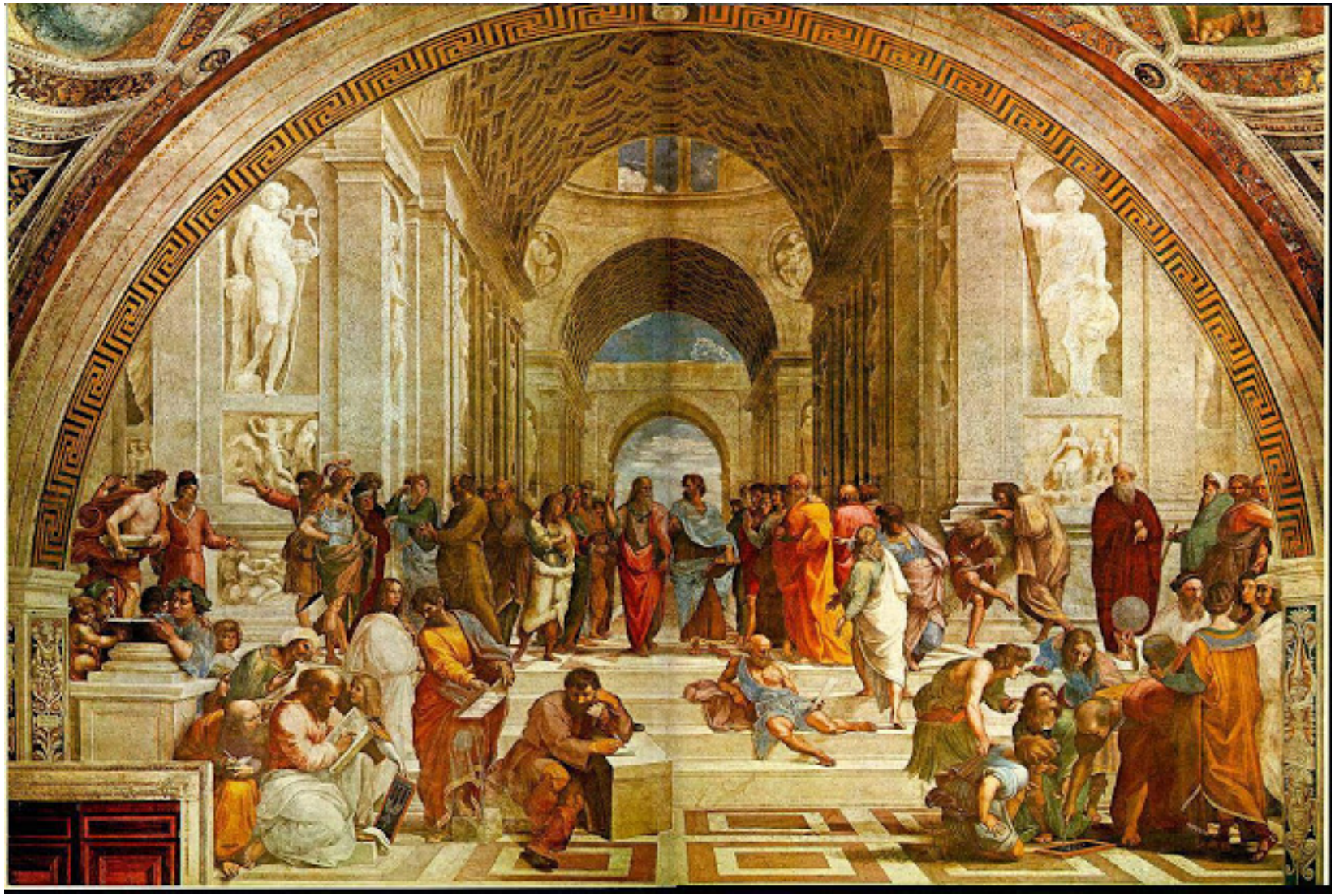
"The School of Athens"



"ND by Cunning '17"

New Alliance between Hadrodynamics/MEP & HEP (& LQCD)

`Applications of QFT to Phenomenology'

"ND by Cunning '17"