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# Complementarity between Dark Matter Searches and Collider Experiments

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**Motivations**  
**Context**  
**Goals**  
**Program**

# Motivations

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Bring together two communities focusing on two central scientific questions which may be related

## Astrophysics

The nature of the dark side of the universe!

In particular the nature of the dark matter which plays a critical role in the structure formation

## Particle/Nuclear Physics

The energy scale hierarchy and unification of forces

In particular

Why a electro-weak scale at  $\approx 100 \text{ GeV}$ ?

Why is the proton very stable

## Typical of the Quantum Universe:

Growing consensus in the community: we need to push **three** frontiers

- Astronomy observations from ground and space
- Collider measurements
- Underground experiments

# Context

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## Follow up to a mini-workshop after the Marina del Rey Dark Matter conference in February

42 participants but mostly from Particle/Nuclear Physics community  
Try to involve more strongly the collider community  
An apology for late organization

## Entering interesting time

Major new equipment coming online  
Major new results expected in the next 5 years  
Colliders

Tevatron run 2  
LHC 2007

### Large surveys

SLOAN 1 and 2, DEEP 2  
Gravitational lensing (MEGACAM, PanStar → LSST)

### Direct searches for WIMPs

CDMS II, EDELWEISS II, CRESST II →  $10^{-44}$  cm<sup>2</sup>  
New technologies: Liquid Xenon, Argon/Neon  
Pressurized gas  
COUPP, Picasso, Simple

### Indirect searches

GLAST 2007  
ICECube Antares/Nemo/Nestor

# Context (2)

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## Preparation of the future

e.g. WIMP search: Time to get to the next generation  
Push the scientific frontier with demonstrated technologies  
R&D and demonstration projects for new technologies

### U.S.: Intense prioritization exercise

HEPAP / NSAC

EPP 2010: ILC and other foci: e.g. particle astrophysics  
P5

Dark Matter SAG: first meeting June 29-30  
reporting to HEPAP and Astronomy and Astrophysics Adv. Com.

### Europe: Define European projects

Illias

Eureca

# Goals

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## Common understanding of theoretical landscape

Common language

Clean generic arguments

How to describe a many-dimensions parameter space

Benchmarks and understanding of their limitation

Open issues (e.g. naturalness/fine tuning)

## Identify major components of the experimental program that we need

Experimental challenges

Complementary capabilities of individual experiments

Going beyond proponent propaganda

Strategies to minimize risk within a limited budget

## How can we make progress together?

In the short run?

Incomplete experimental information

Combine what we get on both side + simplicity assumptions

In the long run?

Full determination of properties at colliders

=> more realistic models going beyond minimum ones

measure the detailed astrophysics ("gastrophysics")

# Framework

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## Conventional General Relativity: Dark Matter puzzle

### Inflationary Big Bang

Occam's razor: keep things simple unless we are obliged to complicate  
No late release of energy  
No late decays  
⇒ Cold Dark Matter (non relativistic at time of galaxy formation)

### Dark Matter = Weakly Interactive Massive Particles

Dark Matter  $\leftrightarrow$  Electroweak scale

### Complementarity of approaches at

Accelerators: supersymmetry/additional dimension

Detection in cosmos

Better understanding of dark matter in large scale structure

Direct detection (elastic scattering)

Indirect detection (annihilation)

- gamma rays
- positrons/antiprotons
- high energy neutrinos from Sun/Earth

# Weakly Interactive Massive Particles

Particles in thermal equilibrium  
+ *decoupling when nonrelativistic*

Freeze out when annihilation rate  $\approx$  expansion rate

$$\Rightarrow \Omega_x h^2 = \frac{3 \cdot 10^{-27} \text{ cm}^3 / \text{s}}{\langle \sigma_A v \rangle} \Rightarrow \sigma_A \approx \frac{\alpha^2}{M_{EW}^2}$$

By crossing  $\sigma_{\chi q \rightarrow \chi q} = k \frac{\alpha^2}{M_{EW}^2} \quad k \approx 0.05$

Cosmology points to W&Z scale  
Inversely standard particle model requires new physics at this scale (e.g. supersymmetry)  $\Rightarrow$  significant amount of dark matter

**Note: not only supersymmetry**

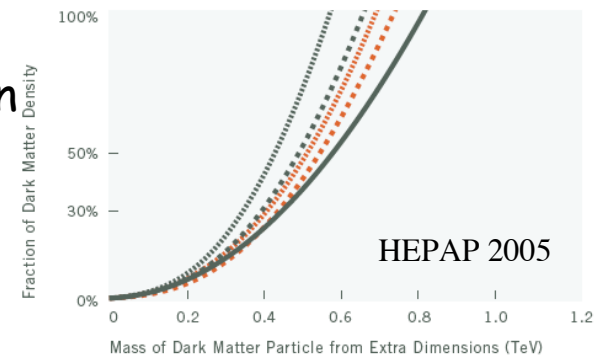
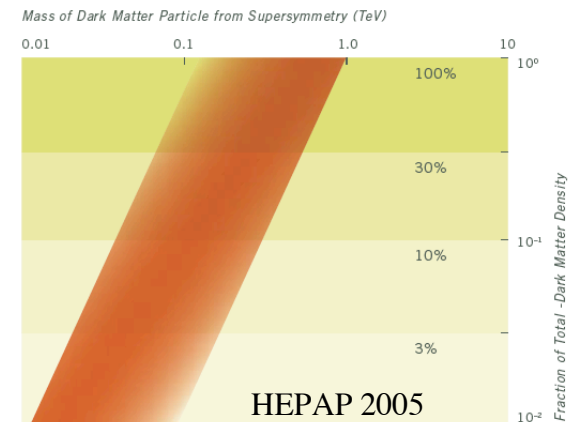
*Ex. Additional dimensions*

WIMP could be stable Kaluza Klein excitation in additional dimensions (compact or warped)

Cross sections also in the same region

Spin 0 instead of 1/2

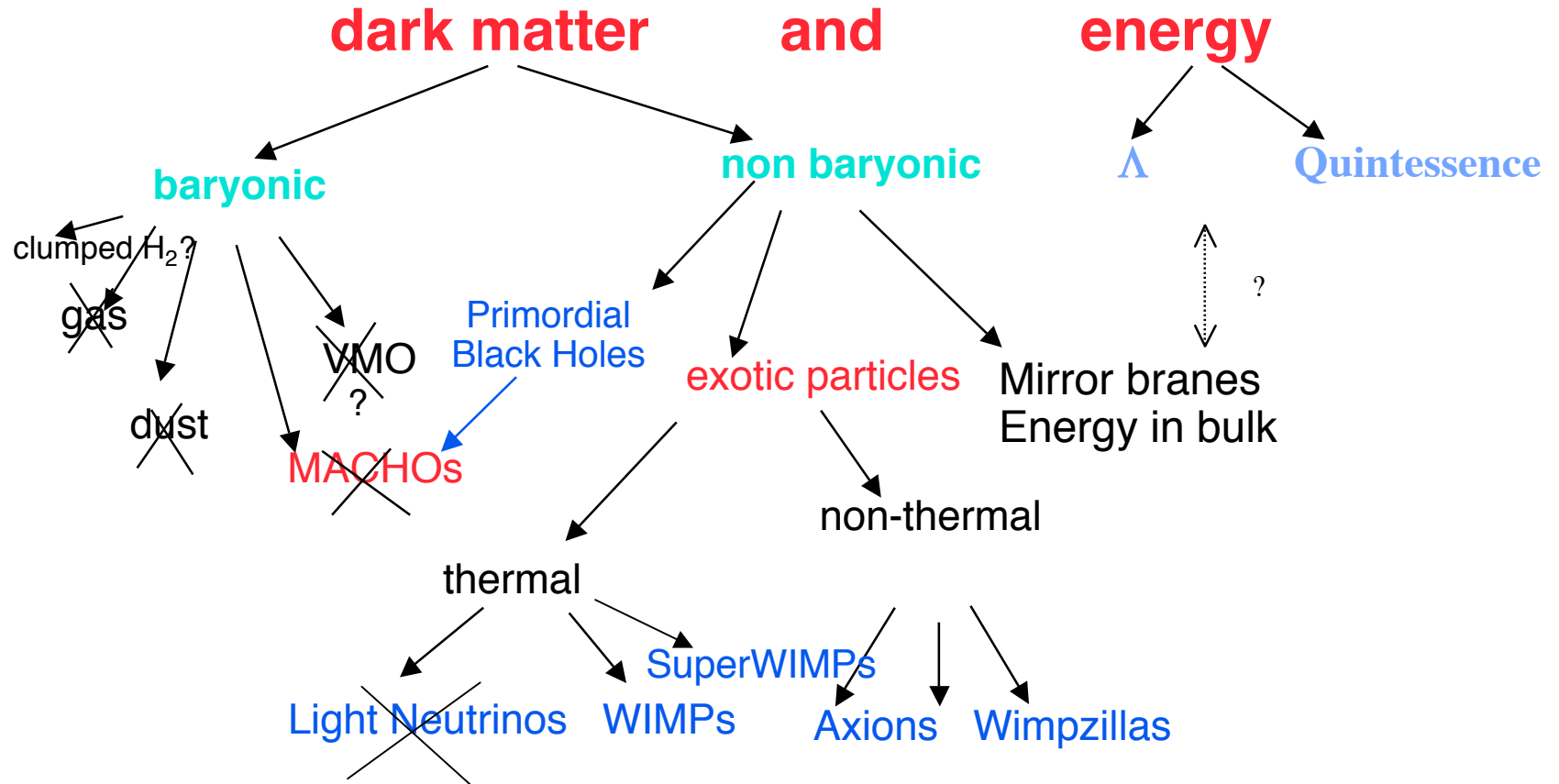
*Generic Class*



# But Nature May Be More Complex

## WIMPs not the only possibility

Systematic mapping of the possibilities



+ Non minimal scenarios

+ Failure of framework: e.g. G.R.



# Program

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## Saturday June 10

9:30 Start

Welcome and logistics : Steve Barwick (10 min)

Scientific goals of the workshop: Bernard Sadoulet (15+5 min)

### 1. Scientific context 10:00 - 12:30

- Dark Matter: What do we know from Cosmology?: Joel Primack (35 +10 min)

10: 45 -11:15 Coffee Break

- Supersymmetry, Dark Matter and Accelerators: Keith Olive (35 +10 min)
- Additional Dimensions, Dark Matter and Accelerators: Jose Ruys Cembranos (25+5 min)

12:30 - 1:30 Lunch

- Non Minimal Scenarios (Cosmology): Paolo Gondolo (25+5 min)
- Non Minimal Scenarios (Supersymmetry): Xerxes Tata (25+5 min)

# Program Saturday Afternoon

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## 2. The next five years: LHC and Direct Detection 2:30-6:00

- Basic Detection Schemes at Colliders and LHC reach in the next five years : Naoko Kanaya (30+10 min)
- SUSY Signals of Stau-Neutralino Coannihilation at Colliders: Bashkar Dutta (15+5min)

3:30 - 4:00 Coffee Break

- Direct Detection in the next five years: Experimental challenges and Phonon Mediated Detectors: Blas Cabrera(30+10min)
- Direct Detection with liquid Xenon : Tom Shutt (20+5 min)
- Direct Detection with liquid Argon: Cristiano Galbiati (20+5min)
- The importance of the zeptobarn scale: Jeff Filippini (15+5 min)
- The measurement of WIMP mass with direct detection: Richard Schnee (15+5 min)
- General discussion

# Program Sunday Morning

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## Sunday June 11

8:30 Start

### 3. The next five years: What is indirect detection likely to bring?

8:30-10:50

- Have we already discovered WIMPS in gamma rays: Wim de Boer (20+10min)
  - TeV scale gamma rays (HESS-MAGIC-VERITAS): TBA (20+5 min)
  - Dark Matter and GLAST: Larry Wai (20+5min)
  - Dark Matter and High Energy neutrinos: TBA (15+5min)
  - Electrons and positrons: TBA (15+5min)
- Coffee Break 10:25-10:55
- Complementarity between Direct and Indirect Detection: Ted Baltz (20+5 min)

### 4. The long term: LHC + ILC (15 years?) 11:20-12:30

- How much will the colliders fix the physics?
    - Theoretical perspective : Michael Peskin (30+ 10 min)
    - Experimental perspective : Marco Battaglia (30+10 min)
- Lunch 12:30-1:30

# Program Sunday Afternoon

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## 5. Additional inputs: 1:30-3:30

- WIMPs from Early Decays: Manoj Kaplinghat (15+5min)
- SuperWIMPs: Fumihiro Takayama (15+5 min)
- Kaluza Klein Dark matter: Hsin-Chia Cheng(15+5 min)
- Non thermal WIMPs: Graziella Gelmini (15+5min)
- Methods to Prove Dark Matter Detection: David Cline (15+5min)
- Directional methods: TBA (15+5)

Coffee break 3:30-4:00

## 6. Strategic implications: 4:00-6:00

3 round table discussions introduced by the workshop speakers with the participation of the audience

- Round table discussion 1: The next five years (moderator: Bernard Sadoulet)
- Round table discussion 2: The asymptotic regime (moderator: Marco Battaglia)
- Round table discussion 3: Pressing theoretical issues (moderator: Graziella Gelmini)