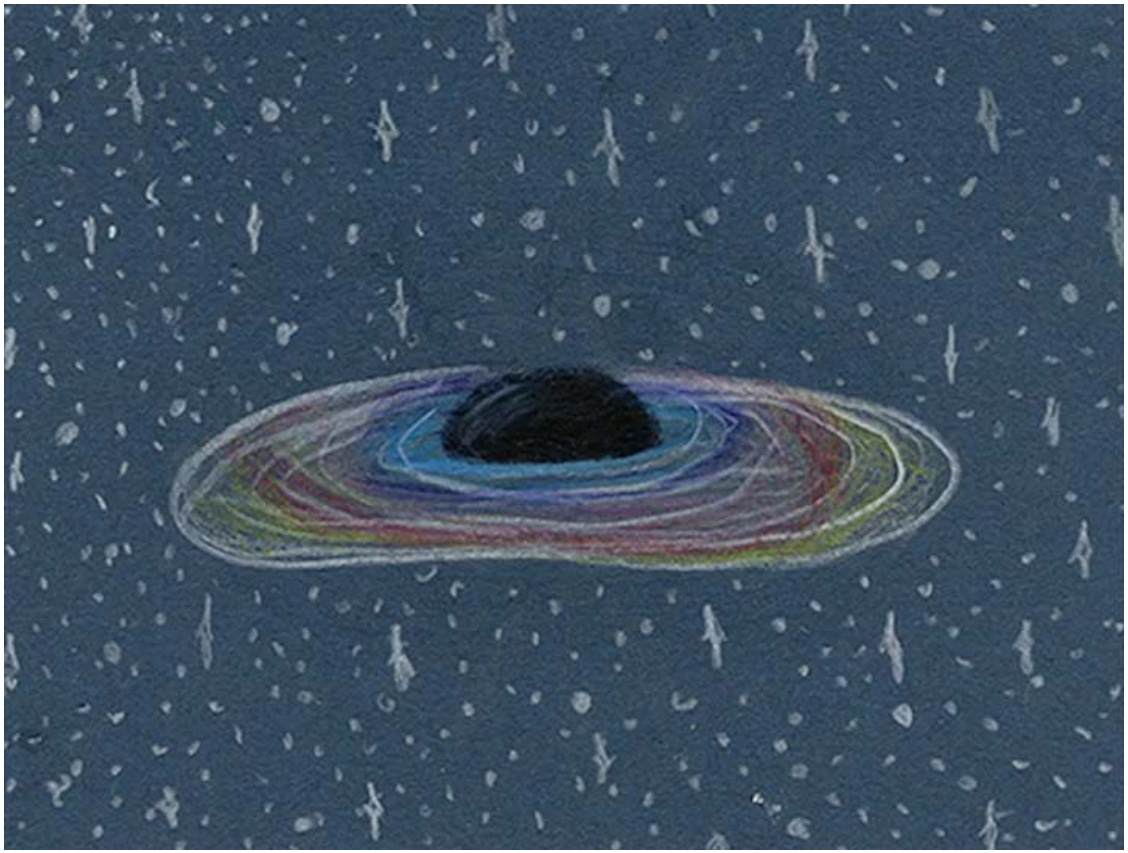
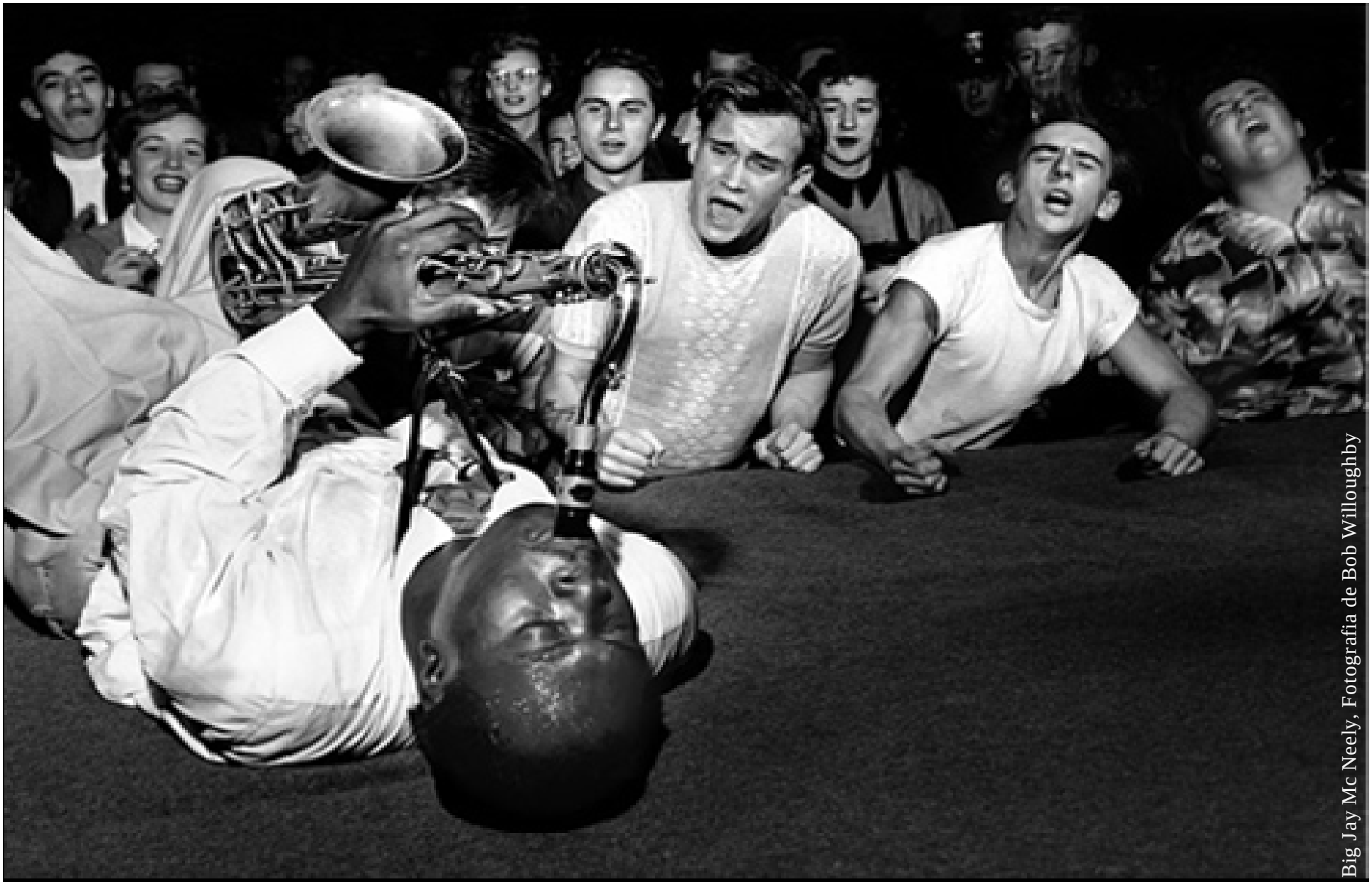
“In my entire scientific life, extending over forty-five years, the most shattering experience has been the realization that an exact solution of Einstein’s equations [...] provides the *absolutely exact representation* of untold numbers of black holes that populate the universe.”
S. Chandrasekhar, The Nora and Edward Ryerson lecture, Chicago April 22 1975



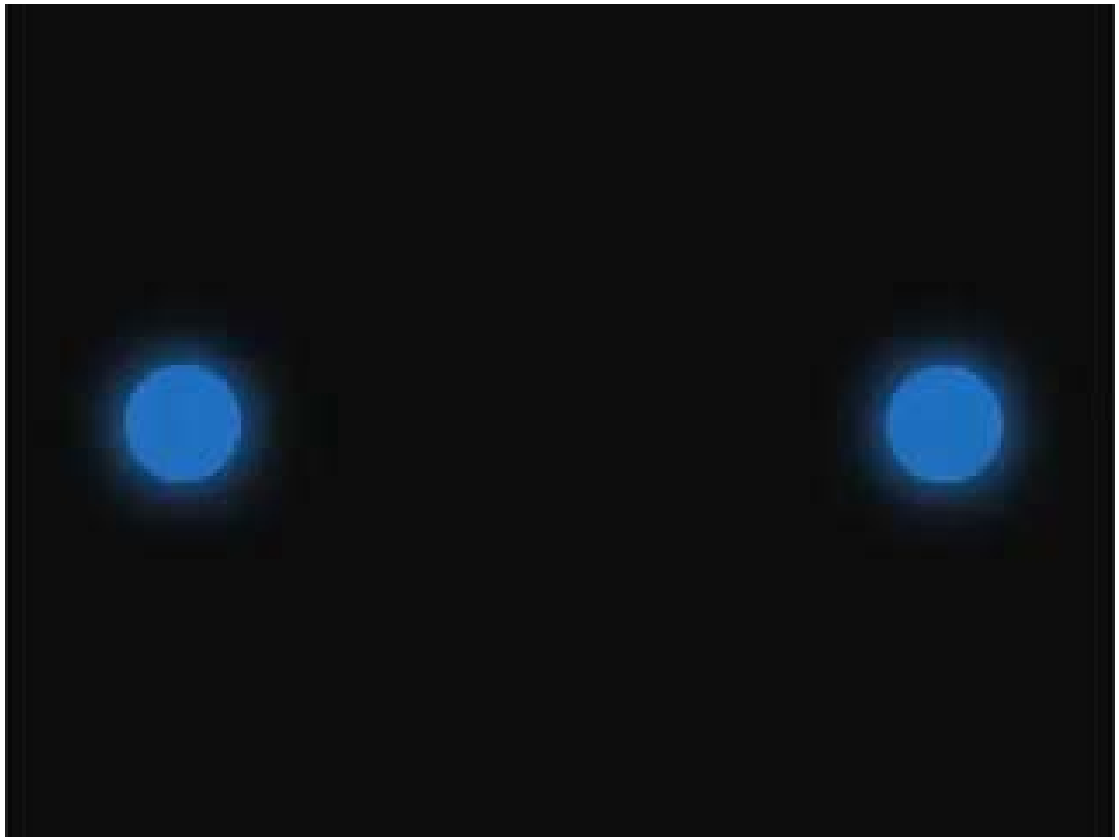
Vítor Cardoso, Leor Barack, Carlos Herdeiro, Samaya Nissanke, Thomas Sotiriou



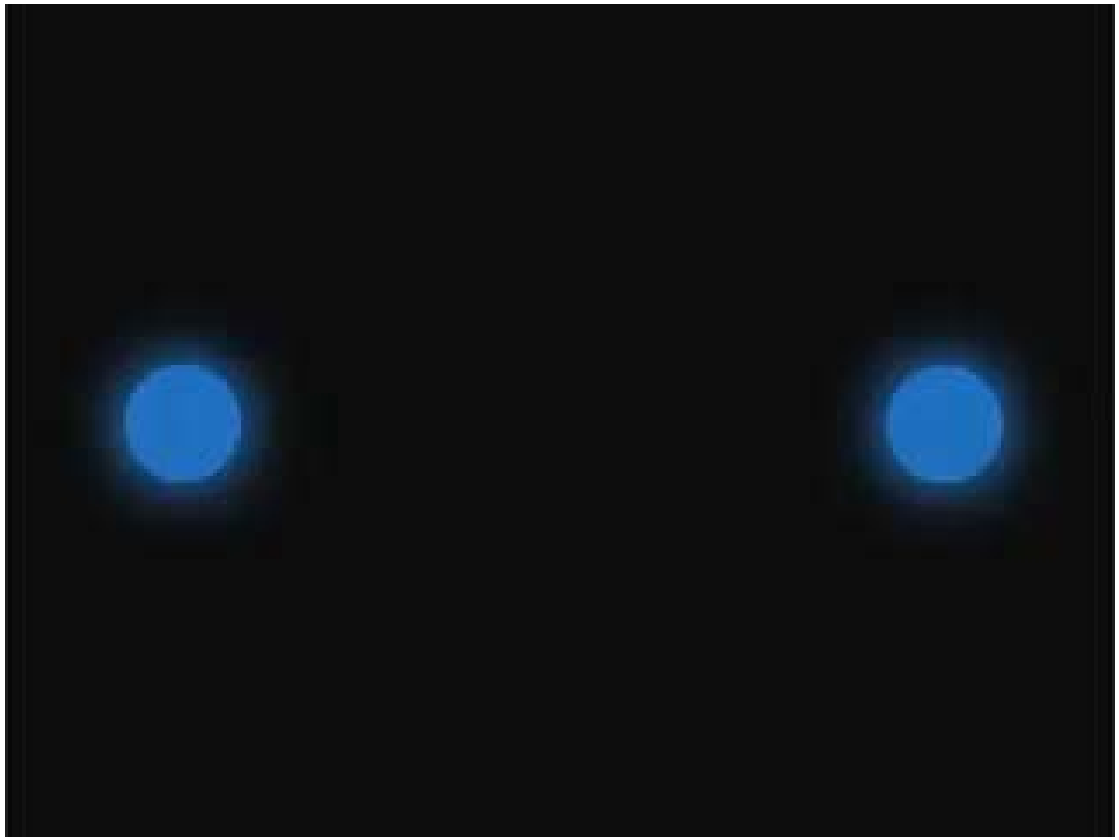
Big Jay Mc Neely, Fotografia de Bob Willoughby

“Imagine being able to see the world but you are deaf, and then suddenly someone gives you the ability to hear things as well - you get an extra dimension of perception” B. Schutz, BBC

Black holes: the elementary particle of gravitational interaction



Black holes: the elementary particle of gravitational interaction



GW physics contains 100 years of developments in

astrophysics
black hole physics
instrumentation
mathematical relativity
numerical methods
quantum mechanics
signal processing
...and more

and is the work of thousands of colleagues

Purpose of this Action

To understand how sources form and distribute
How to model GW emission
To understand the science encoded in a GW-signal

Form a single interdisciplinary network, facilitating a common language and a framework to discuss

Train the next generation of leaders in the field, the very first "native" GW/multi-messenger astronomers

Disseminate results across society and academia

Research Coordination Objectives

European researchers have strong international leadership in many aspects of BH and GW research, but there is often only loose dialogue or interaction between groups. The Action will coordinate the efforts of these communities

- **Develop, share and disseminate** relevant knowledge across the wide community, forming a single, interdisciplinary network;
- **Create and maintain freely available catalogues** in the context of waveform models for GW searches, and modified theories of gravity.

WG1: Astrophysics and Cosmology of Binary Black Holes (BBHs)

Aim: Interpreting and placing GW and/or EM observations of BBH mergers in their full astrophysical and cosmological context

ORIGIN, EVOLUTION, FATE and ECOLOGY of BBHs

- Systems that span the entire mass spectrum: stellar, intermediate and massive mass BBHs
- Probe astrophysical processes that govern star formation and evolution, galaxy clustering and the most violent and luminous phenomena in the Universe (quasars, gamma ray bursts)
- Constrain expansion history of the Universe though measurements of cosmological parameters.

WG1: Key science questions we will answer I

Stellar mass BBHs

1) How, when and where heavy BBH form and in which type of galaxy?
2) Are there maximum or minimum masses for stellar BHs?
3) Do stellar binary BH and BH-neutron star mergers have EM counterparts?
   What does the combined GW-EM information give us about the merger process and BH births?

<u>COST with close interchange with WG2</u>:

Synergy among experts on astronomical observations of transient sources as GRBs , on stellar formation and evolution models, on GW detections and EM counterparts.

WG1: Key science questions we will answer II

Intermediate- mass BBHs

1) How do IMBHs form?
2) Is the desert between stellar mass BBH and MBBHs due to observational election effects?
3) Does the formation of BH seeds require a peculiar environment, and/or a specific cosmic epoch to occur?
4) Do IMBH mergers have EM counterparts?

<u>COST with close interchange with WG2 and WG3</u>:

Synergy among experts on N-body simulation modellers, GW observers and modellers, EM transient observers, also dark matter experts and particle physicists.

WG1: Key science questions we will answer III

Massive BBHs

1) What is the contribution of MBH mergers to their growth?
2) How fast do MBHs spin and what is their evolution?
3) Do BHs stall forever or merge? Are stars or gas the main drivers of final evolution in galaxies?
4) How can we identify close MBH binaries in EM surveys?
5) Can we identity the host galaxy of a GW event that PTA/LISA will register?
6) What are the astrophysical rates of extreme mass ratio inspirals and what can we infer from them?

<u>COST with close interchange with WG2 and WG3</u>:

Synergy among state-of-the-art simulations of galaxy collisions with observers, numerical modeling of circumbinary discs and fueling around MBBHs.

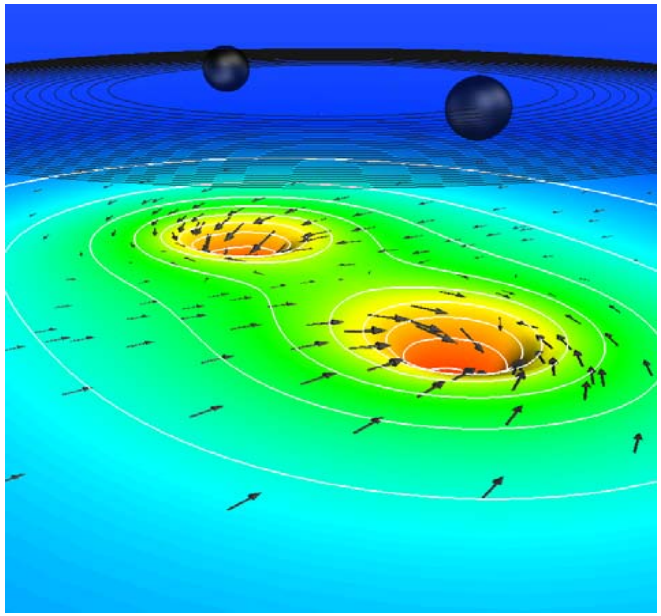
WG1: Topical subgroups

- SMBH growth and evolution
- Transient observerations (X-ray, optical, radio)
- Numerical relativity/SPH with GR+matter+plasma
- N-body dynamics
- Binary stellar evolution/population synthesis
- Dark matter experts
- Cosmology

WG2: Modelling black-hole sources of gravitational waves

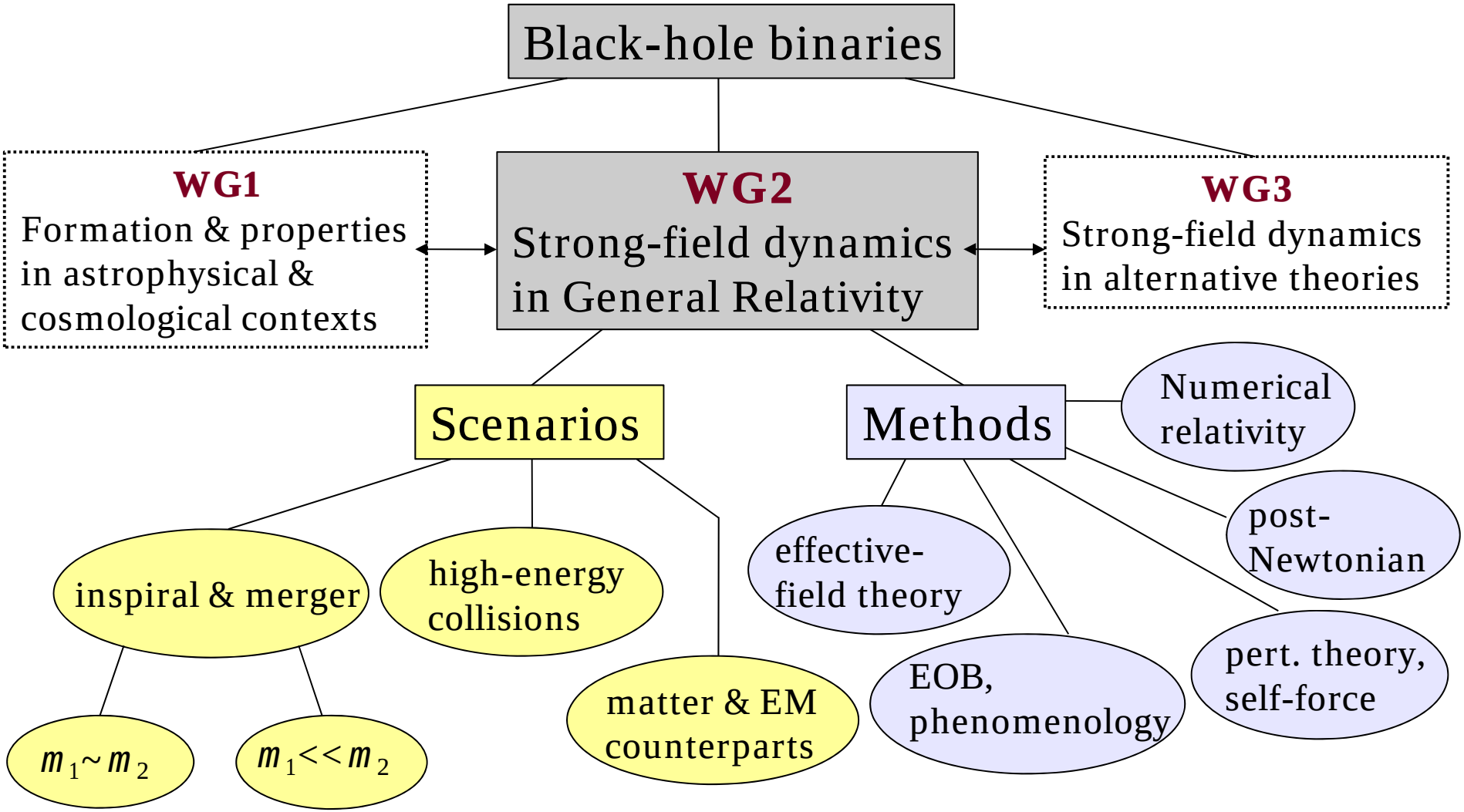
Crucial component of experimental GW programme:

- Interpretation of observed signals
- Enables very detection of weak signals
- Informs design decisions (e.g., LISA)
- Underpins science case for detector projects



H. Pfeiffer/CITA

WG2: Proposed remit



WG2: objectives & initiatives

- Promote and oversee exchange between modelling methods
- Generate easy-access single-point source of information about state of the art in BBH modelling
- Inform WG1 & WG3 activities and foster cross-collaboration
- Support & encourage training of young scientists in relevant modelling techniques, also cross-culturally
- See that data-analysis studies for detector projects are informed with state-of-the-art models

WG2: Topical subgroups

- Perturbation methods
- Post-Newtonian & post-Minkowskian methods
- Numerical Relativity (inspiral)
- Numerical Relativity (high-energy)
- Effective and phenomenological methods
- Impact on data analysis problem

WG3: Black holes and Fundamental Physics

Major Scientific Questions

- Do observations conclusively tell us that black holes exist?
- Are they as simple as predicted from General Relativity?
- Can we parametrize deviations?
- What is the structure of black holes in other theories?
- Can we use them to test GR and fundamental phsyics? How?

WG3: Black holes and Fundamental Physics

Mandate

- Use data from observations (WG1) and modelling (WG2) in order to vindicate/disprove theoretical predictions regarding the structure and properties of BHs
- Obtain novel predictions and use them to guide targeted observations and modelling
- Act as a link between this COST action and other communities (e.g. cosmology and theoretical physics)

WG3: Black holes and Fundamental Physics

Key Initiave: “Gravity Data Group”

Role: to collect and comprehensively present all possible constraints on gravity theories, to develop a common language that will facilitate cross-disciplinary interaction and to organise interaction events (workshops, conferences, online discussions) with wide participation

WG3: Black holes and Fundamental Physics

Topical Subgroups

- Testing the Black Holes hypothesis
- Strong field parametrizations
- Black holes in alternative theories of gravity
- Black hole perturbation theory and fundamental physics
- Binaries in alternative theories of gravity

- Gravity Data Group

Dissemination plan (from the proposal):

2.2.2. Dissemination and/or Exploitation Plan

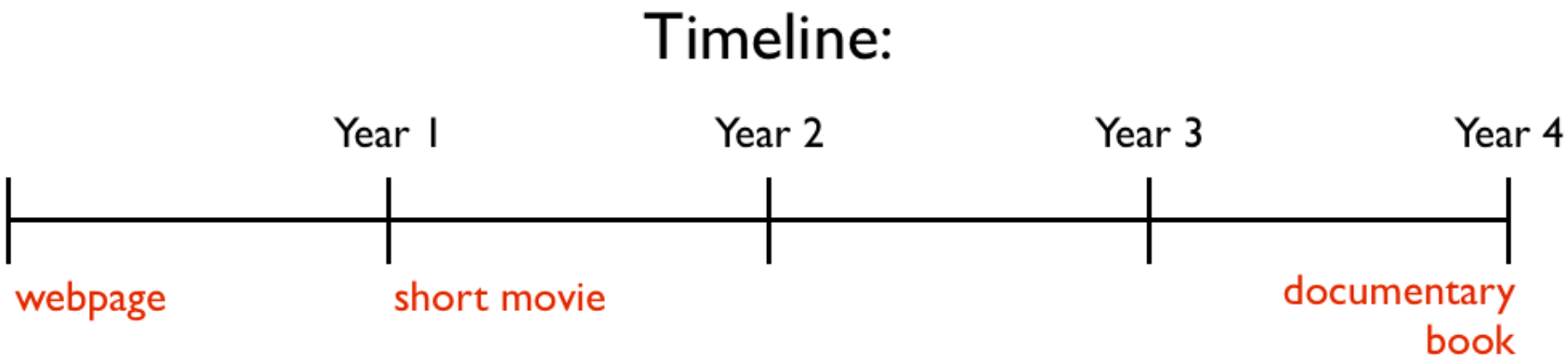
The science protagonists of this action -- BHs and GWs -- have an incredible potential to capture human imagination and the attention of the global society. Such potential can be capitalized upon, moreover, to attract young minds towards science. In this respect, this action could hardly be more timely; the recent announcement of the direct detection of GWs got worldwide media coverage and the public is not only willing, but actually wanting, to be given more quality outreach from scientists, deciphering these topics for the laymen. To fulfil this pressing need, we plan to produce a number of multimedia contents and outreach events, making the science and networking produced in this action reach the society as a whole. The outreach information will be centralized in the website of this COST action, containing a non-technical description of our work and updated information about public talks and other events by network members, which we plan to deliver on a regular basis. We shall endeavour to produce the following deliverables:

1) One short movie (1-2 minutes duration) explaining the science of this COST network. This will be produced during the first year of the network and released in its second year, through our website, youTube, social networks and television stations.

2) One television documentary on "Gravitational Wave science in Europe" (30 min - 1 hour length). This will feature multimedia original contents for understanding the science of the network, footage of experimental facilities and research centres, together with interviews of network scientist. A partnership with one or more television networks will be sought. This will be released during the final year of the network.

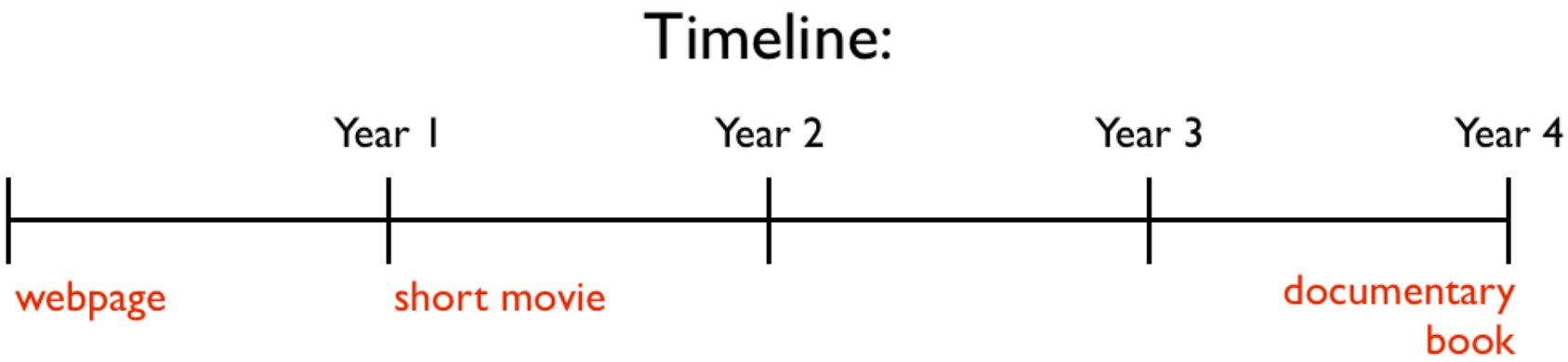
3) An accompanying photography book of the documentary, featuring images of the science, science infrastructures and scientists involved in this action, with descriptive texts and eye-catching images.

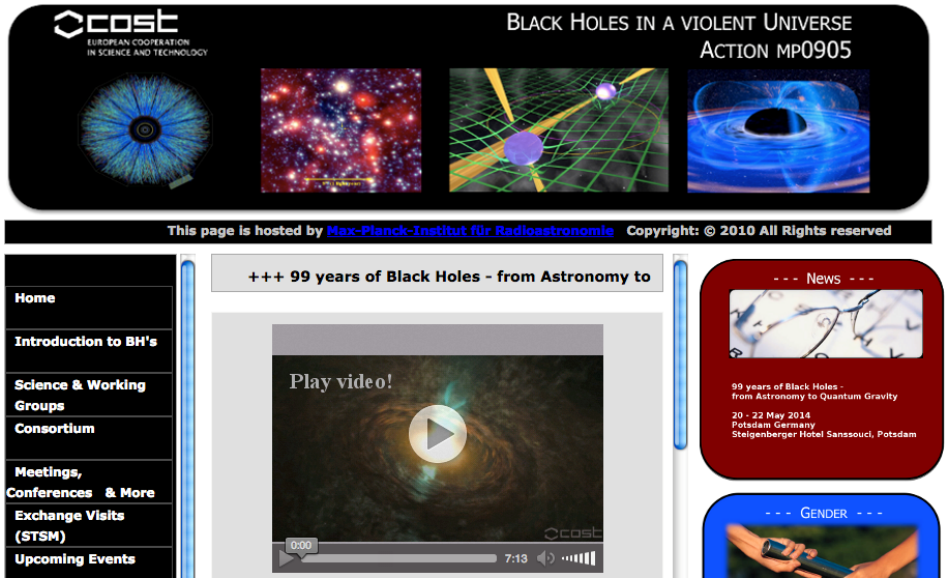
Dissemination plan (from the proposal):



gwverse.tecnico.ulisboa.pt

Dissemination plan (from the proposal):

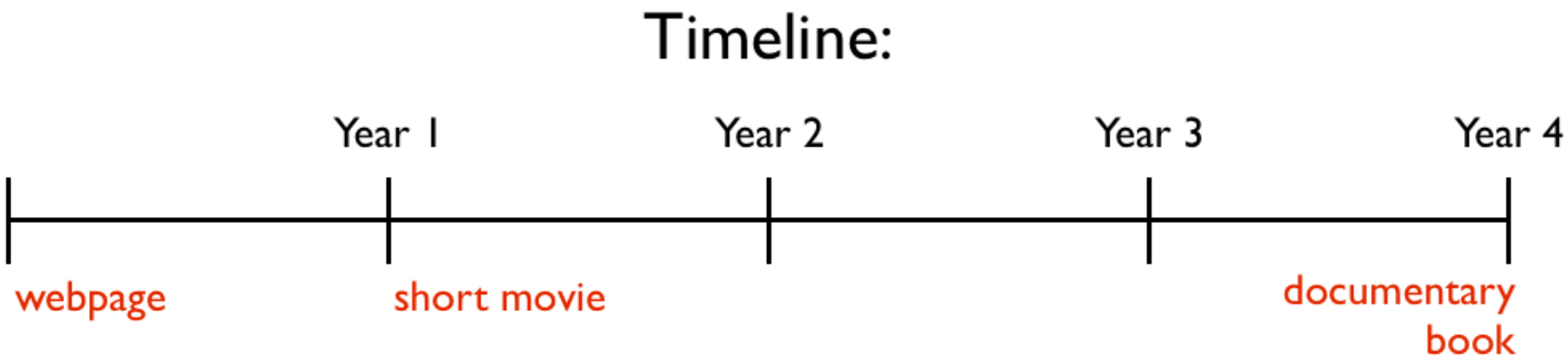




http://www3.mpifr-bonn.mpg.de/div/vlbi/COST/

Our input: suggestions; images/videos from our research;...

Dissemination plan (from the proposal):



Contents from the scientific area/team of the COST action (images/videos about science, people, infrastructure...)