Baryonic Cosmic Structures inputs from Astrofrontiere
(and two personal wild speculations)

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Maximize the return from major infrastructures

Science topics from Astrofrontiere

Top extragalactic science topics

- **ESO Large/Legacy/GTO programs:**
  - A Planck/ESO legacy sample of the **most massive clusters** (EFOSC2, Aghanim+)
  - SUPER: a SINFONI Survey for Unveiling the Physics and the Effect of Radiative feedback (Mainieri, Fiore, Marconi+) **AGN/Galaxy feedbacks/coevolution**
  - GASP: Dissecting GAs Stripping Phenomena in galaxies with MUSE (Poggianti+) **Galaxy transformations, environmental effects**
  - The formation and evolution of galaxies from cosmic dawn to high-noon under a magnifying GLASS (Fontana+) **First galaxies**
  - A MUSE survey of the dense halo gas in z ~ 3 galaxies near optically-thick absorbers (Fumagalli+) **GCM**
  - A KMOS Survey to Grasp the Essential Astrophysics of High Redshift Galaxies (Cirasuolo+) **Stellar a gas dynamics, disks, outflows in z=1-2 galaxies**
  - VANDELS: A deep VIMOS survey of the CANDELS fields (McLure, Pentericci+) **Physics driving galaxy evolution at z>1.5**
  - KMOS GTO (MPE, Durham, Edinburgh) **Galaxy dynamics (disks, outflows) z=1.5-3**
  - MUSE GTO (Lyon, ETH) **High-z galaxies, CGM**

Top extragalactic science topics

- **HST Legacy/Treasury**
  - GOODS, COSMOS, CANDELS - **Galaxy evolution, AGN evolution**
  - 3D-HST, FIGS, PEARS, - **spectroscopic galaxy evolution**
  - Frontier Fields, RELICS, GLASS, BORG - **High-z Universe, lensing clusters**
  - LEGUS **Extragalactic UV Legacy survey**
  - **ACS nearby galaxy survey**
  - **Coma cluster**
  - A COS Legacy Study of **Circumgalactic Baryons**
  - Legacy Survey of the **Cosmic Web**
  - **Gas cycle of galaxies and the CGM**

Top extragalactic science topics

- **Chandra LP/VLP/Legacy**
  - Deep Surveys: CDFS/N, C-COSMOS (Elvis+, Civano+), C-EGS (Nandra+), C-AGES (Murray), QSOs at z=6 (Gilli+) - **AGN evolution, high-z**
  - **AGN inflow/outflow** (Lee+, King+, Tombesi+, Veilleux+, Evans+, Reeves+, Kaastra+)
  - Cluster of galaxies
    - **Virial region** (Vikhlinin)
    - **Massive clusters** Planck selected (Jones), SPT selected (Benson)
  - Normal galaxies
    - SMBHs (Irvin), SgrA* (Baganoff)
    - LMXB (Fabbiano), M101 (Kunz), M33 (Sasaki), Virgo (Treu)
  - **Warm IGM** (Nicastro, Fang)

Top extragalactic science topics

- **XMM-Newton Large Programs**
  - **Surveys** - Lockman hole, ELAIS-S1, COSMOS, CDFS, XXL, Stripe82
  - **Iron line & reverb. mapping** - MCG 6-30-15, 1H0707-495, NGC3516, NGC2992, Ark564, simultaneous with NuStar, NGC4151
  - **AGN outflows/feedback** - NGC1365, Mrk509, QSO outflows, MR2251-178, NGC5548, PDS456, PG1211+143
  - **Clusters** - cool core clusters, groups, shocks, massive (Planck), DM distribution, cosmology
  - Normal galaxies - **M33, M32, M31**
  - **Warm IGM**

Top extragalactic science topics

- **ALMA & NOEMA**
  - High-z galaxies & AGN
  - Gas fraction & gas depletion timescale
  - Gas dynamics, disks vs. winds: SF & feedback
  - Gas chemistry, PDR, XDR, shock tracers

Top extragalactic science topics

- **Main science cases of next large infrastructures:**
  - **JWST**: First stars, First BHs, galaxy evolution
  - **AO assisted 8m telescopes**: resolved stellar populations, stellar disks vs. gas discs vs metallicities vs dynamics
  - **Euclid** legacy: SDSS@z=1.5
  - **E-ELT**:
    - Resolved stellar populations.
    - Galaxy dynamics, disks, winds. CGM.
    - First galaxies/BHs
  - **SKA**:
    - EoR.
    - Magnetic fields in clusters and galaxies.
    - 21cm surveys, velocity width function of galaxies and HI outflows up to z=1.5
  - **CTA**: DM, shocks
  - **Athena**:
    - Hot baryons physics, feedbacks, the formation of the first groups & clusters
    - BH accretion and BH winds and feedbacks through the cosmic times

Lesson learned

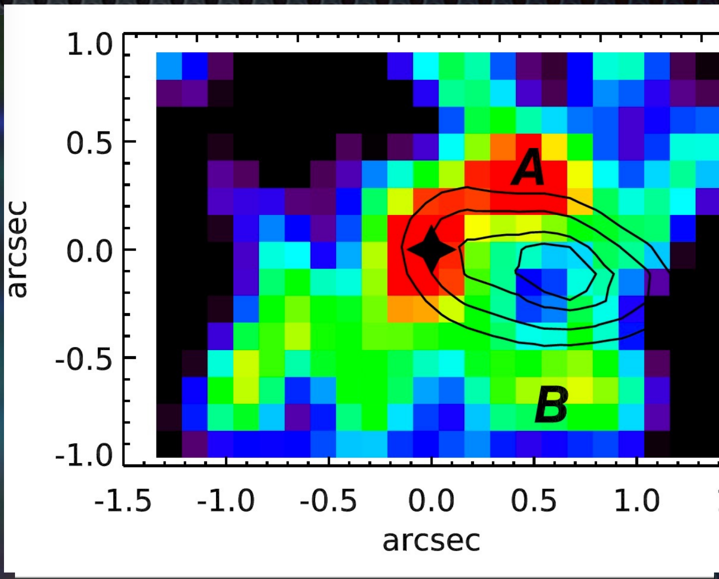
- The main scientific results of future infrastructures are often different from what planned and written in proposals and white books (see the cases of HST, XMM, etc..)

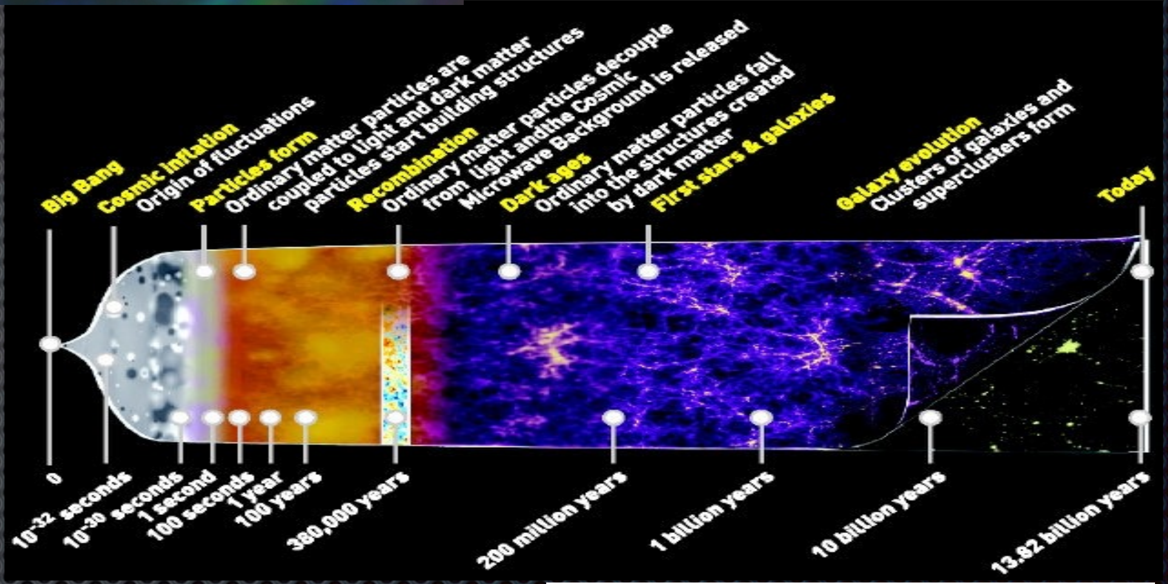
ergo

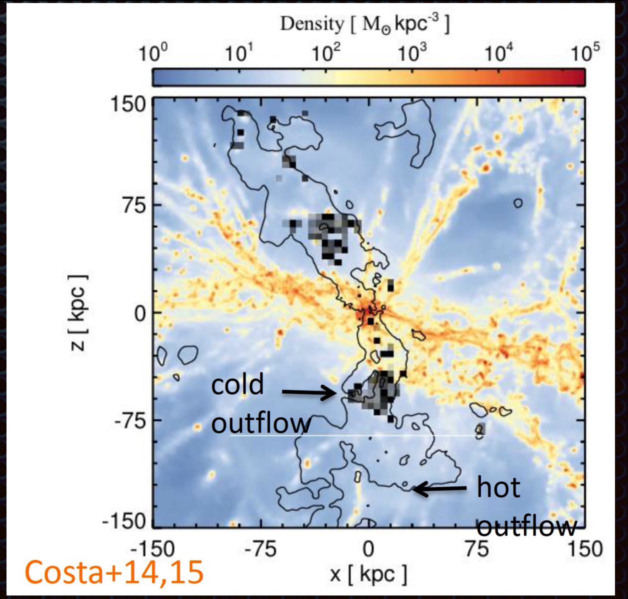
- Main purpose of writing science cases for future infrastructures is: ***ensure to cover the widest possible discovery space.***

Three top extragalactic science topics

- Wrapping up
  - **Galaxy transformations**, dynamics: disks vs winds, feedback vs. SF —> 8m AO telescopes, ALMA/NOEMA, JWST, Euclid, E-ELT, SKA, Athena
  - **The first luminous objects & EoR** —> **JWST!**, ALMA/NOEMA, Euclid, E-ELT, SKA, Athena
  - **Ins & outs**: Cold/Warm/hot diffuse baryons —> 8m class telescopes, E-ELT, SKA, Athena







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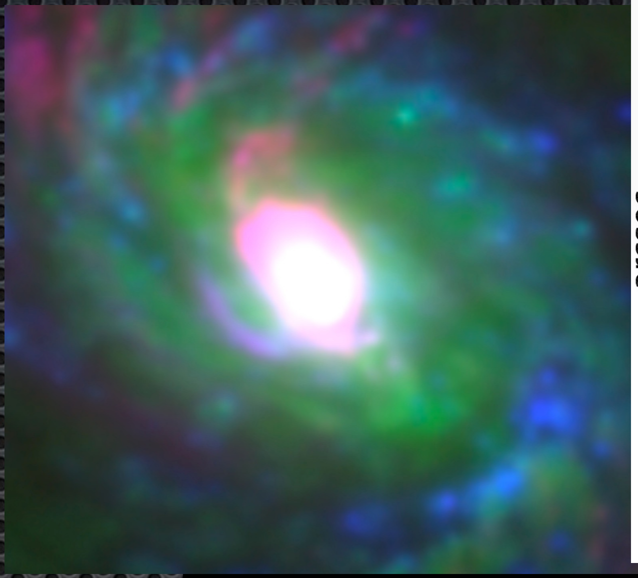
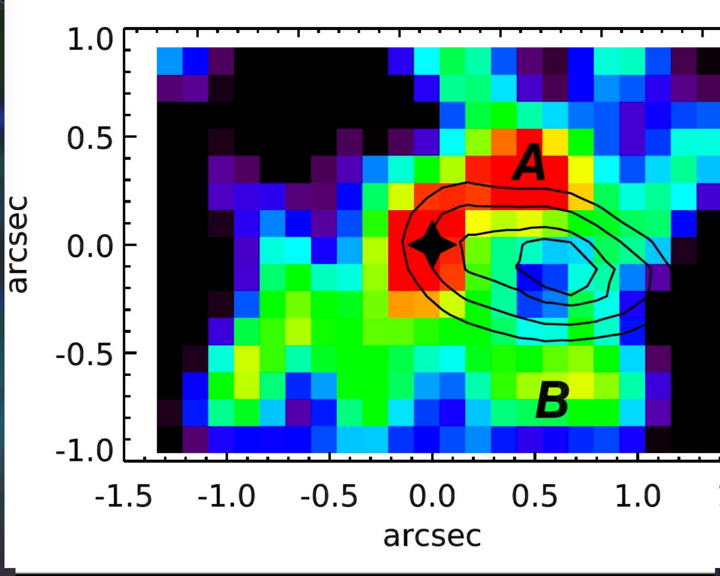
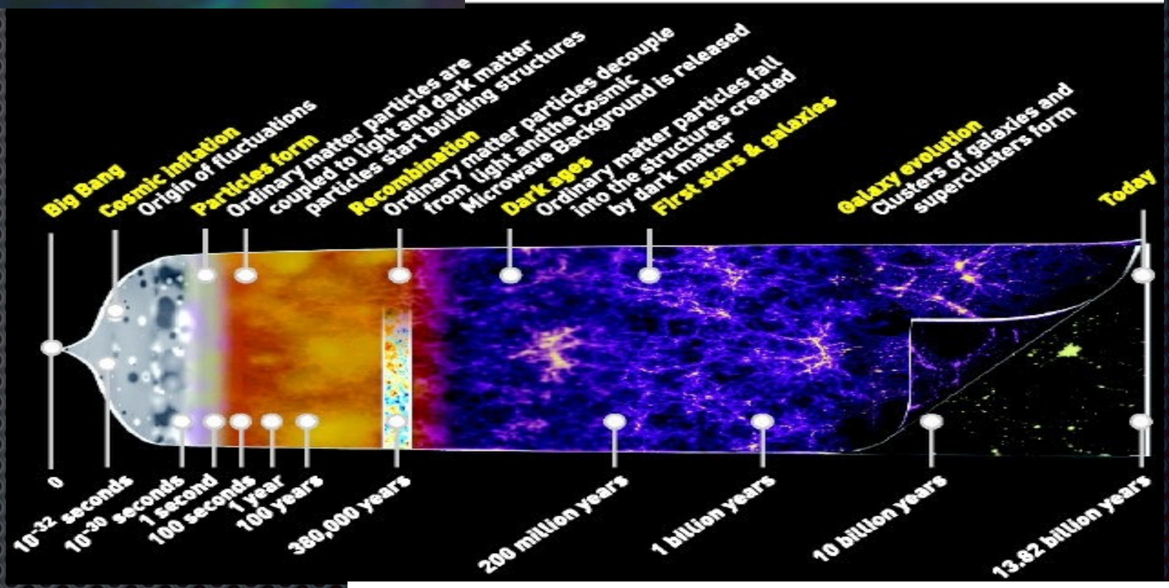
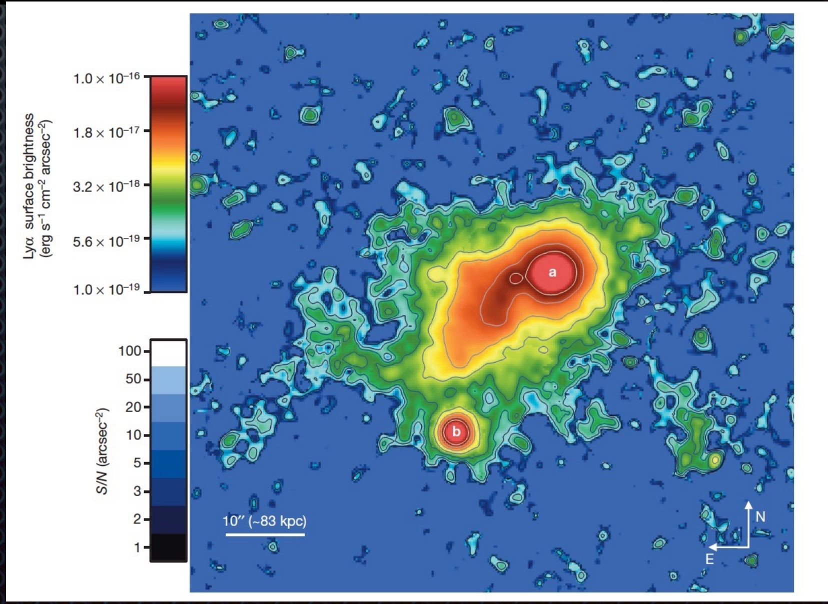
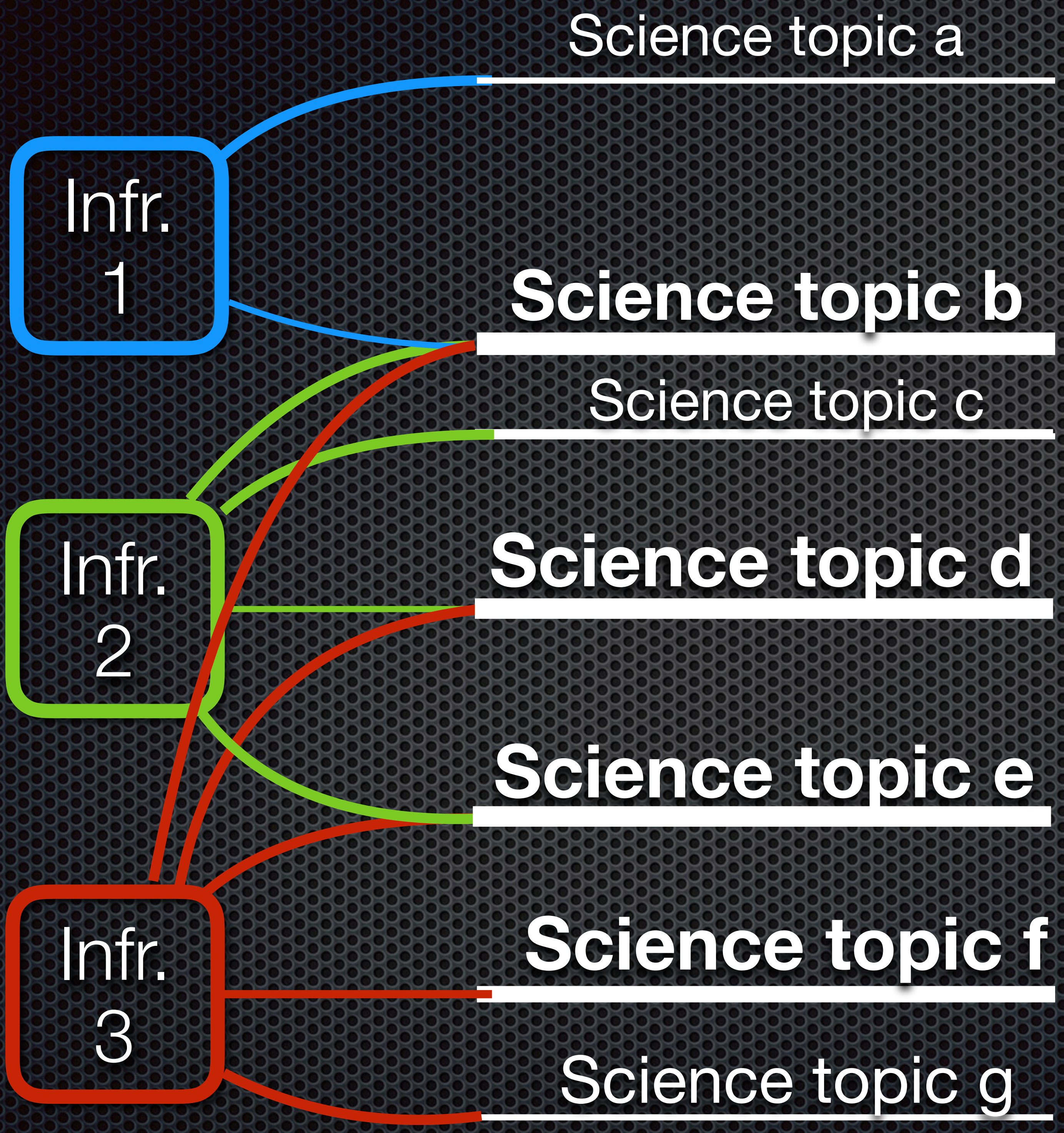








A richness &/or a potential problem



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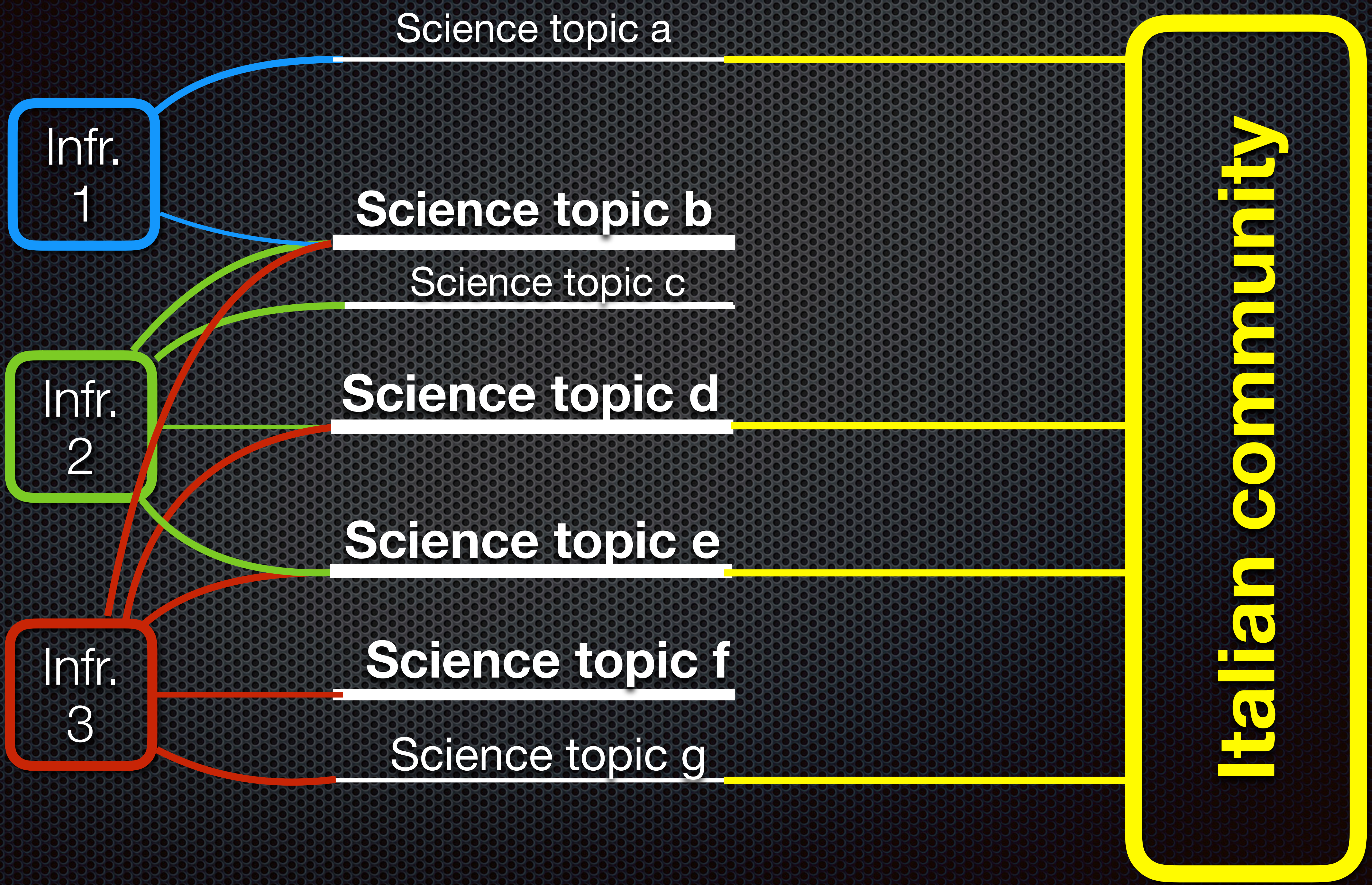

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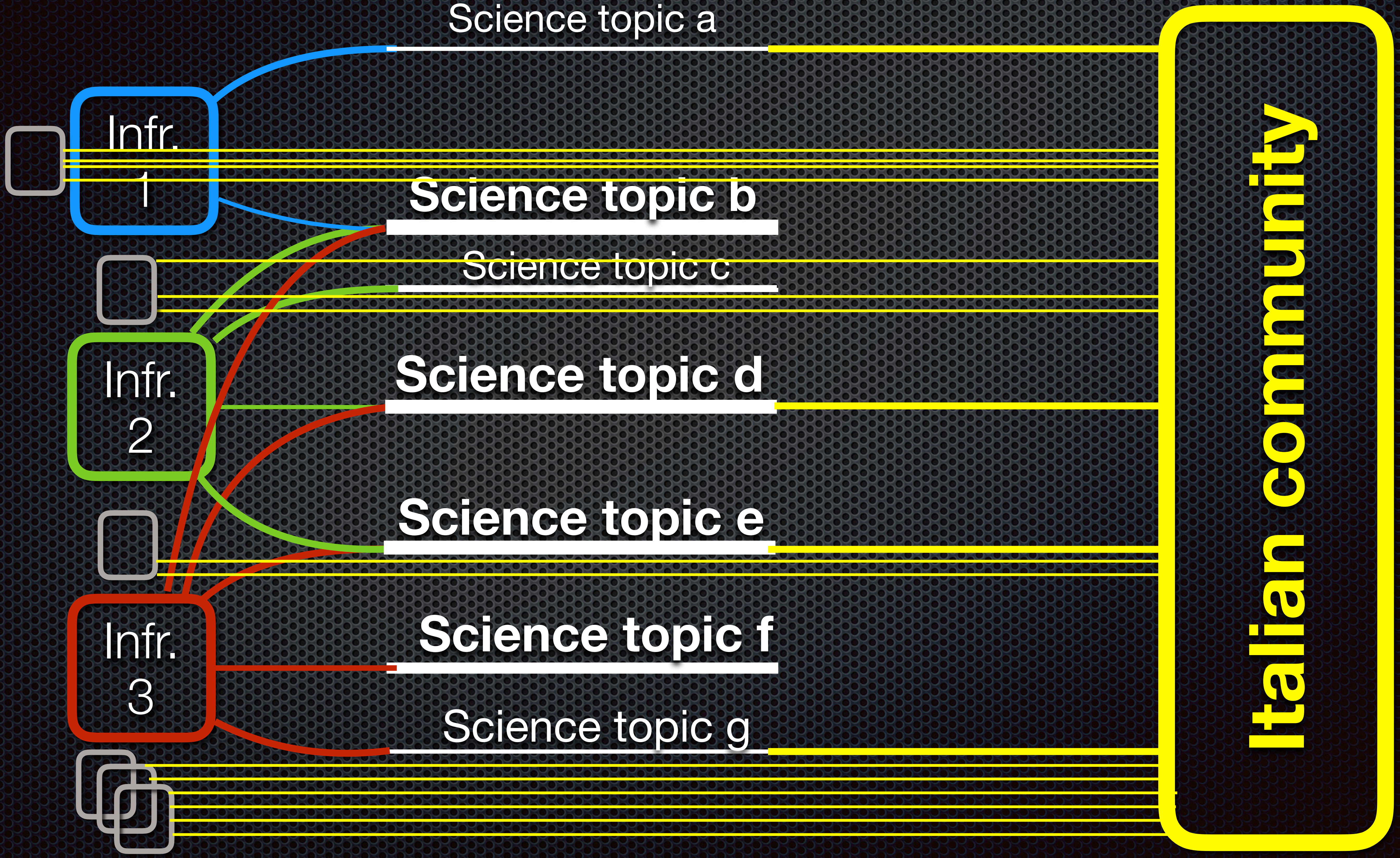
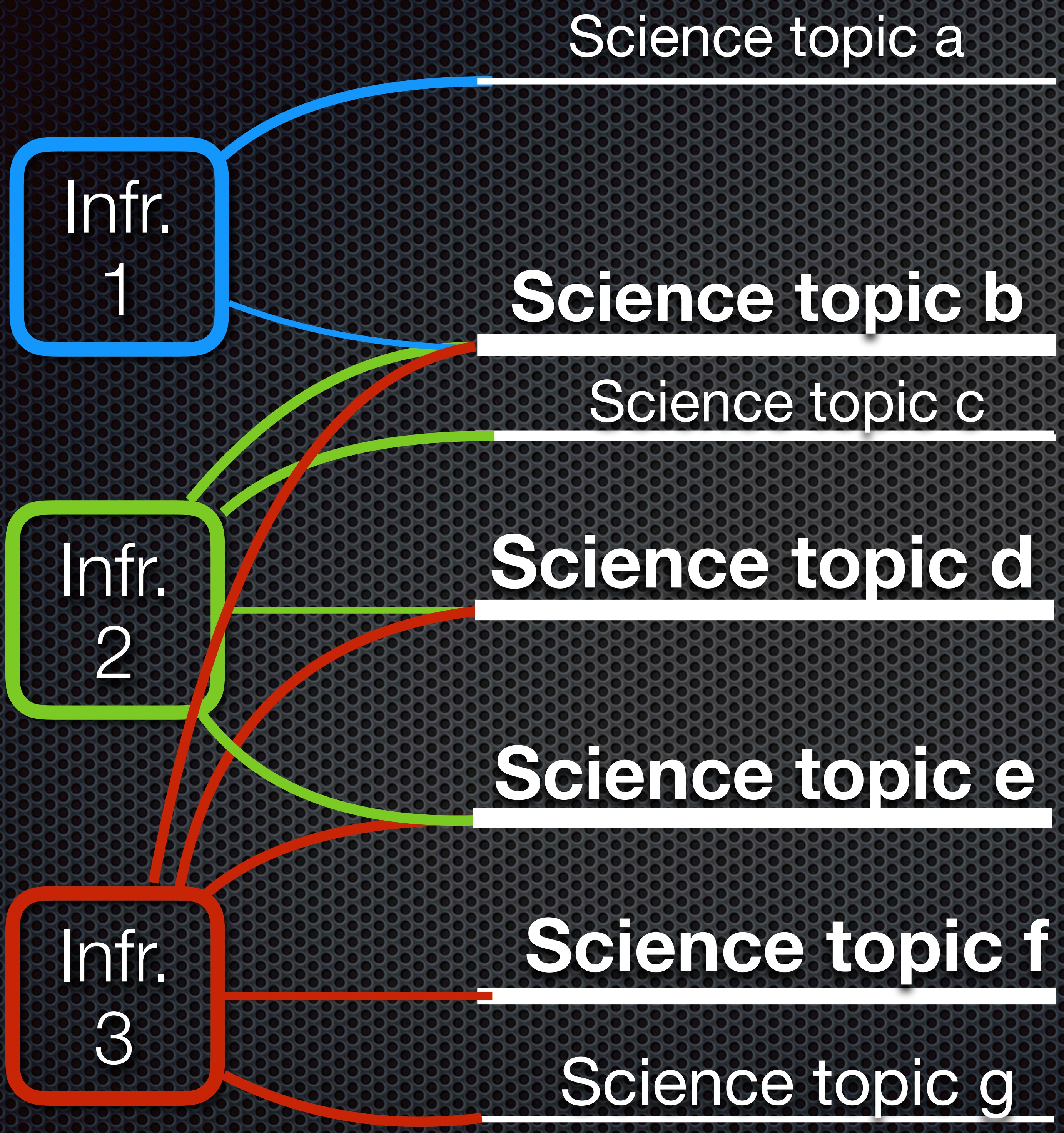
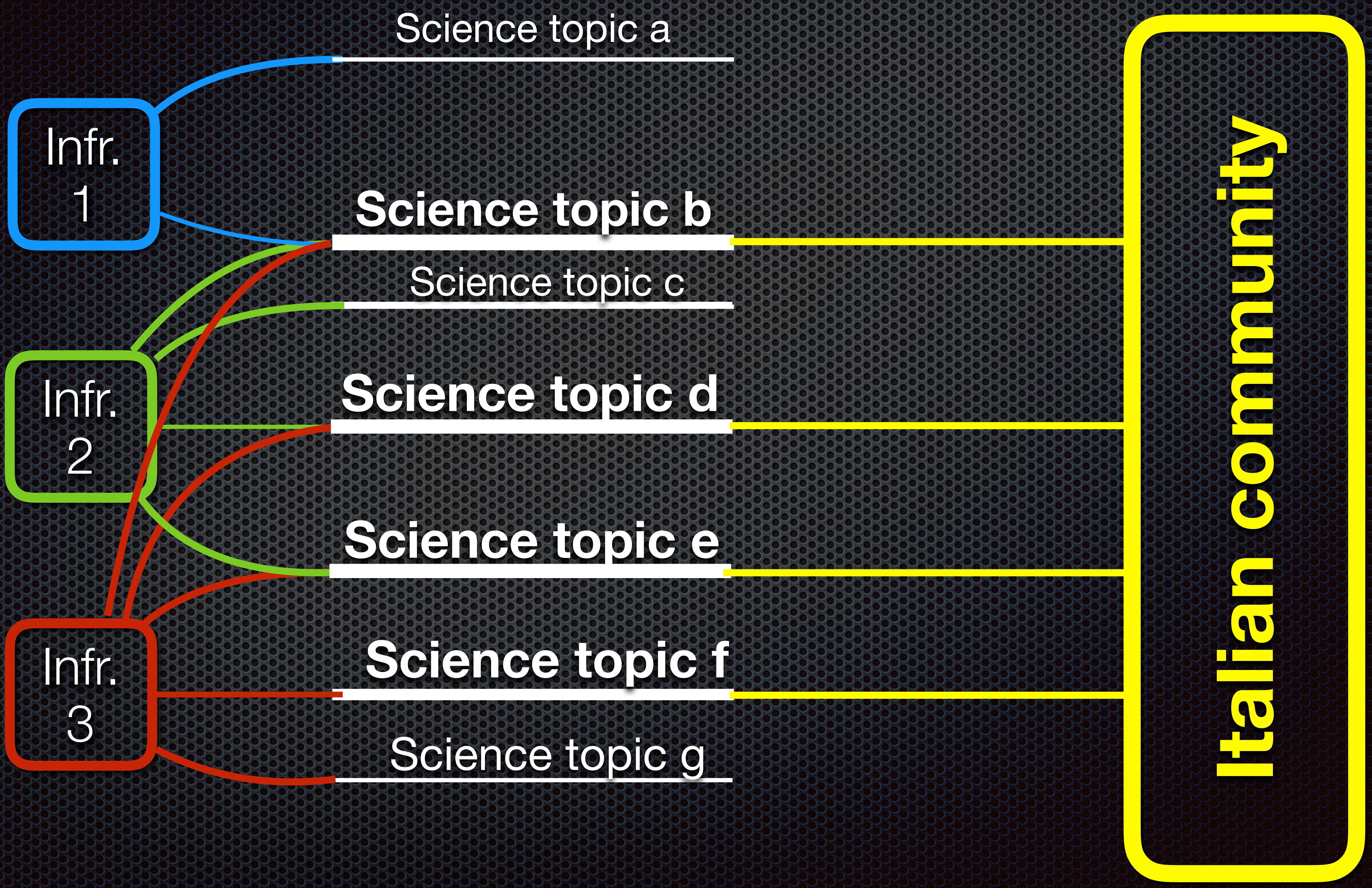


Enhancing the richness



Enhancing the richness



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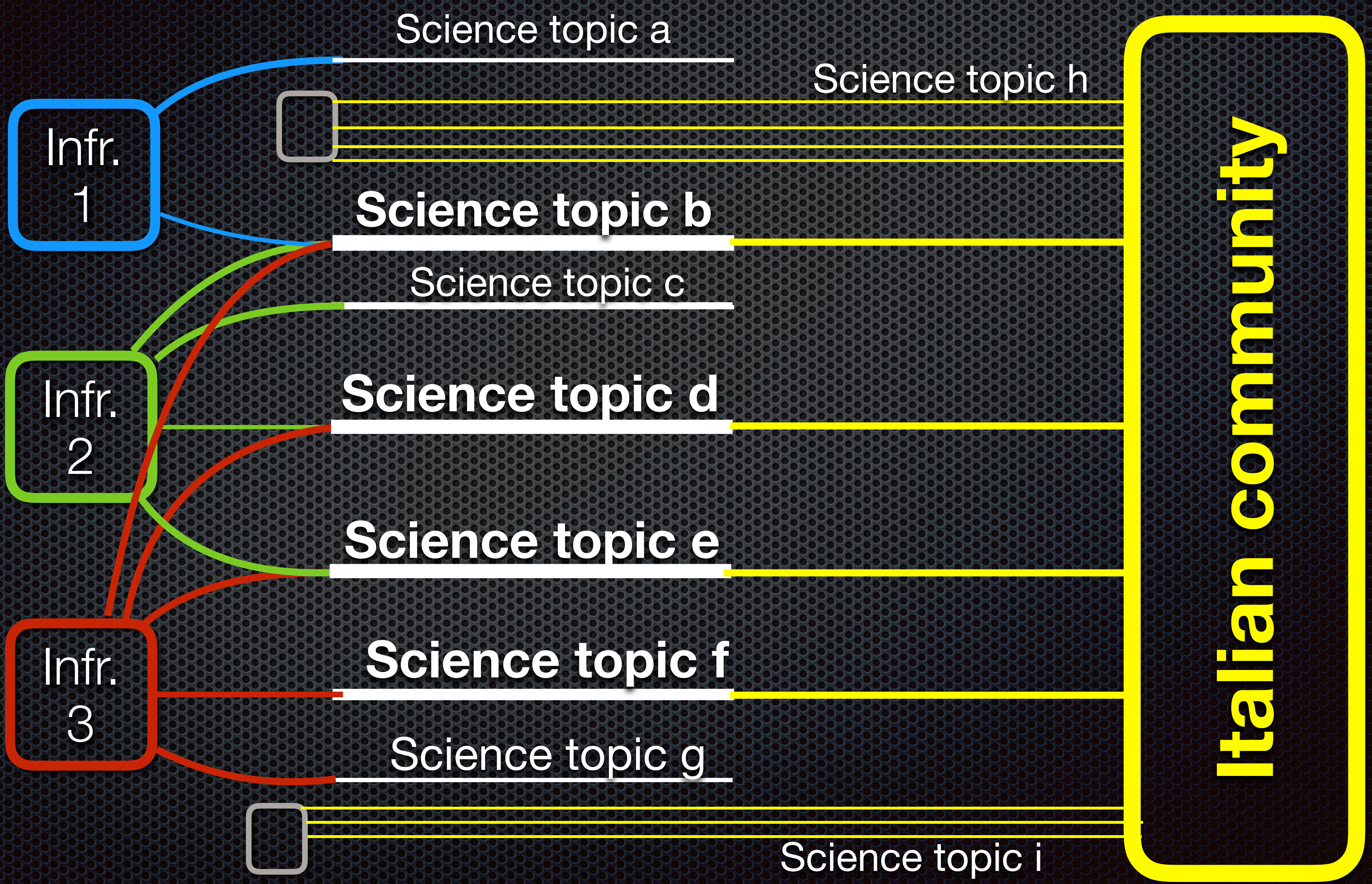
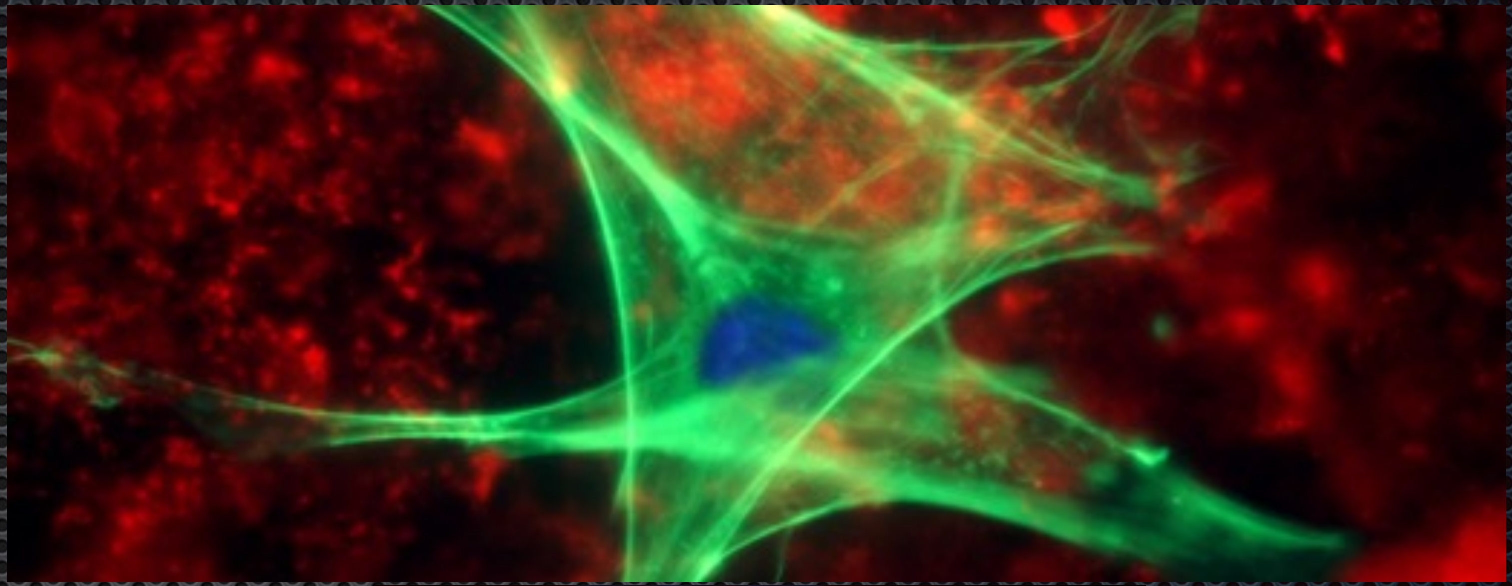


A change in perspective

Universe island ➔ Bio cells

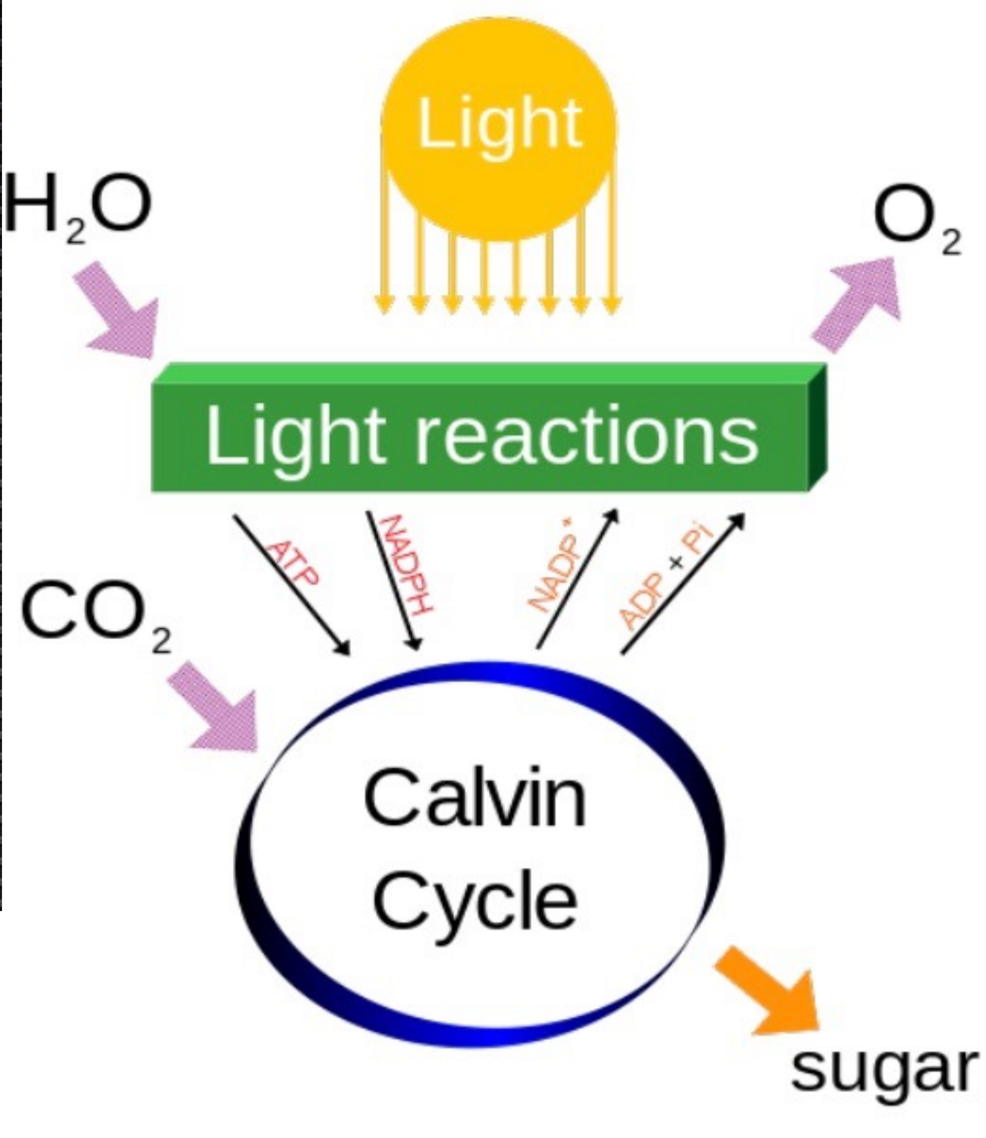


Organisms exchanging matter, energy and entropy with the environment throughout a network of interactions:

The life cycle of galaxies

Photosynthesis

"The substance of a tree is carbon. And it comes from the air, it's CO_2 from the air. The trees come out from the air. The CO_2 goes into the tree and it changes is, kicking out the oxygen. How the tree manage to do this so easily? It is the sunlight that comes down and kicks this oxygen away from carbon, leaving the carbon to make the subtance of the tree."
Richard Feynman



$6CO_2$	+	$6H_2O$	$\xrightarrow{\text{Light}}$	$C_6H_{12}O_6$	+	$6O_2$
Carbon dioxide		Water		Sugar		Oxygen

E is captured by chlorophyll. Transferred and accumulated in *reaction centres*. Oxidation of H_2O!!! (spit out e^-, *burn* water). Current is used to pump out p from the chloroplast membrane. p back-flow is used to make ATP, cell's main energy carrier. ATP and e^- provide the energy to pull out C from CO_2 to form a 6 C sugar, that is then used to produce most of world biomass.

Schroedinger *order from order* (low entropy, high energy photons, highly ordered biological systems)

At a system level, biosphere absorb high E, low entropy optical photons and radiate into space low E, high entropy IR photons (local reduction of entropy).

Gas collapse and star-formation

$E_{kin}=1/2mv^2=1/2p^2/m=3/2KT$

$p=(3mKT)^{1/2}$

$\mathbf{S=\log(V x V_p)^N=N(\log(V)+\log(V_p))}$

$V_p=4/3(3mKT)^{3/2}$

$S=N(\log(V)+3/2\lg(T))+const$

Gas collapse from $R\sim10^{18}$ to 10^{11} cm

V $\downarrow$ 10^{21} factor

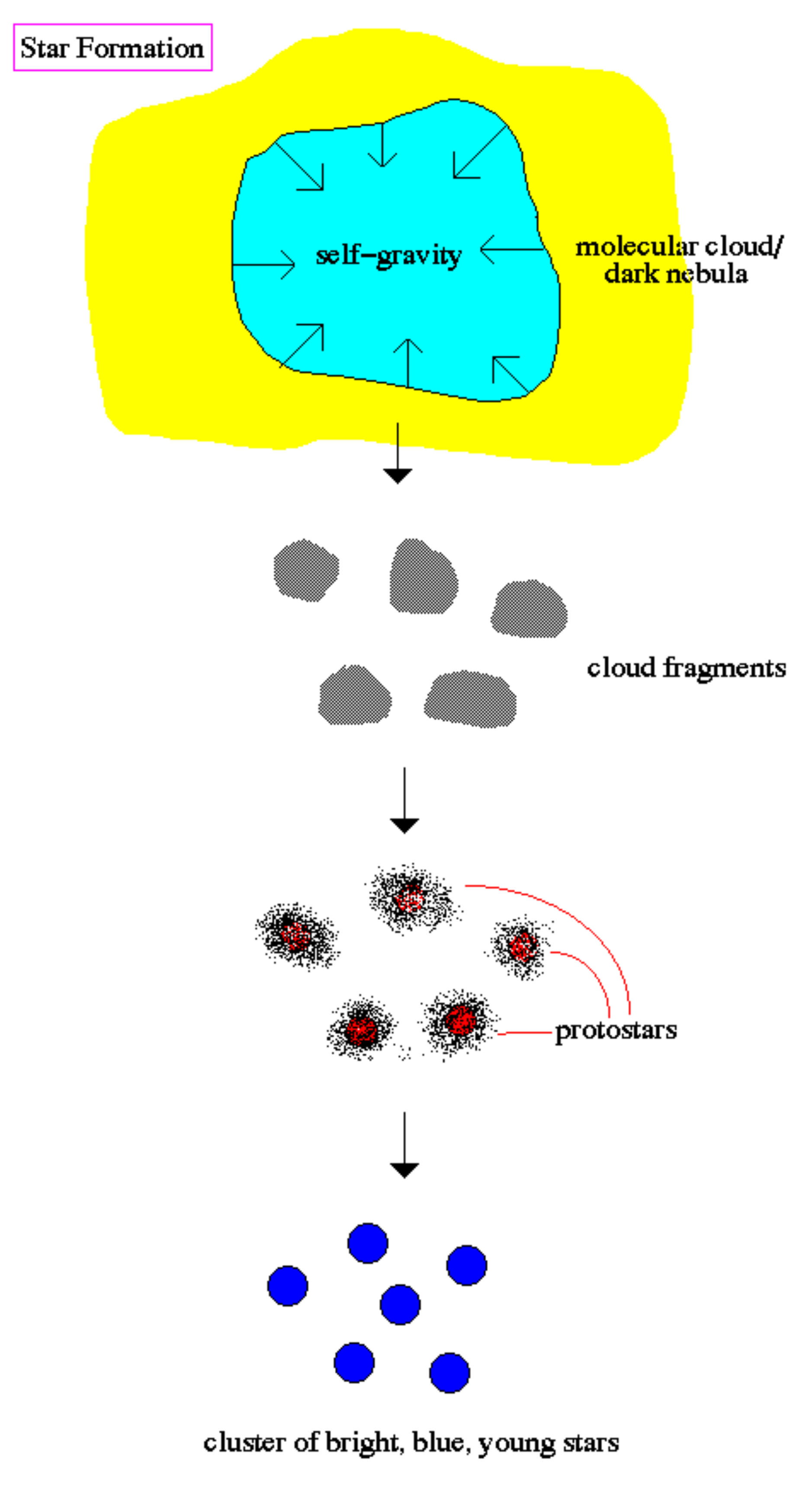
T $\uparrow$ from tens to thousands K

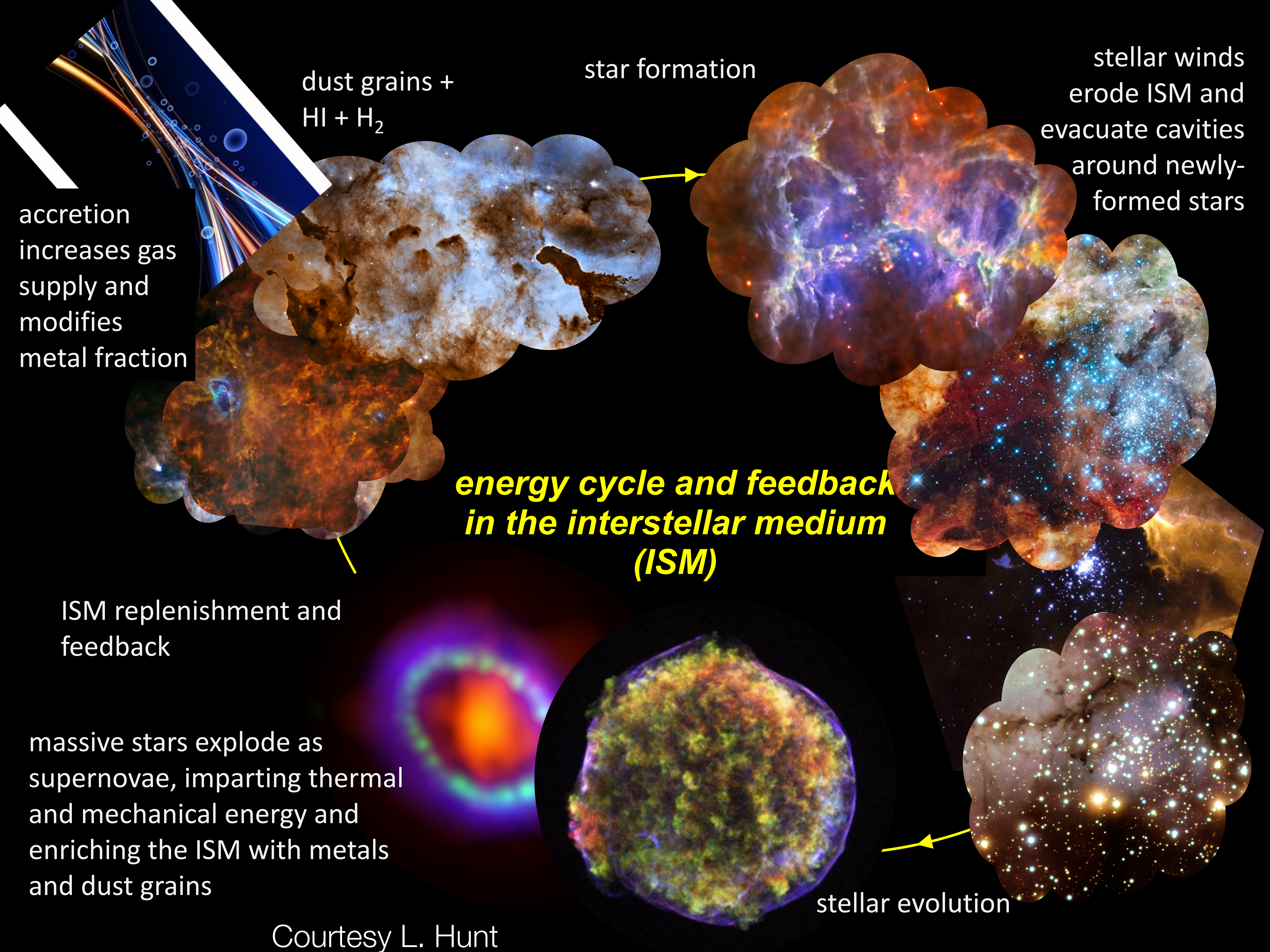
V_p $\uparrow$ by $\sim100^{3/2}$ -> S $\downarrow$

Radiation carries off the entropy that the cloud looses. e.g. To collapse a cloud must efficiently radiate the heat generated by the collapse (short cooling time = small S)

$E_{tot}=P/2=-1/2GM^2/R$ $\downarrow$

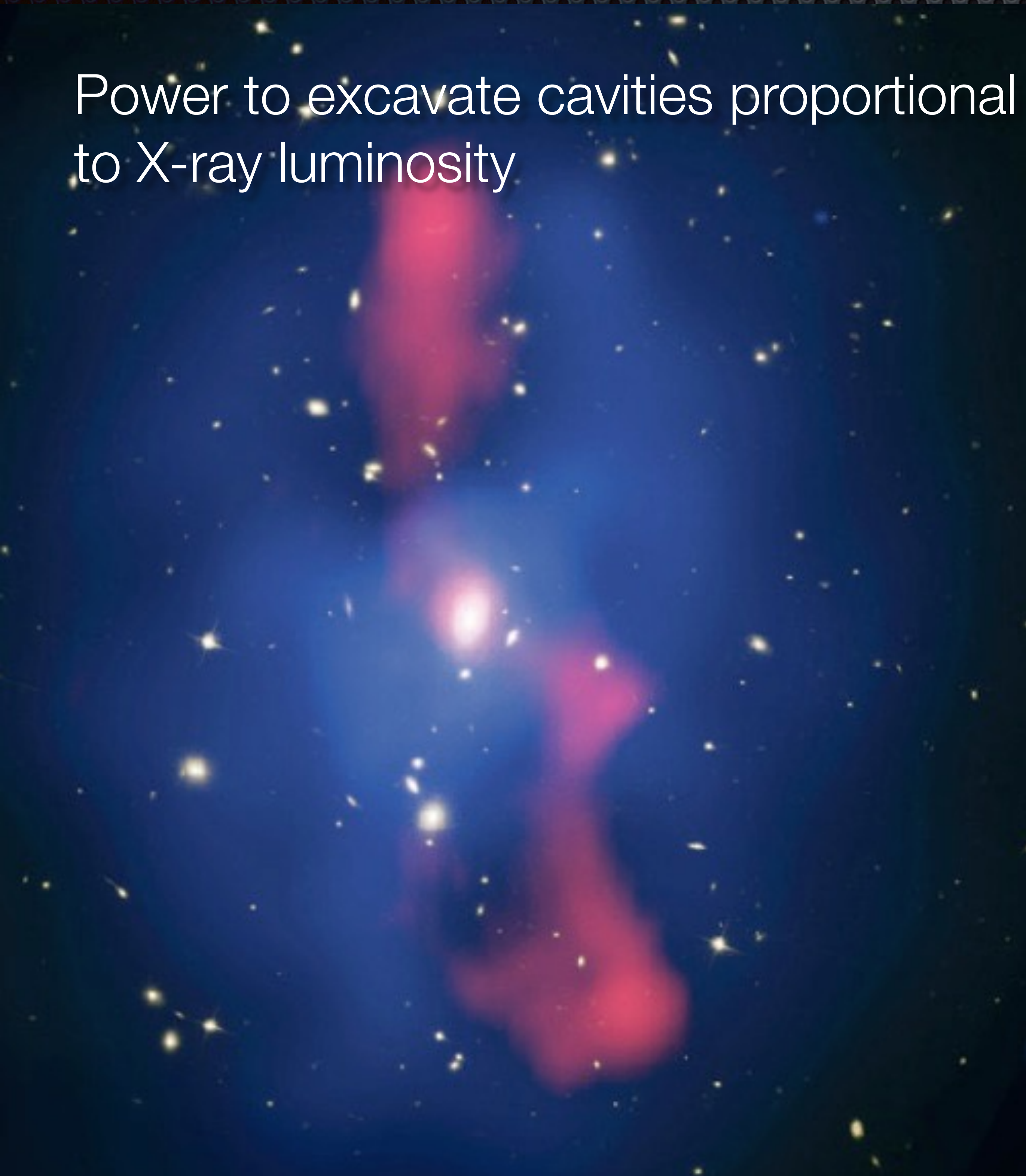
negative specific heat.

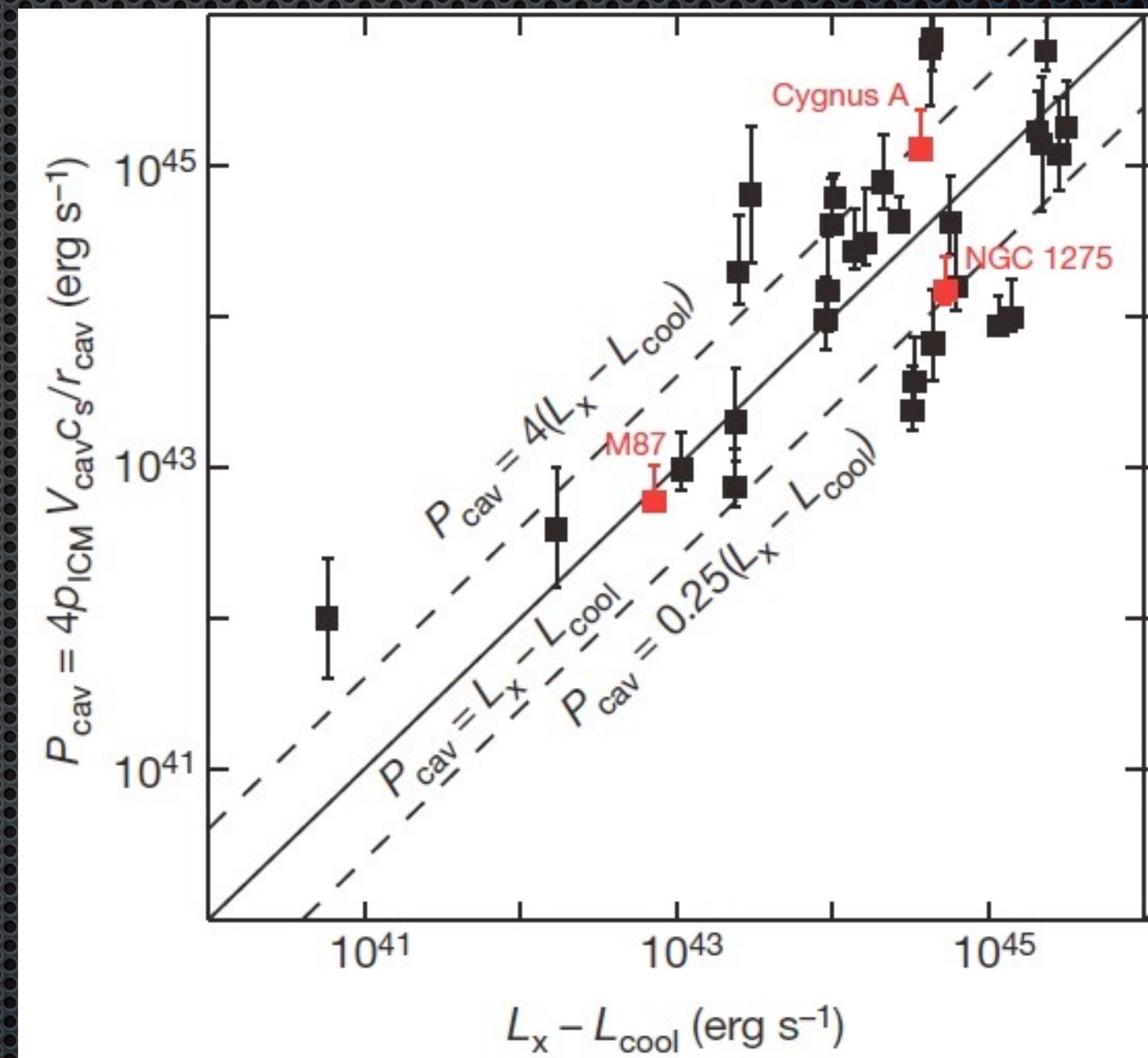



dust grains +
HI + H_2
star formation
stellar winds
erode ISM and
evacuate cavities
around newly-
formed stars
accretion
increases gas
supply and
modifies
metal fraction
energy cycle and feedback
in the interstellar medium
(ISM)
ISM replenishment and
feedback
massive stars explode as
supernovae, imparting thermal
and mechanical energy and
enriching the ISM with metals
and dust grains
stellar evolution
Courtesy L. Hunt

Radio-mode *feedback*

Power to excavate cavities proportional to X-ray luminosity

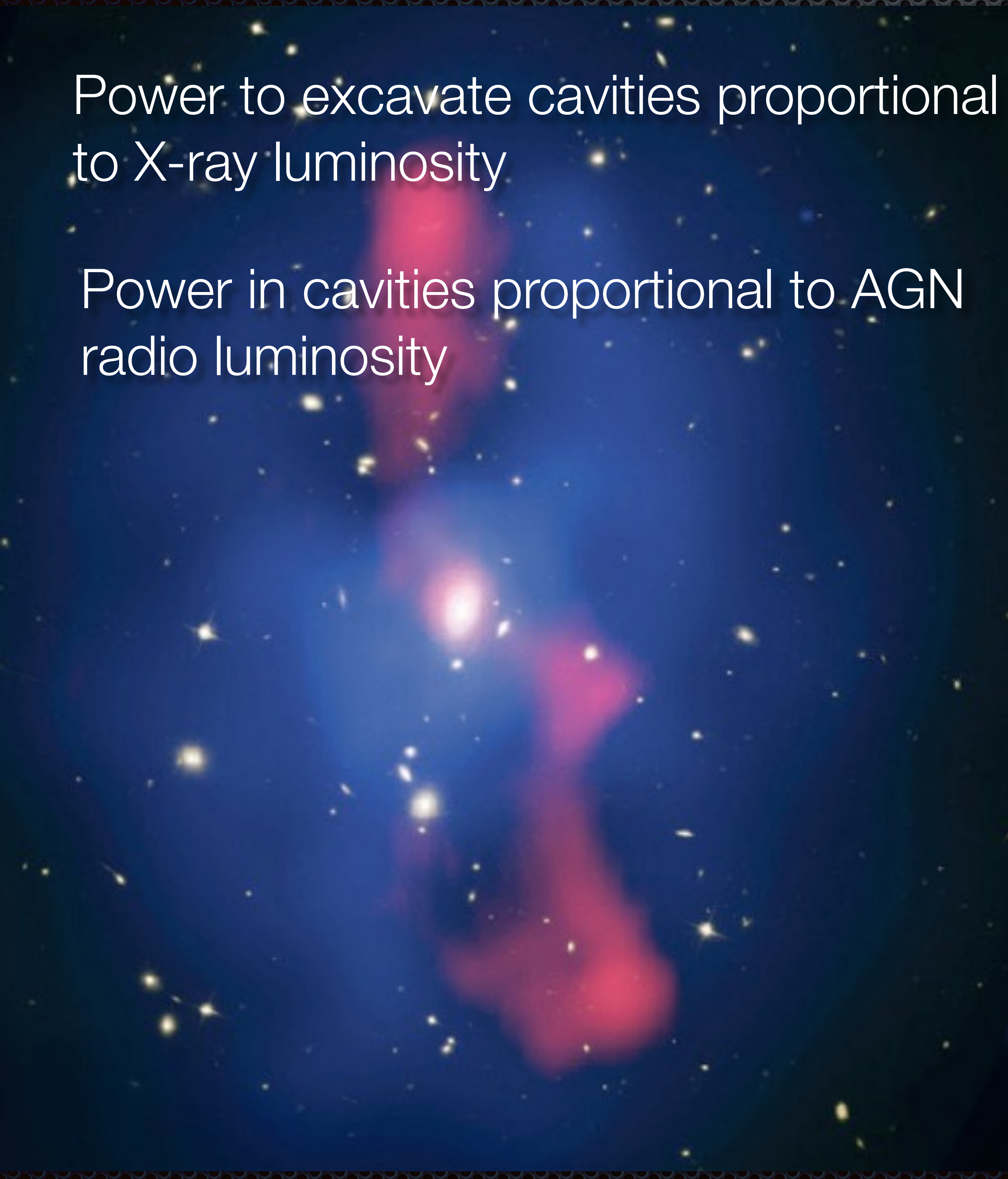


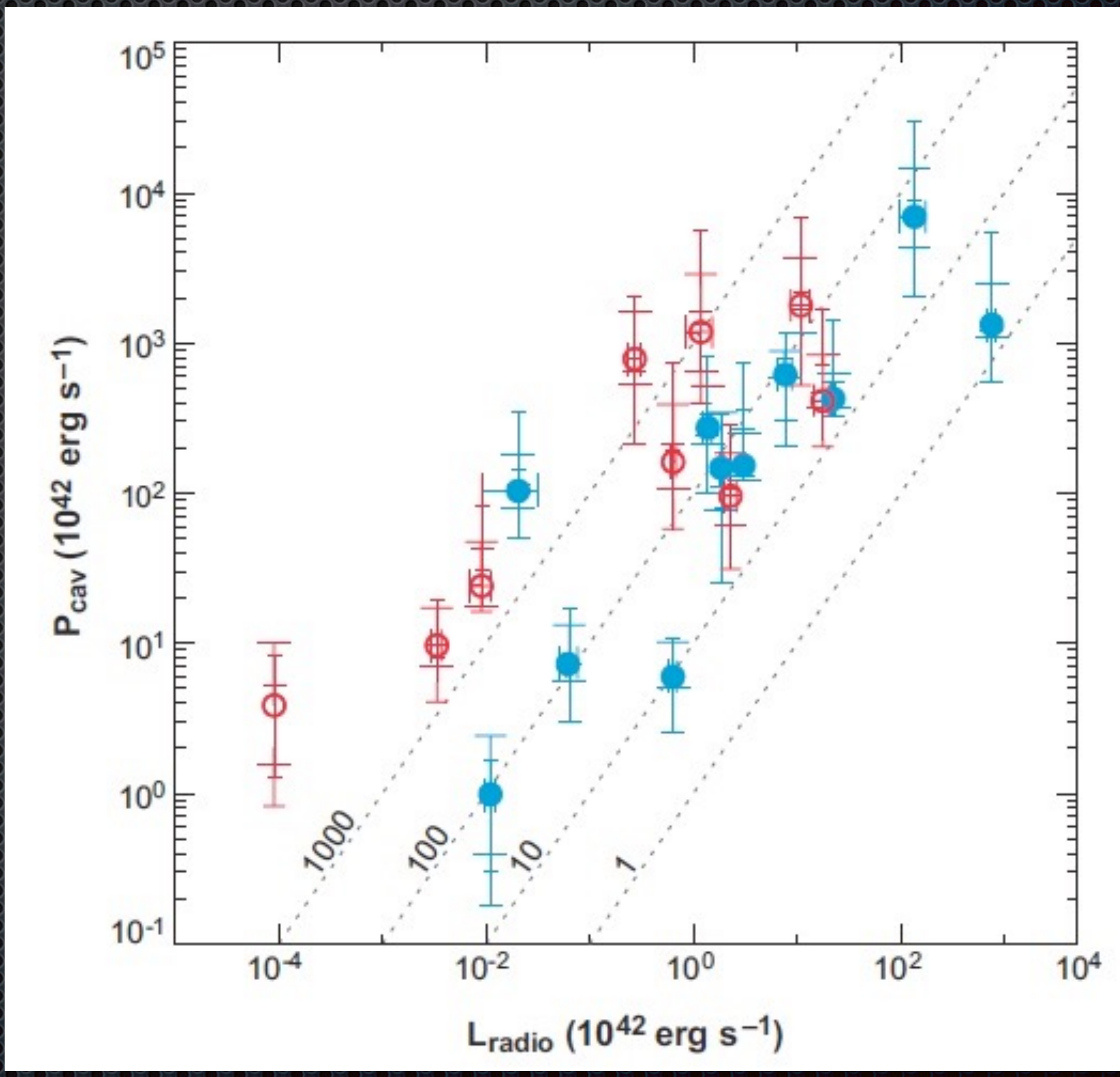


Radio-mode *feedback*

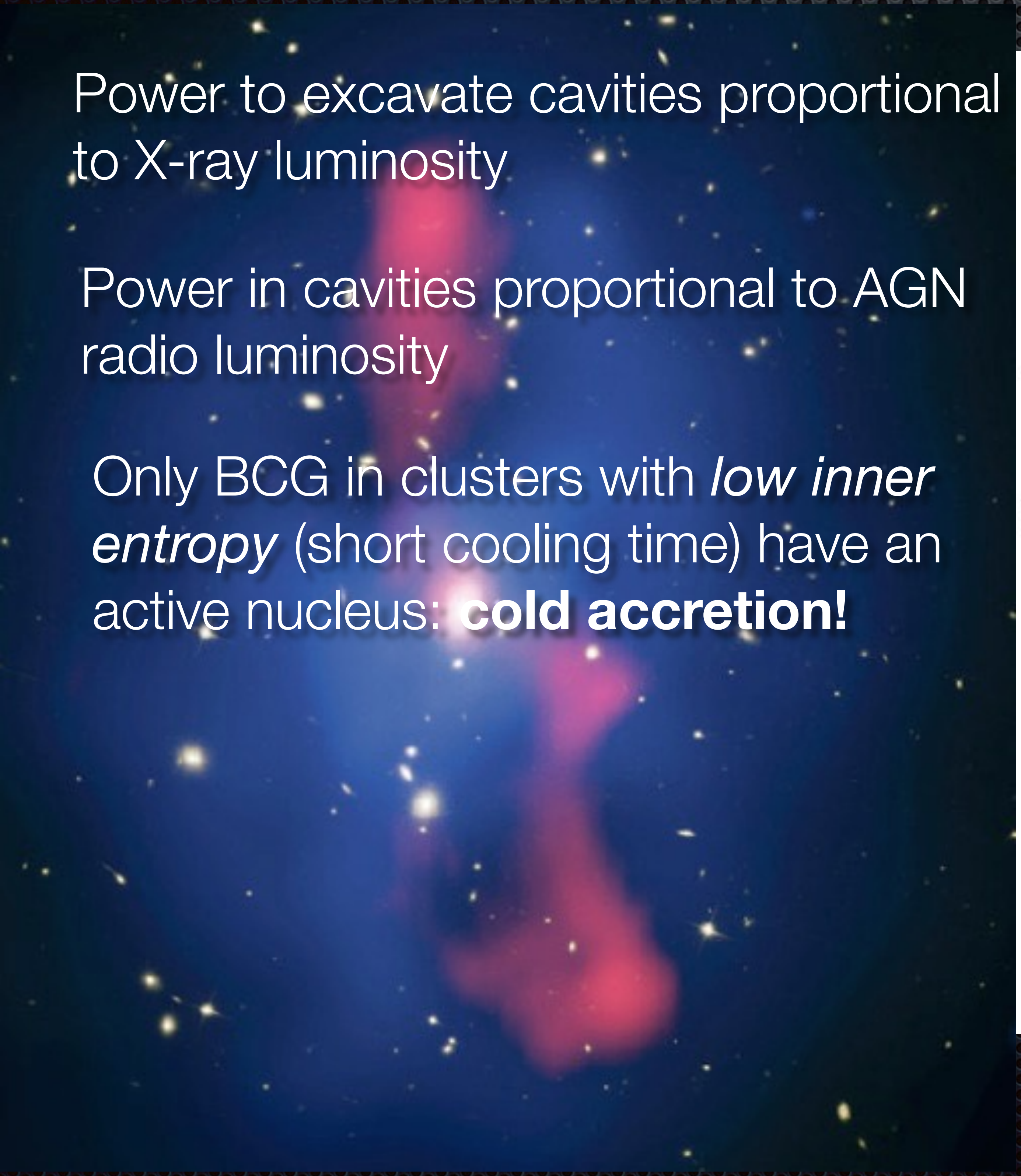
Power to excavate cavities proportional to X-ray luminosity

Power in cavities proportional to AGN radio luminosity





Radio-mode *feedback*



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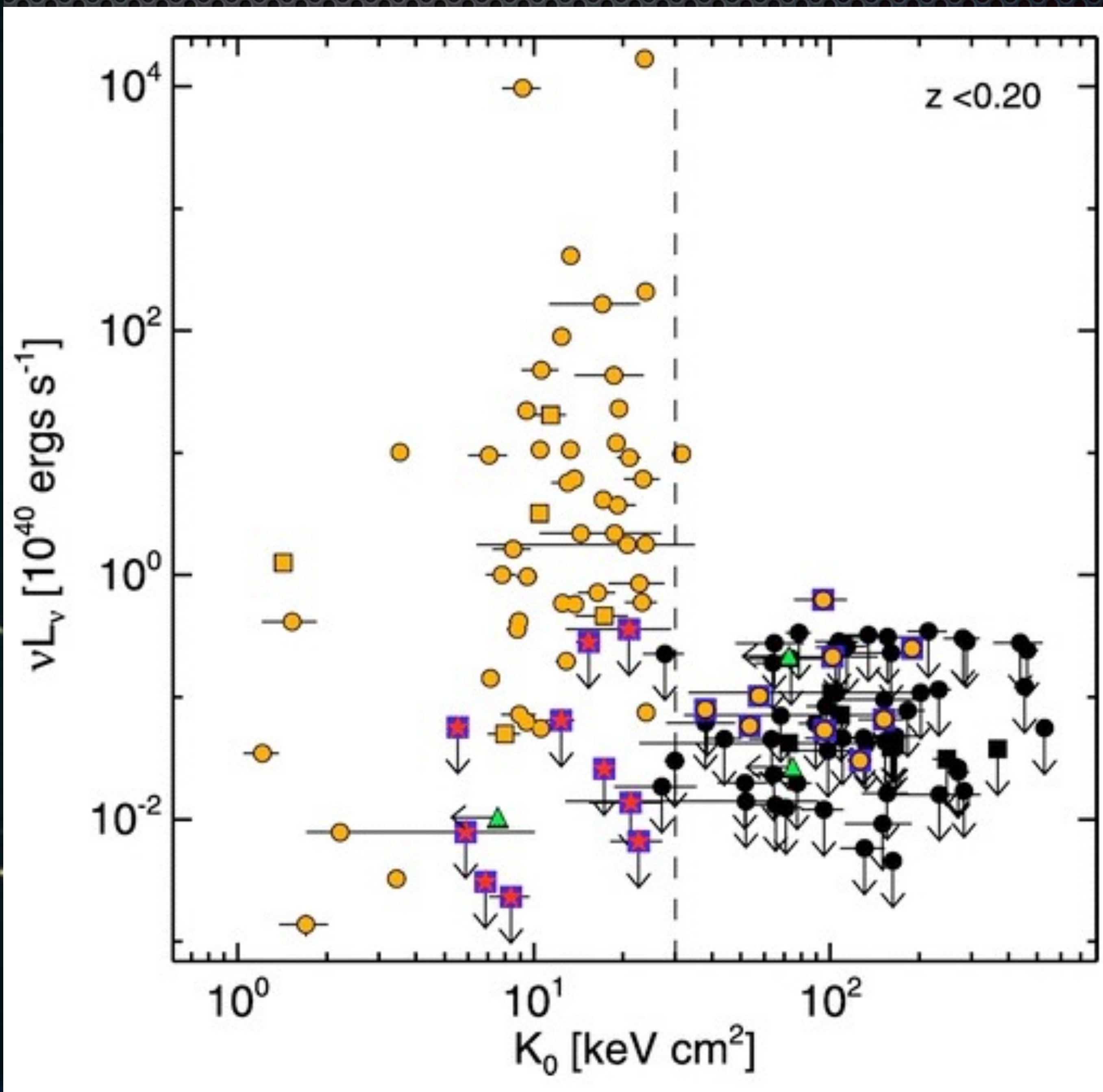
Power in cavities proportional to AGN radio luminosity

Only BCG in clusters with *low inner entropy* (short cooling time) have an active nucleus: **cold accretion!**



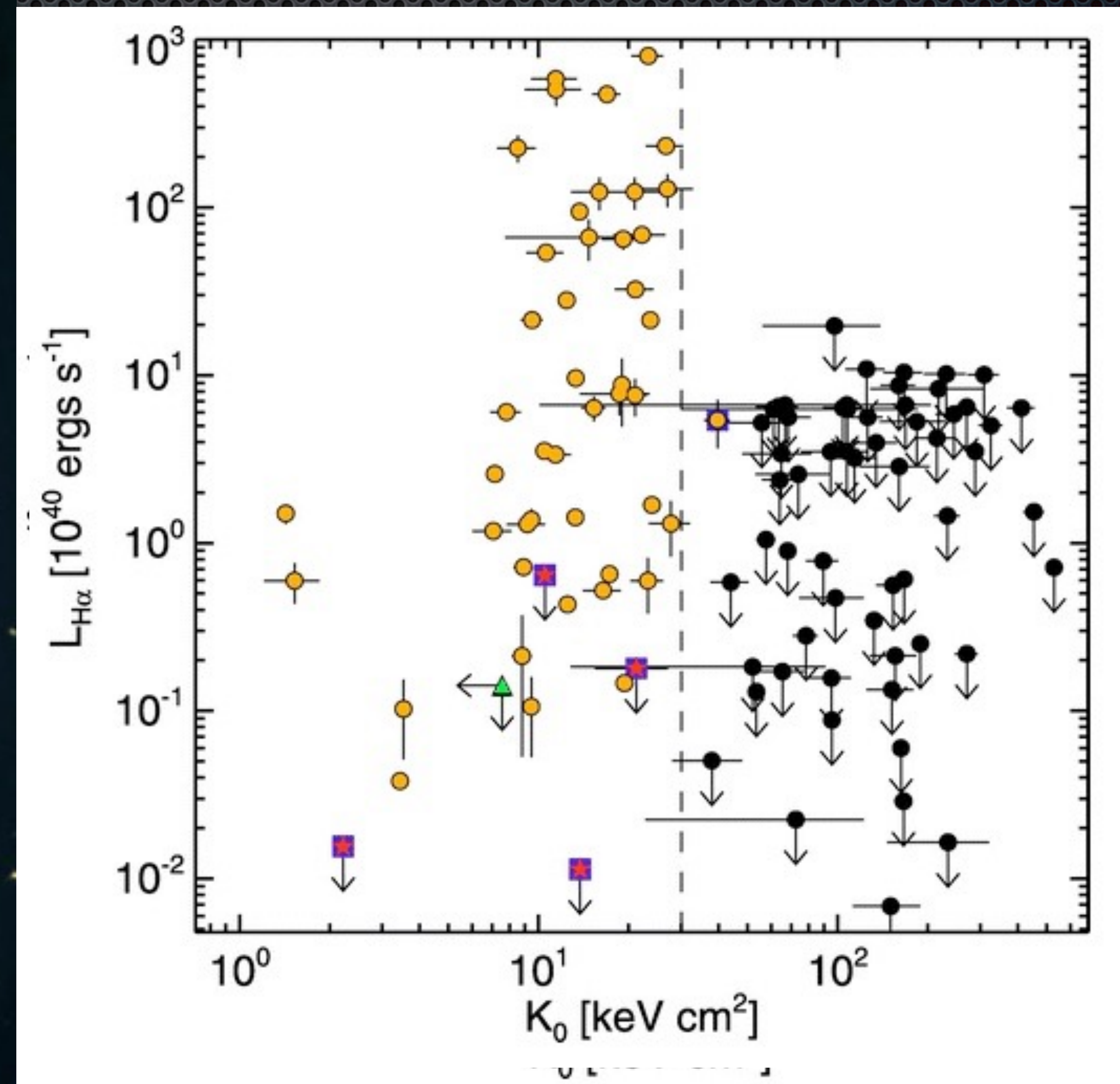
Radio-mode *feedback*

Power to excavate cavities proportional to X-ray luminosity

Power in cavities proportional to AGN radio luminosity

Only BCG in clusters with *low inner entropy* (short cooling time) have an active nucleus: **cold accretion!**

..and only BCG with low inner entropy ***and*** an active nucleus are **actively forming stars!**

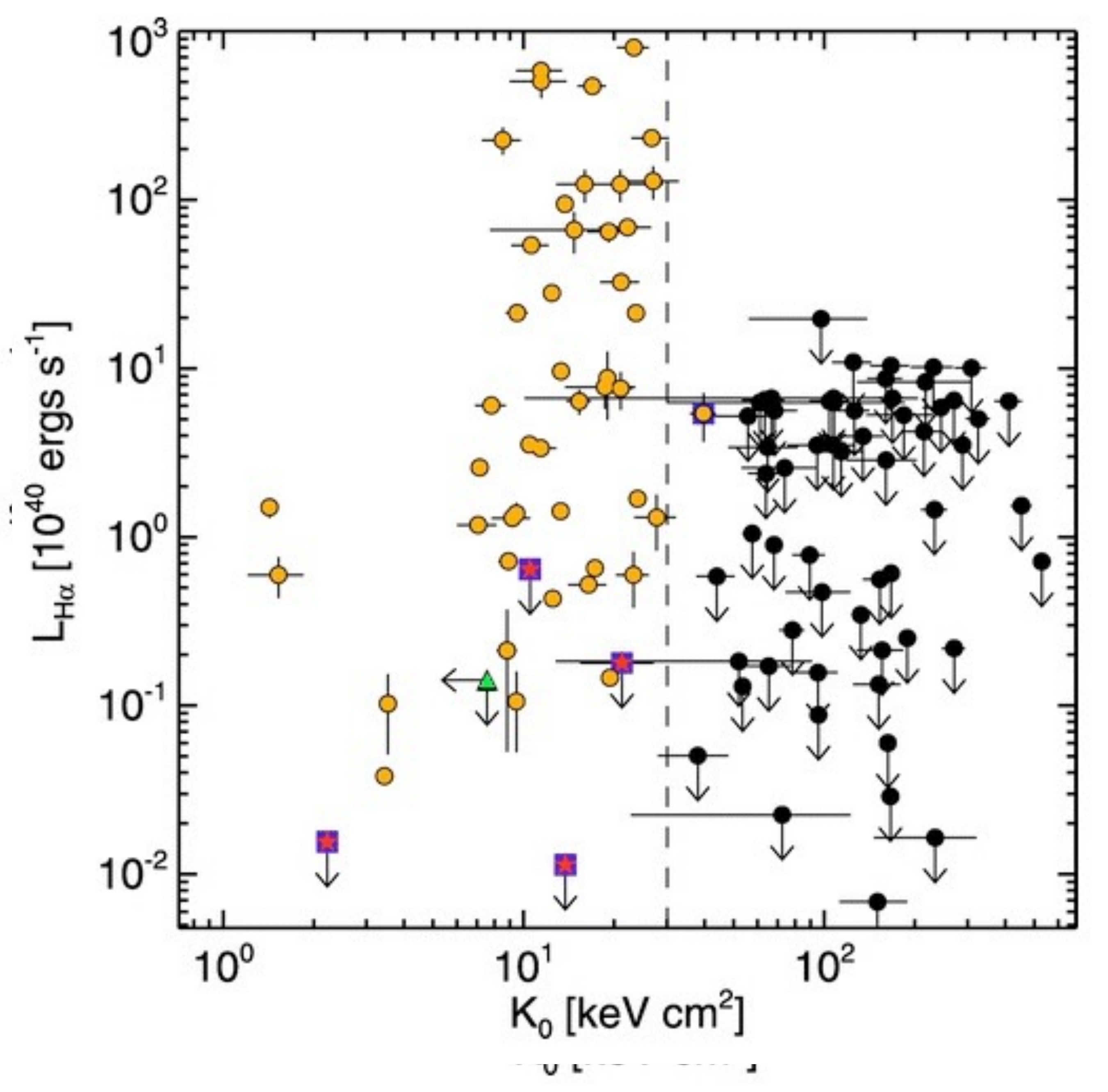


Radio-mode *feedback*

A delicate feedback mechanism:

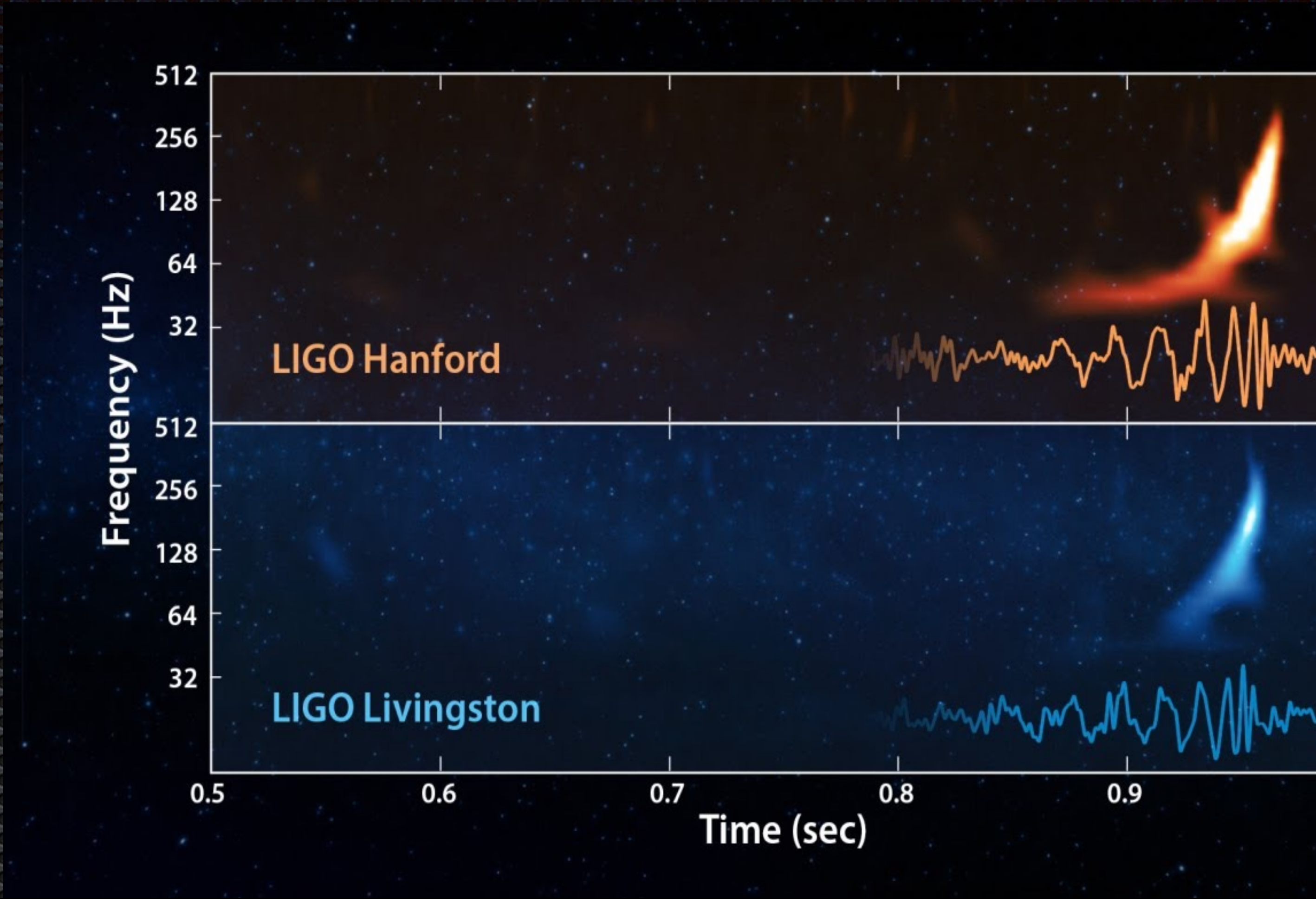
AGN input energy *regulates* the gas entropy and, in turn, further gas accretion and SF (stars can form from low entropy, cold and dense gas only).

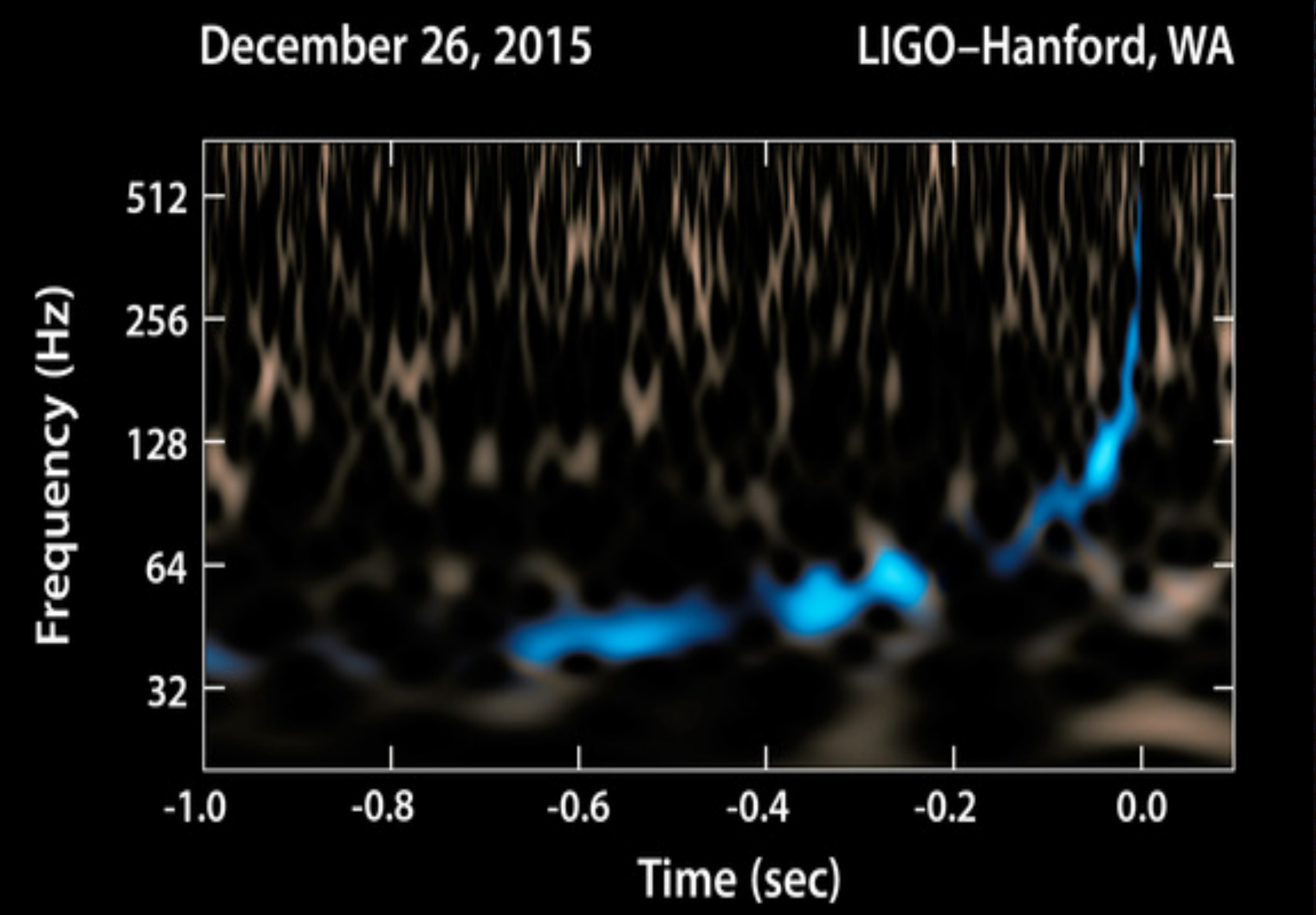
Voit & Donahue 2014



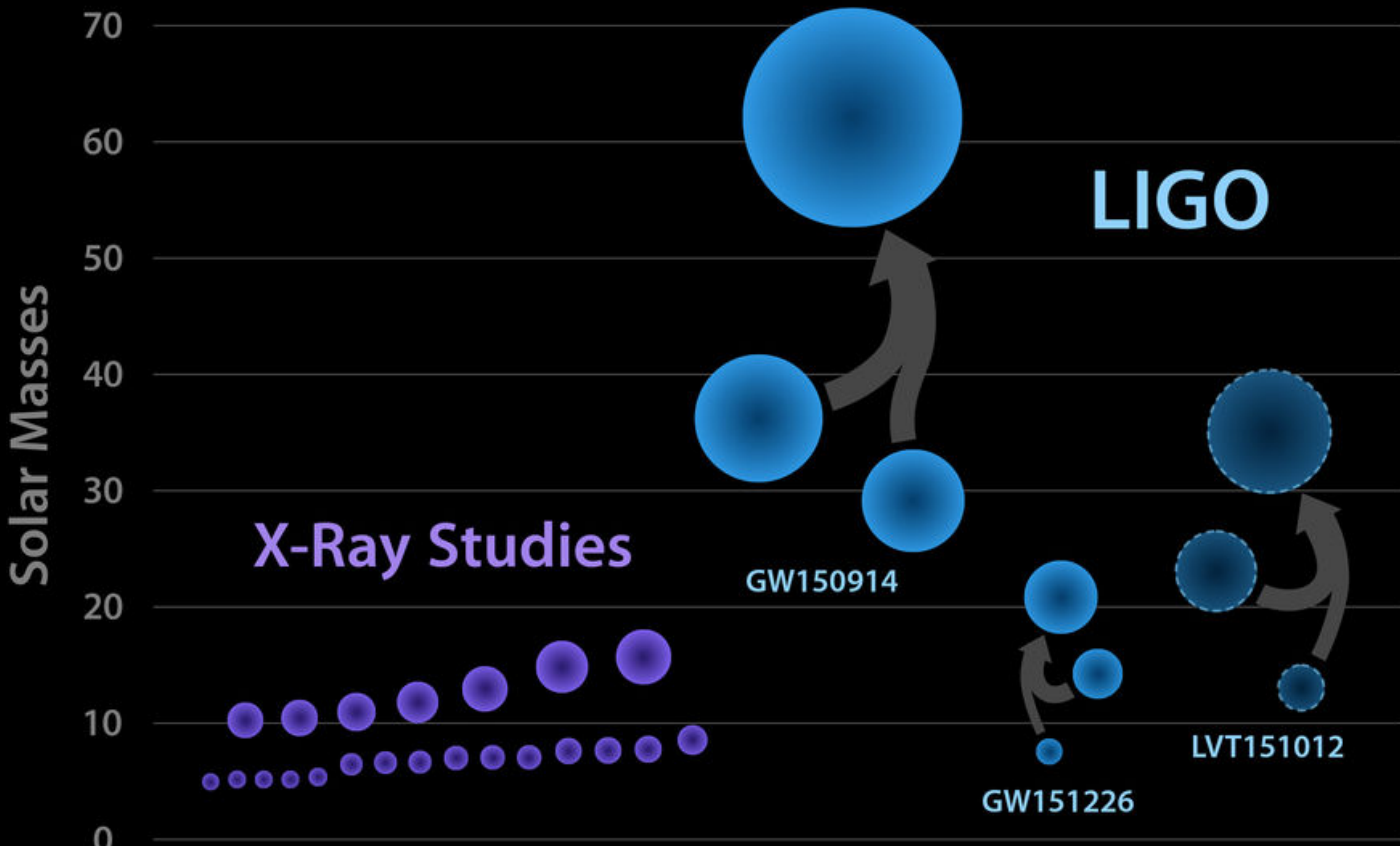
A revolution

- 2(3) events in 39 days of data analyzed within 1Gpc
- BH binaries with masses from 30 to 8 Msun
- Something very weird in stellar evolution/dynamics/IMF
- Primordial BH? big fraction of DM?





Black Holes of Known Mass



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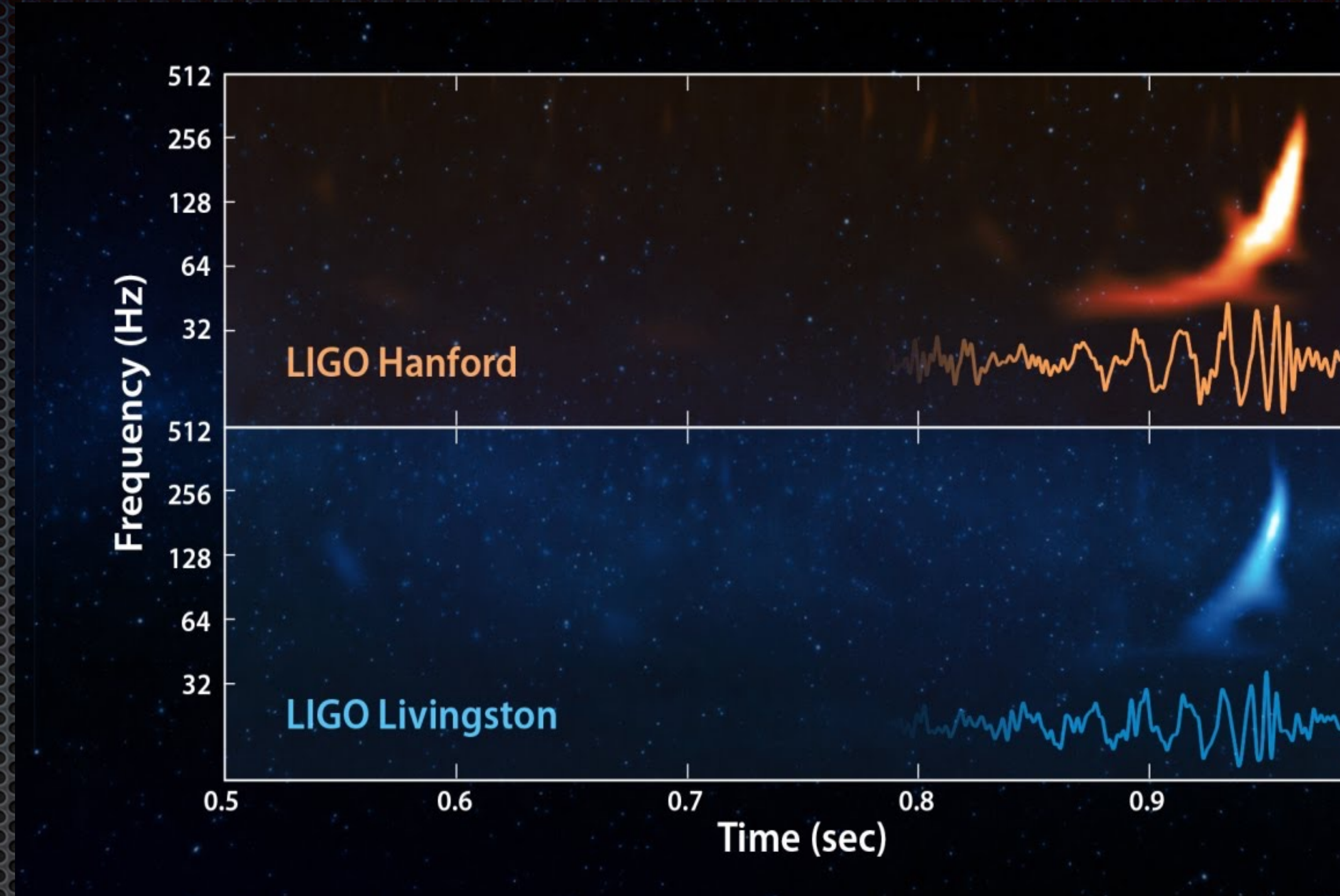

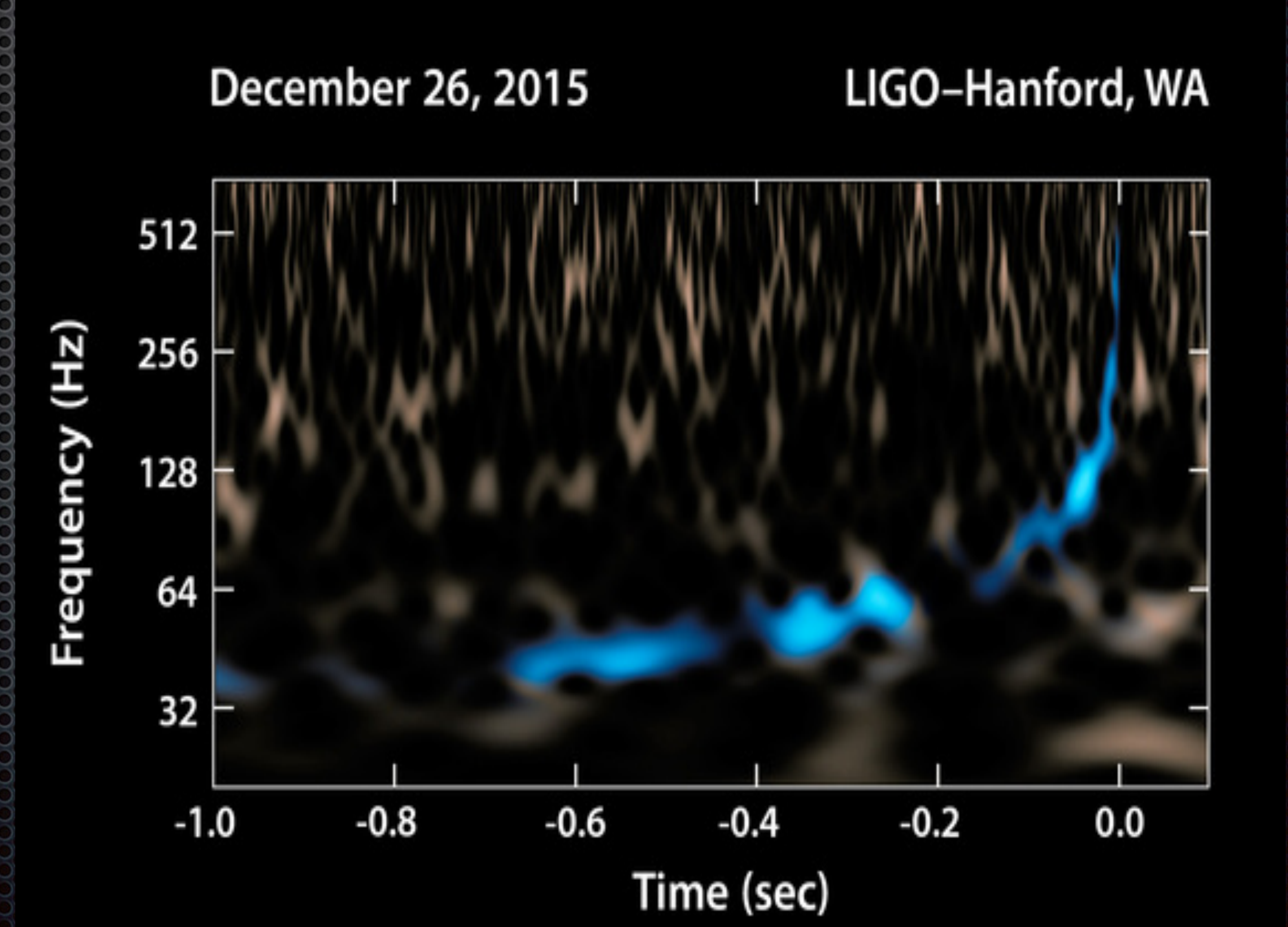

GW event predictions 2013

Epoch			2015 – 2016	2016 – 2017	2017 – 2018	2019+	2022+ (India)
Estimated run duration			4 months	6 months	9 months	(per year)	(per year)
Burst range/Mpc		LIGO	40 – 60	60 – 75	75 – 90	105	105
		Virgo	—	20 – 40	40 – 50	40 – 80	80
BNS range/Mpc		LIGO	40 – 80	80 – 120	120 – 170	200	200
		Virgo		20 – 60	60 – 85	65 – 115	130
Estimated BNS detections			0.0005 – 4	0.006 – 20	0.04 – 100	0.2 – 200	0.4 – 400
90% CR	% within	5 deg^2	< 1	2	> *1 – 2*	> *3 – 8*	> *20*
		20 deg^2	< 1	14	> *10*	> *8 – 30*	> *50*
		median/deg^2	480	230	—	—	—
searched area	% within	5 deg^2	6	20	—	—	—
		20 deg^2	16	44	—	—	—
		median/deg^2	88	29	—	—	—

While the intrinsic rates of neutron star–black hole (NS–BH) and binary black hole (BBH) mergers are expected to be a factor of tens or hundreds lower than the BNS rate, the distance to which they can be observed is a factor of two to five larger. Consequently, the predicted observable rates are similar [14, 92]. Expected rates for other transient sources are lower and/or less well constrained.