A New Model for Science Policy:
Key Projects, GO Funding, Enabling Legacy Science

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Giacconi Memorial Symposium

May 2019, NAS

Riccardo & Early STScI Days

Close friend & colleague, pioneer, visionary, leader, mentor

- Building STScI, science (~1980's; Chair, Science Program Selection)
- Goal → Create Science Legacy

  Create top-rate Science Institute
- Developed new model of science policy

  → Highly successful;

  Now adopted everywhere
- Hubble pioneering science
- Personal reflections

New Model of Science Policy

STScI (1980's – 90's: Chair, Science Program Selection)

→ Goal: Enable Science Legacy

- ✓ Created Large, Medium, & Small programs
- ✓ Key Projects → Currently: Legacy, Treasury,.. programs
- ✓ Created major Science Archive for community (MAST)
- ✓ Provide strong science support to GOs (calibration, software, documentation, community-workshops, other support)
- ✓ GO Funding (for effective analysis of HST data)
- ✓ Science Review Panels & TAC
- ✓ Strong community involvement; outreach program
- ✓ Hubble Fellows Program

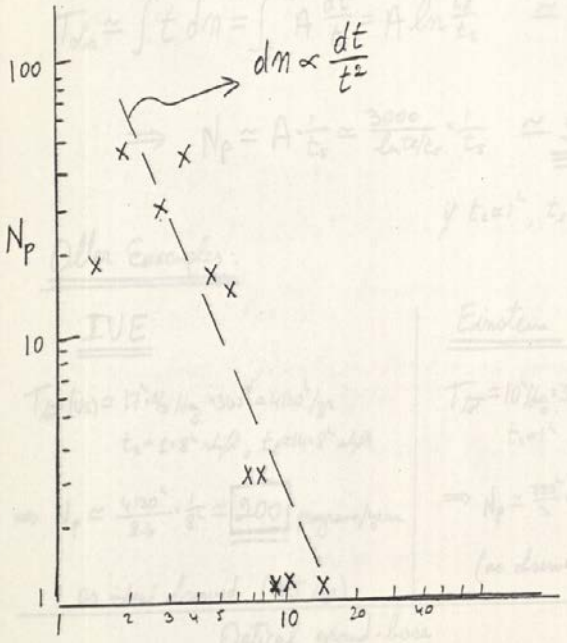
→ Now used successfully in all major observatories

‘Calculation’ of t_{obv} and N_{prog} (N. Bahcall, 1983)

ATTACHMENT A. (pg. 1) N. Bahcall 10/1983

Number of programs on IUE versus allocated time (in 8^h shifts).

(185 programs total (U.S.))



(pg. 2) N. Baha

Program Number versus time (i.e., accepted propos

Use: $dN_p = A\frac{dt}{t^2}$ as observed on IUE.

$$N_p \simeq \int_{t_s}^{t_\ell} A\frac{dt}{t^2} = A\left(\frac{1}{t_s} - \frac{1}{t_\ell}\right) \simeq A\cdot\frac{1}{t_s}$$

$$T_{obs} \simeq \int t\, dn = \int_{t_s}^{t_\ell} A\frac{dt}{t} = A \ln\frac{t_\ell}{t_s} \simeq 3000^h/yr \text{ on}$$

$$\Rightarrow N_p \simeq A\cdot\frac{1}{t_s} \simeq \frac{3000}{\ln t_\ell/t_s}\times\frac{1}{t_s} \simeq \boxed{530} \text{ ST prog per y}$$

if $t_s \simeq 1^h$, $t_\ell \simeq 300^h$.

Other Examples:

IUE

T_{tot} (US) $\simeq 17^h \times 2/3$ /day $\times 365^d \simeq 4130^h/yr$

$t_s \sim 1\times 8^h$ shift, $t_\ell = 14\times 8^h$ shifts

$\Rightarrow N_p \simeq \frac{4130^h}{2.6}\times\frac{1}{8^h} \simeq \boxed{200}$ programs/year

as indeed observed (185/yr).

Einstein

$T_{tot} \simeq 10^h/day \times 365^d \times 1/4 \simeq 880^h/yr.$

$t_s = 1^h$, $t_\ell = 20^h$

$\Rightarrow N_p \simeq \frac{880^h}{3}\cdot\frac{1}{1^h} = \boxed{290}$ prog./

(as observed: ~220/yr.).

Optical ground-base

$T_{tot} \simeq 300^d/yr.$ $t_s = 1^d$, $t_\ell \simeq 10^d$ $\Rightarrow N_p \simeq \frac{300^d}{2.3}\times\frac{1}{1^d} \simeq \boxed{130}$ prog

as indeed observed.

Hubble Initial Key Projects
(~1984 – 2000)

Ensure HST provides most important science

- **Ho:** Extragalactic Distance Scale (Aaronson, Mould, Friedman)

  Ho = 72 +- 8 km/s/Mpc [Current Ho & DE, see Riess talk]

- **Quasar Absorption Lines** (J. Bahcall +)

  UV spectra ~70 QSOs, FOS; Revealed intervening local IGM, Ly-a & metals

- **Medium Deep Survey** (Griffiths +)

  Revealed first view of deep Universe → Led to HDF, HUDF, z ~ 10, JWST

- Selected with broad community input ('community survey')
- Established large expert community GO teams for KPs
- Reviewed carefully by STAC & special TAC (L. Spitzer).

Impact of Large Programs
Treasury, Legacy, Multi-Cycle, ….

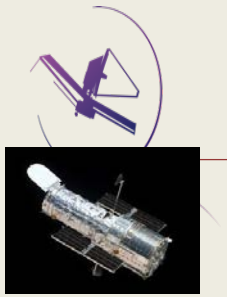
Examples:

- ✓ HDF, HUDF, HLF (Hubble Legacy Field; UV to NIR, ~15 yr data)
  Iconic surveys, reveal 'history book' of galaxies in Universe -- to 13.3 Gy, z ~ 10, galaxy formation & evolution (Illingworth talk)

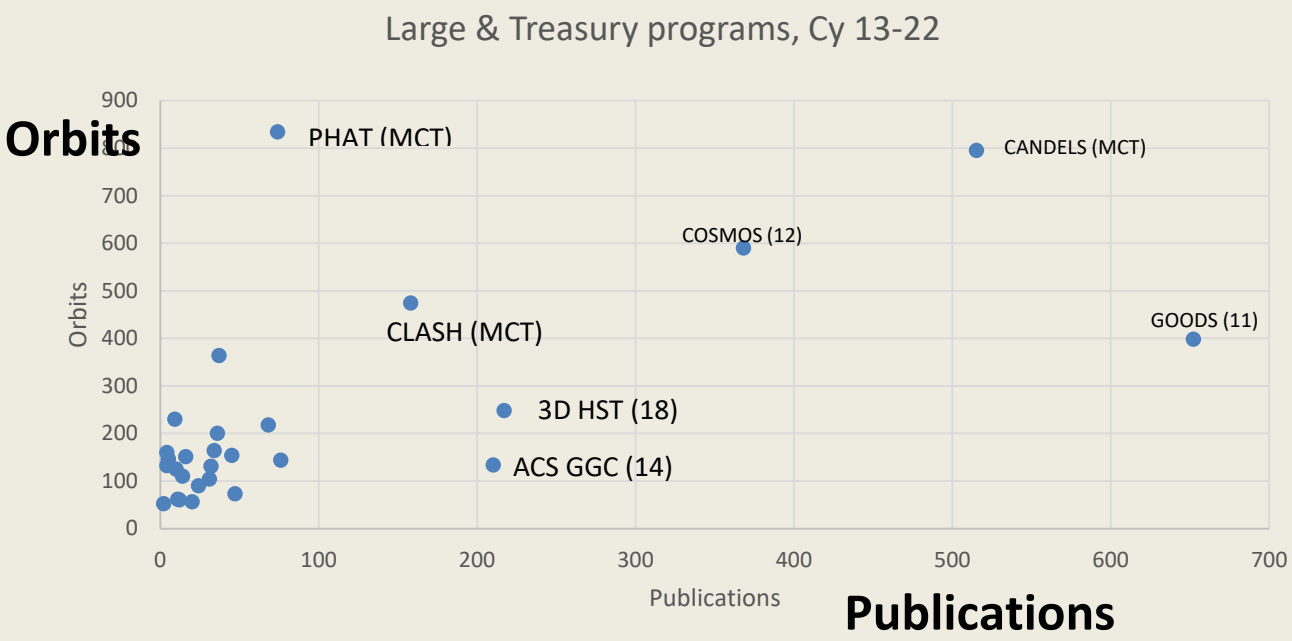
- ✓ GOODs (Great Observatories Origins Deep Survey)
  Most data-rich area of sky in depth and wavelength; expansion history and Dark-Energy (Riess talk)

- ✓ CLASH, FF (Clusters and SN HST) Used 25 clusters as lenses (telescopes) to detect distant galaxies, hi-z SN; measure dark-matter distribution in clusters (strong & weak lensing)

- ✓ COS-Halo Revealed extensive Circumgalactic Medium gas halos around galaxies; contain much of the 'missing Baryons

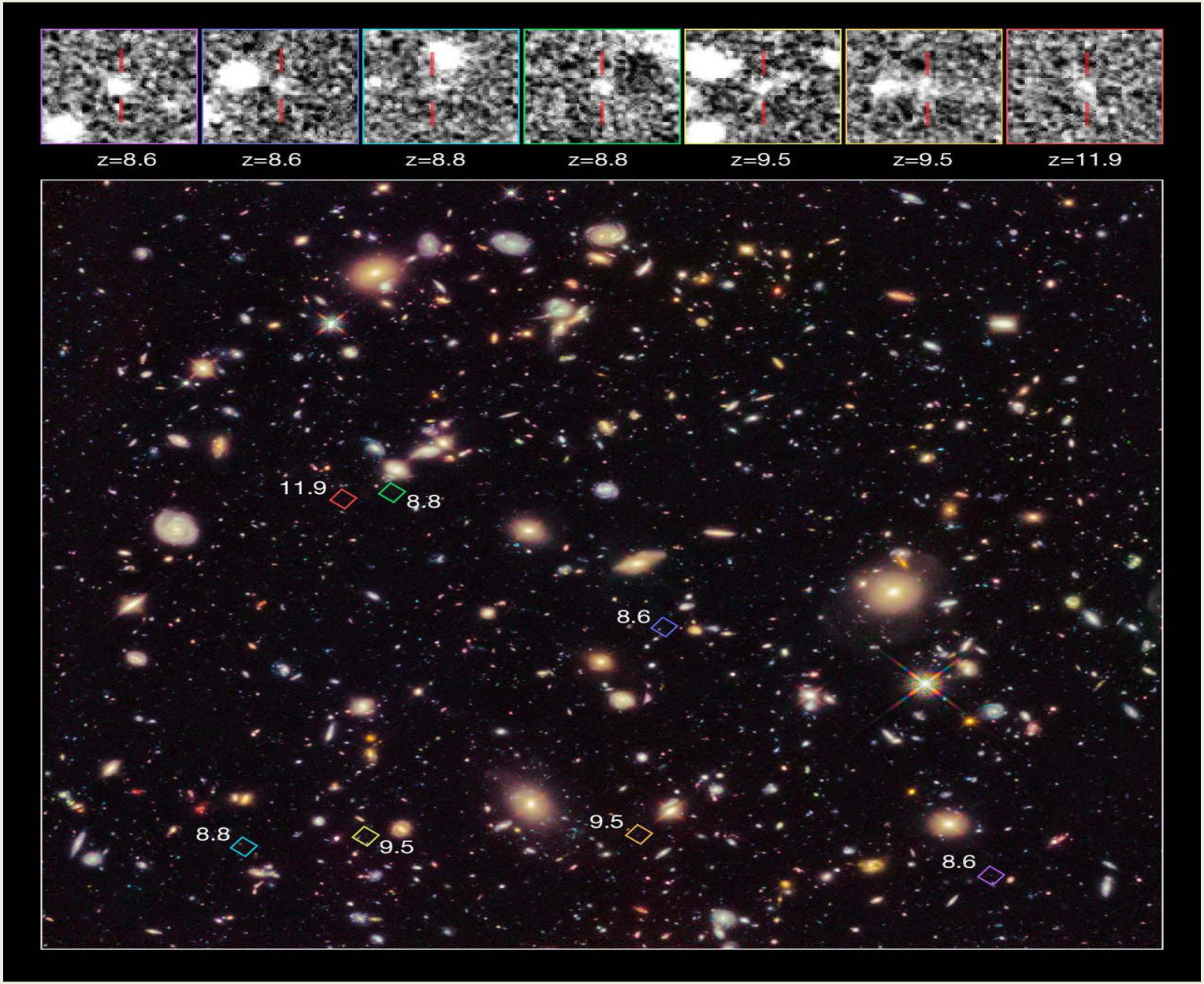


Outcomes - publications



From HST Treasury, Archival Legacy and Large Programs web page
http://archive.stsci.edu/hst/tall.html

HUDF

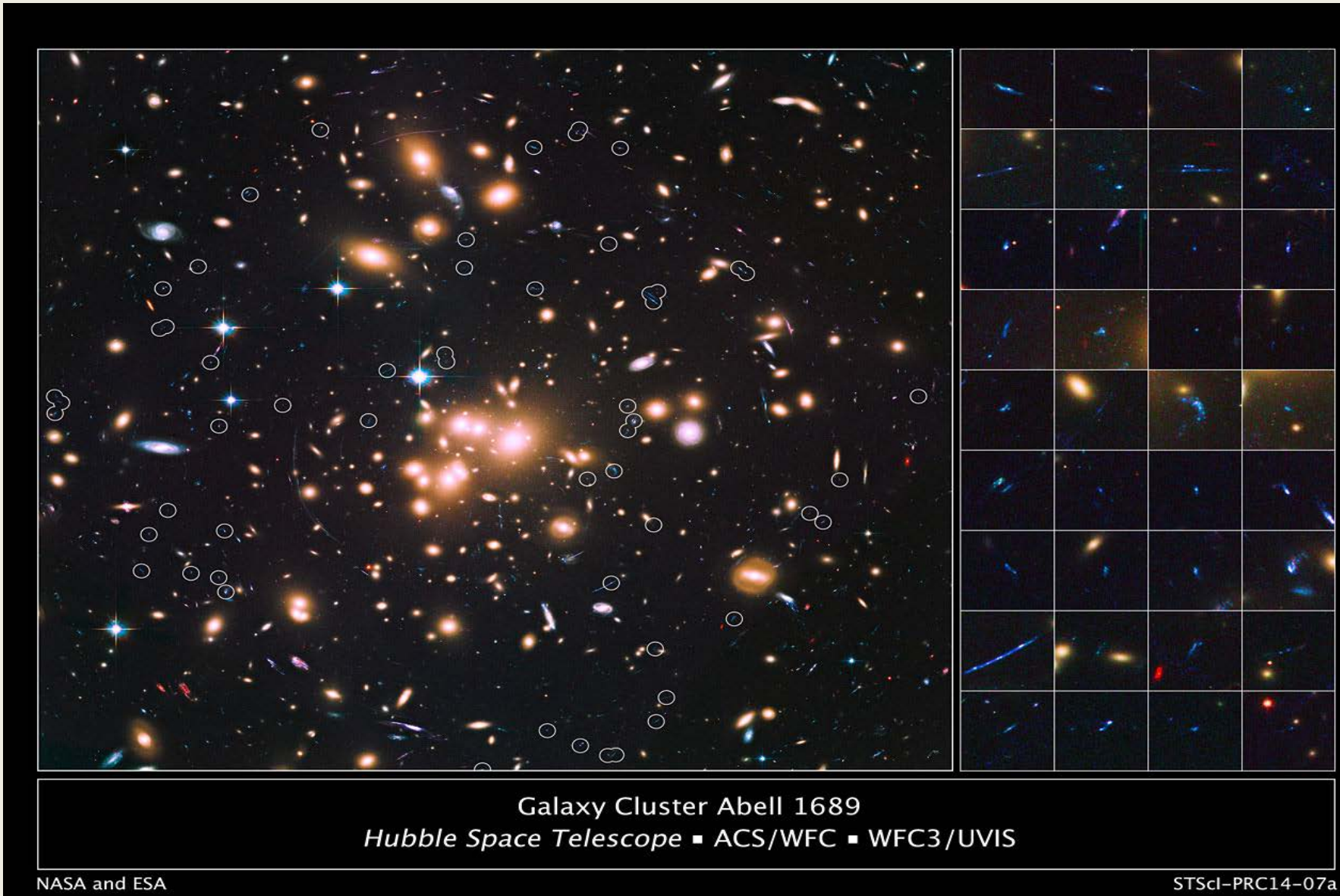


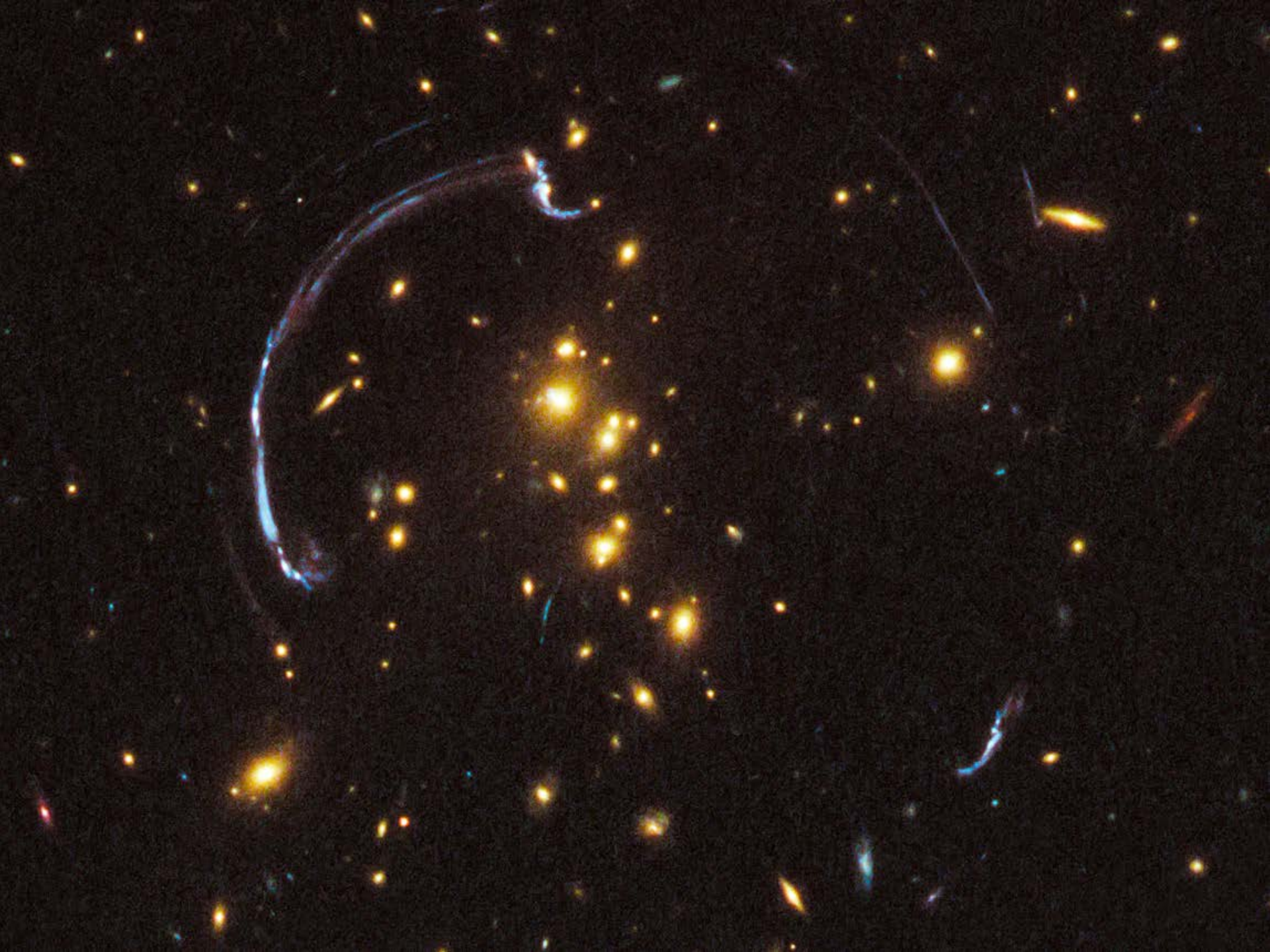
Clusters of Galaxies

A370 (Frontier Fields)

- From X-ray discovery (Uhuru) to Hubble optical & lensing
- Powerful for Cosmology, Structure Formation & Evolution, Baryon cycle in Universe (hot gas ~14%, stars ~ 2%)
- Mass distribution (lensing) important for Cosmology (→ M ~ L ~ M*)
- Used as 'telescopes' to reveal hi-z lensed galaxies

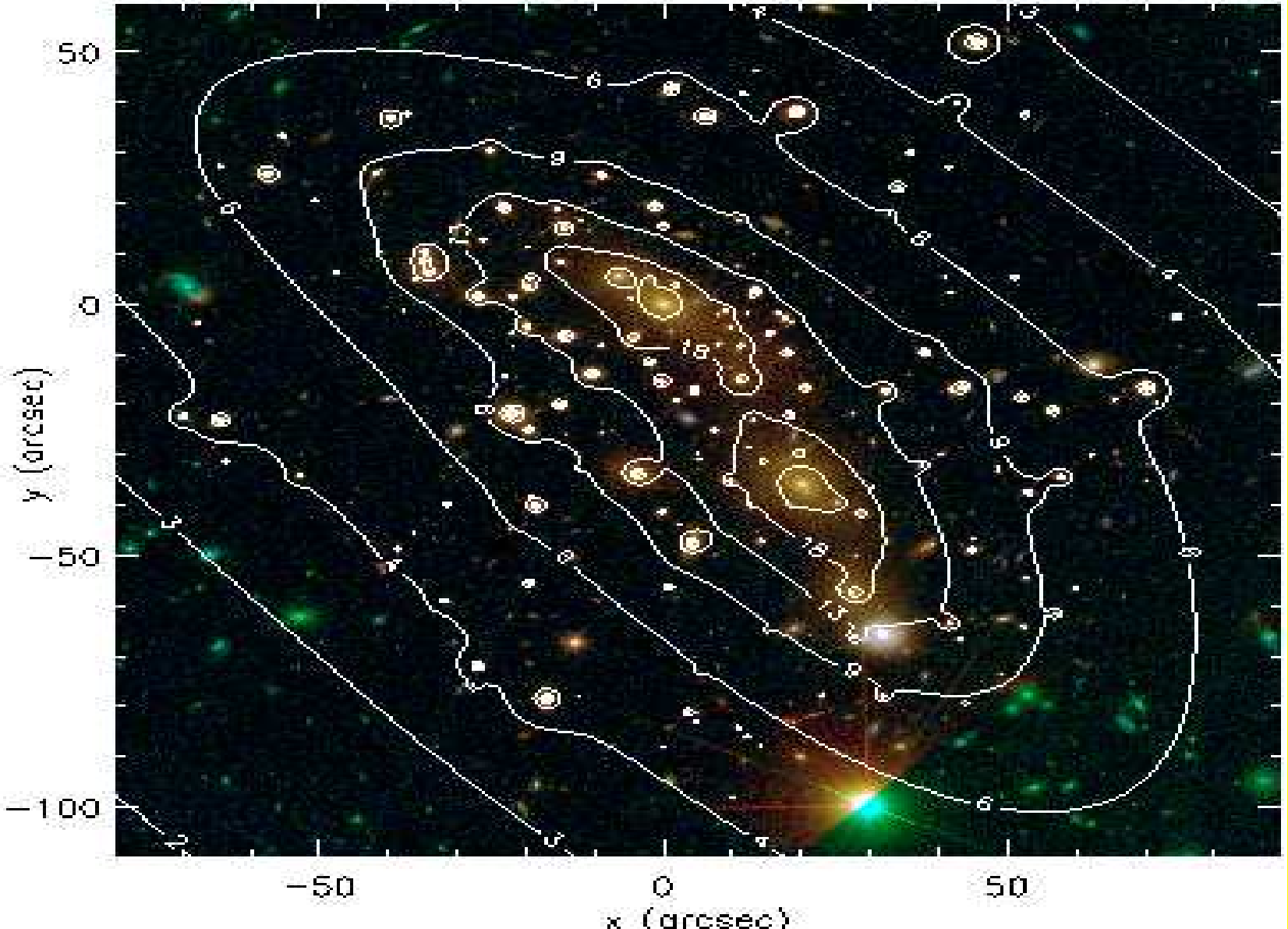
A1689 and Distant Galaxies



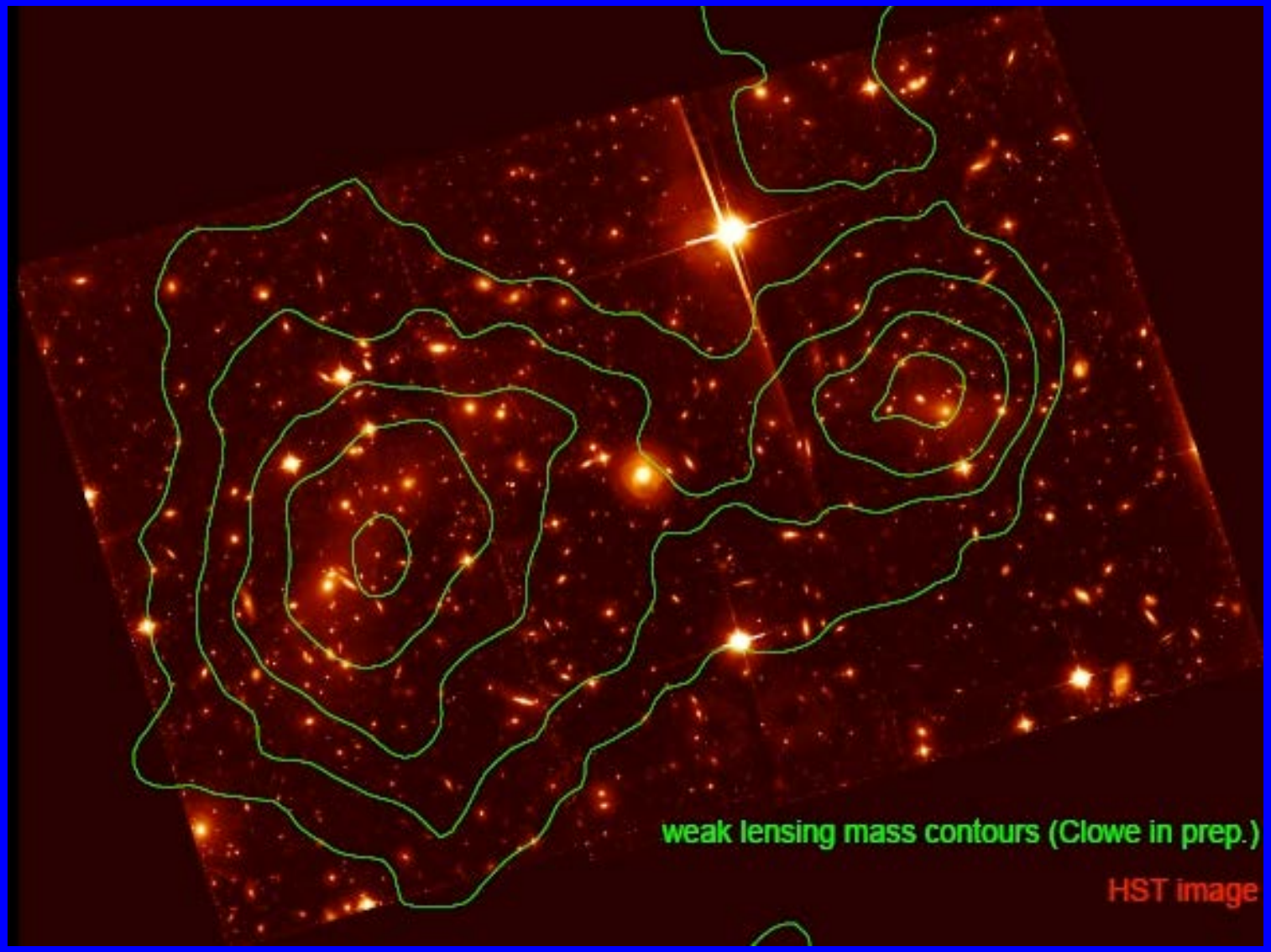


Mass versus Light

(CLASH HST Lensing cluster, Grillo+ ‘14)



The Bullet Cluster (Lensing M vs. L)



GO Funding – and more

- Worked with NASA to establish significant GO funding to support science analysis → ensure data is properly analyzed and published.

→ Critically important for science and community

- GO Funding, Large Projects, Science Archive are now standard model in most observatories
- Importance of sharing science discoveries and beautiful images with the public; strong public outreach program
- Importance of good support & communication with the Astronomical community

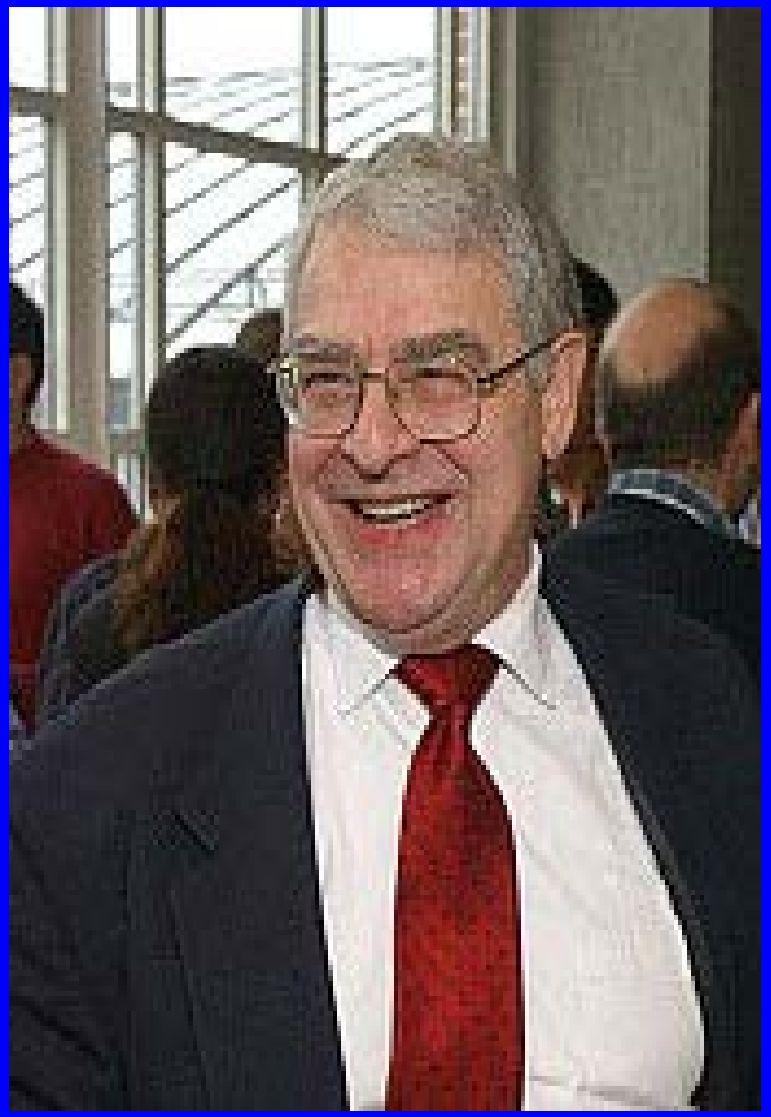
HST

Pillars of Creation

- Solar System
- Exo-Planets
- Star-Formation
- SNs
- Star Clusters
- Nearby Galaxies
- SMBHs
- Quasars & AGNs
- Gravitational Lensing (weak & strong)
- Galaxy Evolution to z ~ 10
- Dark Matter, Dark Energy
- Expansion history of Universe
- Deep Surveys
- ……

Riccardo

- Friend, colleague, leader, mentor
- Feisty & dynamic, persistent & persuasive, inspiring, visionary, highest standards, courageous, warm, generous, and fun
- Appreciation & gratitude from the NAS



His Legacy continues to shine

Thank You, our friend!