# The Science Impact and Productivity of the Hubble Space Telescope

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STScI

# Motivation

A) Complete census of HST science

B) Guide Internal Policy Decisions

(e.g. instrument modes, time allocation policy)

C) Comparison to other NASA/ESA missions

# High reliability, conservative approach.

*Standard method* for the community.

# Team

Daniel Apai, Jill Lagerstrom, Iain Neill Reid, Karen Levay, Elisabeth Fraser, Antonella Nota, Edwin Henneken

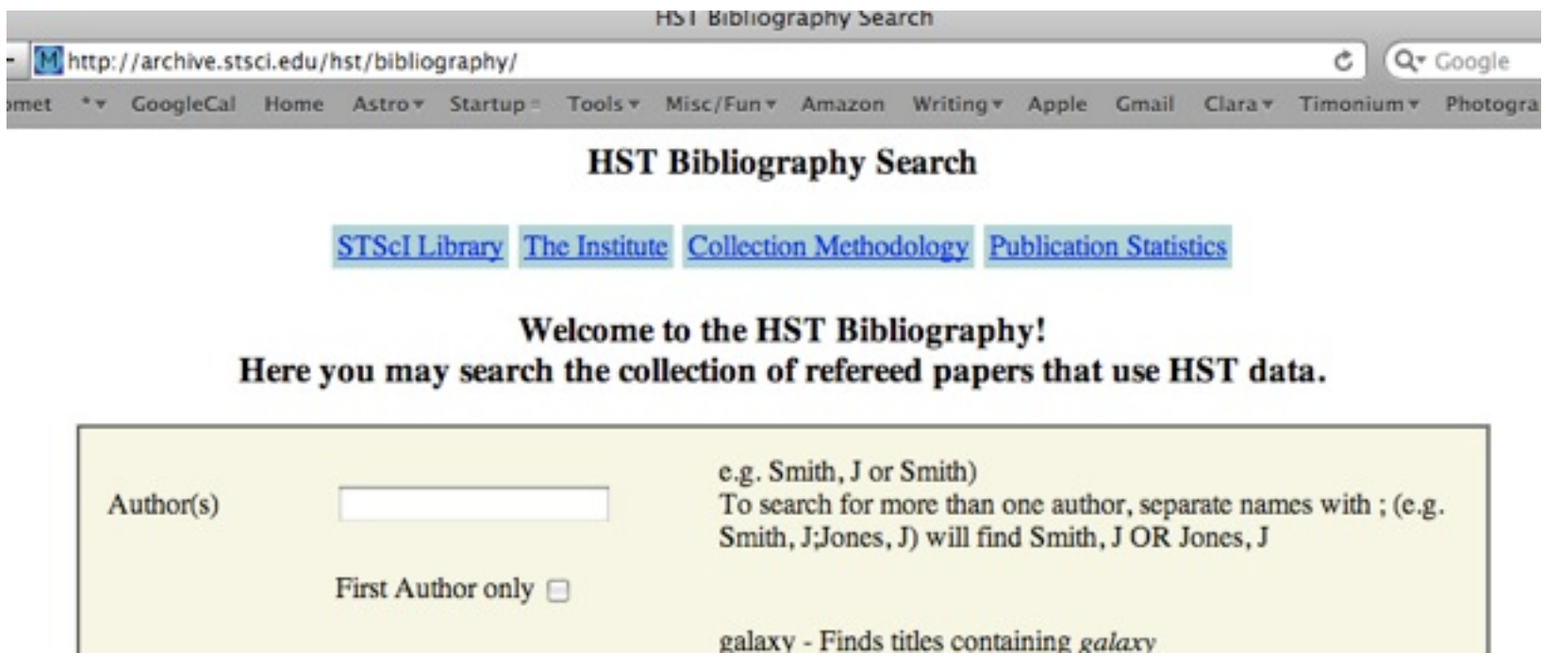
# Database

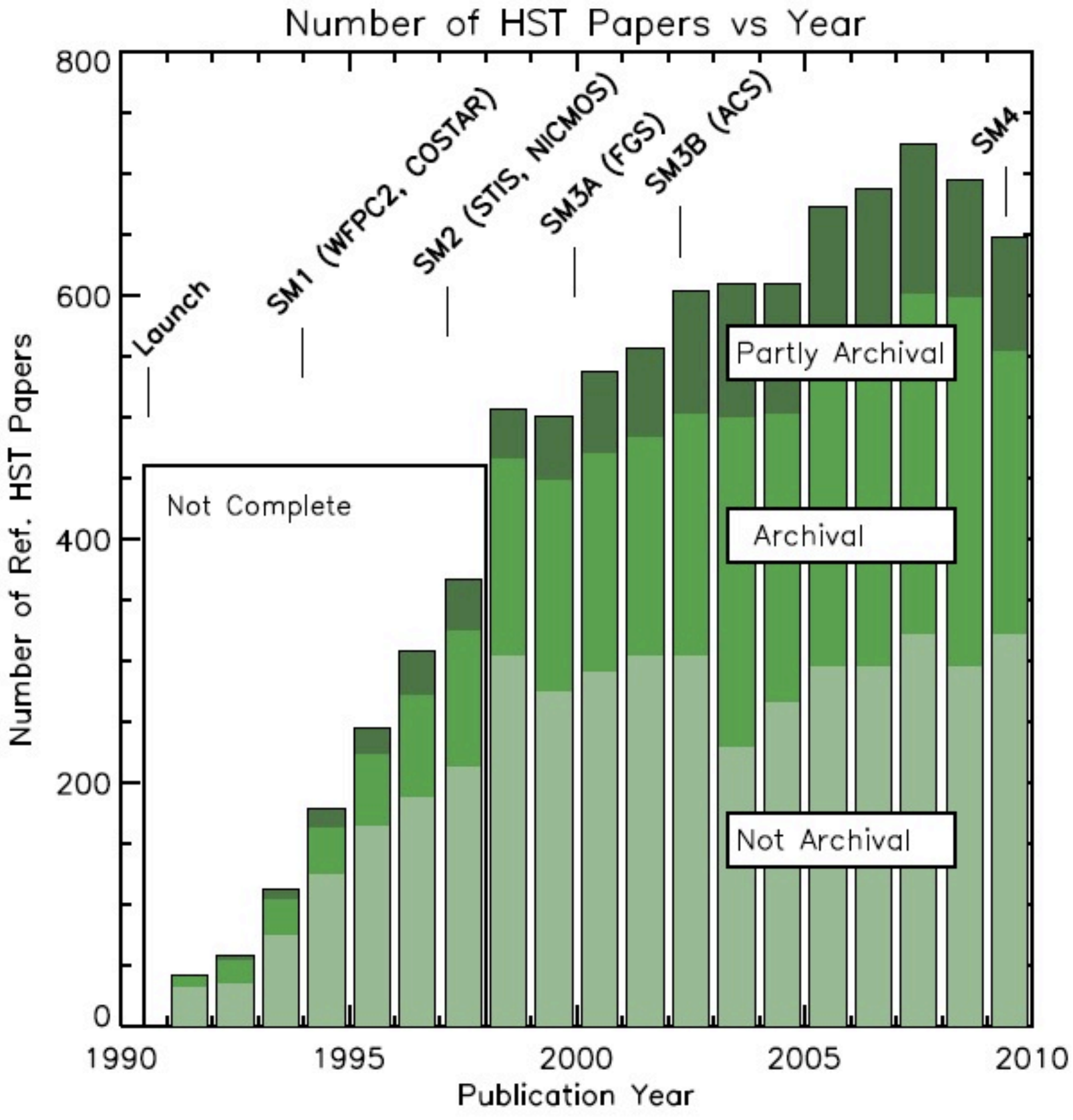
1) Well-defined classification criteria
2) Complete (>95%) and unbiased
3) Verified
4) Uncertainties/Incompleteness characterized

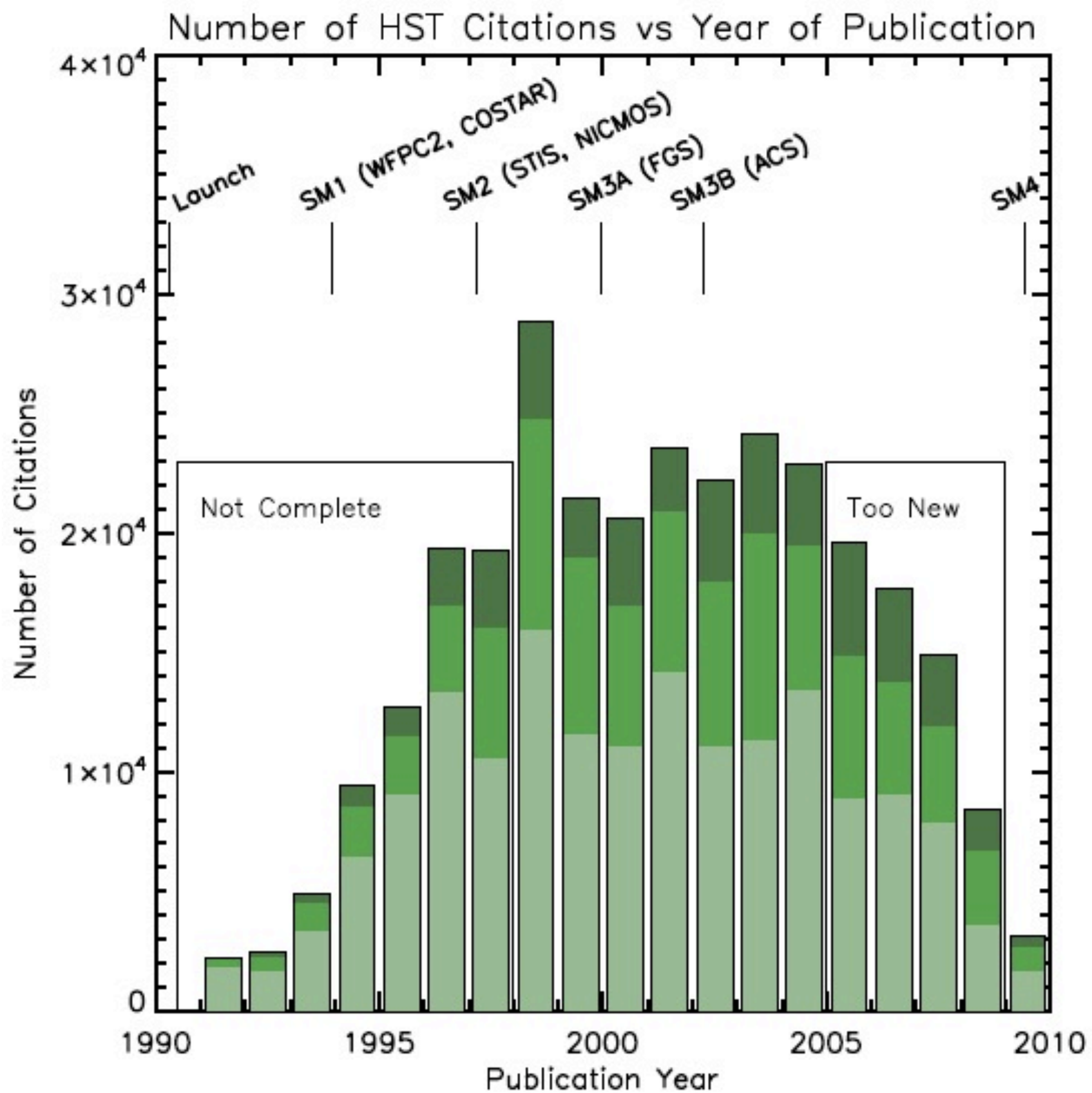
8800+ refereed papers, 300,000+ citations to them

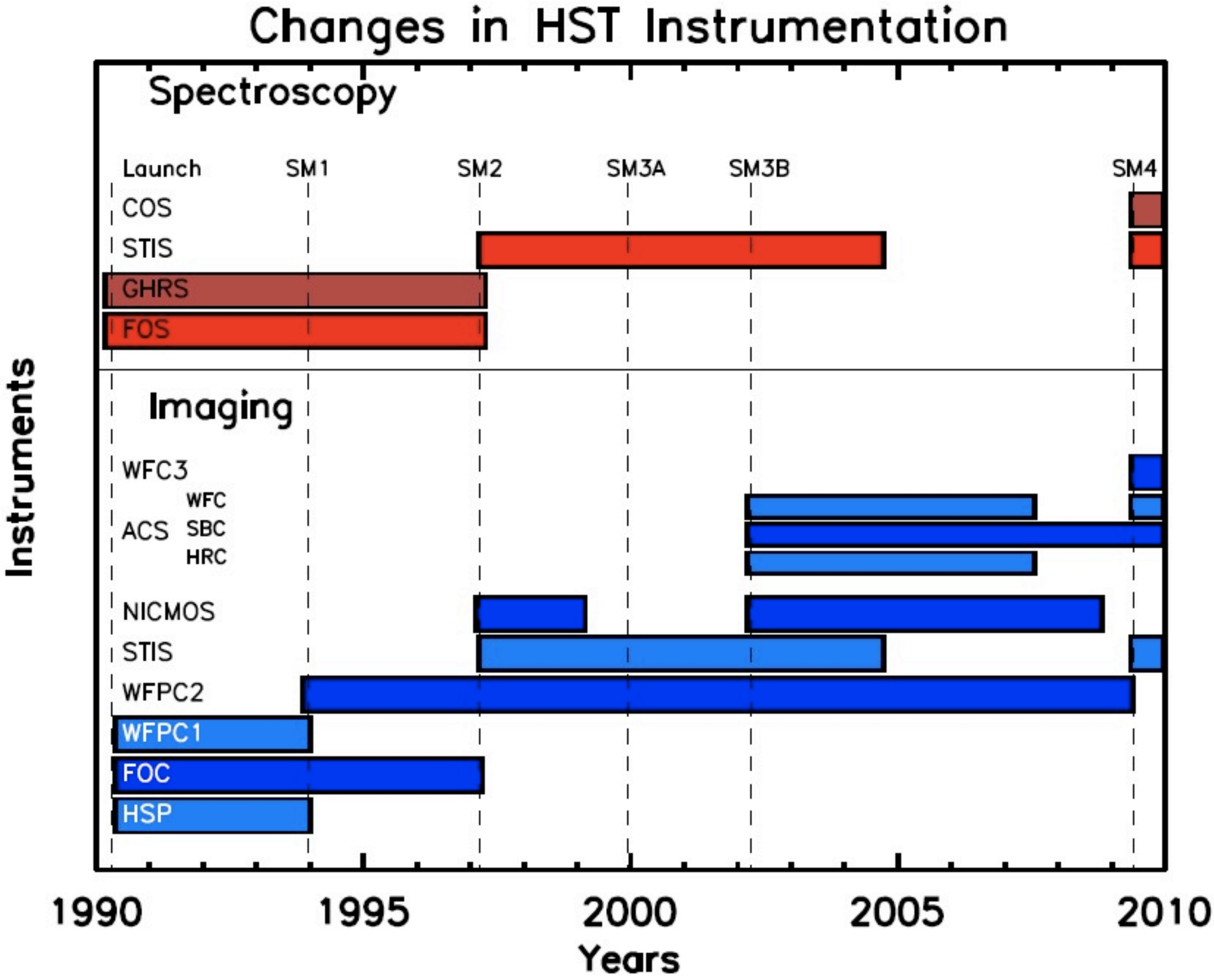
# Public and Available Online

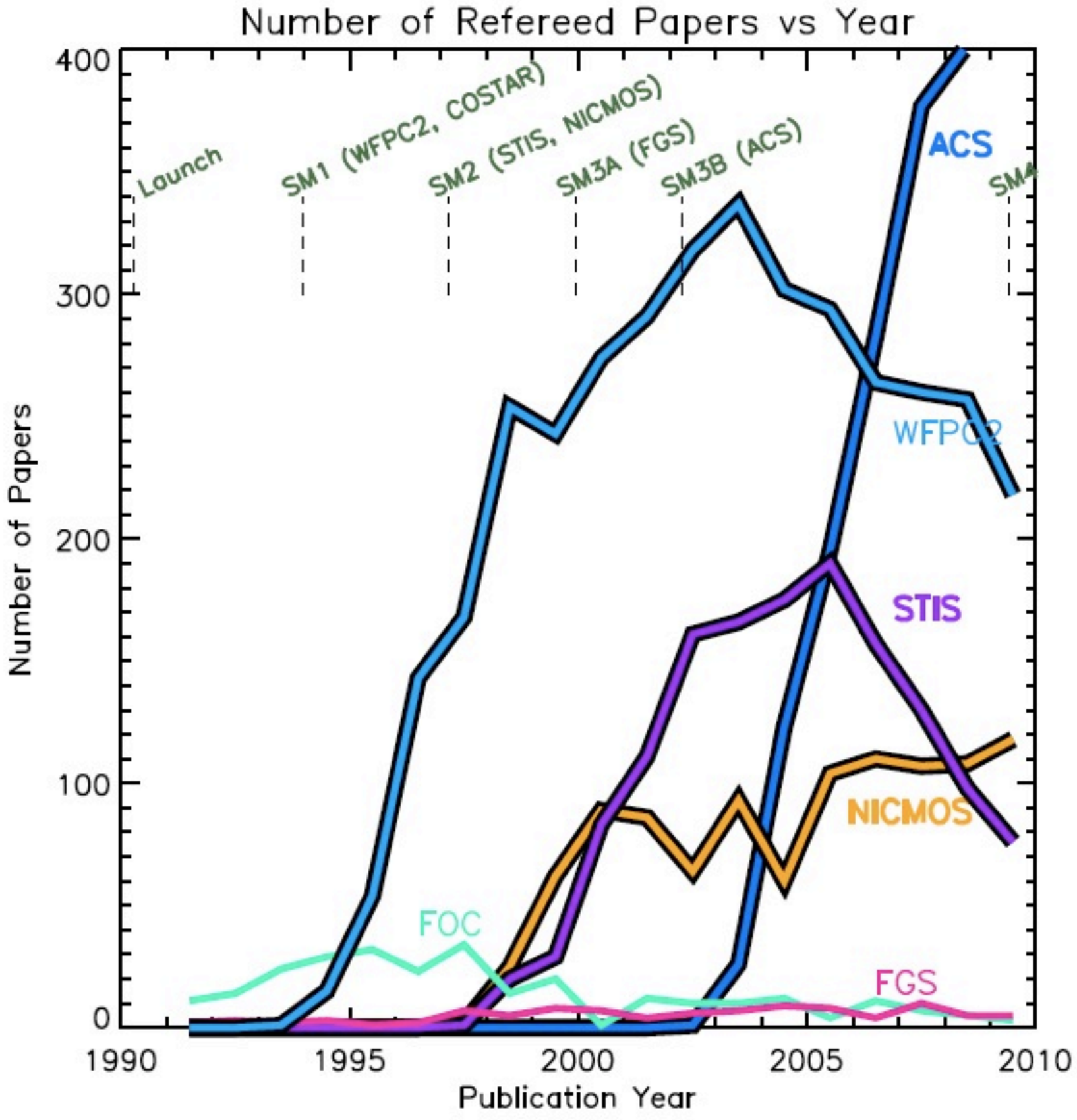
http://archive.stsci.edu/hst/bibliography/index.html

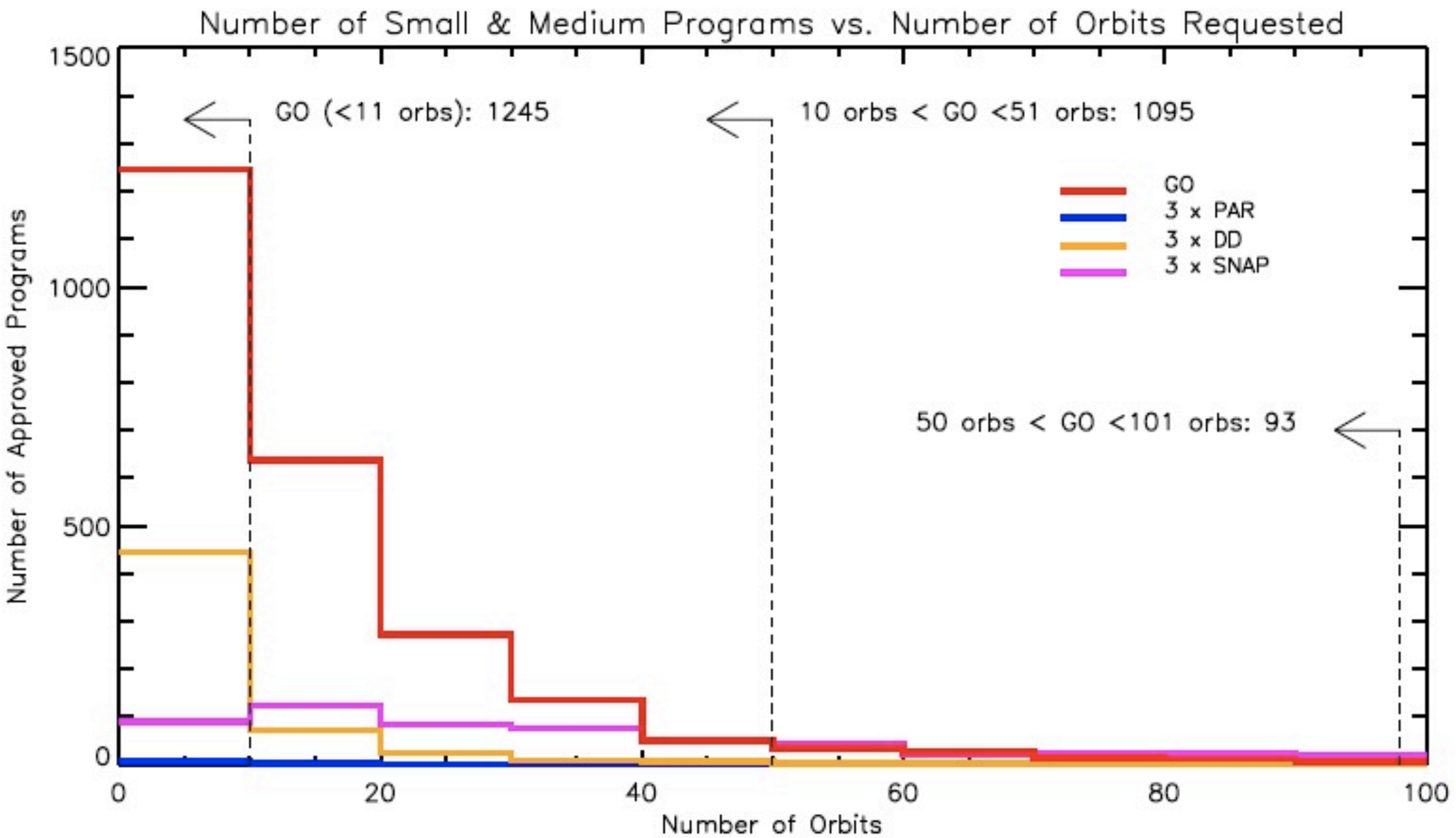


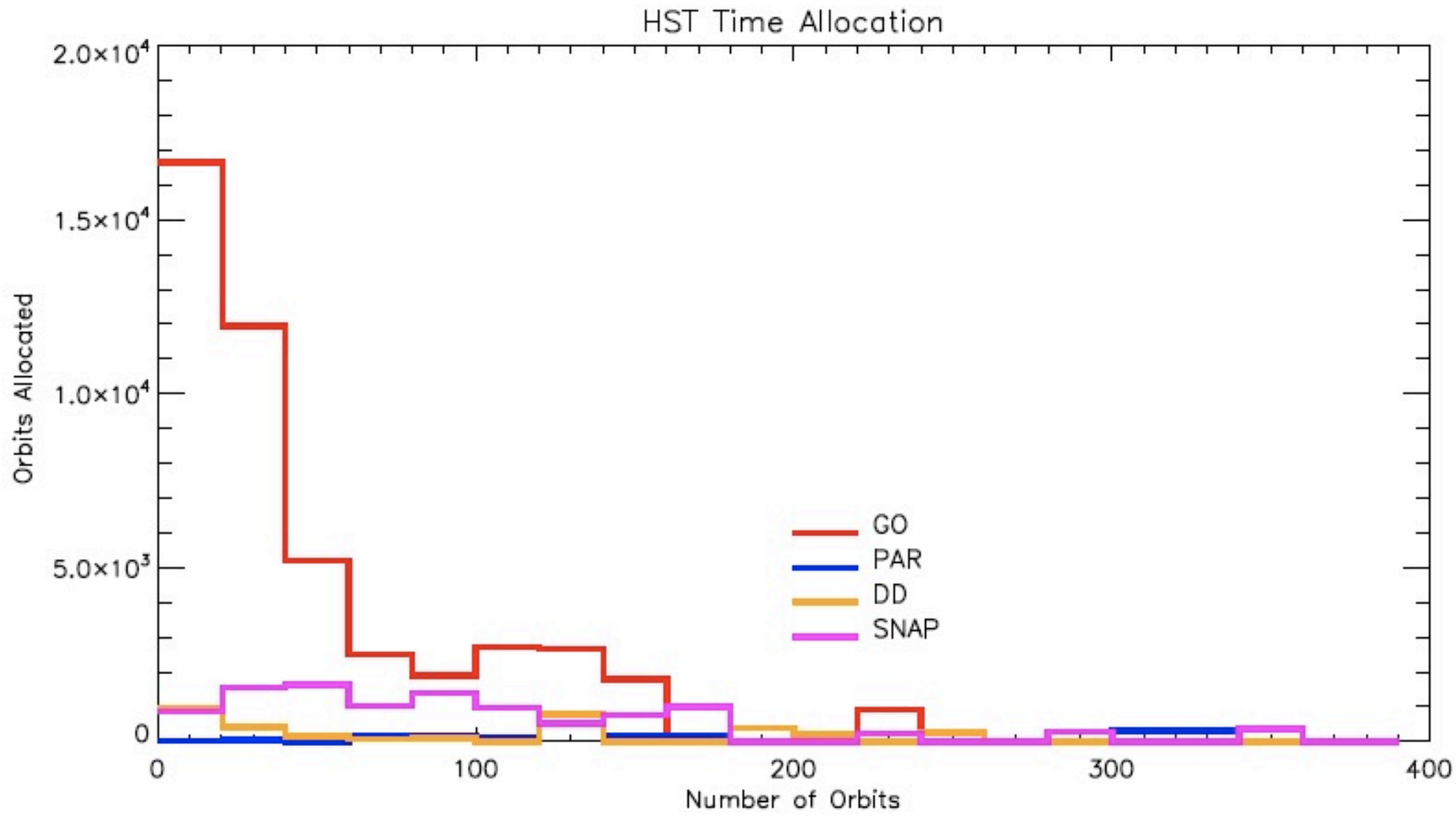

Number of HST Papers vs Year
Launch
SM1 (WFPC2, COSTAR)
SM2 (STIS, NICMOS)
SM3A (FGS)
SM3B (ACS)
SM4
Partly Archival
Archival
Not Archival
Not Complete
Number of Ref. HST Papers
0
200
400
600
800
1990
1995
2000
2005
2010
Publication Year

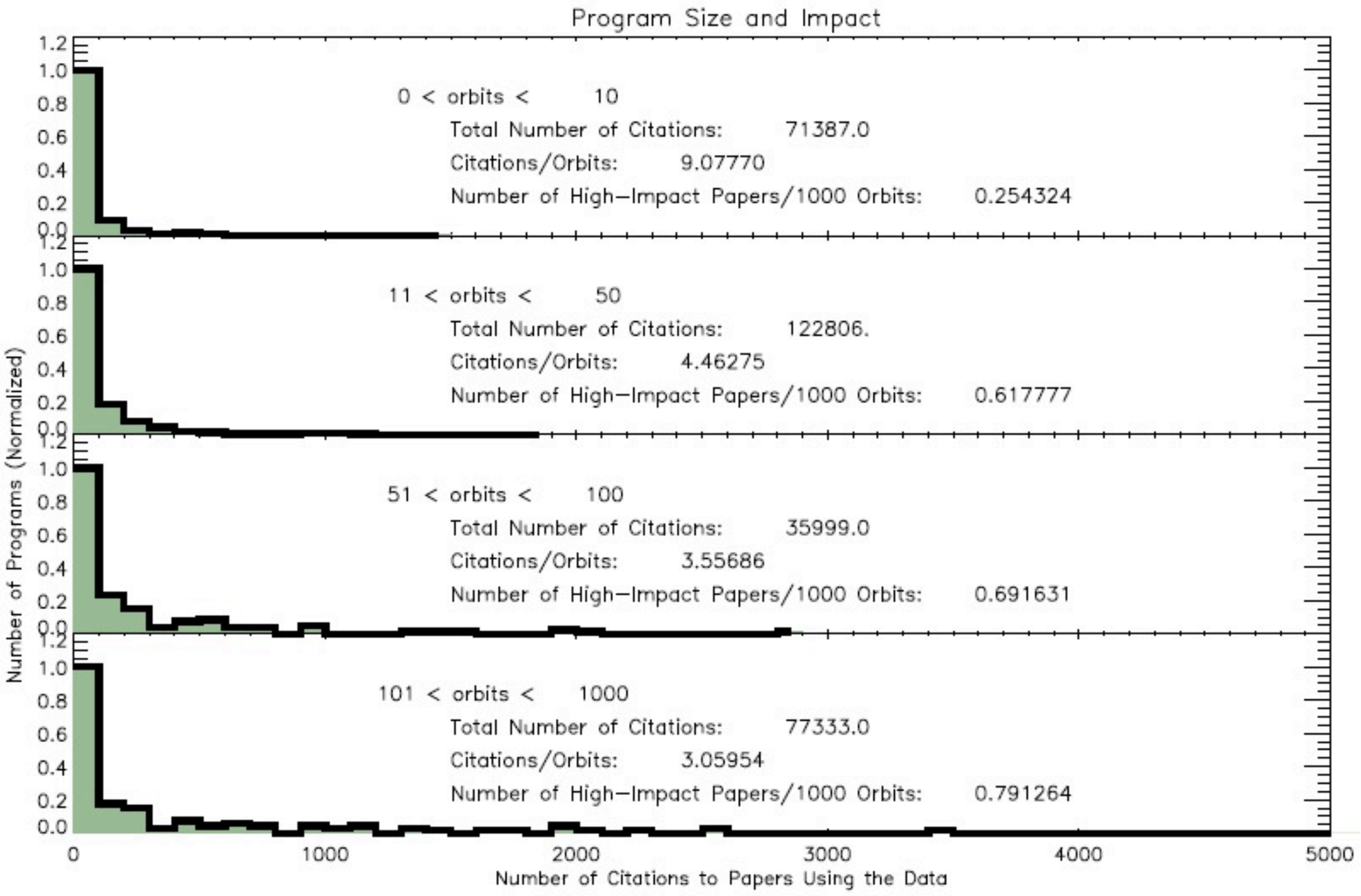

Number of HST Citations vs Year of Publication
Launch
SM1 (WFPC2, COSTAR)
SM2 (STIS, NICMOS)
SM3A (FGS)
SM3B (ACS)
SM4
Not Complete
Too New
Number of Citations
4×10⁴
3×10⁴
2×10⁴
1×10⁴
0
1990
1995
2000
2005
2010
Publication Year

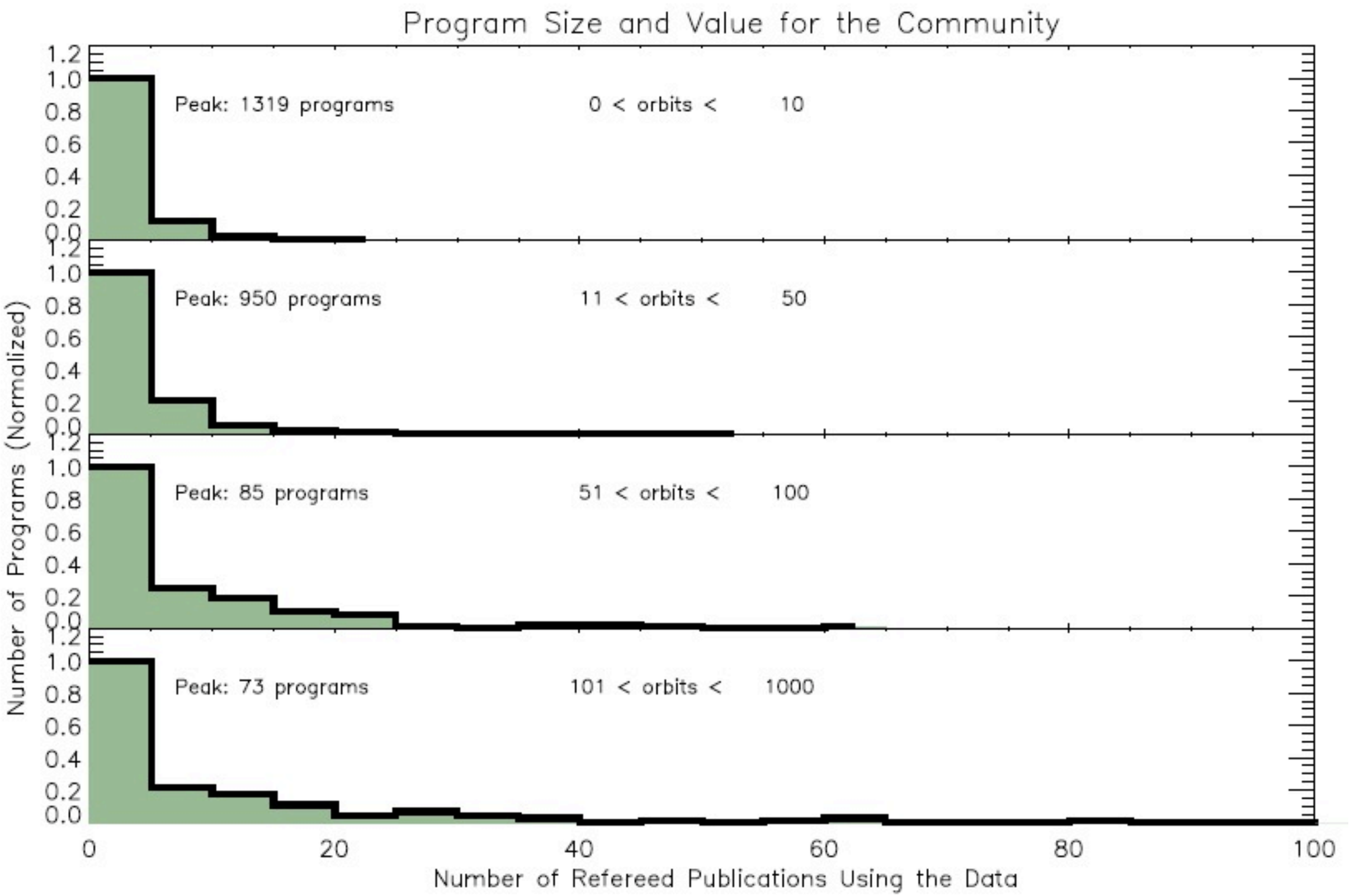

Changes in HST Instrumentation
Spectroscopy
Launch
SM1
SM2
SM3A
SM3B
SM4
COS
STIS
GHRS
FOS
Imaging
WFC3
ACS
WFC
SBC
HRC
NICMOS
STIS
WFPC2
WFPC1
FOC
HSP
Instruments
1990
1995
2000
2005
2010
Years


Number of Refereed Papers vs Year
Launch
SM1 (WFPC2, COSTAR)
SM2 (STIS, NICMOS)
SM3A (FGS)
SM3B (ACS)
SM4
ACS
WFPC2
STIS
NICMOS
FOC
FGS
Number of Papers
0
100
200
300
400
1990
1995
2000
2005
2010
Publication Year


Number of Small & Medium Programs vs. Number of Orbits Requested
GO (<11 orbs): 1245
10 orbs < GO <51 orbs: 1095
50 orbs < GO <101 orbs: 93
GO
3 x PAR
3 x DD
3 x SNAP
Number of Approved Programs
Number of Orbits
1500
1000
500
0
0
20
40
60
80
100


HST Time Allocation
2.0×10⁴
1.5×10⁴
1.0×10⁴
5.0×10³
0
Orbits Allocated
0
100
200
300
400
Number of Orbits
GO
PAR
DD
SNAP


Program Size and Impact
0 < orbits < 10
Total Number of Citations: 71387.0
Citations/Orbits: 9.07770
Number of High−Impact Papers/1000 Orbits: 0.254324
11 < orbits < 50
Total Number of Citations: 122806.
Citations/Orbits: 4.46275
Number of High−Impact Papers/1000 Orbits: 0.617777
51 < orbits < 100
Total Number of Citations: 35999.0
Citations/Orbits: 3.55686
Number of High−Impact Papers/1000 Orbits: 0.691631
101 < orbits < 1000
Total Number of Citations: 77333.0
Citations/Orbits: 3.05954
Number of High−Impact Papers/1000 Orbits: 0.791264
Number of Programs (Normalized)
Number of Citations to Papers Using the Data
0
1000
2000
3000
4000
5000


Program Size and Value for the Community
Peak: 1319 programs
0 < orbits < 10
Peak: 950 programs
11 < orbits < 50
Peak: 85 programs
51 < orbits < 100
Peak: 73 programs
101 < orbits < 1000
Number of Programs (Normalized)
Number of Refereed Publications Using the Data

| All Programs | Orbits | Papers | Citations | Papers/Orbits | Cits/Orbits | Cits/Papers |
|---|---|---|---|---|---|---|
| GO | 51,442 | 7,007 | 209,133 | 0.14 | 4.1 | 29.8 |
| DD | 4,323 | 719 | 44,970 | 0.17 | 10.4 | 62.5 |
| Prog <30 orbits | Orbits | Papers | Citations | Papers/Orbits | Cits/Orbits | Cits/Papers |
| GO | 22,385 | 4,807 | 127,115 | 0.215 | 5.68 | 26.4 |
| DD | 1,136 | 374 | 19,573 | 0.329 | 17.2 | 52.3 |

DDT program is very effective in identifying high-impact projects
and adds flexibility and quick response to our time allocation strategy

| Science Category | Props. | Orbits | Papers | Citns | Papers/Orbits | Cits/Orb | Cits/Pap |
|---|---|---|---|---|---|---|---|
| Galaxies | 70 | 2004 | 317 | 8249 | 0.158 | 4.116 | 26.02 |
| Solar System | 27 | 313 | 72 | 801 | 0.230 | 2.559 | 11.12 |
| Cosmology | 36 | 3700 | 229 | 8821 | 0.062 | 2.384 | 38.52 |
| Unclassified | 22 | 342 | 35 | 991 | 0.102 | 2.898 | 28.31 |
| Stellar Populations | 48 | 1300 | 142 | 2551 | 0.109 | 1.962 | 17.96 |
| Ultra Deep Field | 1 | 1114 | 66 | 2181 | 0.059 | 1.958 | 33.05 |
| Agn/quasars | 37 | 576 | 62 | 1076 | 0.108 | 1.868 | 17.35 |
| Hot Stars | 40 | 520 | 51 | 905 | 0.098 | 1.740 | 17.75 |
| Cool Stars | 23 | 399 | 21 | 388 | 0.053 | 0.972 | 18.48 |
| Interstellar And Circumstellar Matter | 41 | 721 | 65 | 992 | 0.090 | 1.376 | 15.26 |
| Star Formation | 23 | 633 | 32 | 567 | 0.051 | 0.896 | 17.72 |
| Quasar Absorption Lines And Igm | 11 | 187 | 11 | 199 | 0.059 | 1.064 | 18.09 |
| Complete Sample | 379 | 11809 | 1103 | 27721 | 0.093 | 2.347 | 25.13 |

| Science Category | Props. | Orbits | Papers | Citns | Papers/Orbits | Cits/Orb | Cits/Pap |
|---|---|---|---|---|---|---|---|
| Galaxies | 70 | 2004 | 317 | 8249 | 0.158 | 4.116 | 26.02 |
| Solar System | 27 | 313 | 72 | 801 | 0.230 | 2.559 | 11.12 |
| Cosmology | 36 | 3700 | 229 | 8821 | 0.062 | 2.384 | 38.52 |
| Unclassified | 22 | 342 | 35 | 991 | 0.102 | 2.898 | 28.31 |
| Stellar Populations | 48 | 1300 | 142 | 2551 | 0.109 | 1.962 | 17.96 |
| Ultra Deep Field | 1 | 1114 | 66 | 2181 | 0.059 | 1.958 | 33.05 |
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| Interstellar And Circumstellar Matter | 41 | 721 | 65 | 992 | 0.090 | 1.376 | 15.26 |
| Star Formation | 23 | 633 | 32 | 567 | 0.051 | 0.896 | 17.72 |
| Quasar Absorption Lines And Igm | 11 | 187 | 11 | 199 | 0.059 | 1.064 | 18.09 |
| Complete Sample | 379 | 11809 | 1103 | 27721 | 0.093 | 2.347 | 25.13 |

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|---|---|---|---|---|---|---|---|
| Galaxies | 70 | 2004 | 317 | 8249 | 0.158 | 4.116 | 26.02 |
| Solar System | 27 | 313 | 72 | 801 | 0.230 | 2.559 | 11.12 |
| Cosmology | 36 | 3700 | 229 | 8821 | 0.062 | 2.384 | 38.52 |
| Unclassified | 22 | 342 | 35 | 991 | 0.102 | 2.898 | 28.31 |
| Stellar Populations | 48 | 1300 | 142 | 2551 | 0.109 | 1.962 | 17.96 |
| Ultra Deep Field | 1 | 1114 | 66 | 2181 | 0.059 | 1.958 | 33.05 |
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| Hot Stars | 40 | 520 | 51 | 905 | 0.098 | 1.740 | 17.75 |
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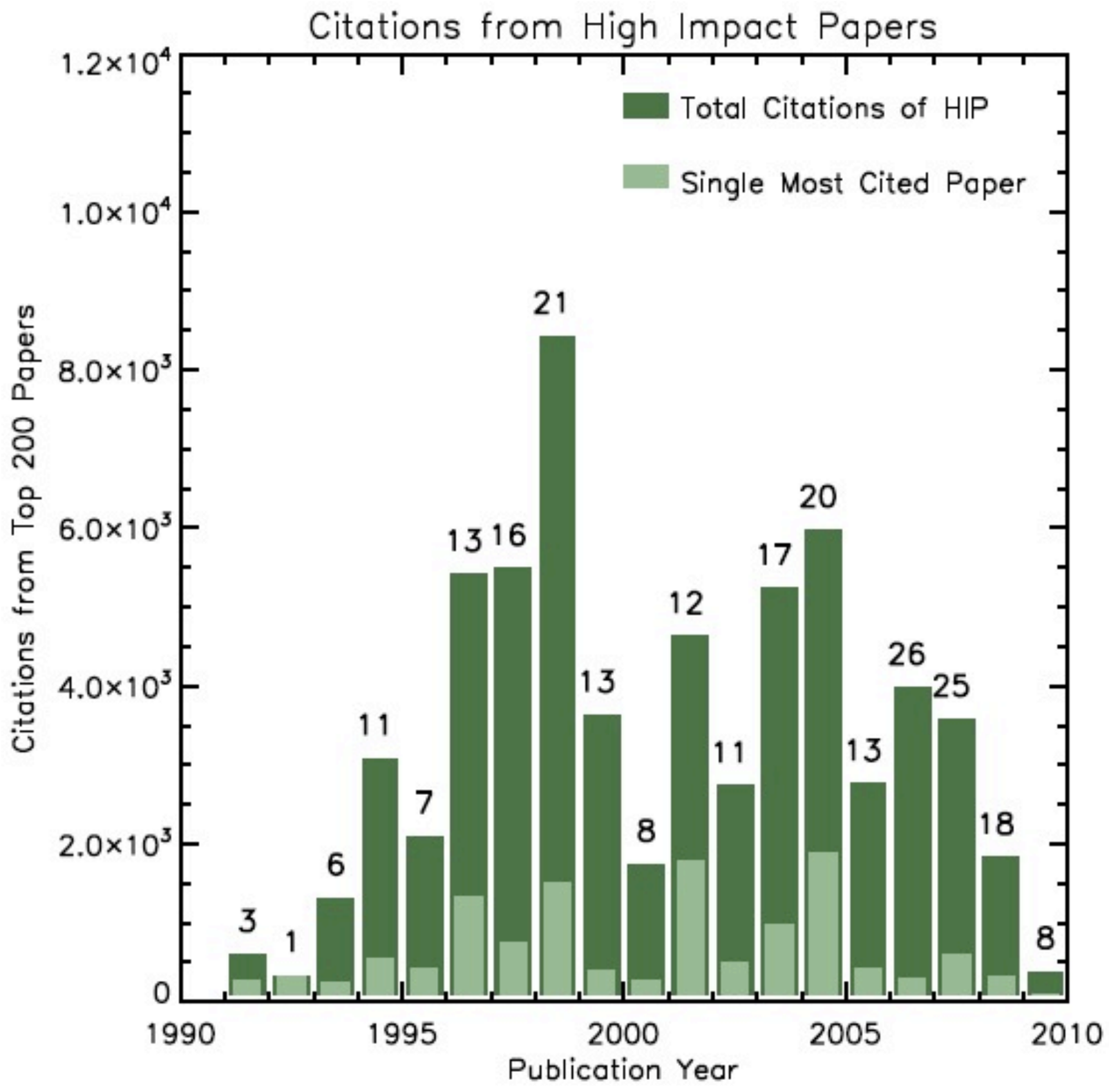
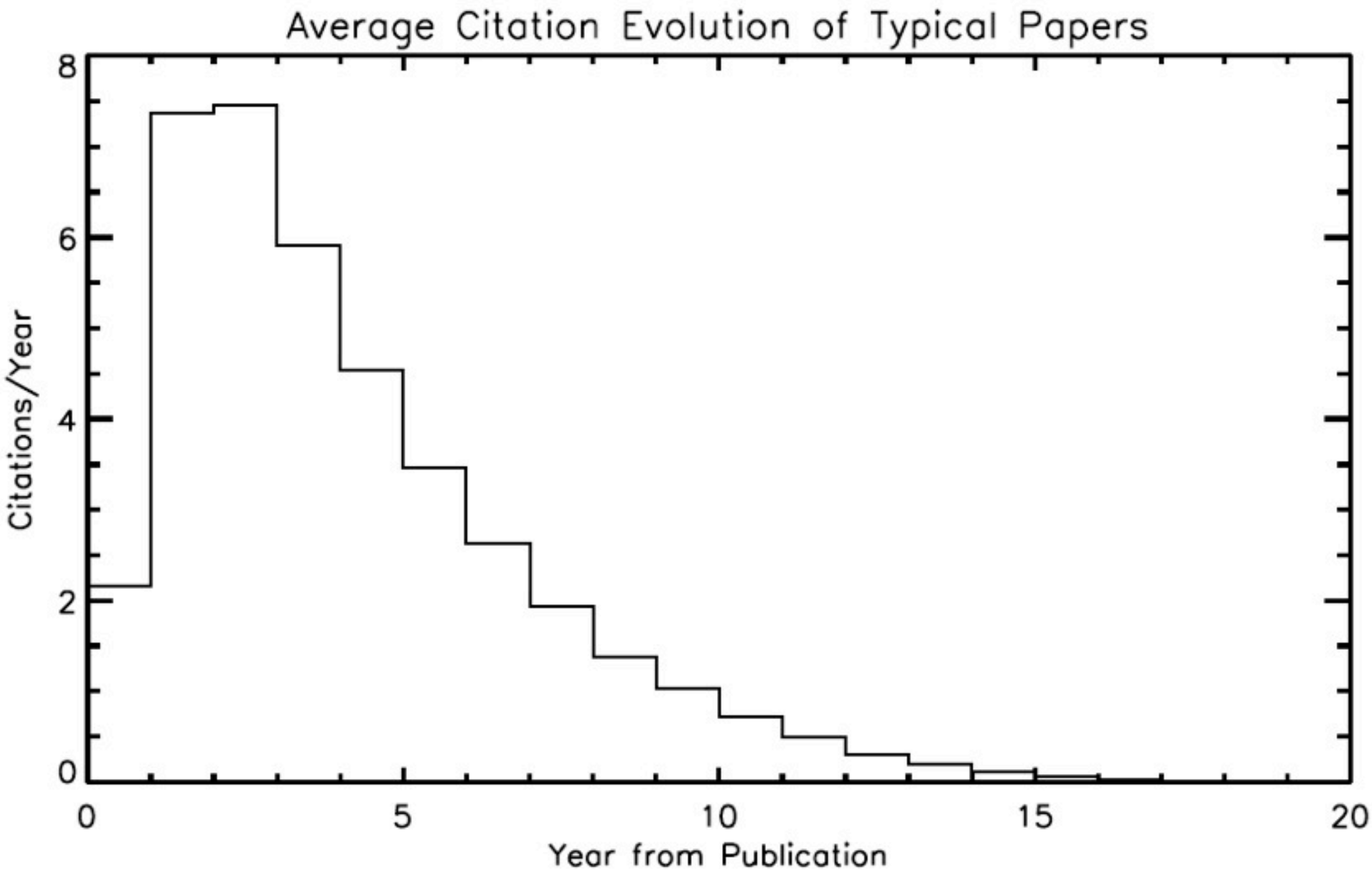
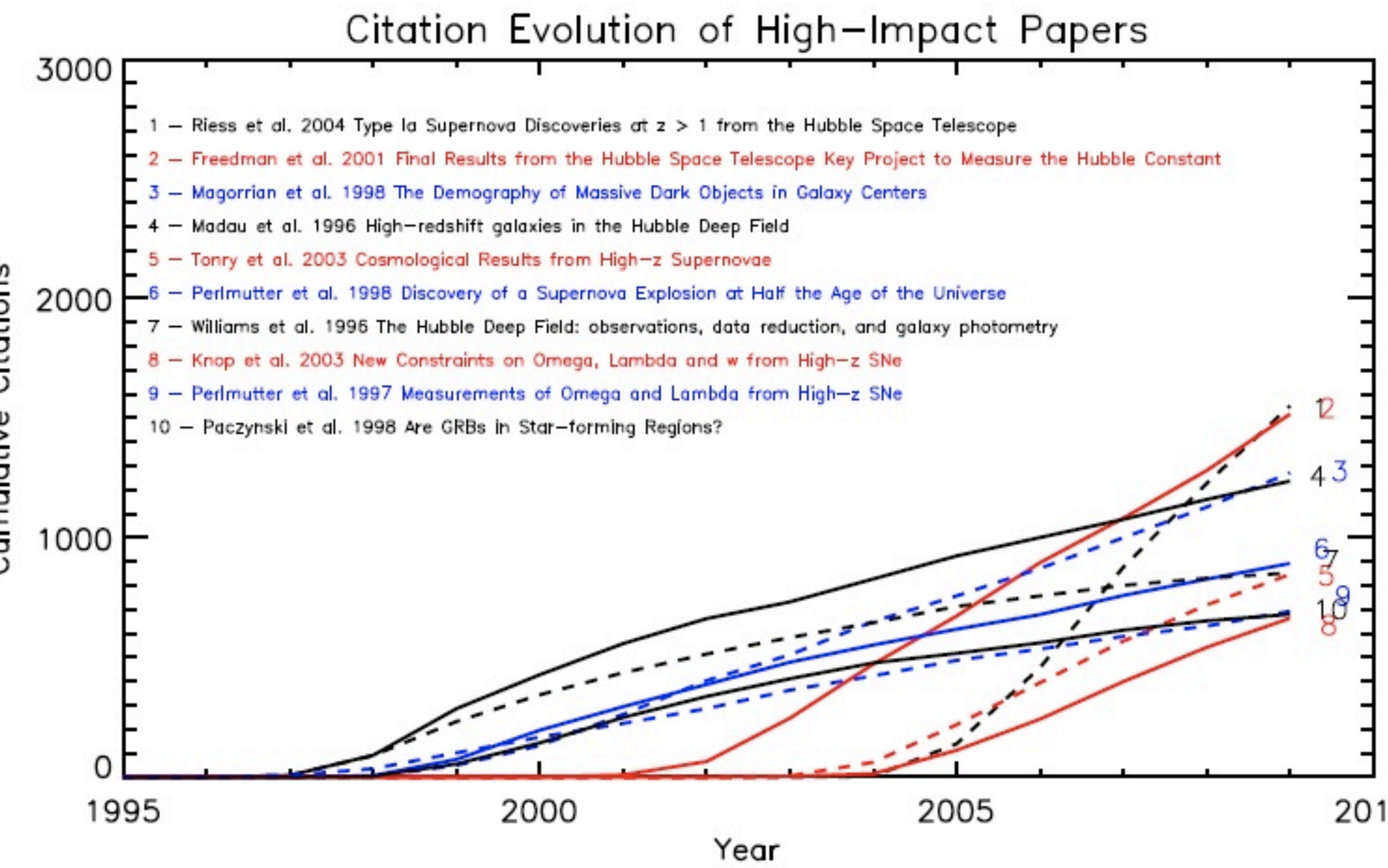
| Star Formation | 23 | 633 | 32 | 567 | 0.051 | 0.896 | 17.72 |
| Quasar Absorption Lines And Igm | 11 | 187 | 11 | 199 | 0.059 | 1.064 | 18.09 |
| Complete Sample | 379 | 11809 | 1103 | 27721 | 0.093 | 2.347 | 25.13 |

| Science Category | Props. | Orbits | Papers | Citns | Papers/Orbits | Cits/Orb | Cits/Pap |
|---|---|---|---|---|---|---|---|
| Galaxies | 70 | 2004 | 317 | 8249 | 0.158 | 4.116 | 26.02 |
| Solar System | 27 | 313 | 72 | 801 | 0.230 | 2.559 | 11.12 |
| Cosmology | 36 | 3700 | 229 | 8821 | 0.062 | 2.384 | 38.52 |
| Unclassified | 22 | 342 | 35 | 991 | 0.102 | 2.898 | 28.31 |
| Stellar Populations | 48 | 1300 | 142 | 2551 | 0.109 | 1.962 | 17.96 |
| Ultra Deep Field | 1 | 1114 | 66 | 2181 | 0.059 | 1.958 | 33.05 |
| Agn/quasars | 37 | 576 | 62 | 1076 | 0.108 | 1.868 | 17.35 |
| Hot Stars | 40 | 520 | 51 | 905 | 0.098 | 1.740 | 17.75 |
| Cool Stars | 23 | 399 | 21 | 388 | 0.053 | 0.972 | 18.48 |
| Interstellar And Circumstellar Matter | 41 | 721 | 65 | 992 | 0.090 | 1.376 | 15.26 |
| Star Formation | 23 | 633 | 32 | 567 | 0.051 | 0.896 | 17.72 |
| Quasar Absorption Lines And Igm | 11 | 187 | 11 | 199 | 0.059 | 1.064 | 18.09 |
| Complete Sample | 379 | 11809 | 1103 | 27721 | 0.093 | 2.347 | 25.13 |


Citations from High Impact Papers
Total Citations of HIP
Single Most Cited Paper
Citations from Top 200 Papers
Publication Year
1.2×10⁴
1.0×10⁴
8.0×10³
6.0×10³
4.0×10³
2.0×10³
0
1990
1995
2000
2005
2010
3
1
6
11
7
13
16
21
13
8
12
11
17
20
13
26
25
18
8


Average Citation Evolution of Typical Papers
Citations/Year
0
2
4
6
8
0
5
10
15
20
Year from Publication


Citation Evolution of High−Impact Papers
1 — Riess et al. 2004 Type Ia Supernova Discoveries at z > 1 from the Hubble Space Telescope
2 — Freedman et al. 2001 Final Results from the Hubble Space Telescope Key Project to Measure the Hubble Constant
3 — Magorrian et al. 1998 The Demography of Massive Dark Objects in Galaxy Centers
4 — Madau et al. 1996 High−redshift galaxies in the Hubble Deep Field
5 — Tonry et al. 2003 Cosmological Results from High−z Supernovae
6 — Perlmutter et al. 1998 Discovery of a Supernova Explosion at Half the Age of the Universe
7 — Williams et al. 1996 The Hubble Deep Field: observations, data reduction, and galaxy photometry
8 — Knop et al. 2003 New Constraints on Omega, Lambda and w from High−z SNe
9 — Perlmutter et al. 1997 Measurements of Omega and Lambda from High−z SNe
10 — Paczynski et al. 1998 Are GRBs in Star−forming Regions?
Cumulative Citations
3000
2000
1000
0
1995
2000
2005
2010
Year

# Medium-sized programs

20 most-cited medium programs

Broad range of topics covered:
high-z galaxies, stellar populations, ISM, QSRs, IGM, SNe, galaxies, debris disks, hot stars

Medium-sized surveys (5-20) with multiple epochs/target (e.g. polarimetry, coronagraphy, deep multi-color imaging)

**Cycles 9 - 17** for each cycle: ~12 medium proposals approved with ~60 orbits (median)

No significant trend in the number of orbits allocated, number of proposals, and the size of the proposals

# Summary

## Publication Database

Single database, clear definitions, significantly expanded,
completeness/uncertainties tested, publicly available

## Analysis of Impact/Productivity

Instruments, temporal evolution, science categories, proposal types,
high-impact papers, high-impact programs

Apai, Lagerstrom, Reid, Levay, Fraser, Nota, Henneken 2010 PASP, submitted
*Available from the authors*

| Date | Major Anomaly | Servicing/Change |
|---|---|---|
| 04/25/1990 | | HST Deployed |
| 09/23/1991 | GHRS Side–1 Failure | Switch to Side–2 |
| 12/1993 | | SM1 – COSTAR replaced HSP, WFPC2 replaced WFPC |
| 01/20/1997 | GHRS Side–2 Failure | GHRS in Safe Mode |
| 2/1997 | | SM2 – STIS replaced GHRS, NICMOS replaced FOS, FGS refurbished |
| 1/3/1999 | NICMOS: Cryogen Depleted | NICMOS Safe Mode |
| 12/1999 | | SM3A – new gyros, new FGS, maintenance |
| 5/16/2001 | STIS Side–1 Failure | Switch to Side–2 |
| 3/2002 | | SM3B – ACS replaced FOC, NICMOS Cryocooler repair |
| 8/3/2004 | STIS Side–2 Failure | STIS Safe Mode |
| 6/19/2006 | ACS Side–1 Failure | Switch to Side–2 |
| 1/27/2007 | ACS Side–2 Failure | ACS/WFC and ACS/HRC lost |
| 9/11/2008 | NICMOS Cooling System Restart Failure | |
| 9/27/2008 | SI C&DH Side–1 Failure | Switch to Side–2 |
| 05/2009 | | SM4 (WFC3 replaced WFPC2, COS, ACS/WFC repair, STIS repair, improv. FGS, new SI C&DH) |

| Year | Cits. | First Author and Abridged Title | Instr. |
|---|---|---|---|
| 1998 | 1,520 | Magorrian: Demography of Massive Dark Objects in Galaxy Centers | W |
| 1998 | 980 | Perlmutter: Discovery of a Supernova Explosion at Half the Age of the Universe | S |
| 1998 | 712 | Paczynski: Are Gamma–Ray Bursts in Star–forming Regions? | S |
| 1999 | 393 | Kulkarni: The afterglow, redshift and extreme energetics of the $\gamma$-ray burst of 23 Jan 1999 | S |
| 1999 | 391 | Whitmore: The Luminosity Function of Young Star Clusters in 'the Antennae' Galaxies | G,W |
| 1999 | 327 | Dressler: Spectroscopic Catalog of 10 Distant Rich Clusters of Galaxies | W |
| 2000 | 270 | Dolphin: WFPC2 Stellar Photometry with HSTPHOT | W |
| 2000 | 226 | Mould: HST Key Project on Extragalactic Distance Scale | W |
| 2000 | 224 | Barger: Mapping the Evolution of High–Redshift Dusty Galaxies with Submillimeter Observations of a Radio-selected Sample | W |
| 2001 | 1,797 | Freedman: Final Results from the HST Key Project to Measure the Hubble Constant | W |
| 2001 | 480 | Riess: The Farthest Known Supernova: Support for an Accelerating Universe and a Glimpse of the Epoch of Deceleration | W,N |
| 2001 | 448 | Pettini: The Rest–Frame Optical Spectra of Lyman Break Galaxies | W |
| 2002 | 502 | Peng: Detailed Structural Decomposition of Galaxy Images | W |
| 2002 | 315 | Charbonneau: Detection of an Extrasolar Planet Atmosphere | S |
| 2002 | 286 | Bloom: The Observed Offset Distribution of $\gamma$-ray Bursts from Their Host Galaxies | S |

| Year | Cits. | First Author and Abridged Paper Title | Instr. |
|---|---|---|---|
| 2003 | 1002 | Tonry: Cosmological Results from High-z Supernovae | W,N |
| 2003 | 825 | Knop: New Constraints on $\Omega_M$, $\Omega_\Lambda$, and w from an Independent Set of 11 High-z SNe | W |
| 2003 | 419 | Shapley: Rest-frame UV Spectra of z$\sim$3 Lyman-break Galaxies | A |
| 2004 | 1,897 | Riess: Type Ia SN Discoveries at z>1: Past Deceleration and Constraints on Dark Energy | A,N |
| 2004 | 633 | Giavalisco: GOODS – Initial Results from Optical and Near-Infrared Imaging | A |
| 2004 | 363 | Kormendy: Secular Evolution and Formation of Pseduobulges in Disk Galaxies | S |
| 2005 | 439 | Maraston: Evolutionary population synthesis | N |
| 2005 | 282 | Ferrarese: Supermassive Black Holes in Galactic Nuclei | A,S,W |
| 2005 | 236 | Pérez-González: Spitzer View on the Evolution of Star-forming Galaxies z=0-3 | A |
| 2006 | 295 | Clowe: A Direct Empirical Proof of the Existence of Dark Matter | A |
| 2006 | 250 | Cappellari: SAURON IV incl. mass-to-light ratio, virial mass estimator | W |
| 2006 | 218 | Fruchter: Long $\gamma$-ray bursts and core-collapse SNe have different environments | A,S,W |
| 2007 | 626 | Riess: New HST Type Ia SNe at z>1: Narrowing Constraints on the Early Behavior of Dark Energy | A,N |
| 2007 | 344 | Faber: Galaxy Luminosity Functions to z$\sim$1 from DEEP2 and COMBO-17 | W |
| 2007 | 268 | Davis: Scrutinizing Exotic Cosmological Models Using ESSENCE SN Data | A,N |