Hubble Space Telescope:

II. Stars & Resolved Stellar Systems

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ESO Summer School
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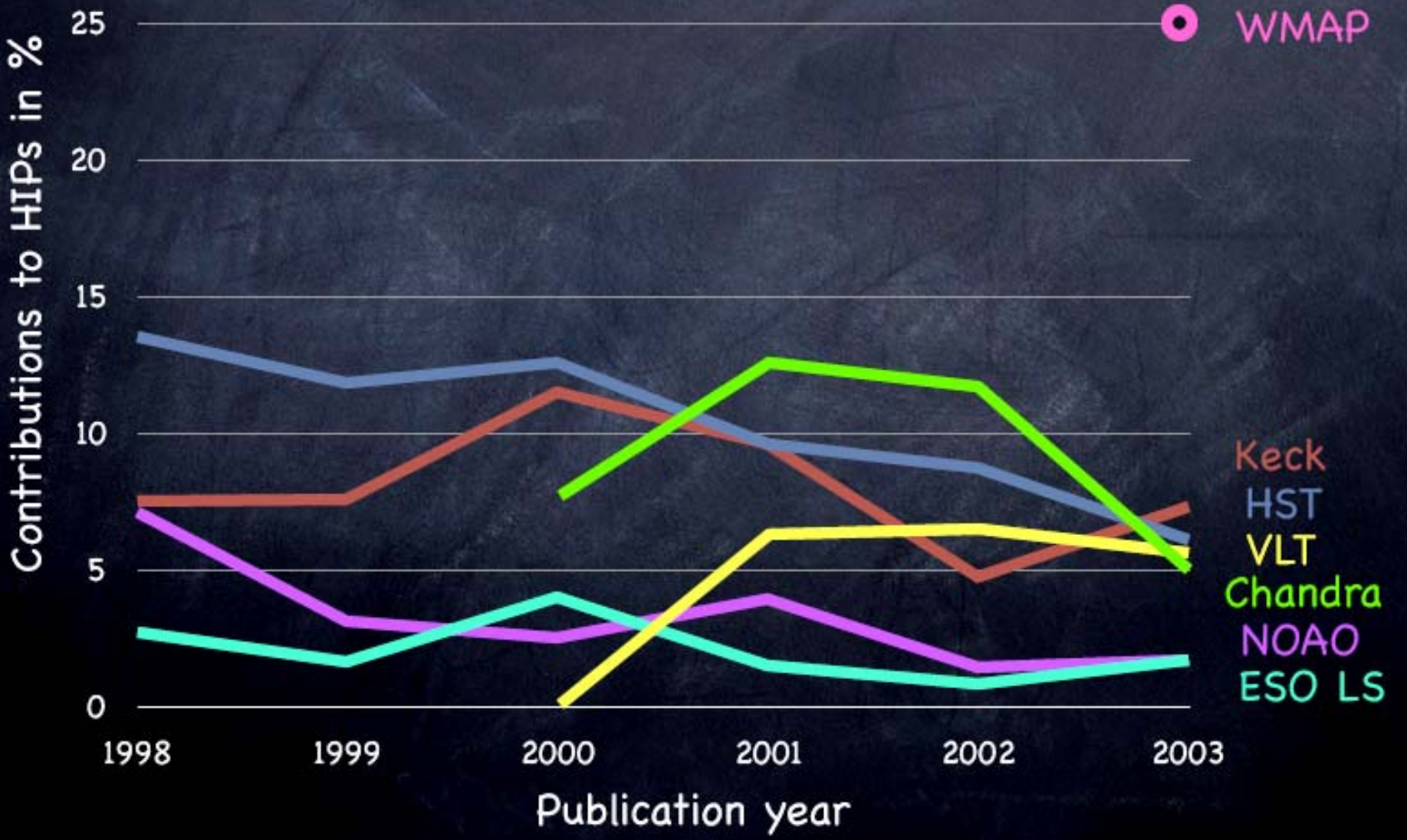
Hubble Telescope Unique Characteristics

- High spatial resolution: 0.05 arcsec
- UV sensitivity
- Low, stable background (no atmos.) → faint detection limits
- Stable detectors & point spread function (PSF)

…… So, what are the most important discoveries and results that HST has produced?

High Impact Papers *

(J. Madrid, STScI)



* The 200 most highly cited papers published that year

Hubble Discoveries*

Most Important Scientific Results:

1) Determined from SNe Ia supernovae distances that universe is accelerating
2) Detected distant galaxies at very high redshifts before Hubble sequence formed
3) Characterized (age & composition) previously unresolved stellar populations
4) Spectroscopic detection of atmosphere of planet around another star
5) Measured masses of black holes in centers of galaxies
6) Characterized environment & optical properties of Gamma Ray Bursters
7) Mapped dark matter from gravitational arcs (associated with galaxies)
8) Observed unusual solar system phenomena
9) Resolved host galaxies of quasars
10) Demonstrated association between disks and jets, and that disks around young stars are common

Others: Evolution of IGM from QSO absorption lines
Determination of Hubble Constant (H_o = 75 km s^{-1} Mpc^{-1})
UV spectroscopy of the ISM, nebulae, winds, & galaxies

**A significant component of many Hubble discoveries has been observations made by other telescopes.*

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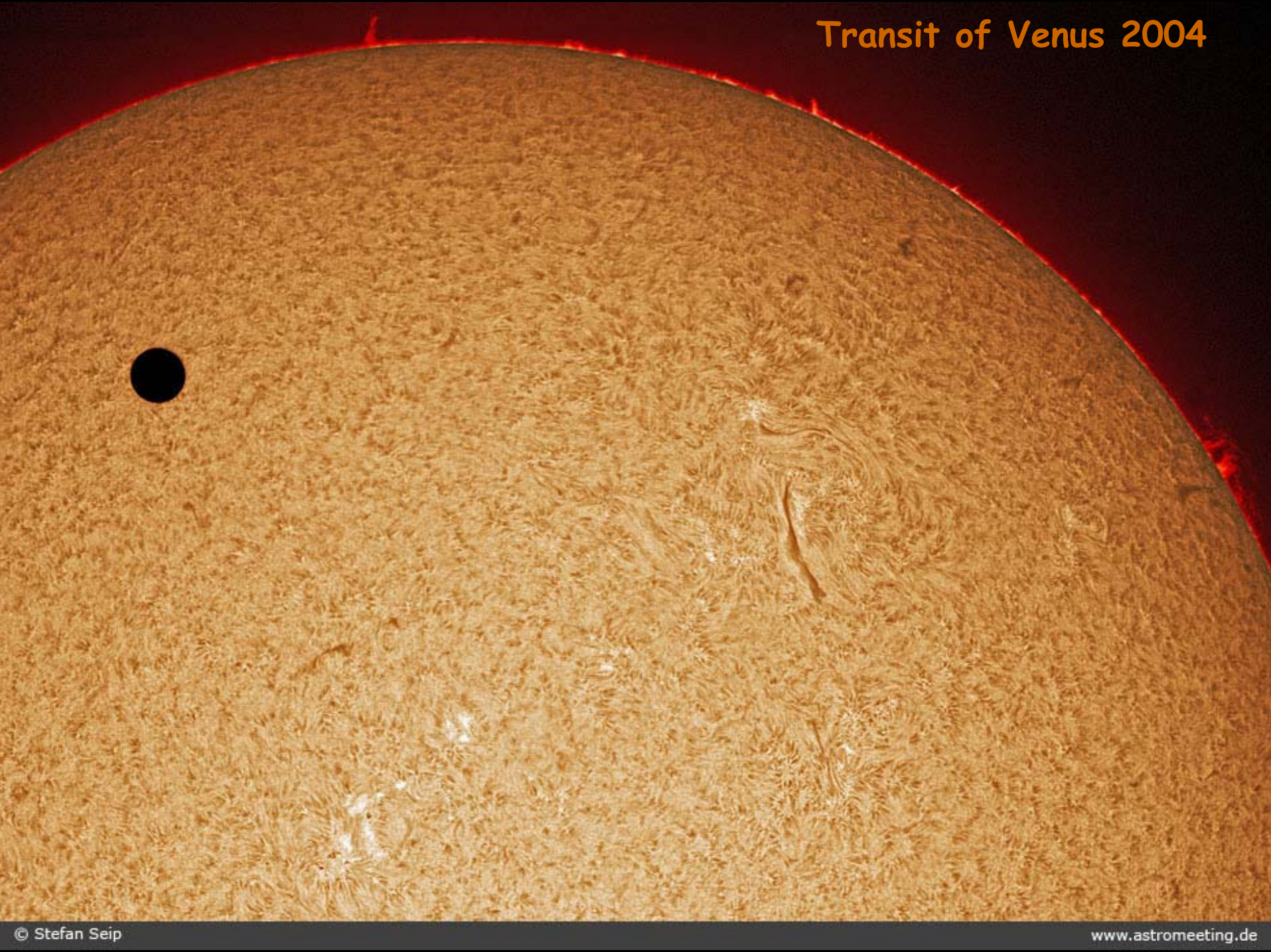
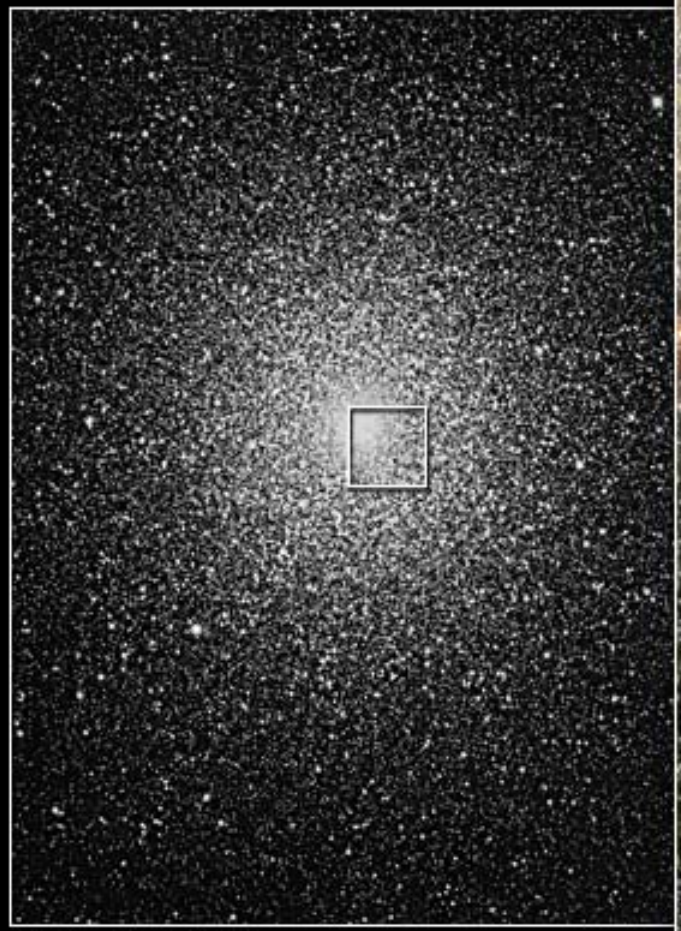
Extra-Solar Planets

(Exoplanets)


Transit of Venus 2004
© Stefan Seip
www.astromeeting.de

Globular Cluster 47 Tucanae



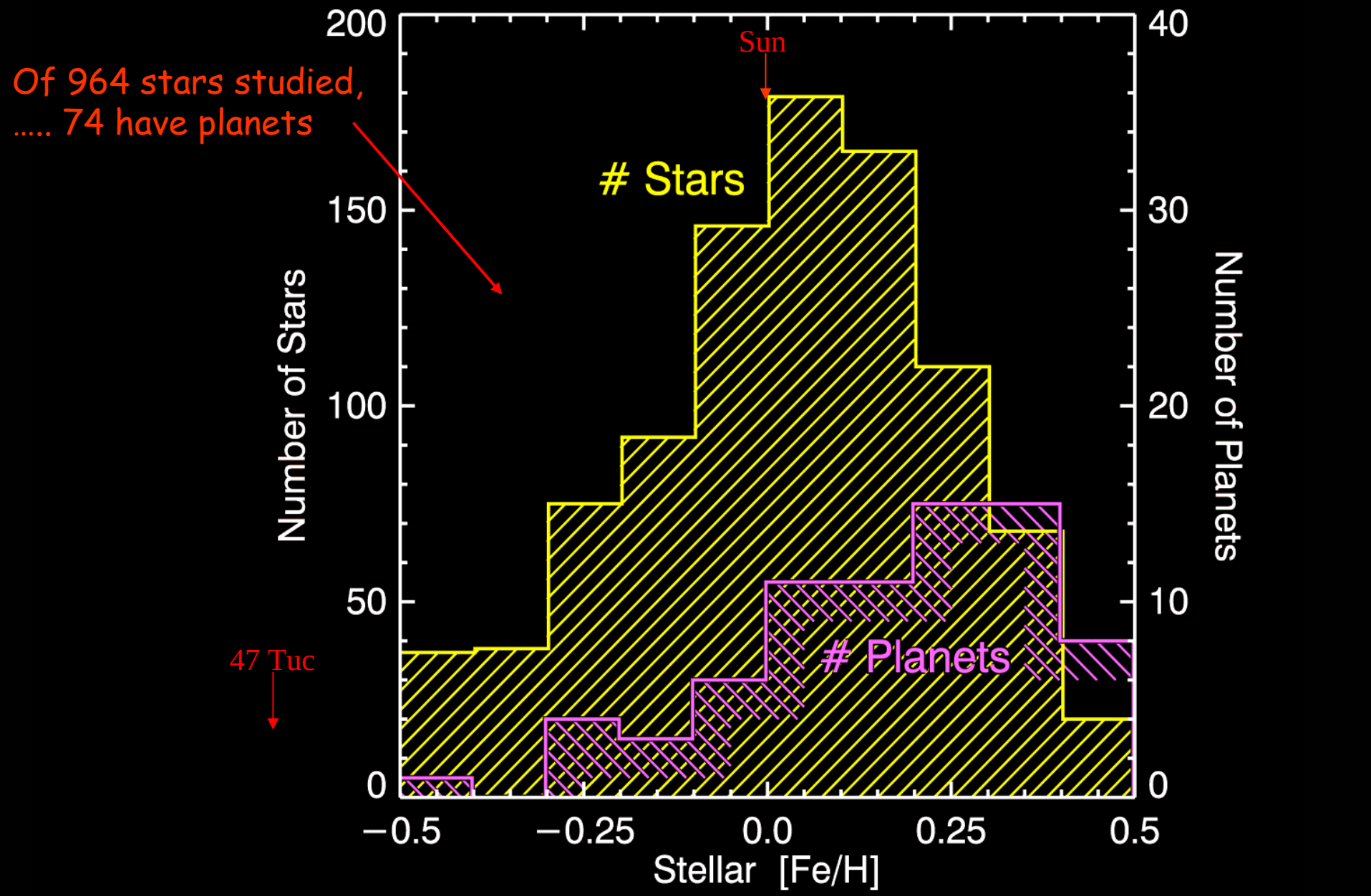
Ground • AAT

NASA and R. Gilliland (STScI)
STScI-PRC00-33

Hubble Space Telescope • WFPC2

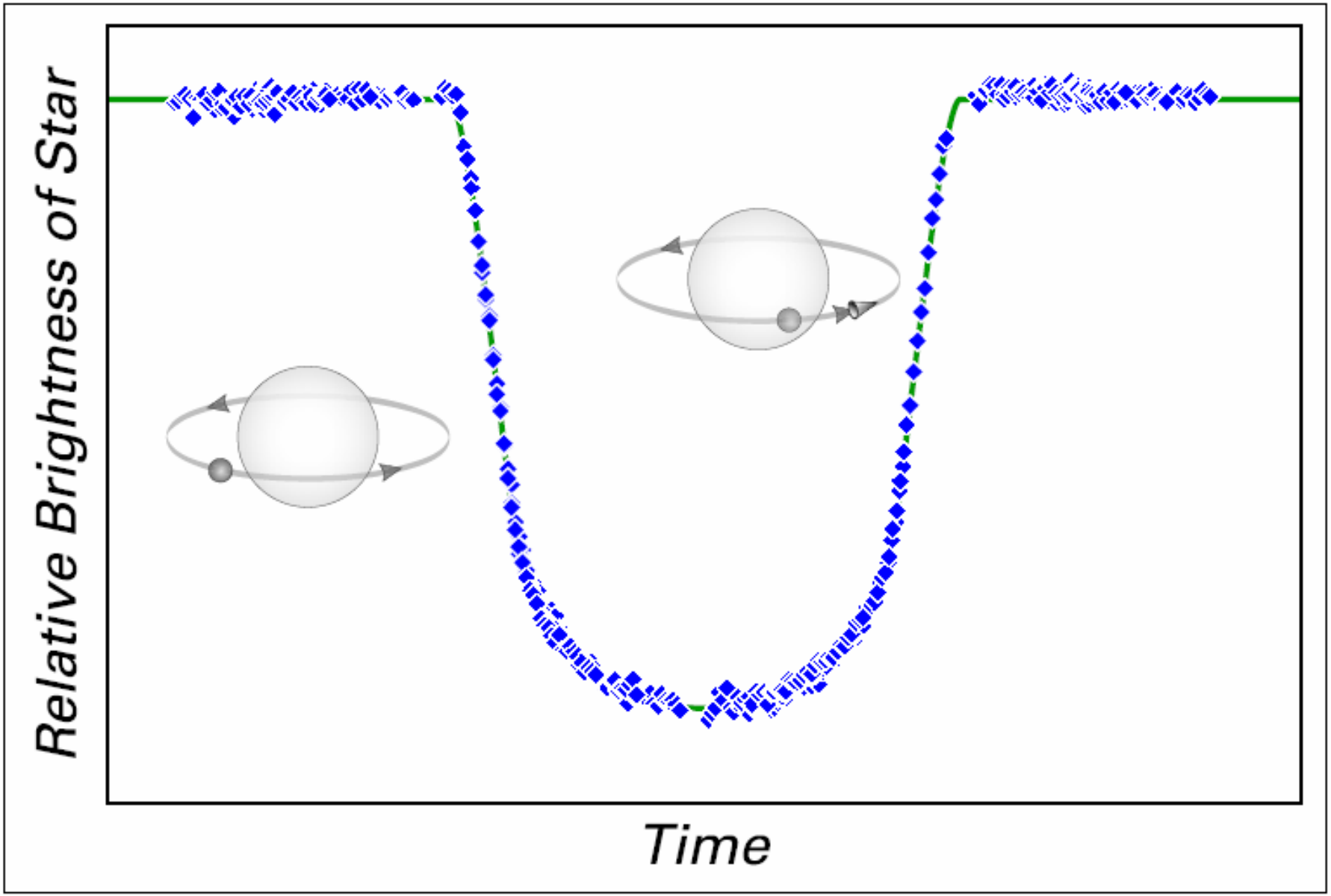
→ From known exoplanet systems, one expects 17 transits with $\Delta m > 0.01$ mag (Jupiter-like) among the 30,000 stars.

Composition of Planet Host Stars

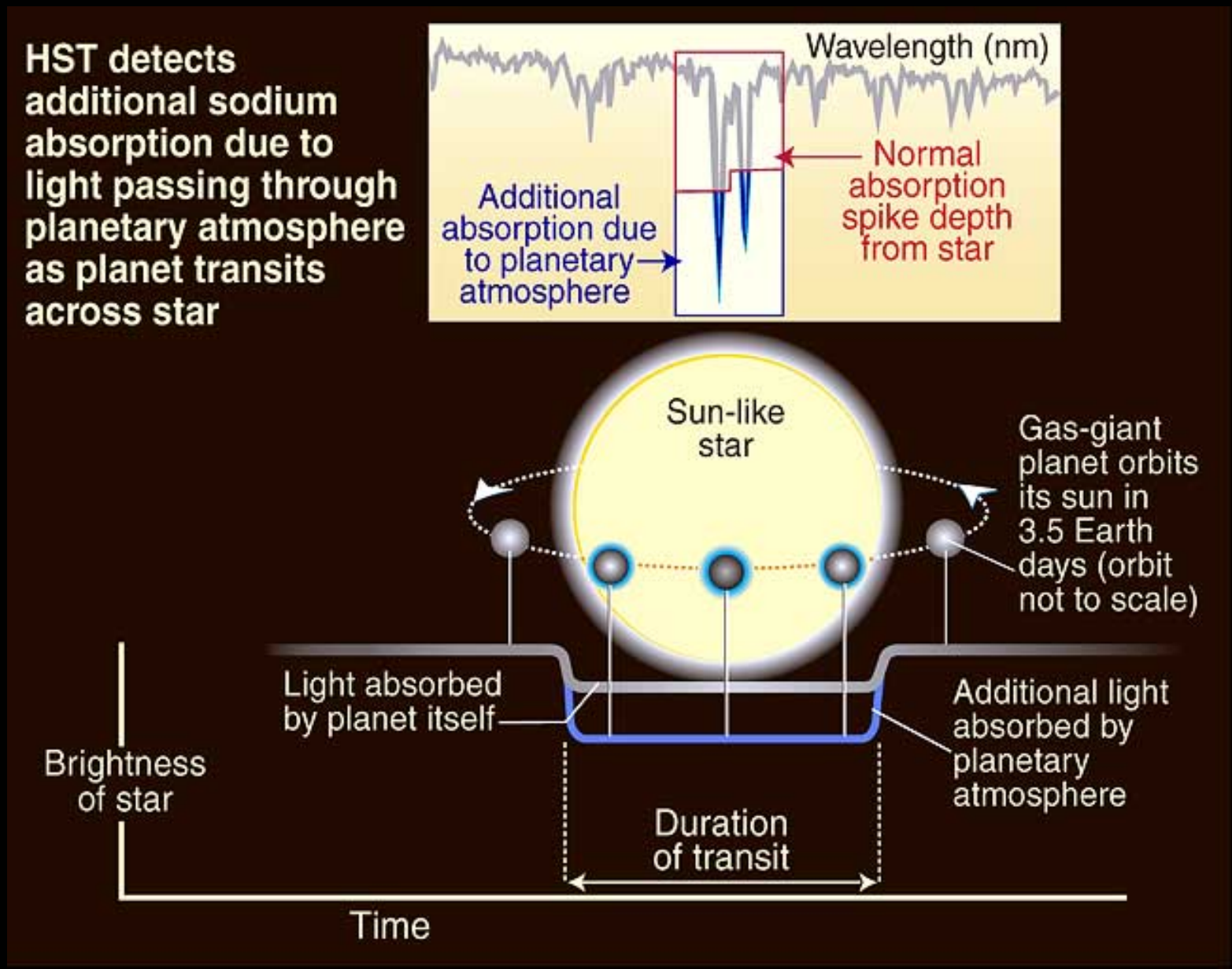


Fischer & Valenti. 2005, in Protostars & Planets V (LPI: Houston)

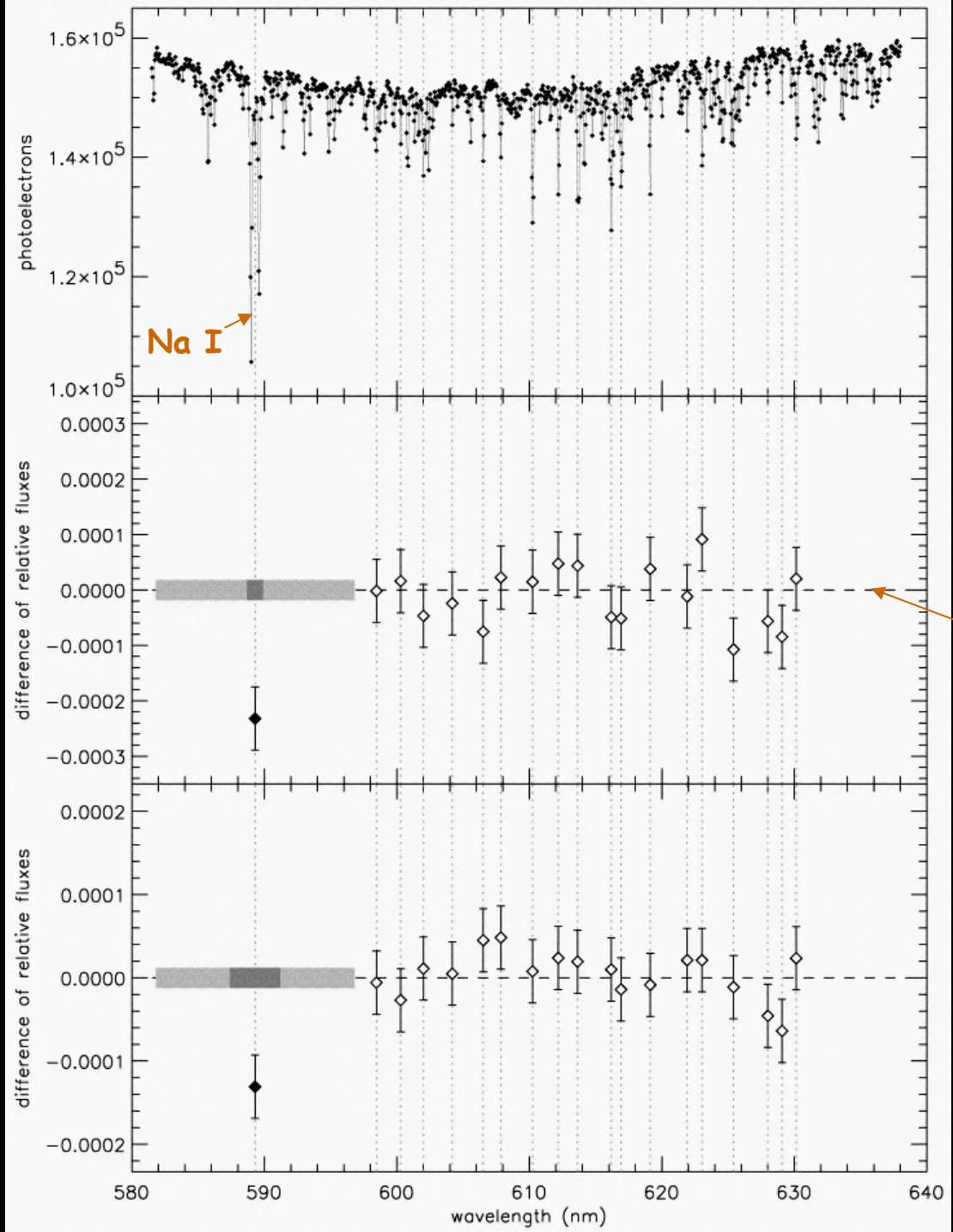
Planet Eclipsing Star HD 209458



Star: HD 209458



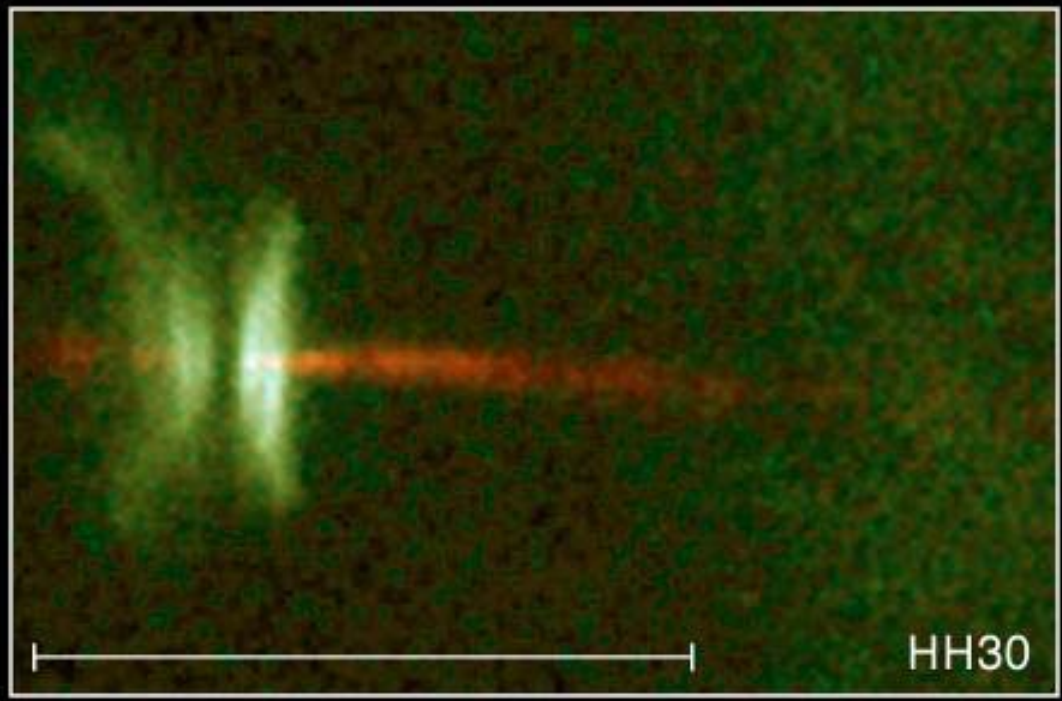
HD 209458 Spectrum

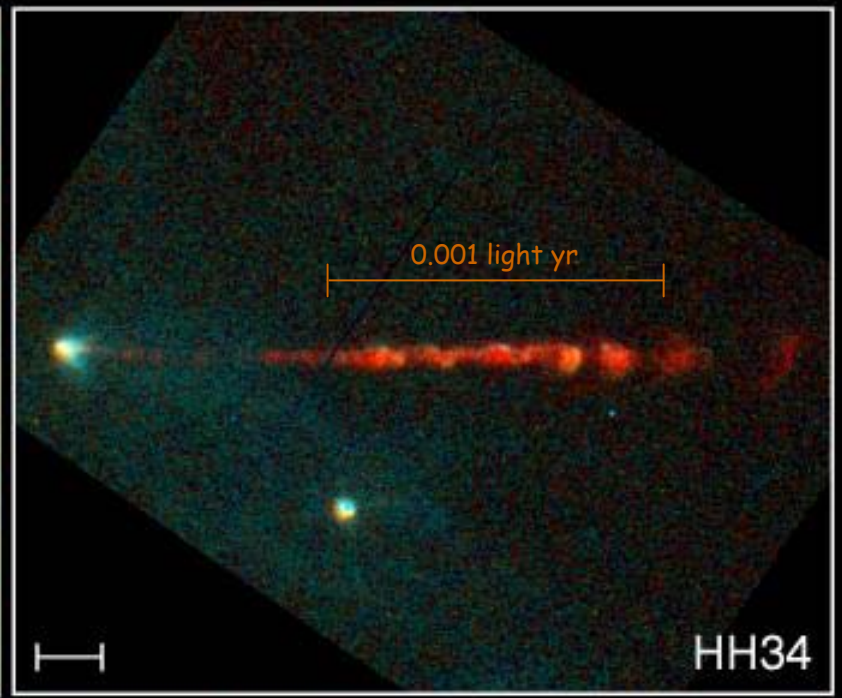


(Spectrum of star during transit)
(Normal spectrum of star)

Charbonneau et al. 2002, ApJ, **568**, 377

Jets & Disks



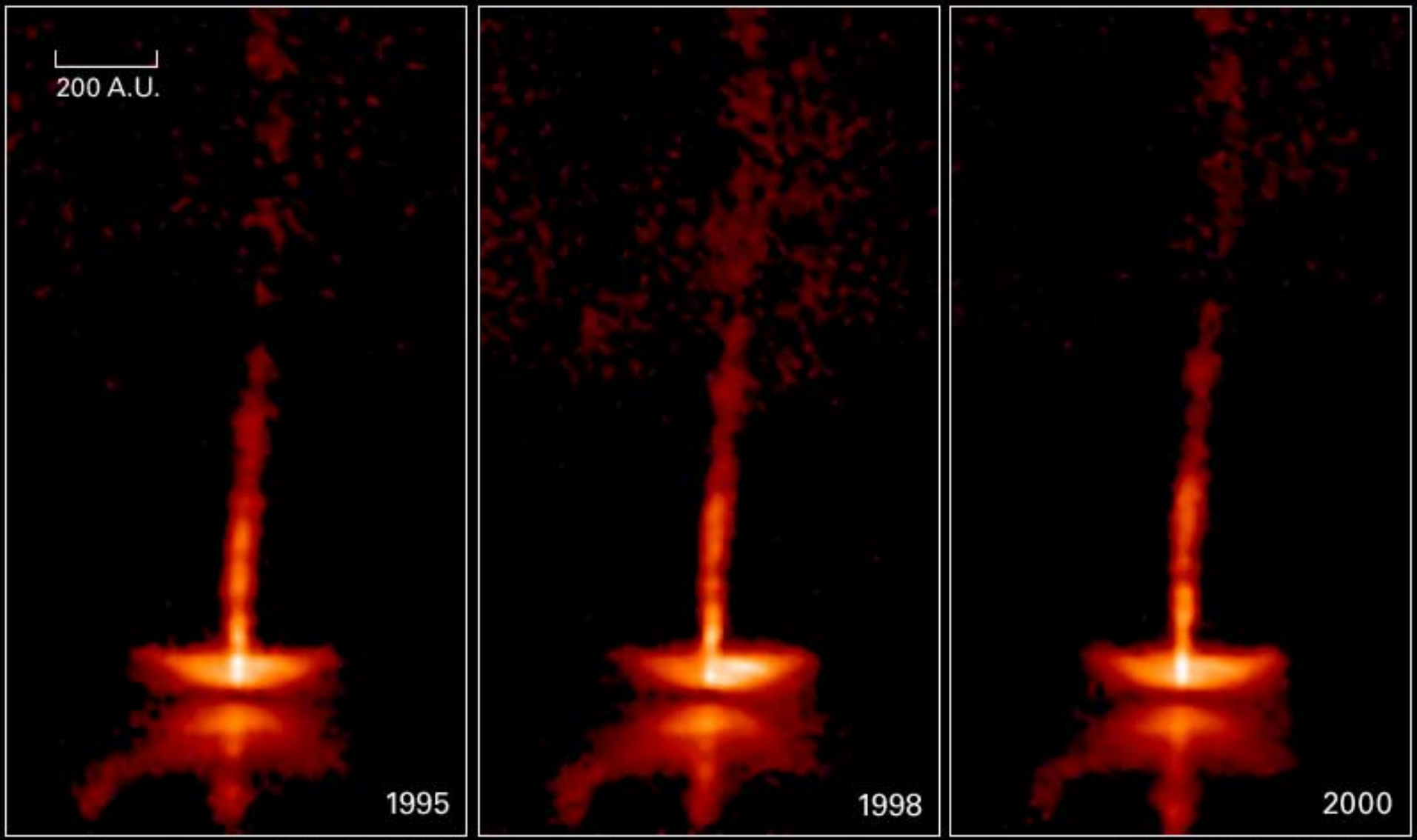


Jets from Young Stars

HST · WFPC2

PRC95-24a · ST ScI OPO · June 6, 1995

C. Burrows (ST ScI), J. Hester (AZ State U.), J. Morse (ST ScI), NASA



The Dynamic HH 30 Disk and Jet

HST • WFPC2

NASA and A. Watson (Instituto de Astronomía, UNAM, Mexico) • STScI-PRC00-32b

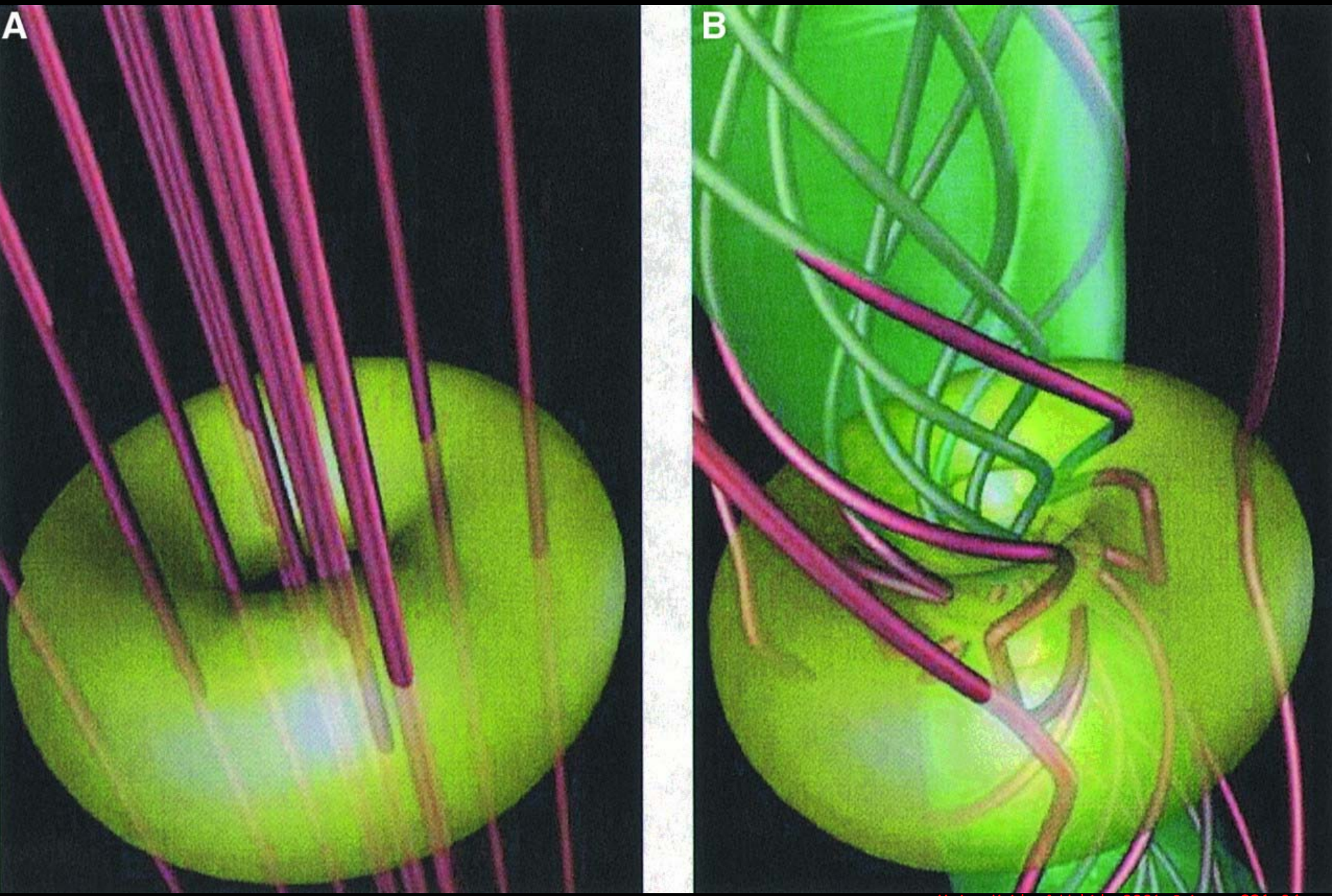
Crab Nebula Pulsar with Disk & Jet

Hester. 2002, ApJ, **577**, L49

Galaxy M87 Jet

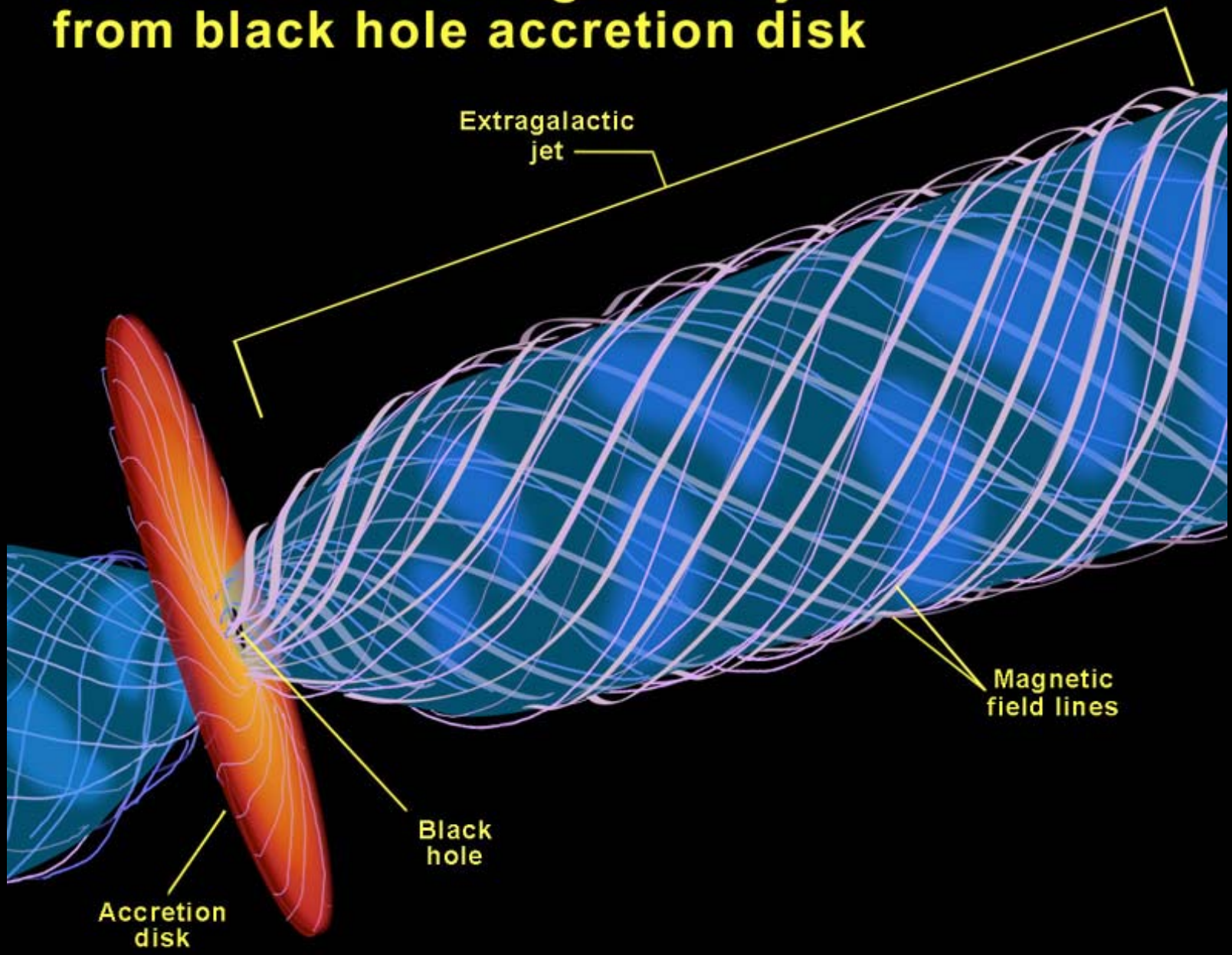
J. Biretta

Computer Simulation of Accretion Disk with Magnetic Field



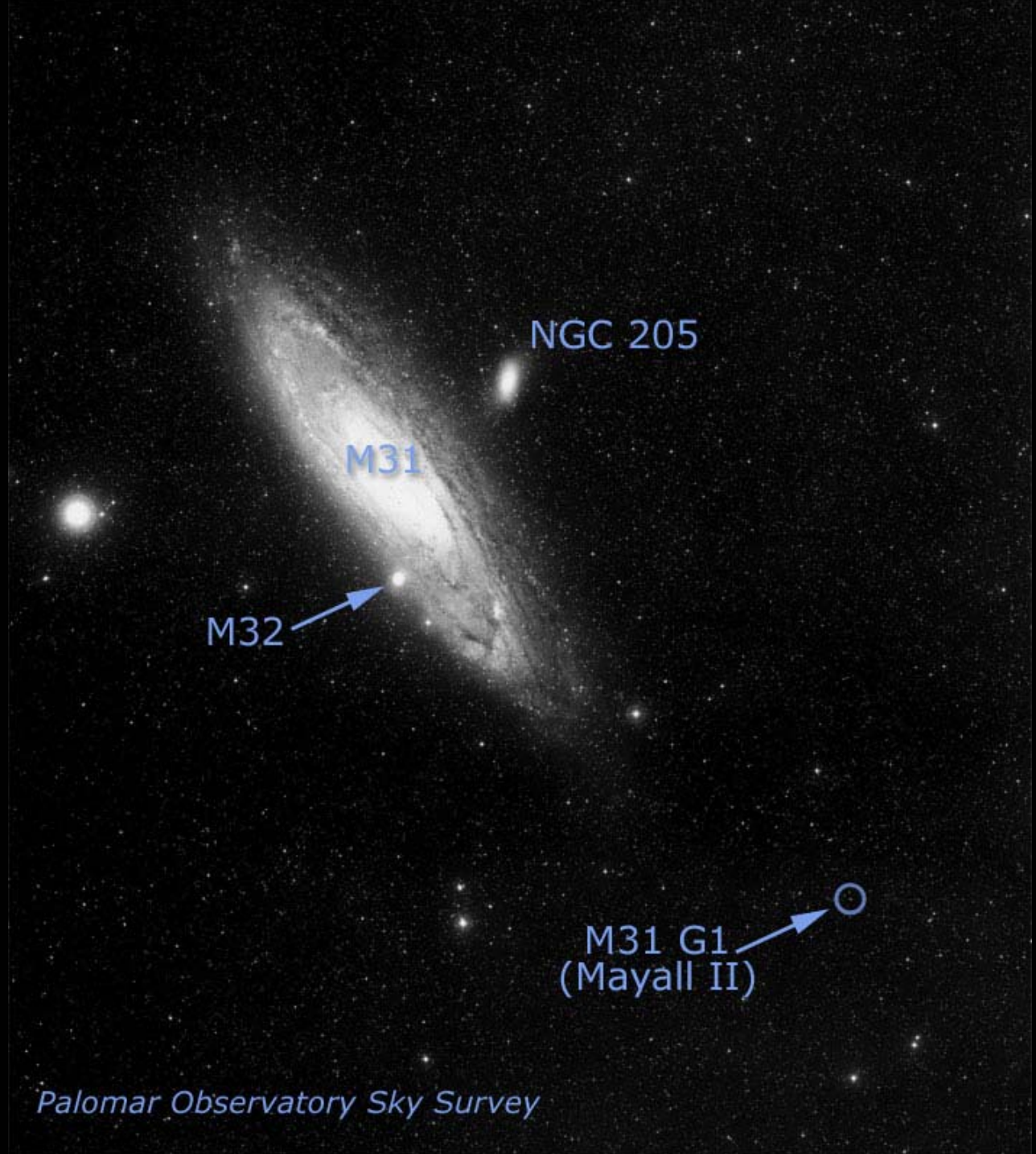
Meier, Koide, & Uchida 2001, Science, 291, 84

Formation of extragalactic jets from black hole accretion disk

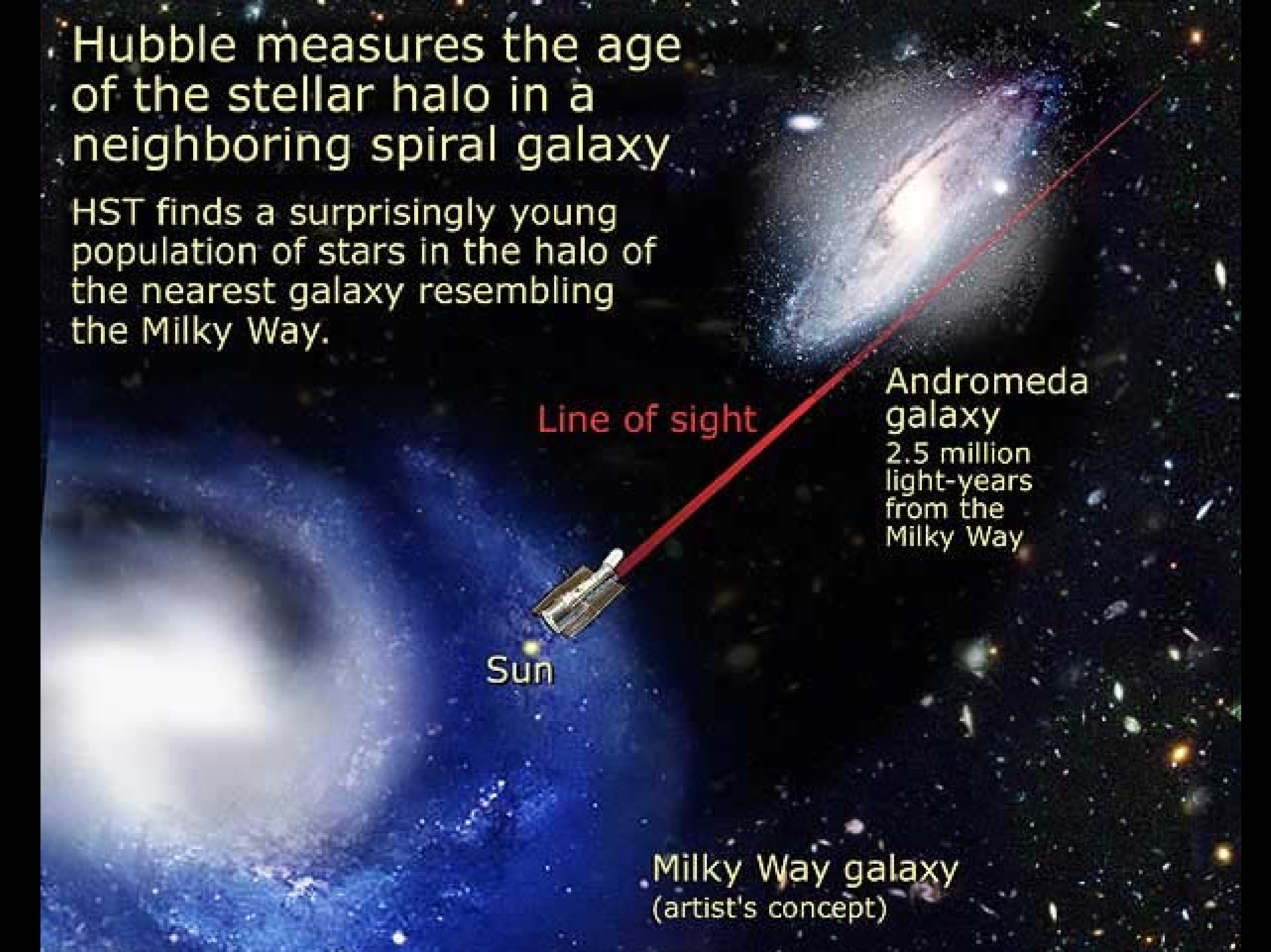


Resolved Stellar Populations:

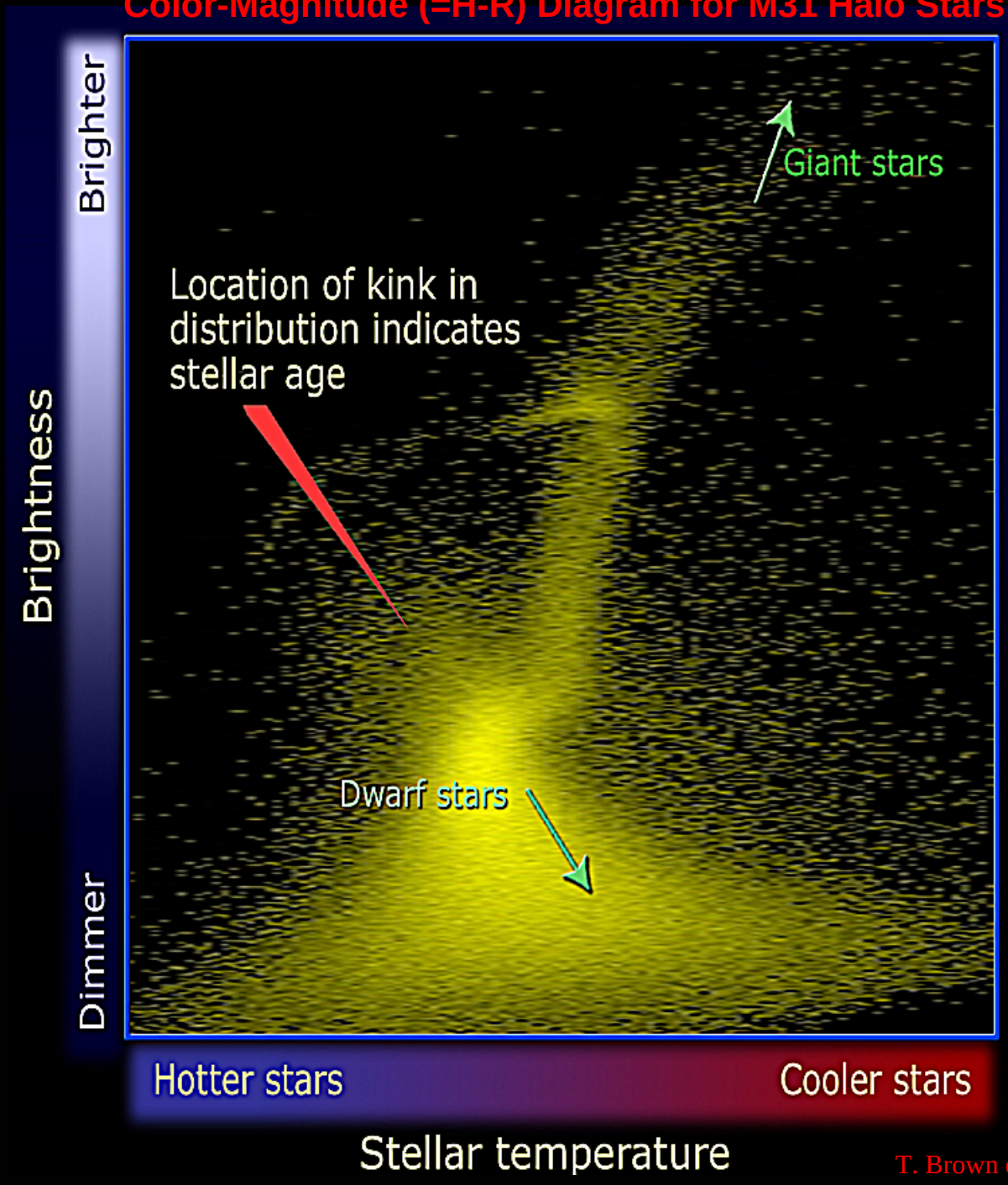
Ages, Abundances, Mass function


NGC 205
M31
M32
M31 G1
(Mayall II)
Palomar Observatory Sky Survey

Globular Cluster G1

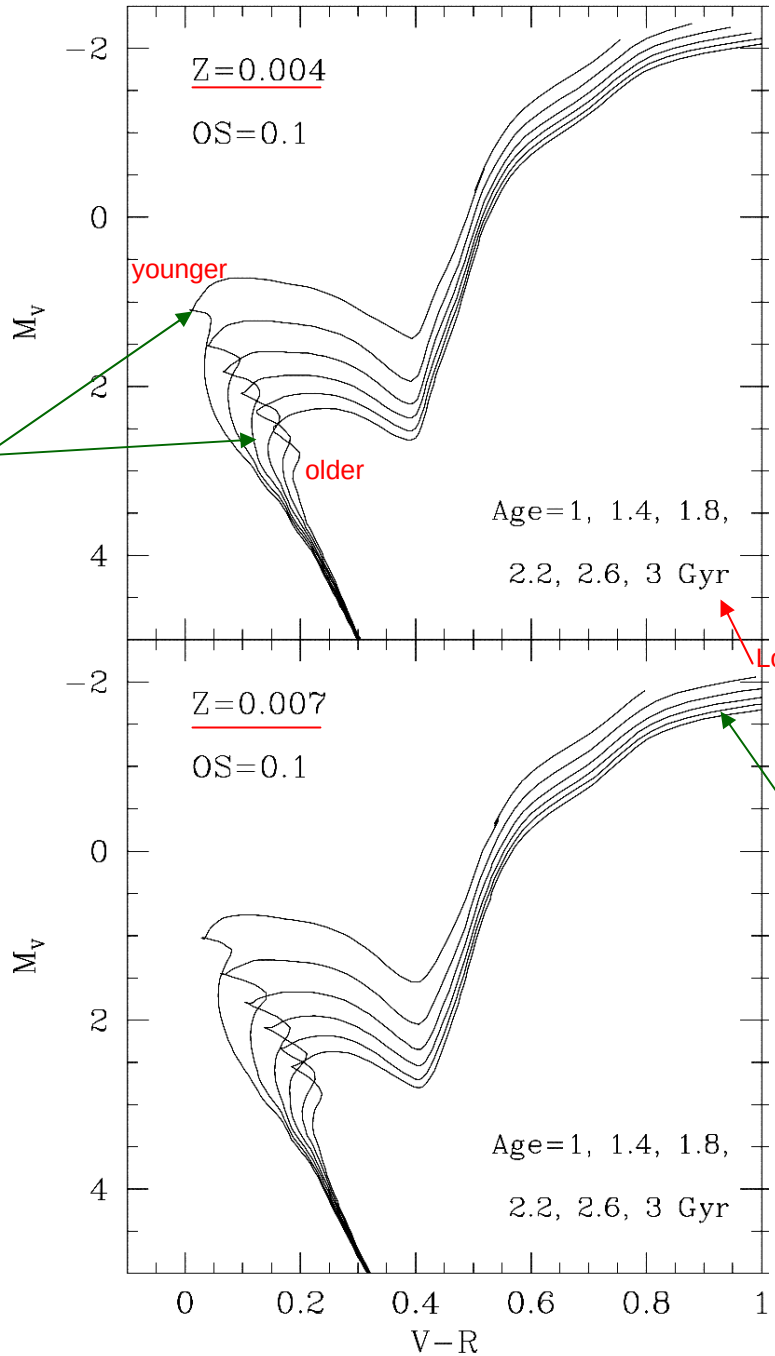

Hubble measures the age of the stellar halo in a neighboring spiral galaxy
HST finds a surprisingly young population of stars in the halo of the nearest galaxy resembling the Milky Way.
Line of sight
Andromeda galaxy
2.5 million light-years from the Milky Way
Sun
Milky Way galaxy
(artist's concept)

Color-Magnitude (=H-R) Diagram for M31 Halo Stars



T. Brown et al. 2003, ApJ, **592**, L17

Theoretical Color-Magnitude Diagram (CMD) for Star Clusters



Age

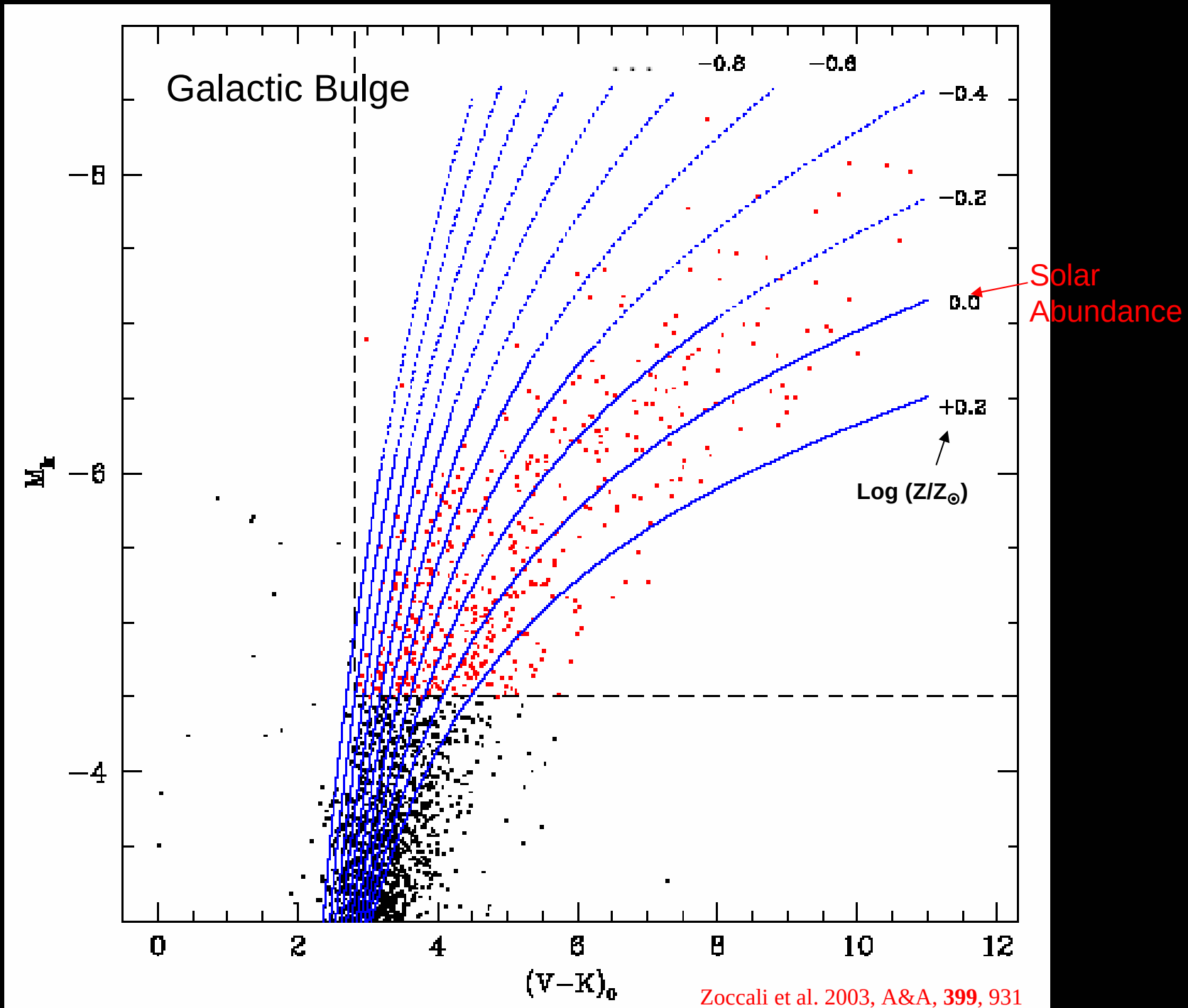
Z=fractional abundance of 'heavy' elements (C,N,O,Ne, … Fe.. = 'metals')

Lower heavy element abundance

Higher heavy element abundance

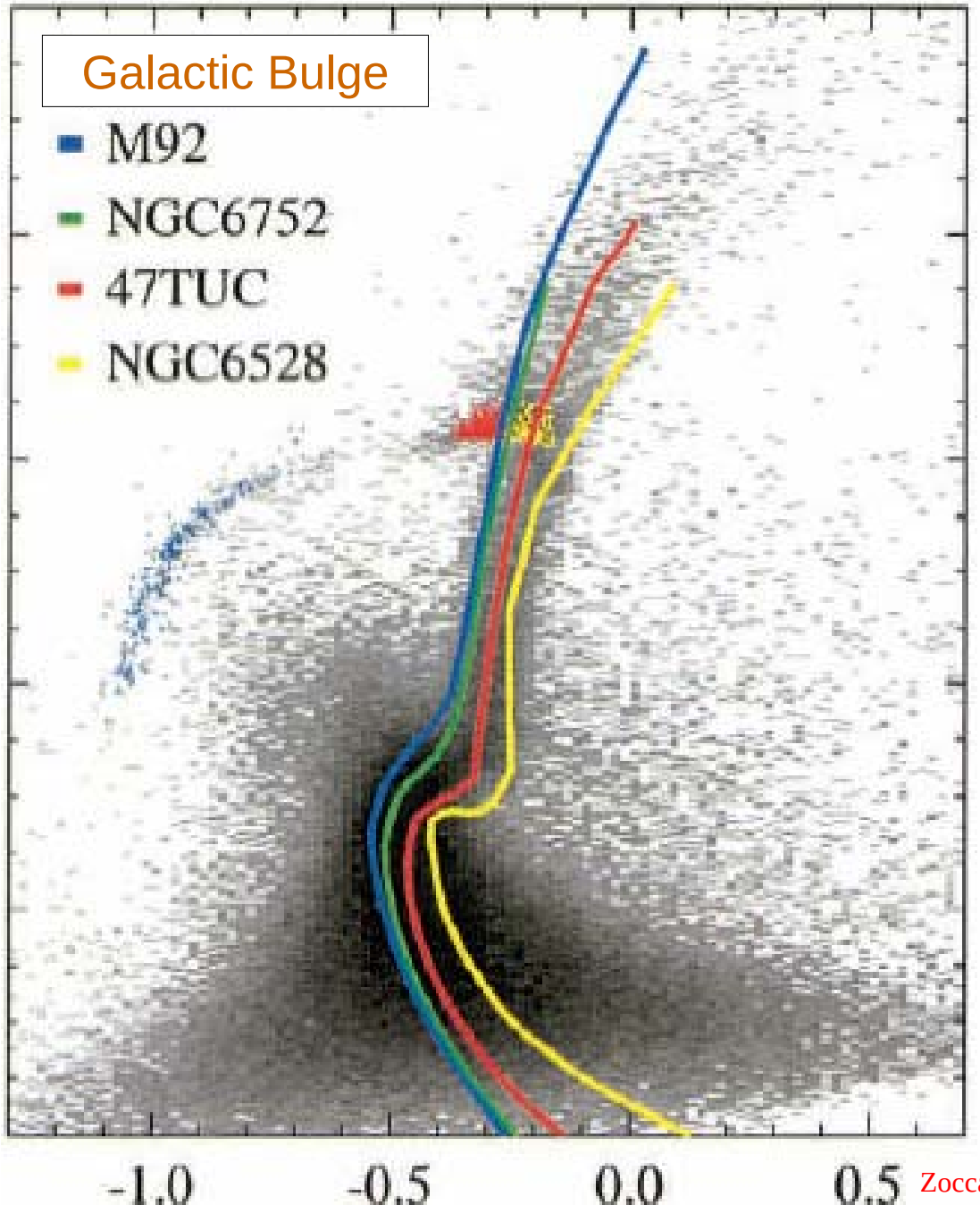
Heavy Element Abundance

Zoccali et al. 2003, A&A, **399**, 931



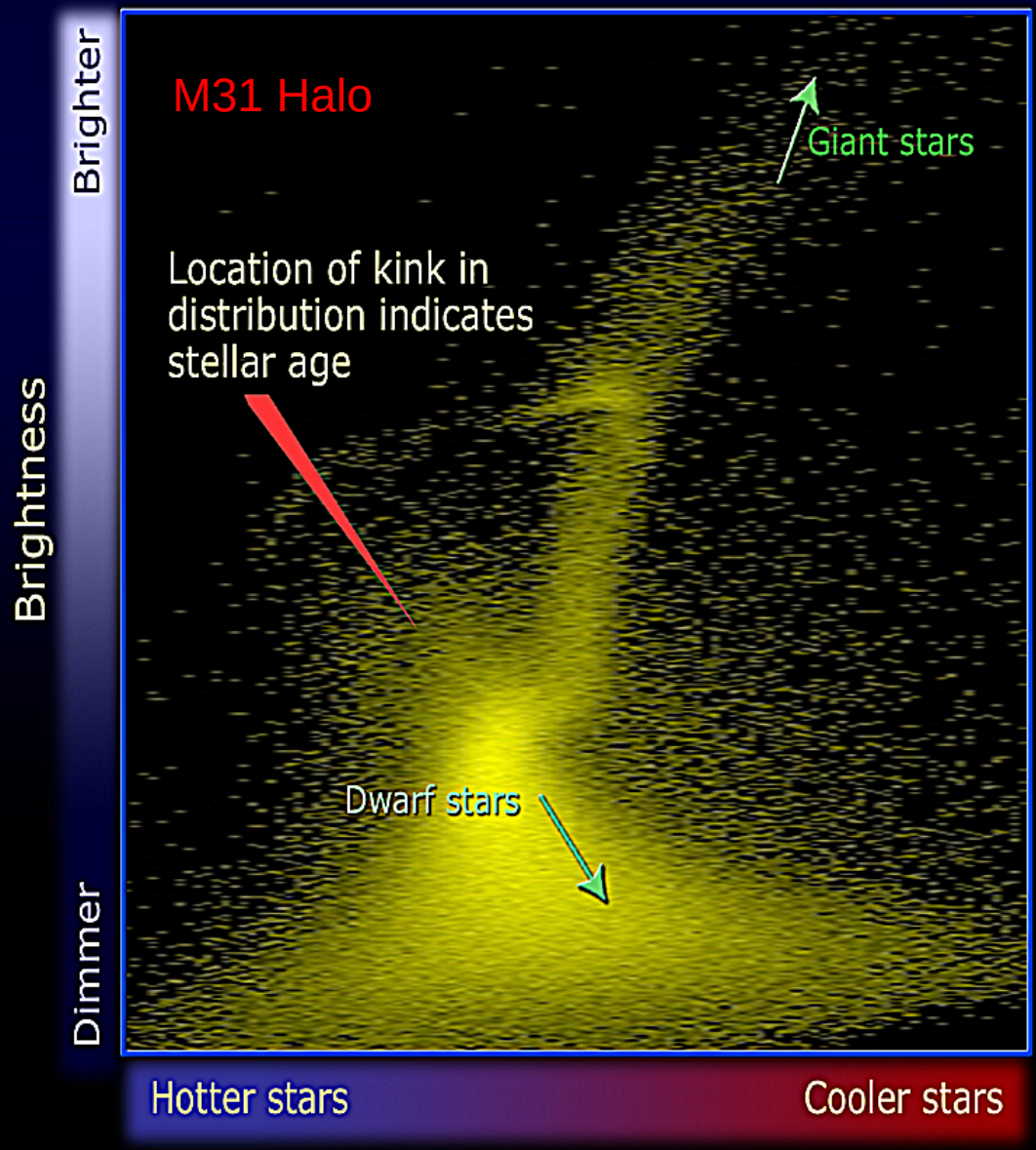
Zoccali et al. 2003, A&A, **399**, 931

CMD Comparison of Milky Way Bulge with Globular Clusters



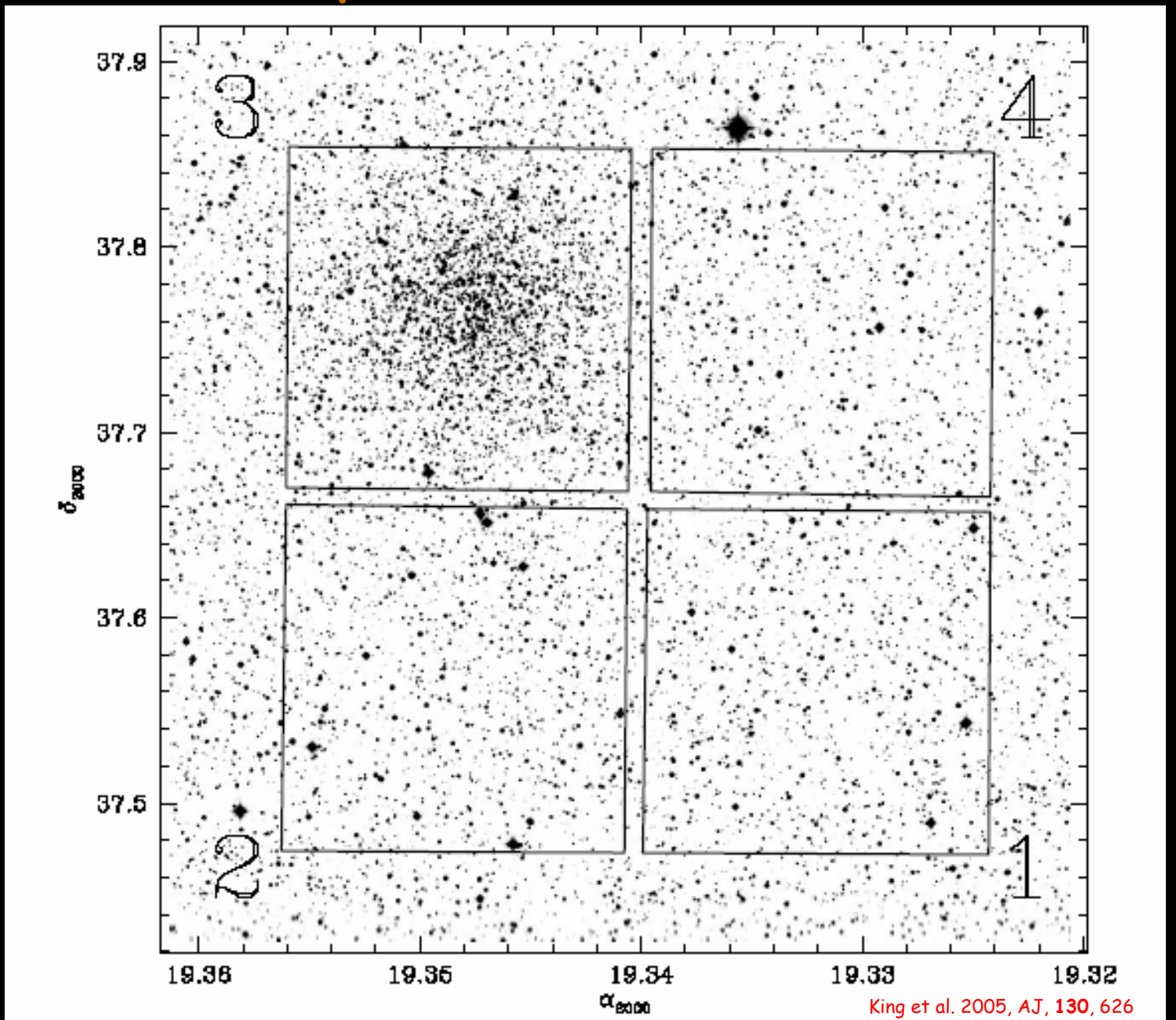
Zoccali et al. 2003, A&A, **399**, 931

Stars in M31 halo have a wider age range (6–13 billion years) than those in the Milky Way halo (11–13 billion years).



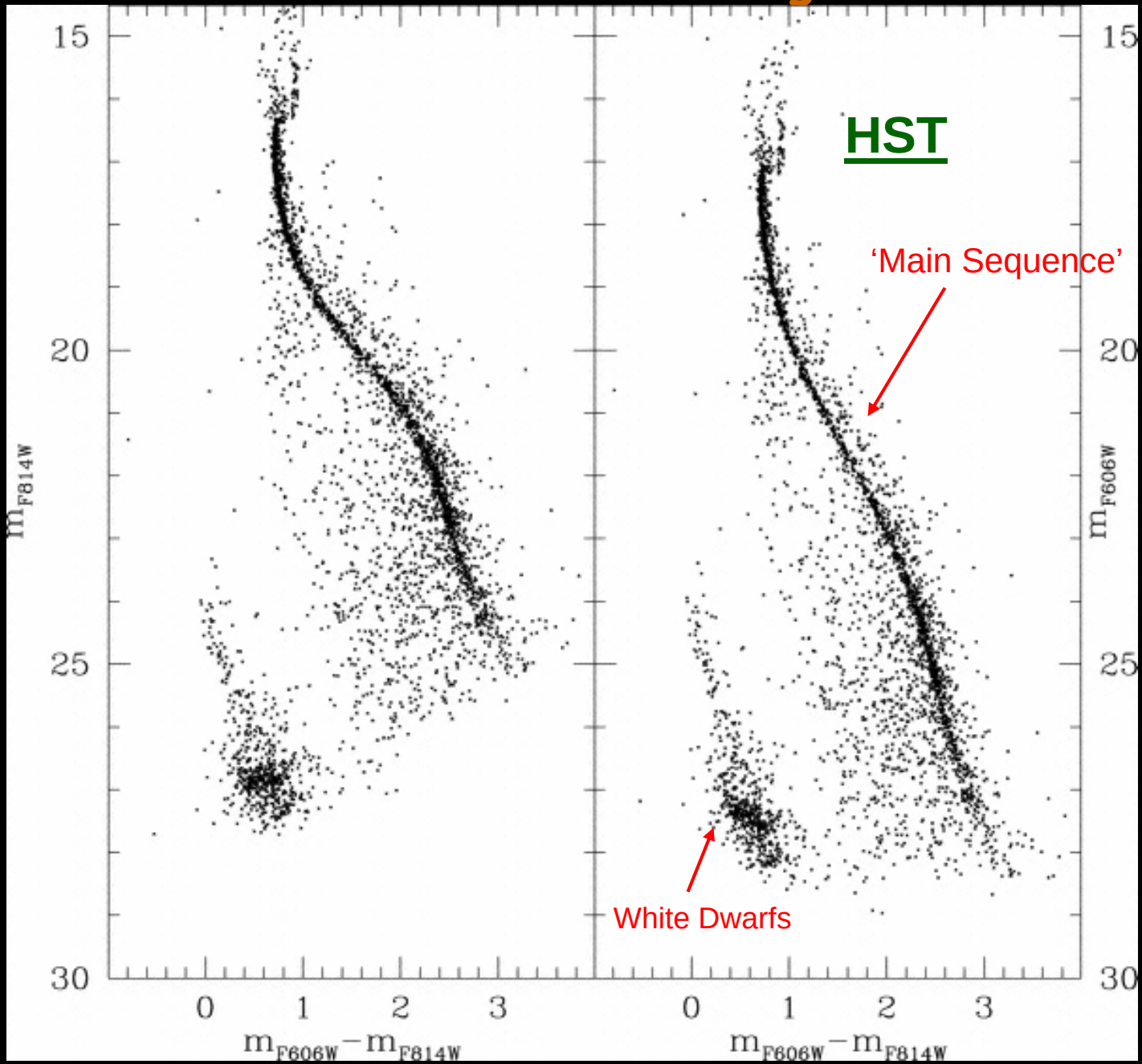
T. Brown et al. 2003, ApJ, **592**, L17

Open Cluster NGC 6791



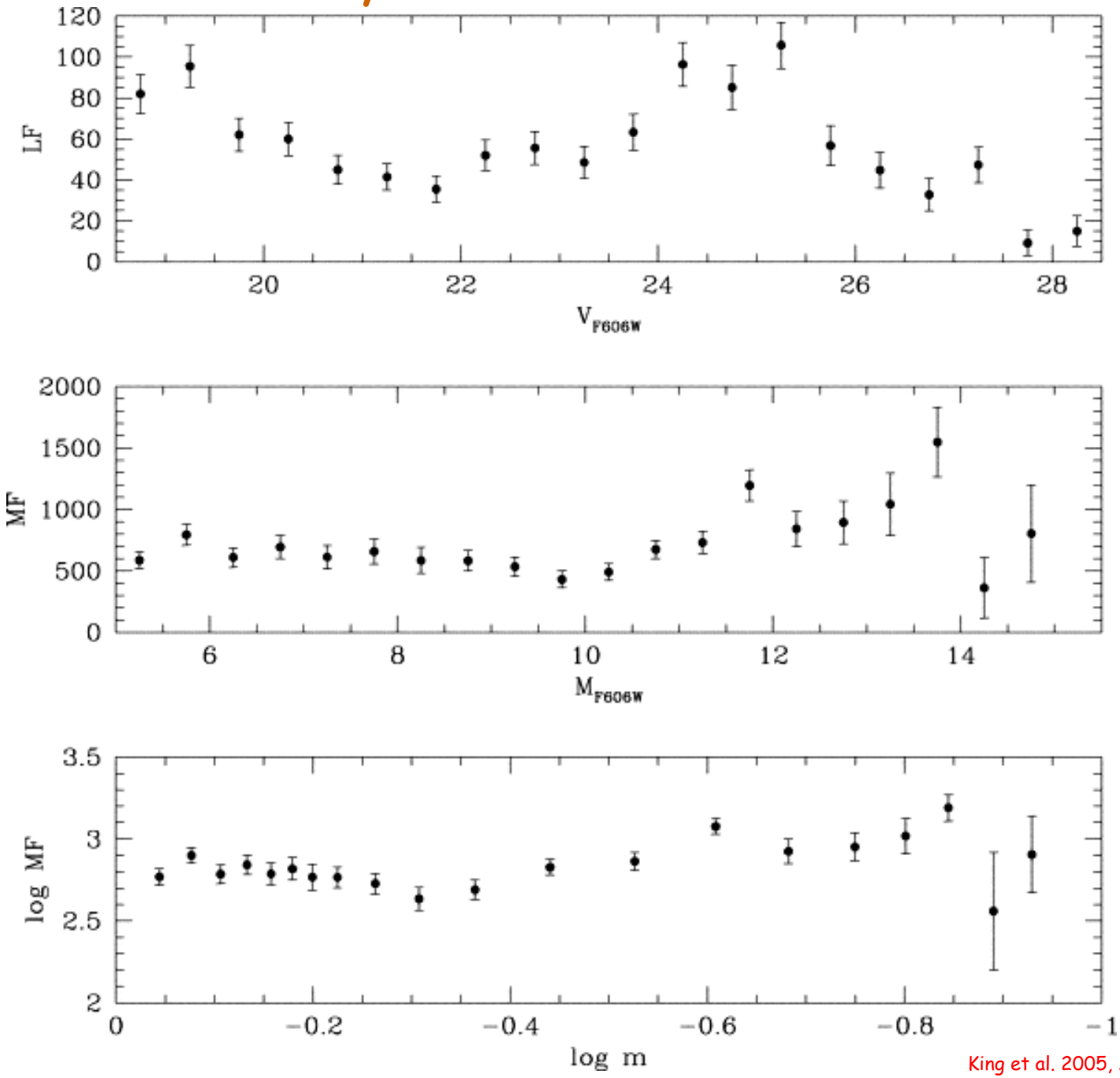
King et al. 2005, AJ, **130**, 626

NGC 6791 – HR Diagram

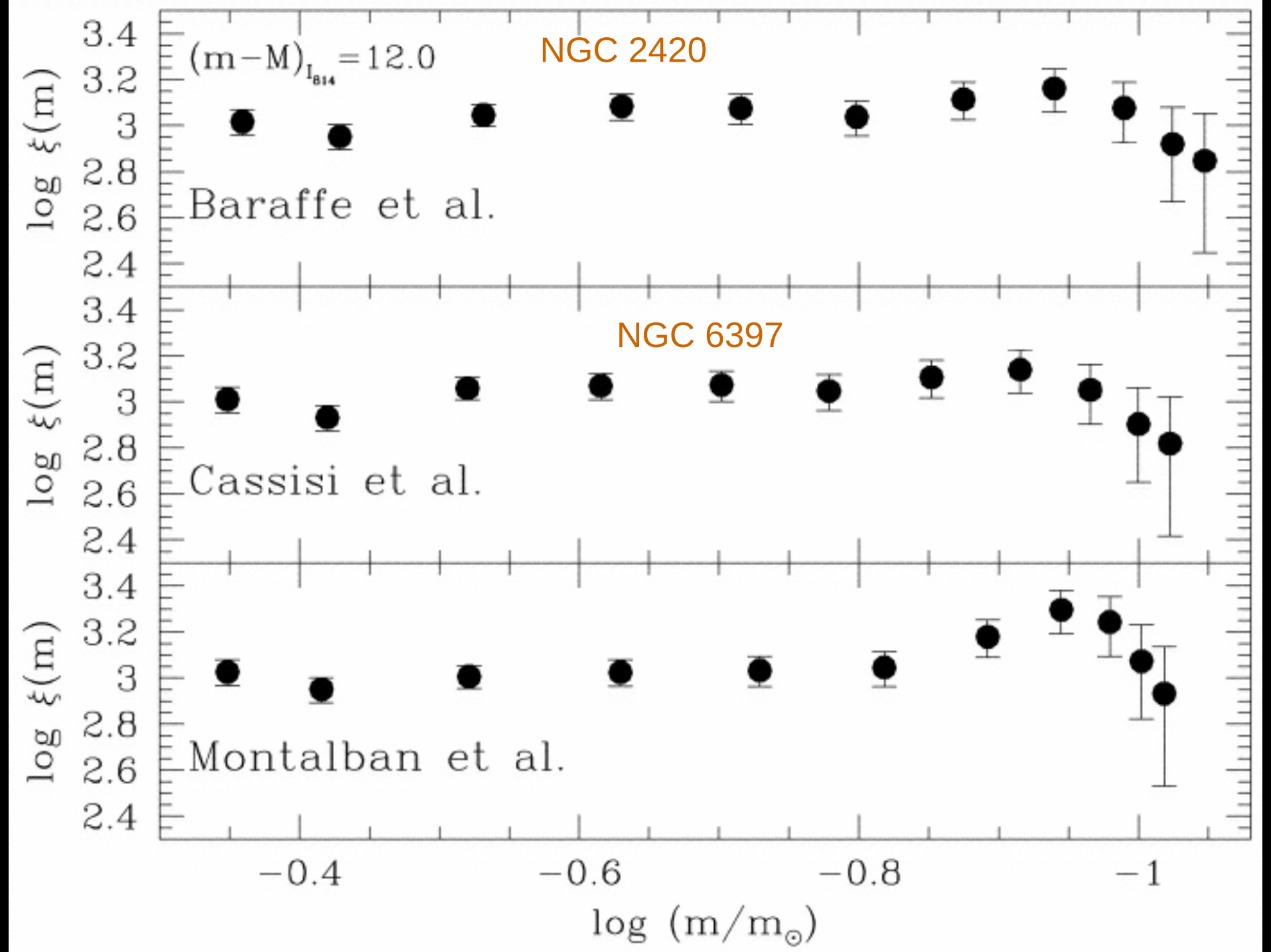


King et al. 2005, AJ, **130**, 626

Luminosity & Mass Function of NGC 6791

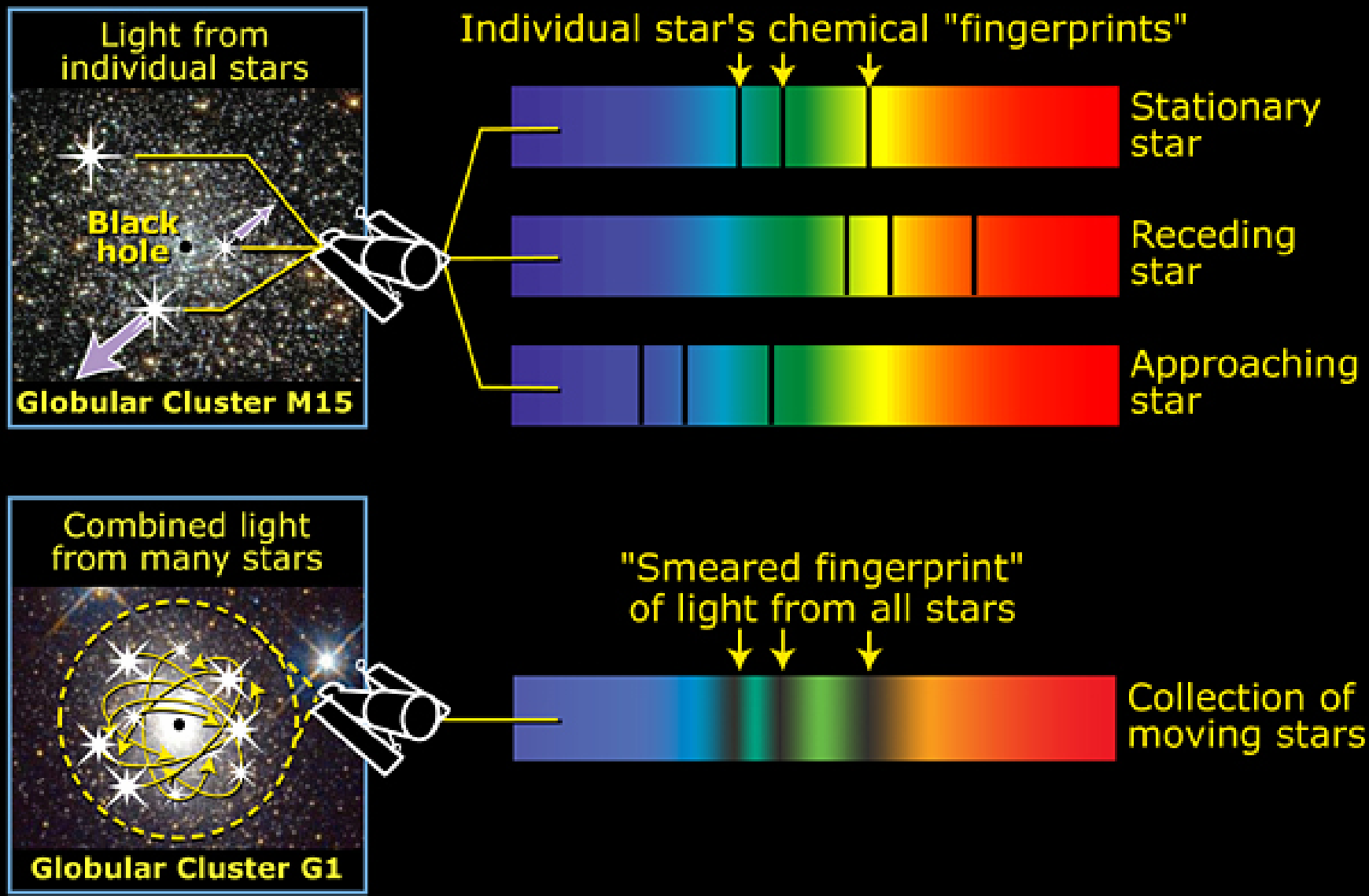


King et al. 2005, *AJ*, **130**, 626

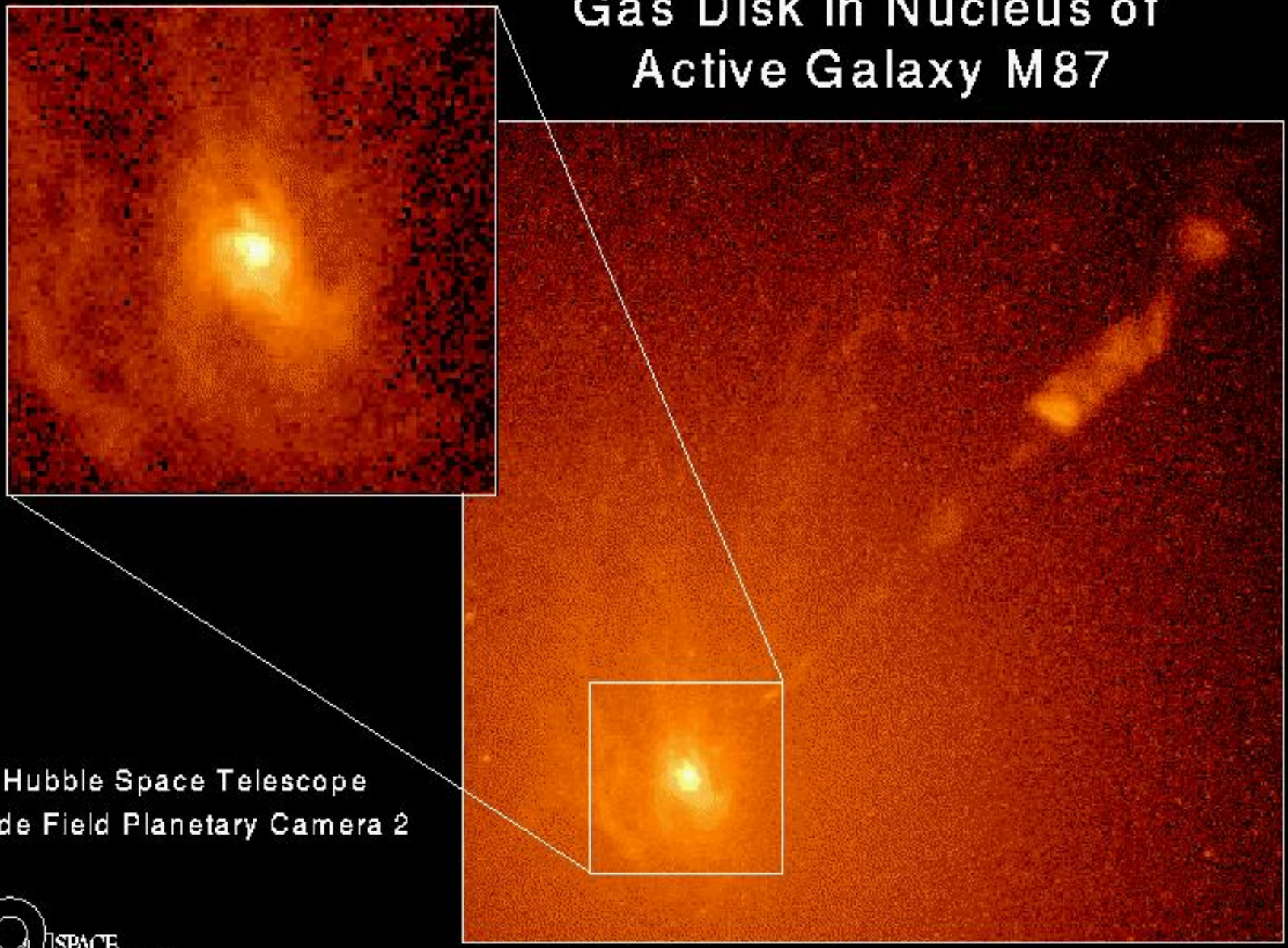

NGC 2420
$(m-M)_{I_{814}}=12.0$
Baraffe et al.
NGC 6397
Cassisi et al.
Montalban et al.
log ξ(m)
3.4
3.2
3
2.8
2.6
2.4
−0.4
−0.6
−0.8
−1
log (m/m⊙)

Massive Black Holes in the Centers of Galaxies

Hubble Black Hole Measurements: Two Methods



Gas Disk in Nucleus of Active Galaxy M87

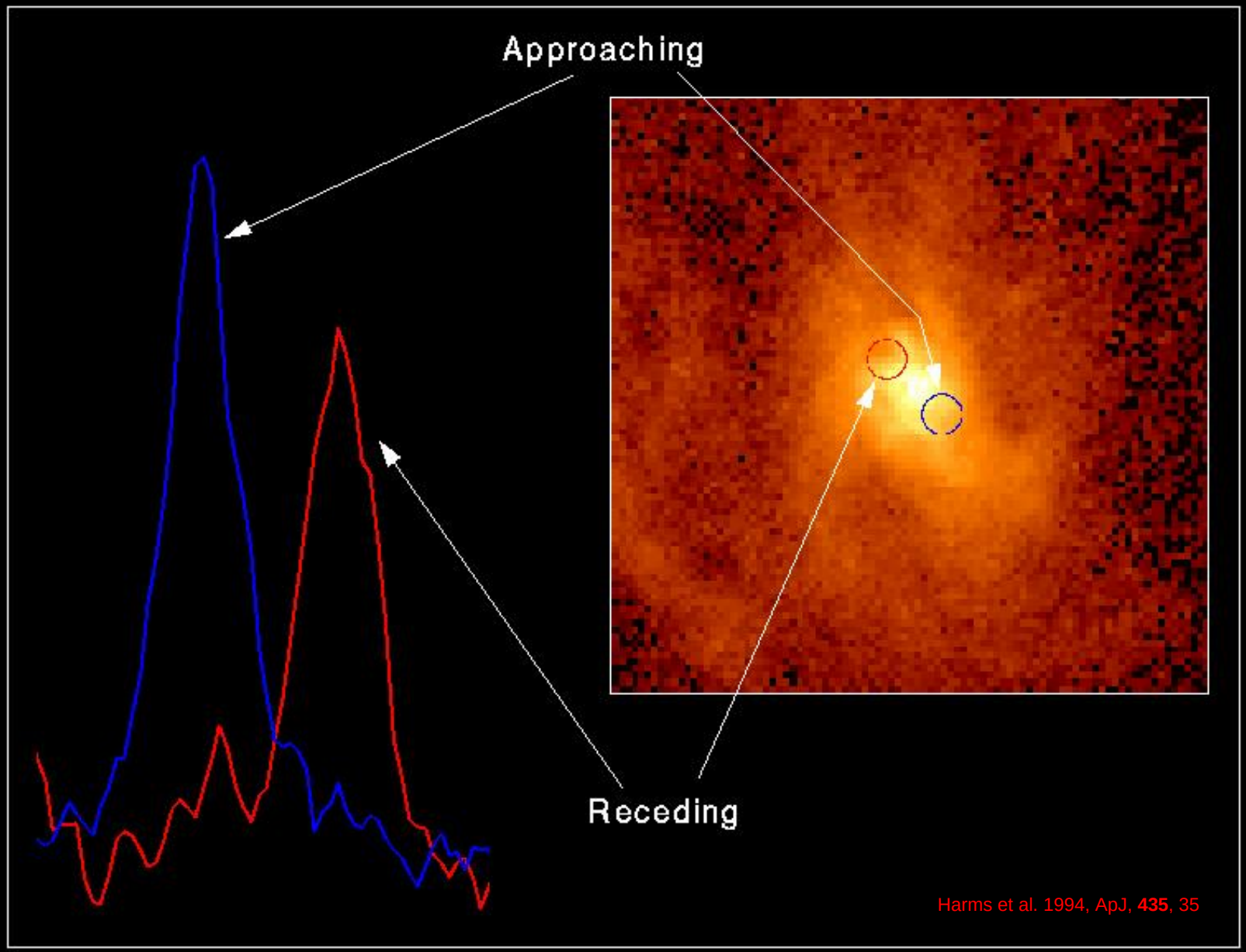


Hubble Space Telescope
Wide Field Planetary Camera 2

SPACE TELESCOPE SCIENCE INSTITUTE

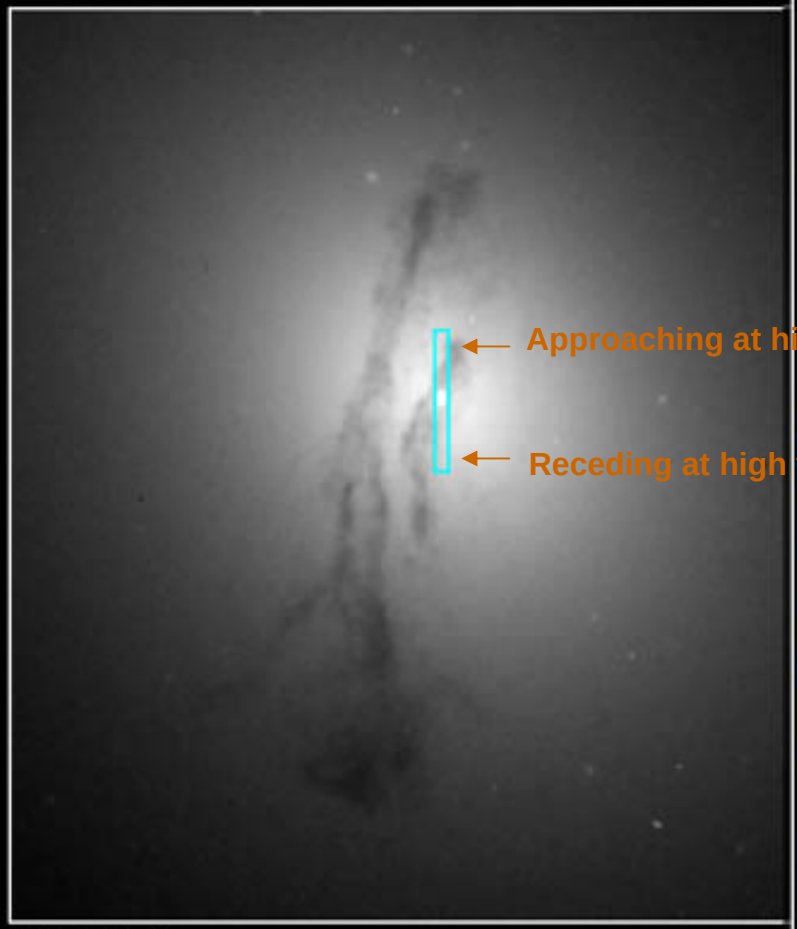
Harms et al. 1994, ApJ, **435**, 35

Spectrum of Gas Disk in Active Galaxy M87

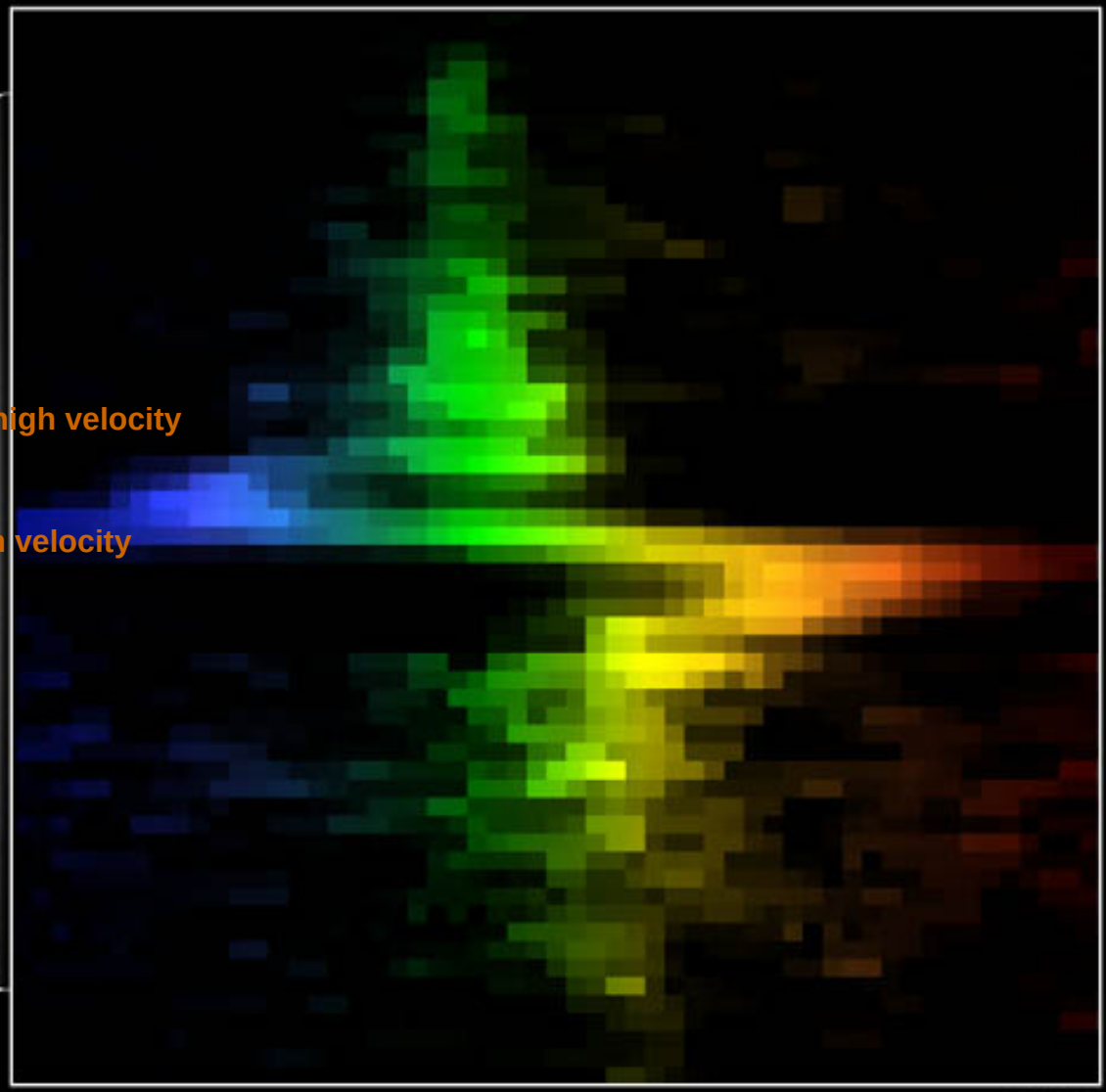


Hubble Space Telescope • Faint Object Spectrograph

Galaxy M84 Nucleus

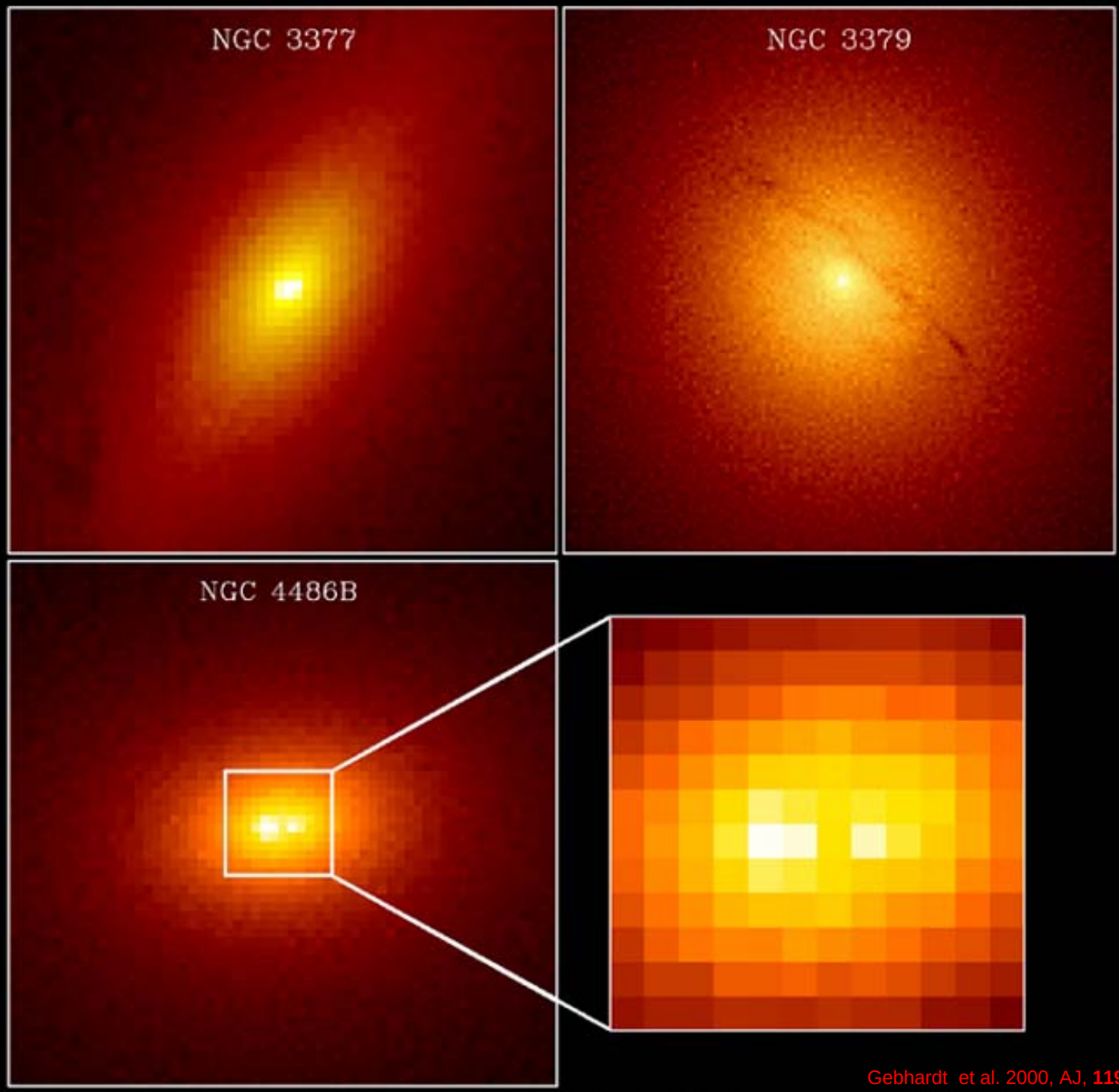


WFPC2



STIS

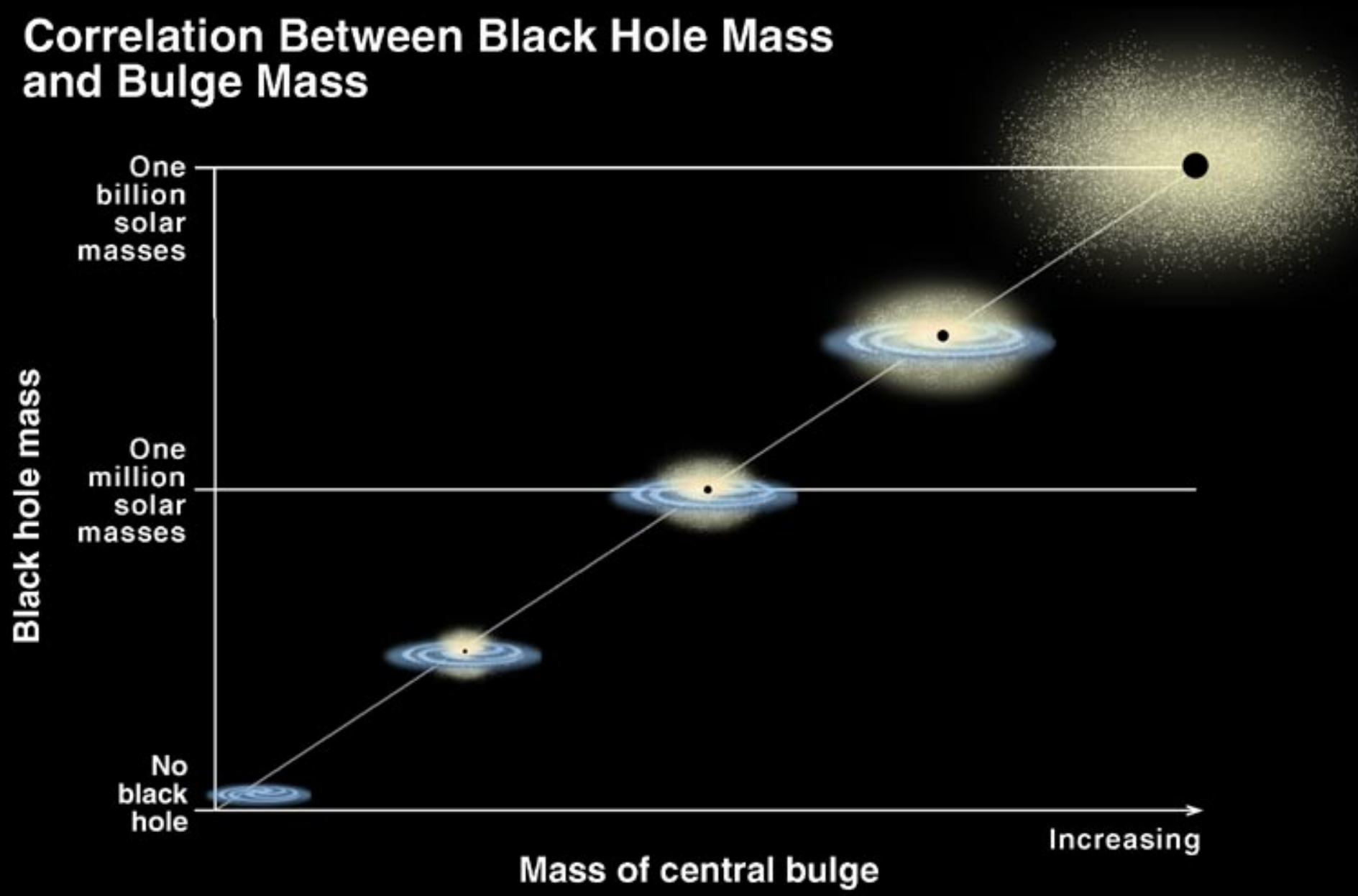
Hubble Space Telescope

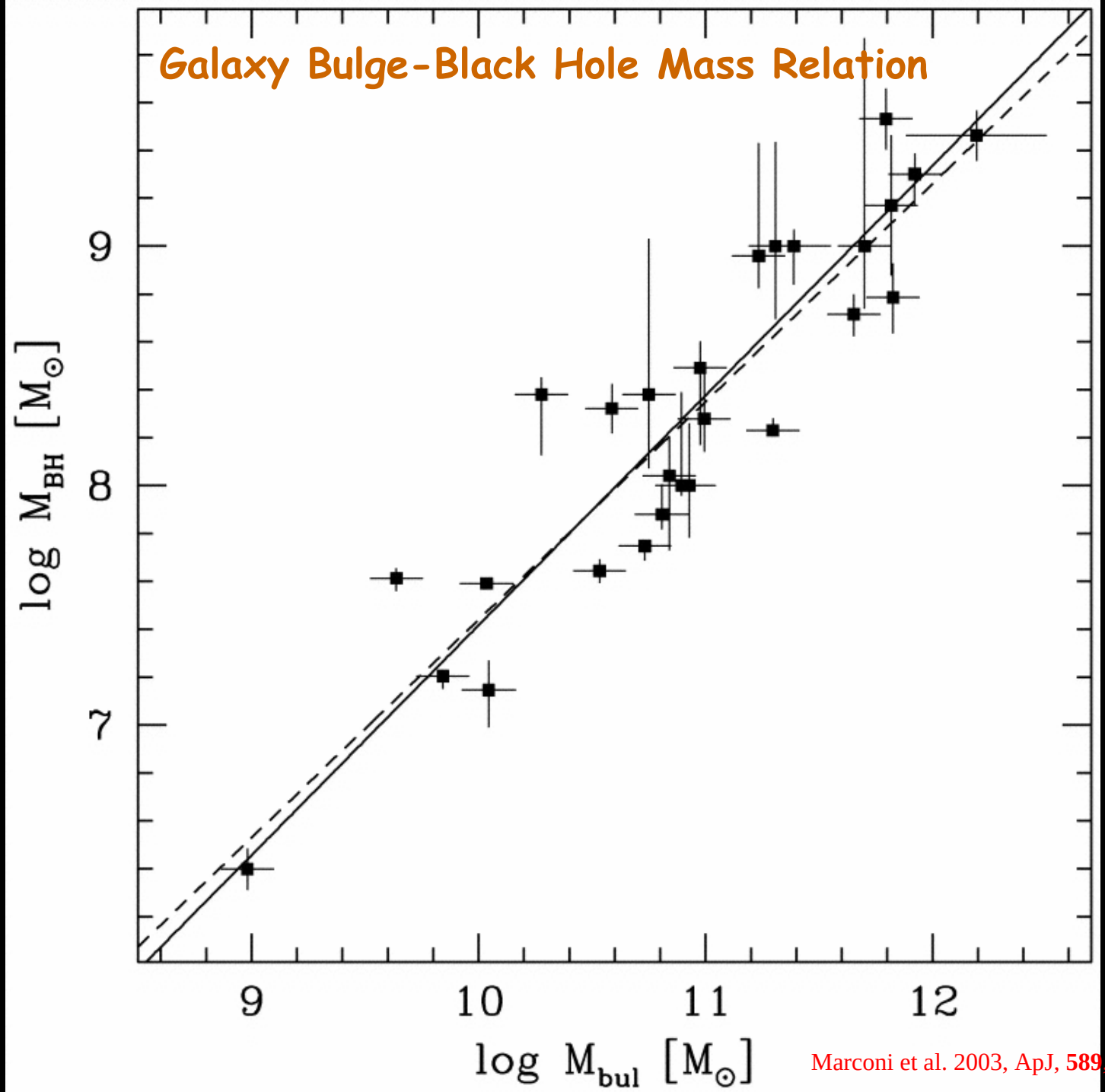


Gebhardt et al. 2000, AJ, **119,** 1157

Galaxies Possibly Containing Black Holes HST • WFPC2

Correlation Between Black Hole Mass and Bulge Mass





Marconi et al. 2003, ApJ, **589**, L21