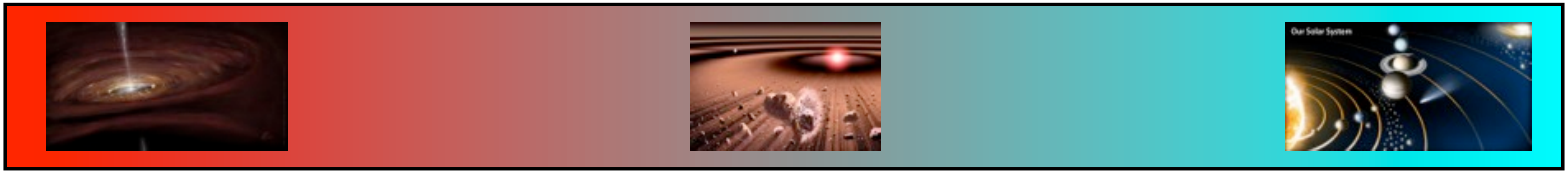
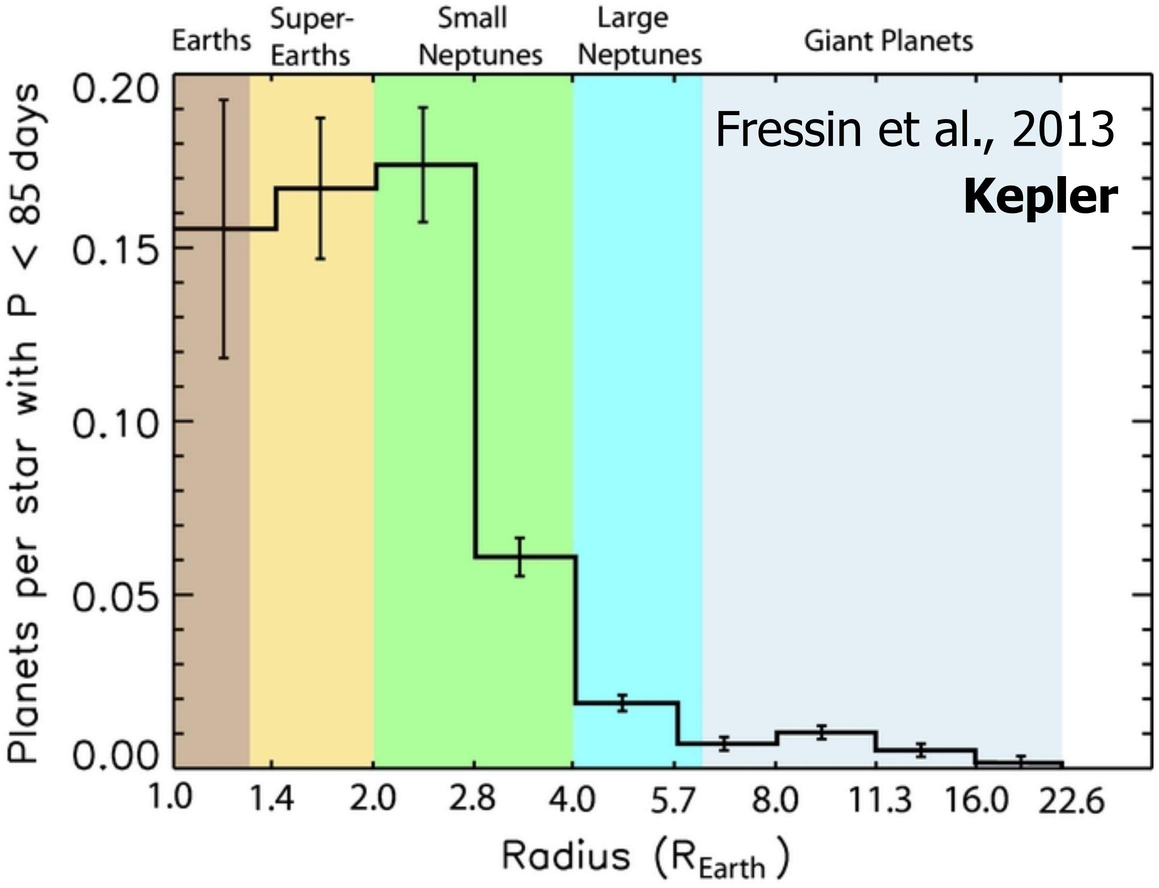
Age 1 Myrs 10 Myrs 100 Myrs 5 Gyrs



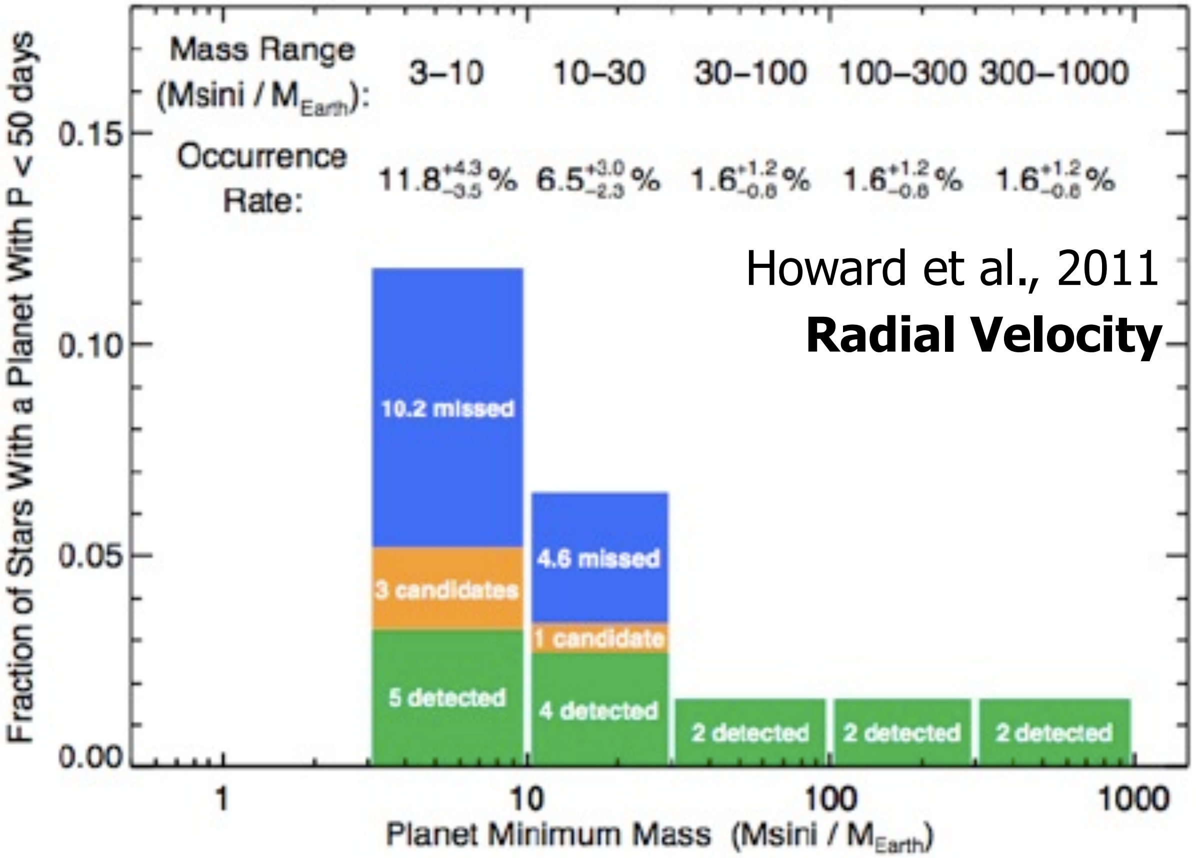
High angular resolution and high contrast to study planetary formation (from an observer’s perspective)

Laurent Pueyo (STScI)

Statistical distribution of exo-planets

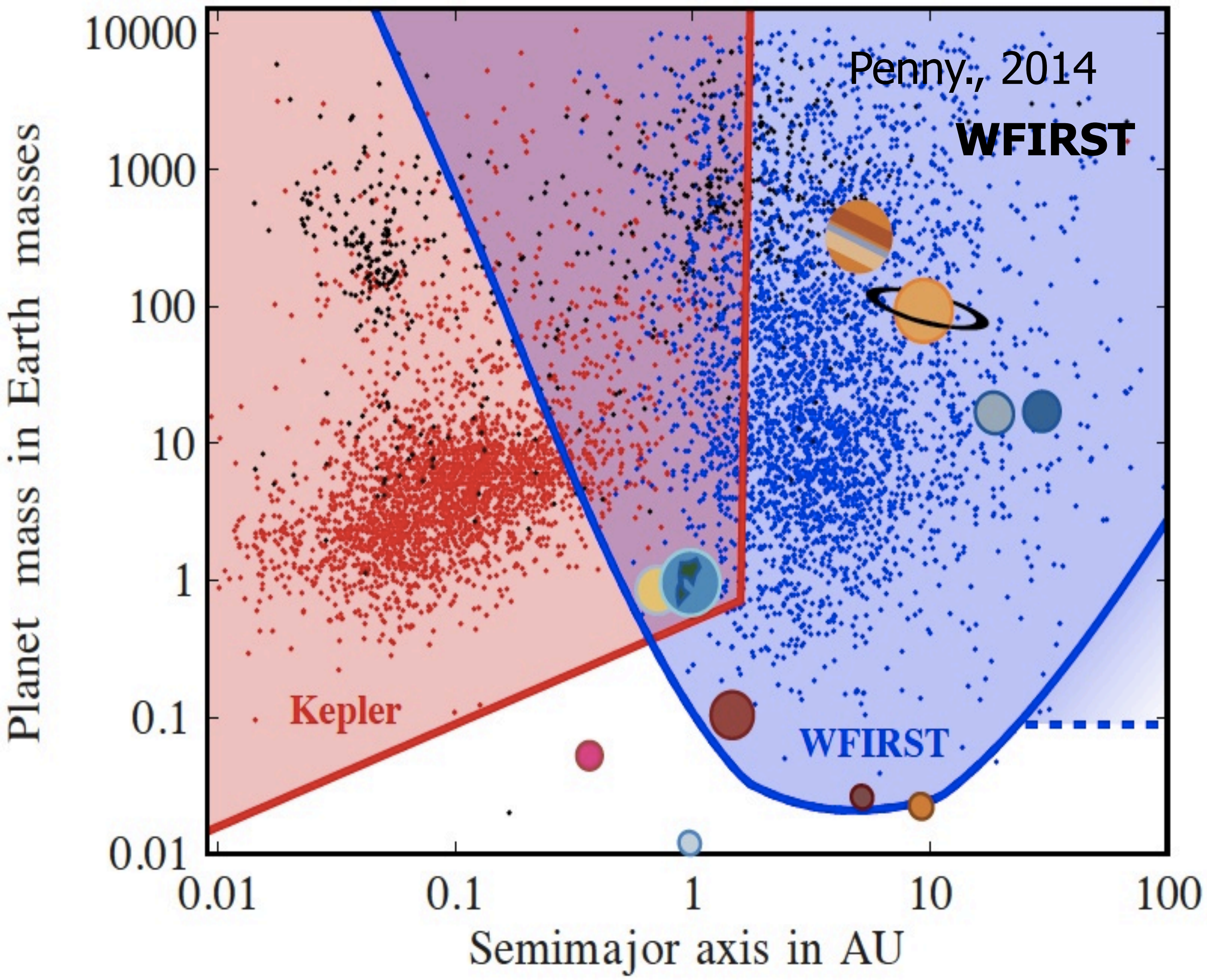


Fressin et al 2013; Kepler FGKM stars P<85 days

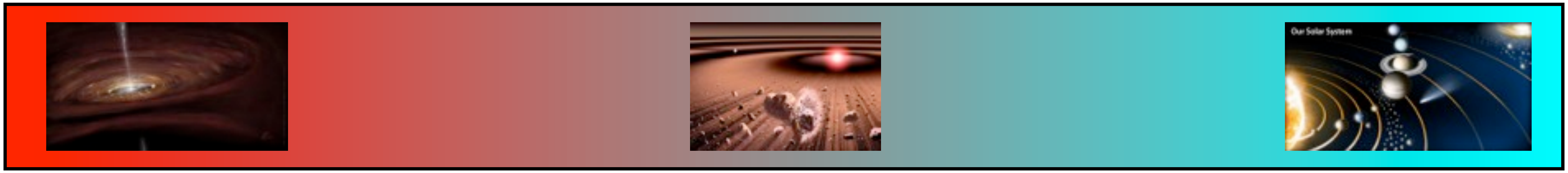


Occurrence of mature systems:

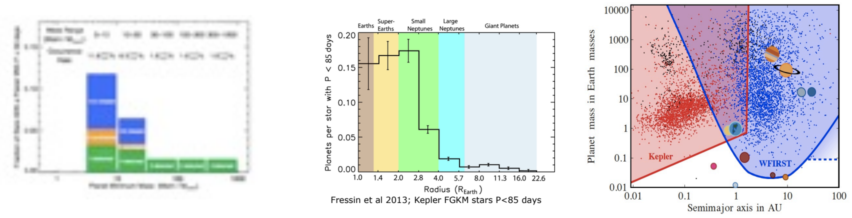
- Radius distribution
- Mass distribution
- Period distribution



Age 1 Myrs 10 Myrs 100 Myrs 5 Gyrs



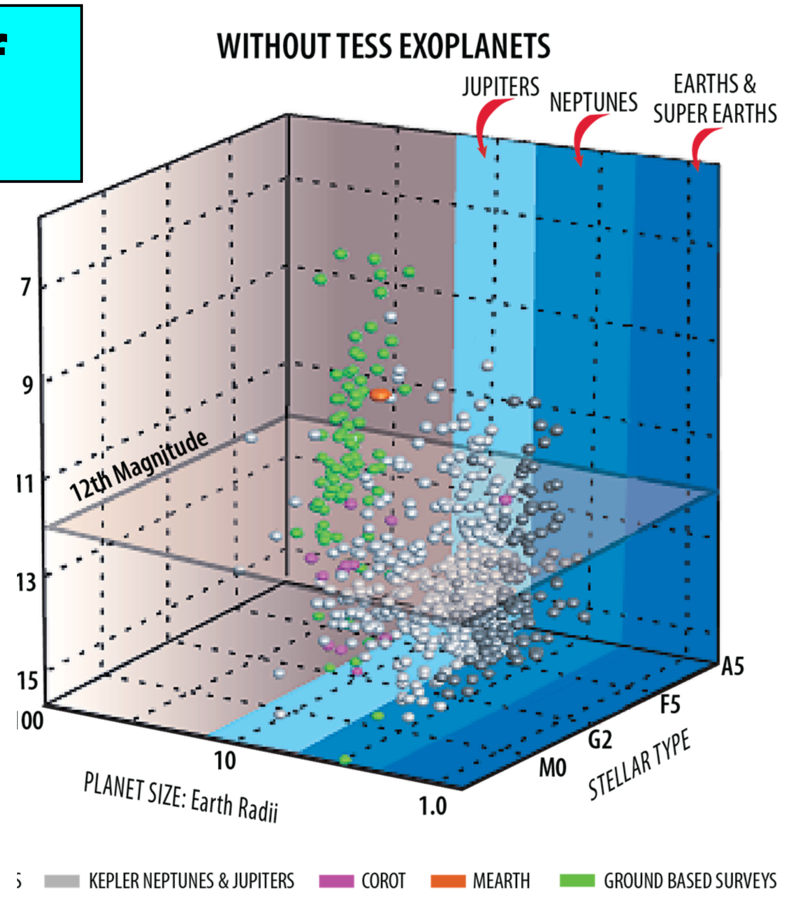
Statistical distribution of mature planets

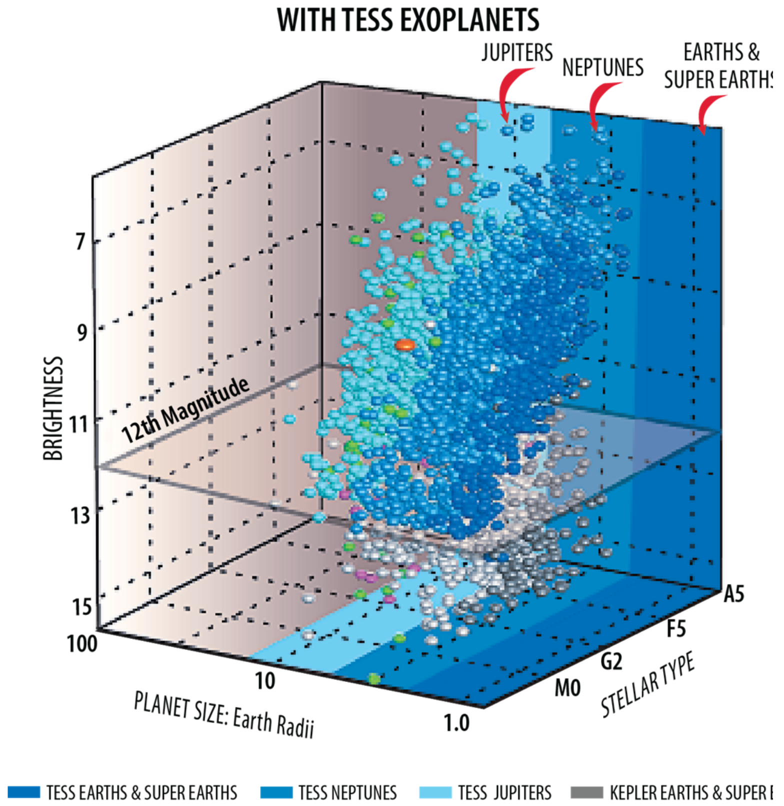


Fressin et al 2013; Kepler FGKM stars P<85 days

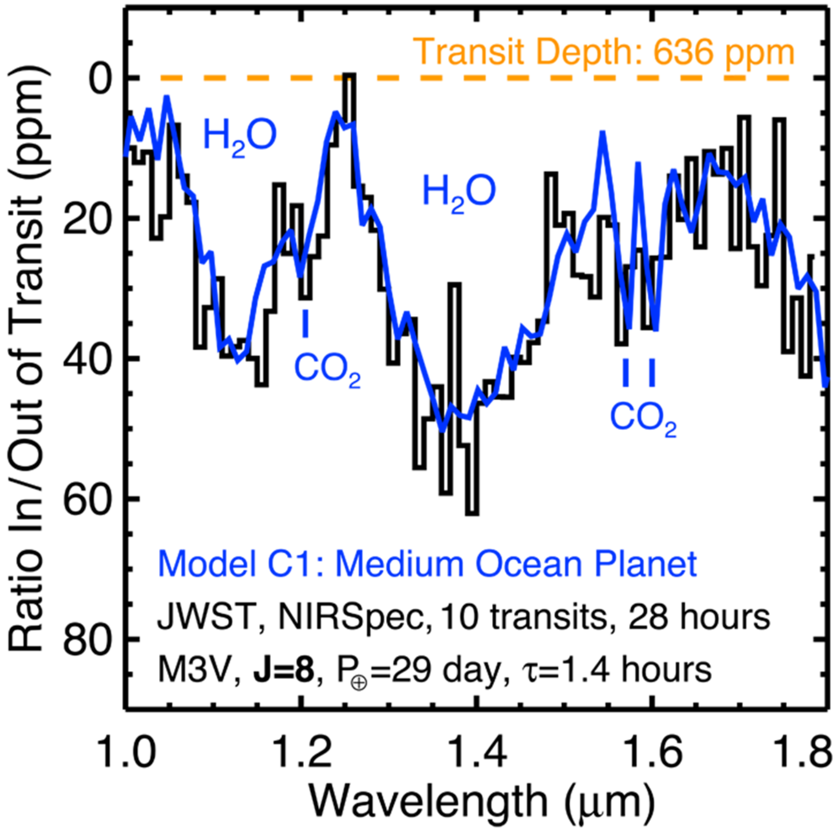
Characterization: transit spectroscopy

Field of Regard





Transit Spectrum of Habitable-Zone Earth-size Ocean Planet (1 R_{Earth}, 0.5 M_{Earth})



Sensitivity

Seager, Deming, & Valenti 2009

Model by Ehrenreich et al.

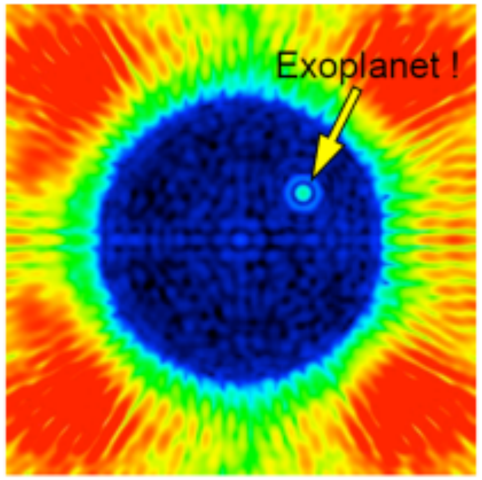
TESS will identify transiting sources for JWST spectroscopy

Characterization: direct imaging (WFIRST-AFTA)

Coronagraph
Architecture:

Primary: OMC
Backup: PIAA

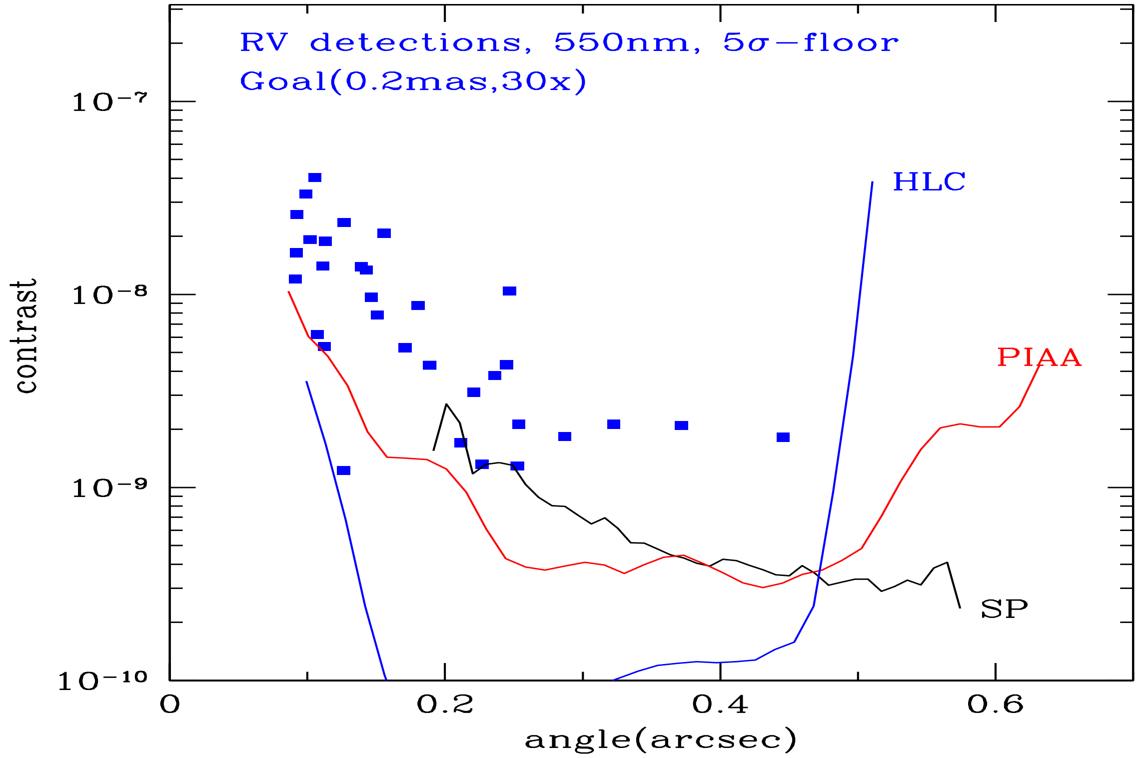
Coronagraph
Instrument

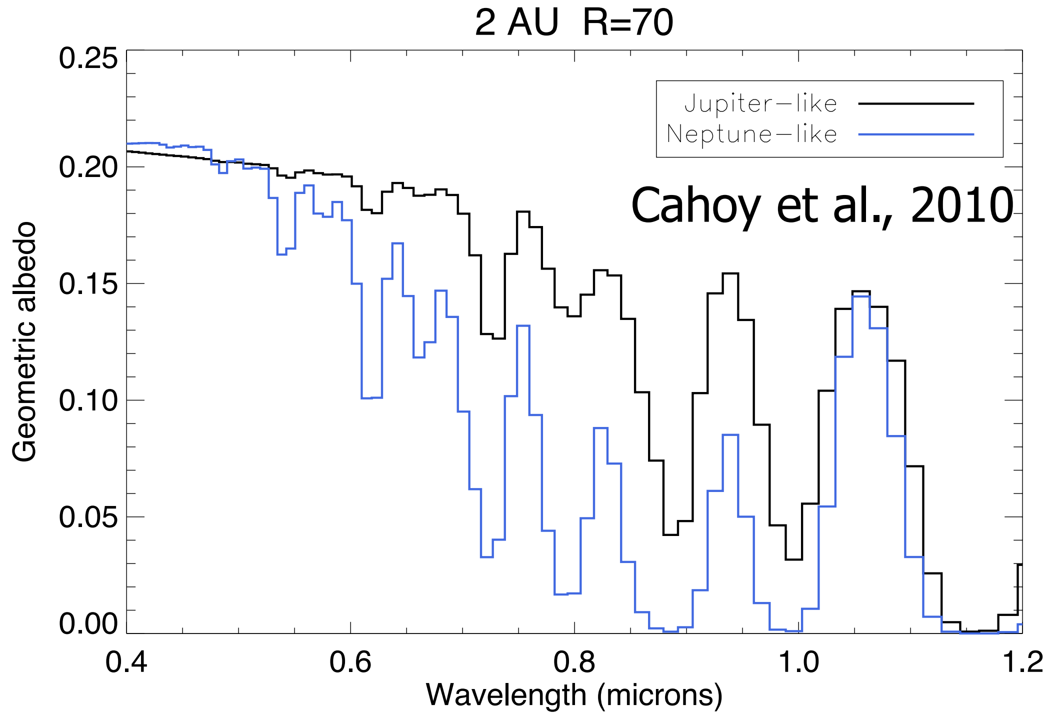


Exo-planet
Direct imaging

Contrast ++
Resolution

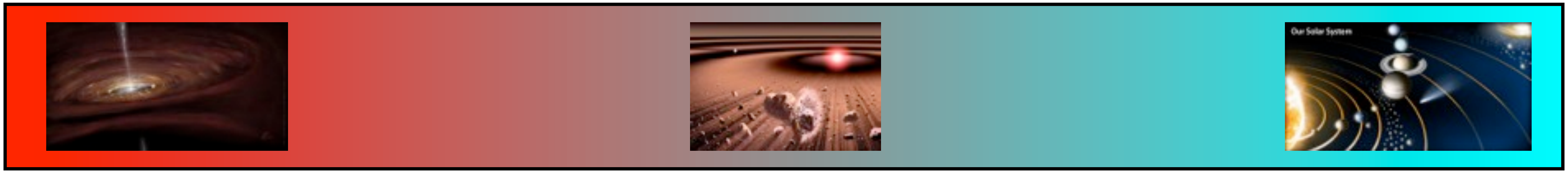
Coronagraph on WFIRST-AFTA will yield Spectra of Giant Planets





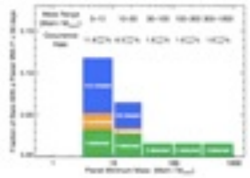
Cahoy et al., 2010

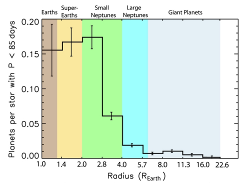
Age 1 Myrs 10 Myrs 100 Myrs 5 Gyrs



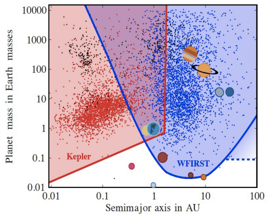
100+ pc 50 pc 10 pc

Statistical distribution of mature planets

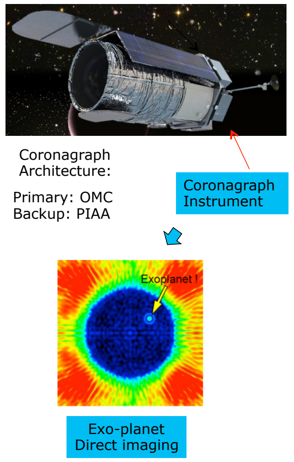




Fressin et al 2013; Kepler FGKM stars P<85 days



Characterization of nearby planets

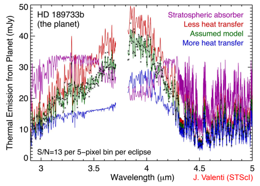


Coronagraph Architecture:

Primary: OMC
Backup: PIAA

Coronagraph Instrument

Exo-planet Direct imaging

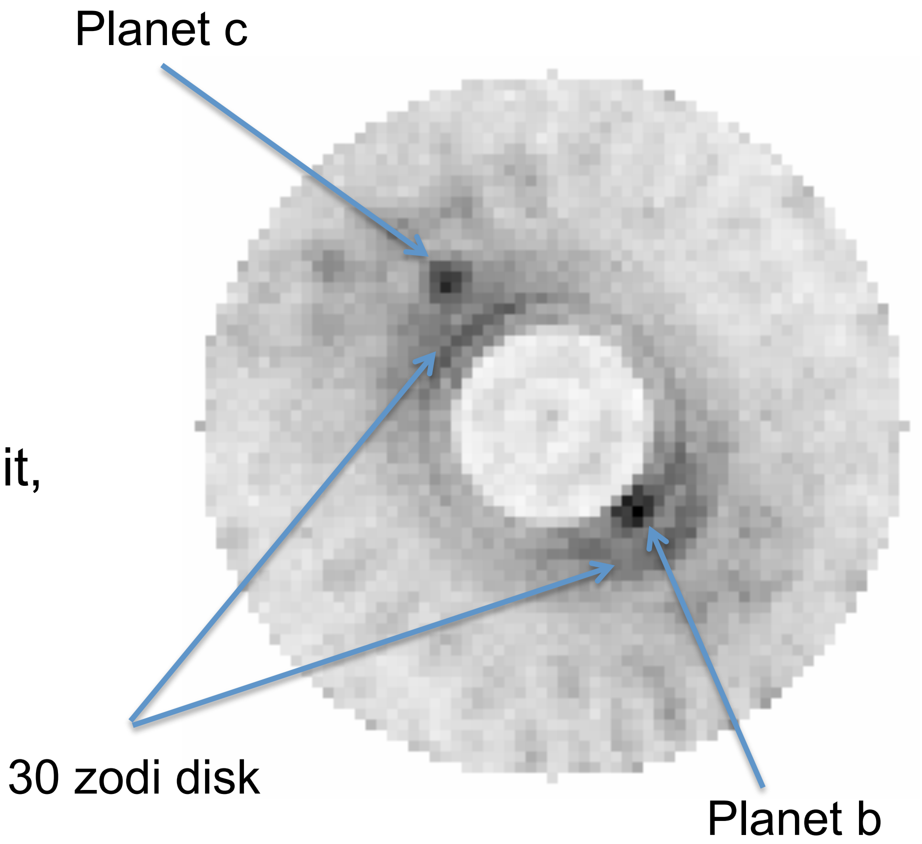


J. Valenti (STScI)

Planets form in disks... characterizing leftover dust

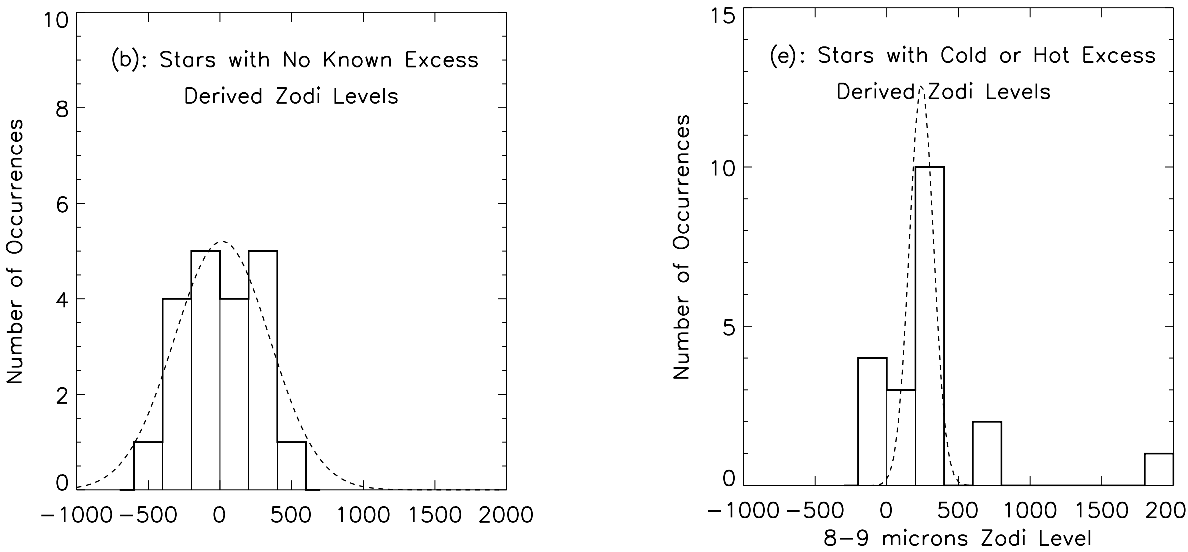
Interferometric Resolution

it,



Credit: Tom Green

Mennesson et al., 2014, **Keck Interferometer**



See also Ertel et al., 2014, **VLT/CHARA**

AFTA-C simulations:
47 Uma with 30 zodi disk

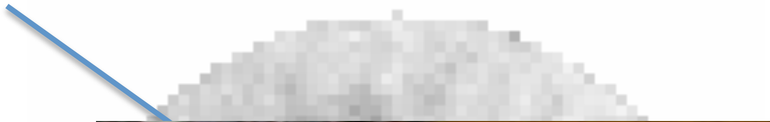
Will zodi be a problem for planet characterization?

- Little zodiacal light around stars with no-far IR excess (<60 zodi).
- Positive correlation between warm and cold dust.

Planets form in disks... characterizing leftover dust

Interferometric Resolution

Planet c

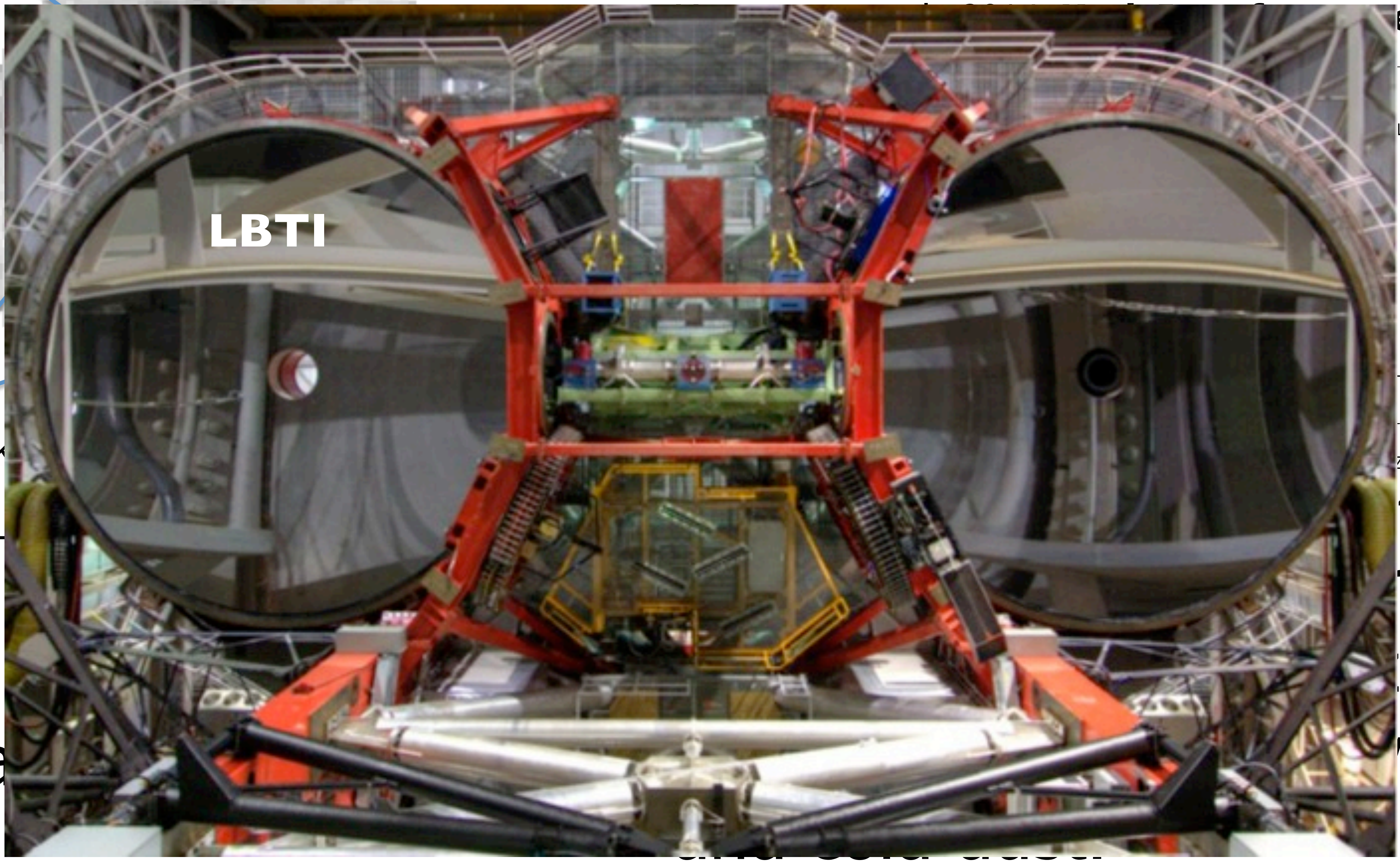


it,

30 zodi disk

Credit: T

AFTA-C
47 Uma



er

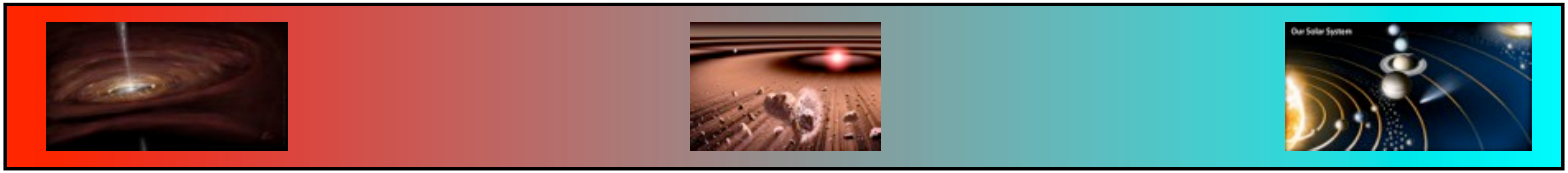
4, **VLT/CHARA**

s with
odi).
warm

Will zodi be a problem for planet characterization?

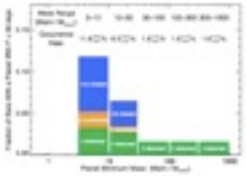
- Ongoing surveys to investigate warm dust vs hot dust.

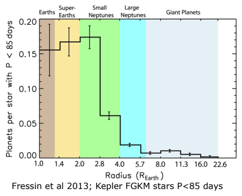
Age 1 Myrs 10 Myrs 100 Myrs 5 Gyrs



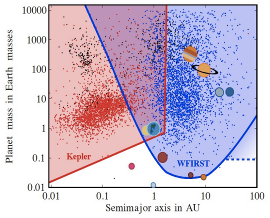
100+ pc 50 pc 10 pc

Statistical distribution of mature planets

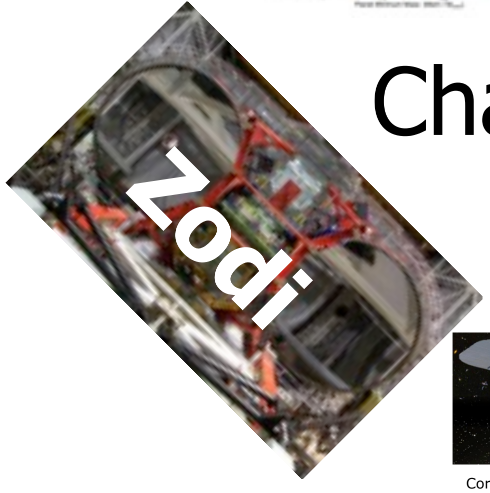


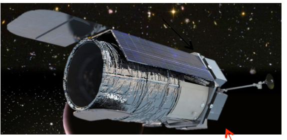


Fressin et al 2013; Kepler FGKM stars P<85 days



Characterization of nearby planets

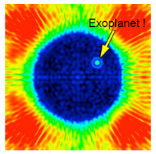




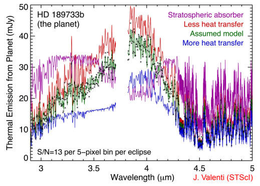
Coronagraph Architecture:

Primary: OMC
Backup: PIAA

Coronagraph Instrument

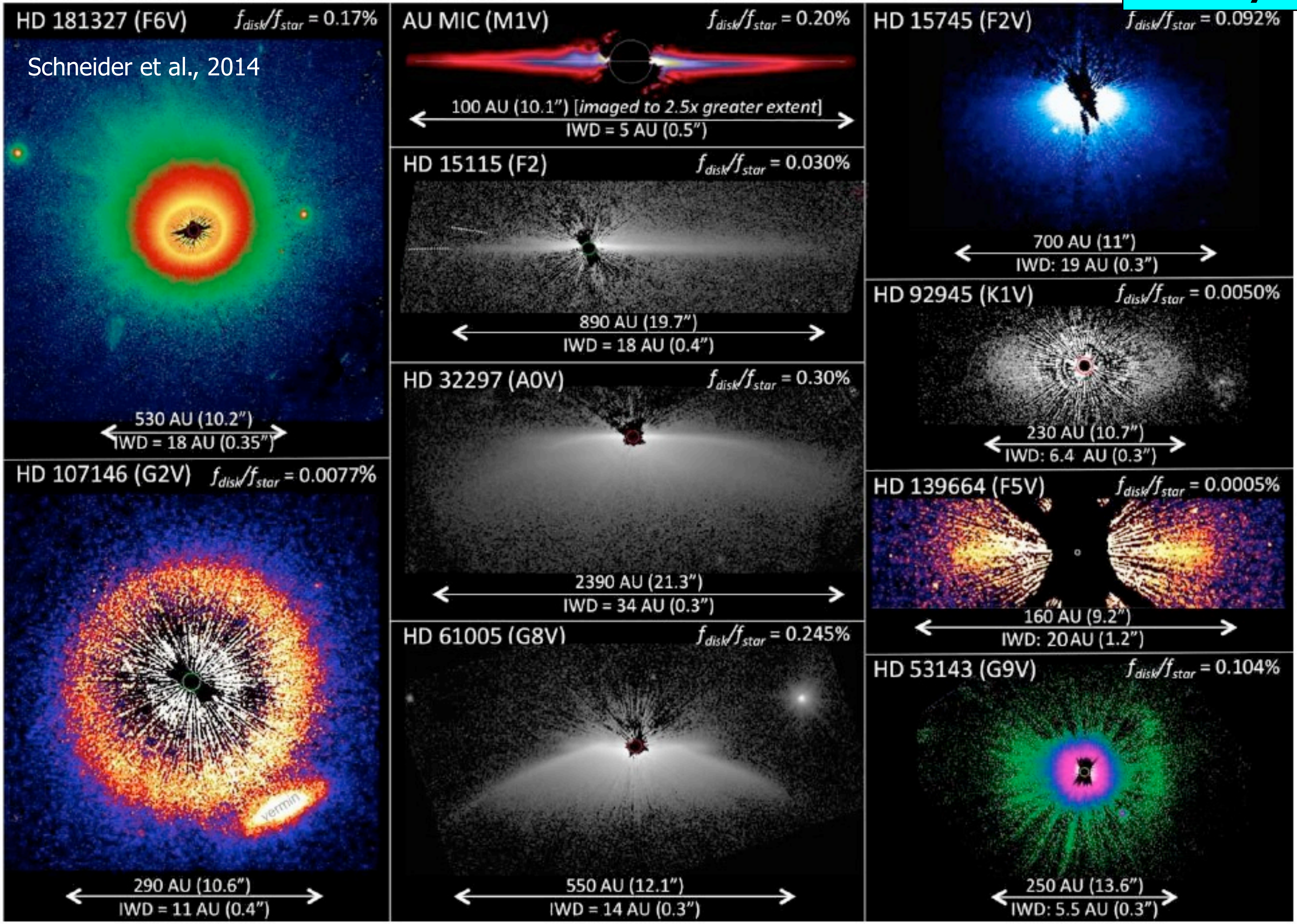


Exo-planet Direct imaging



Debris Disks: second generation dust

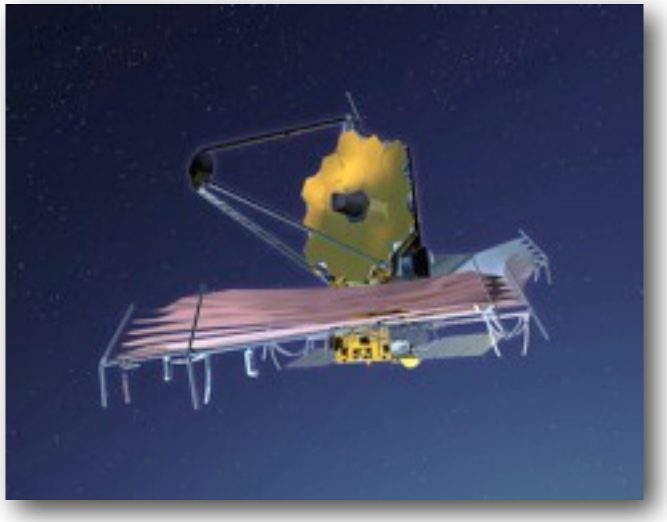
Sensitivity
Stability

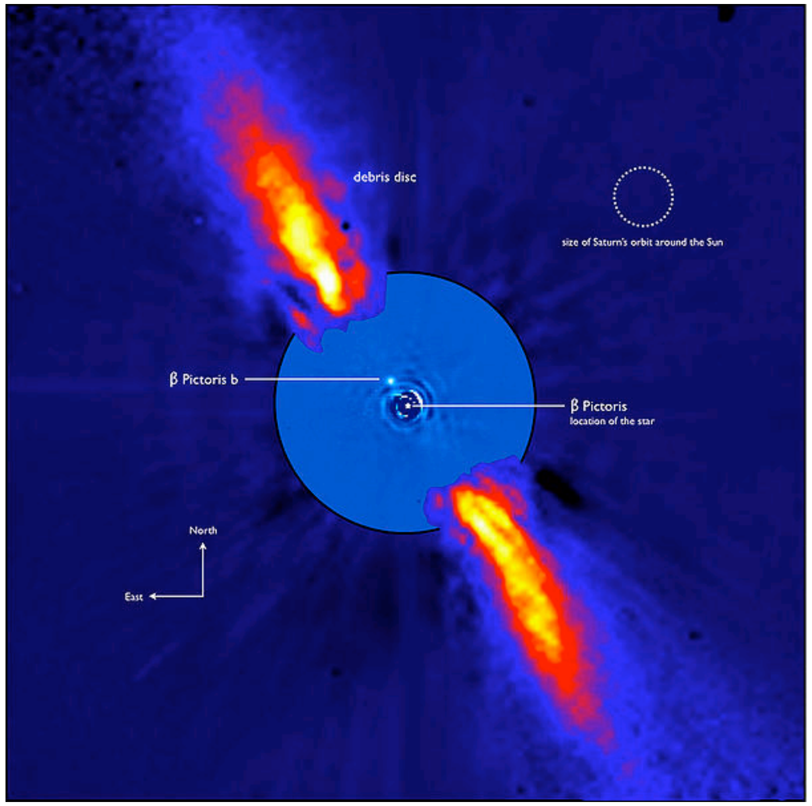


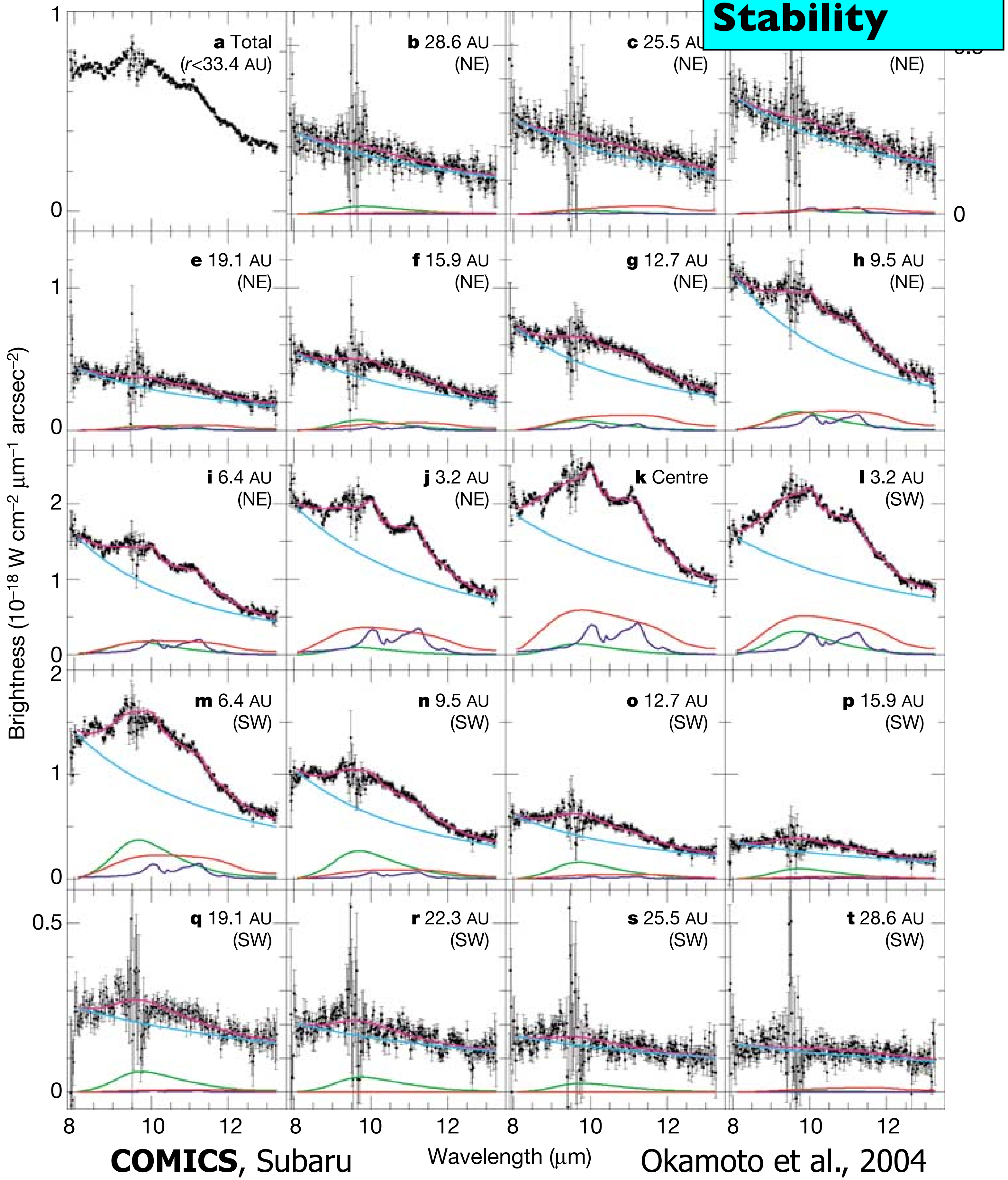
Schneider et al., 2014

JWST: composition of second generation dust

Resolution
Sensitivity
Stability







COMICS, Subaru

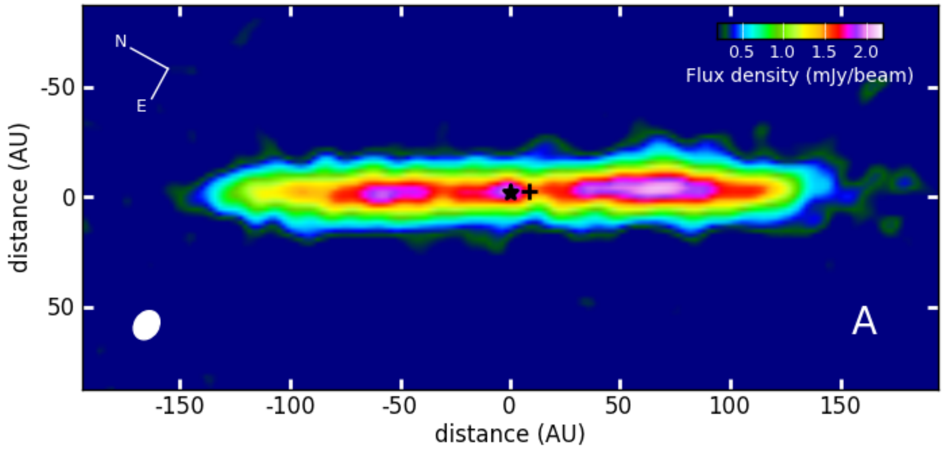
Okamoto et al., 2004

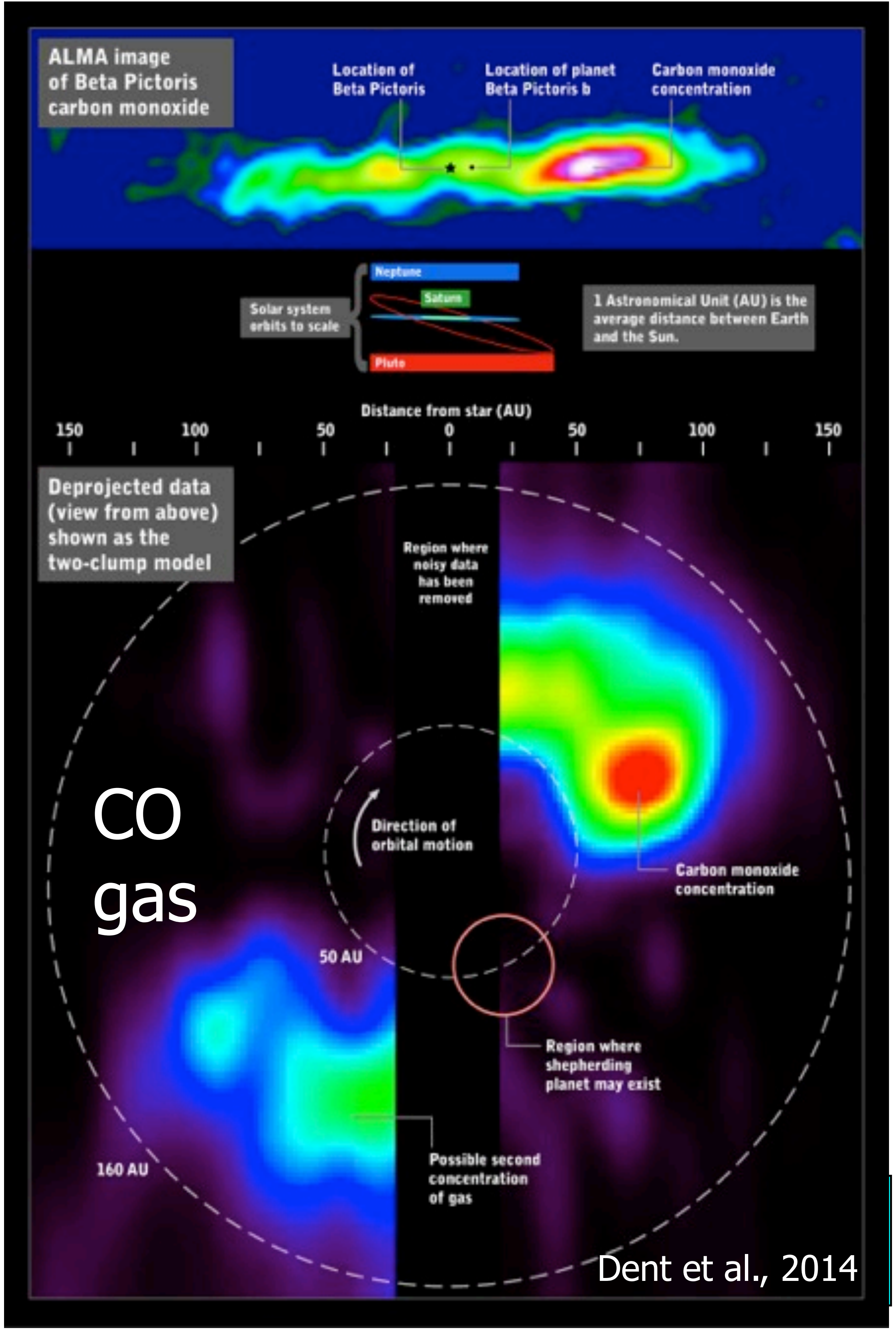
JWST will characterize the dust in debris disks.

ALMA: kinematics of second generation dust

Resolution
Sensitivity

Dust, 850 microns



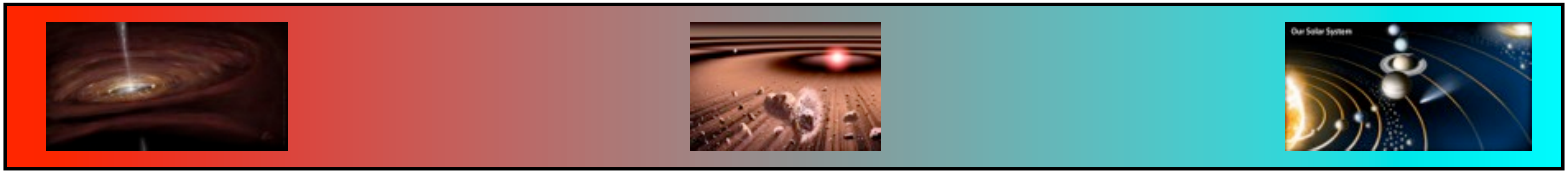


CO gas

Dent et al., 2014

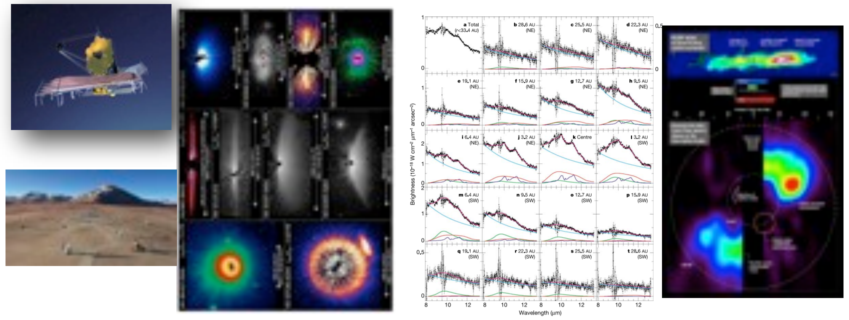
ALMA can identify where collisions occur in debris disks.

Age 1 Myrs 10 Myrs 100 Myrs 5 Gyrs

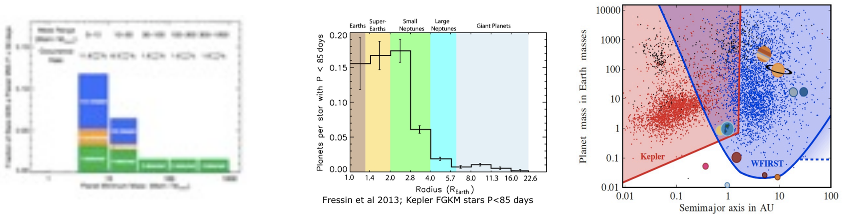


100+ pc 50 pc 10 pc

2nd generation Dust



Statistical distribution of mature planets

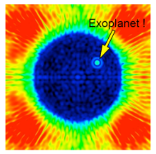


Characterization of nearby planets

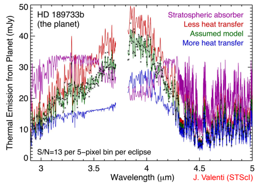
Coronagraph Architecture:

Primary: OMC
Backup: PIAA

Coronagraph Instrument



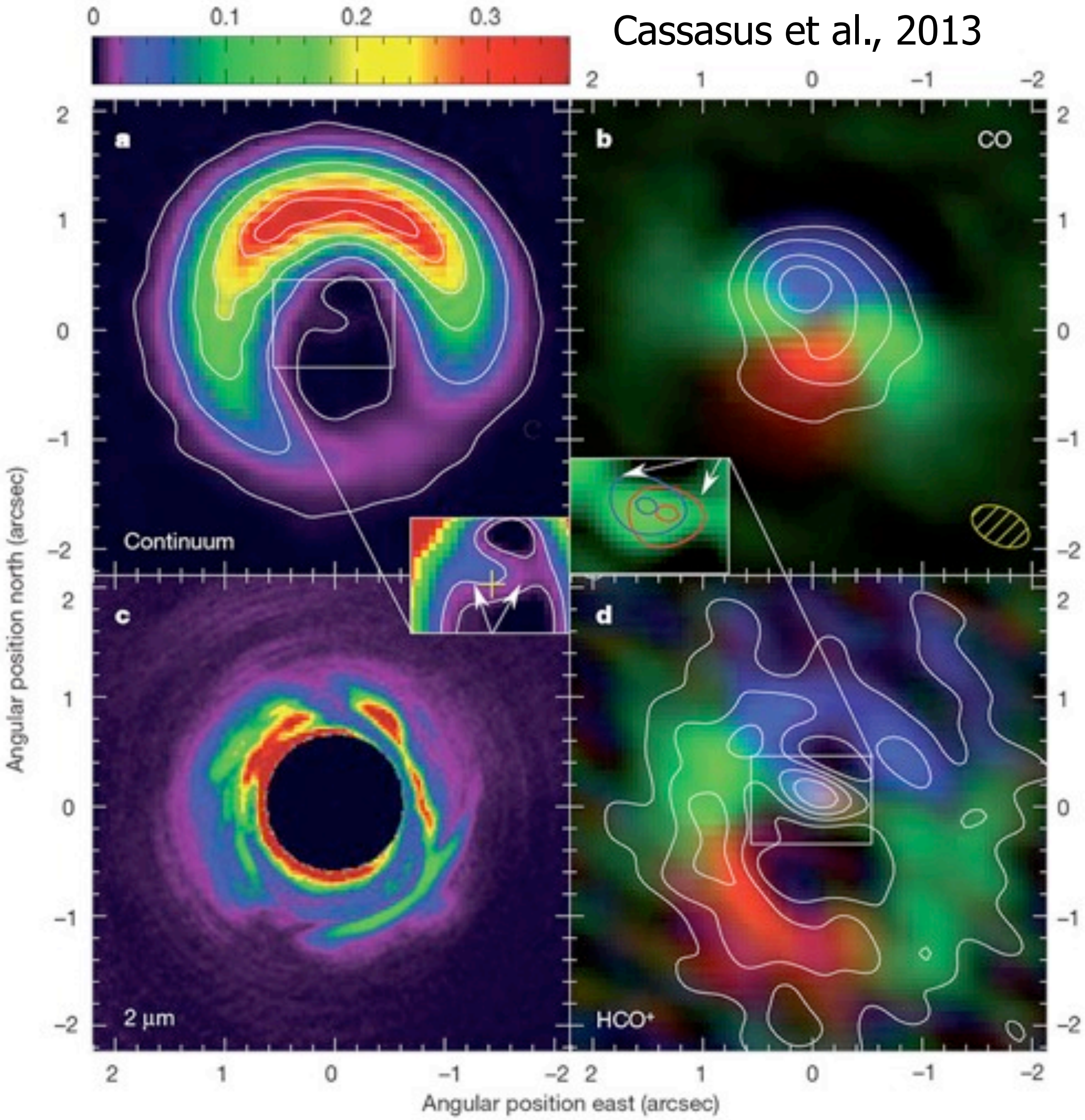
Exo-planet Direct imaging



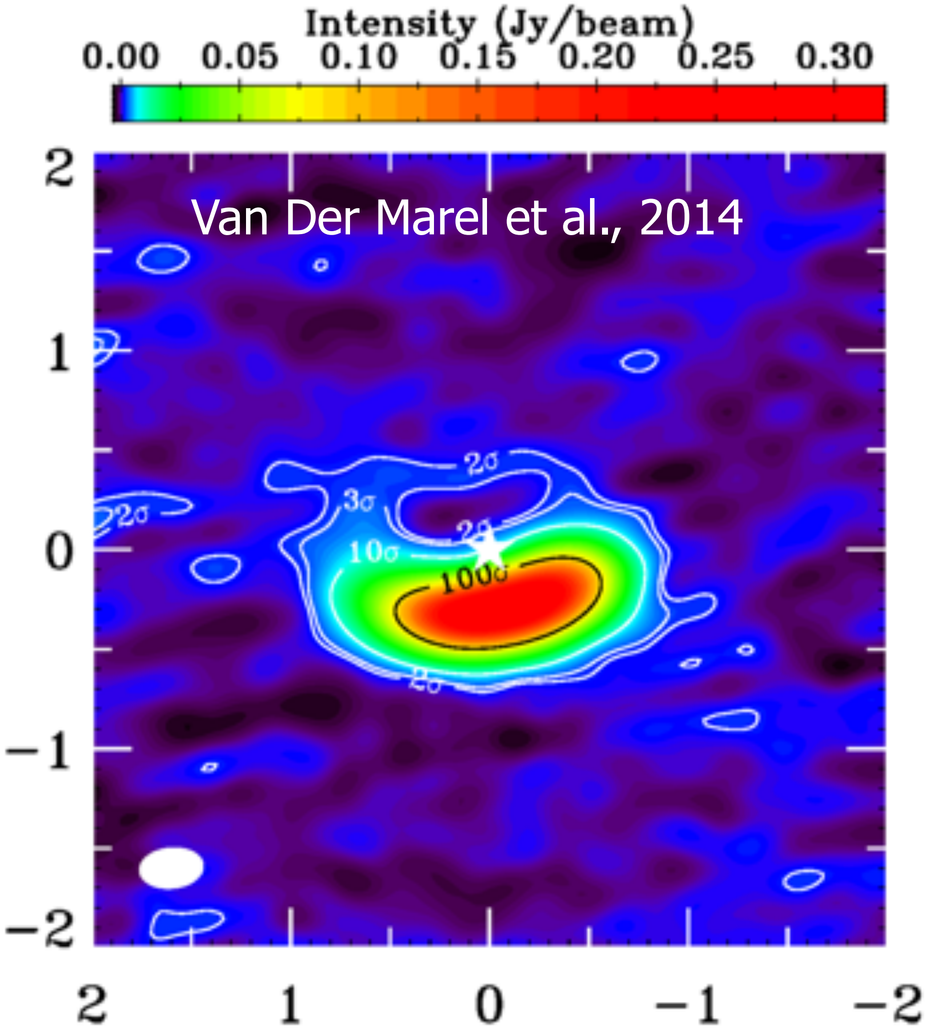
Imaging primordial disk with ALMA

Resolution
Sensitivity

- ALMA will identify dust inhomogeneities in the primordial disk.
- ALMA will trace the kinematics of the primordial gas.



Cassasus et al., 2013



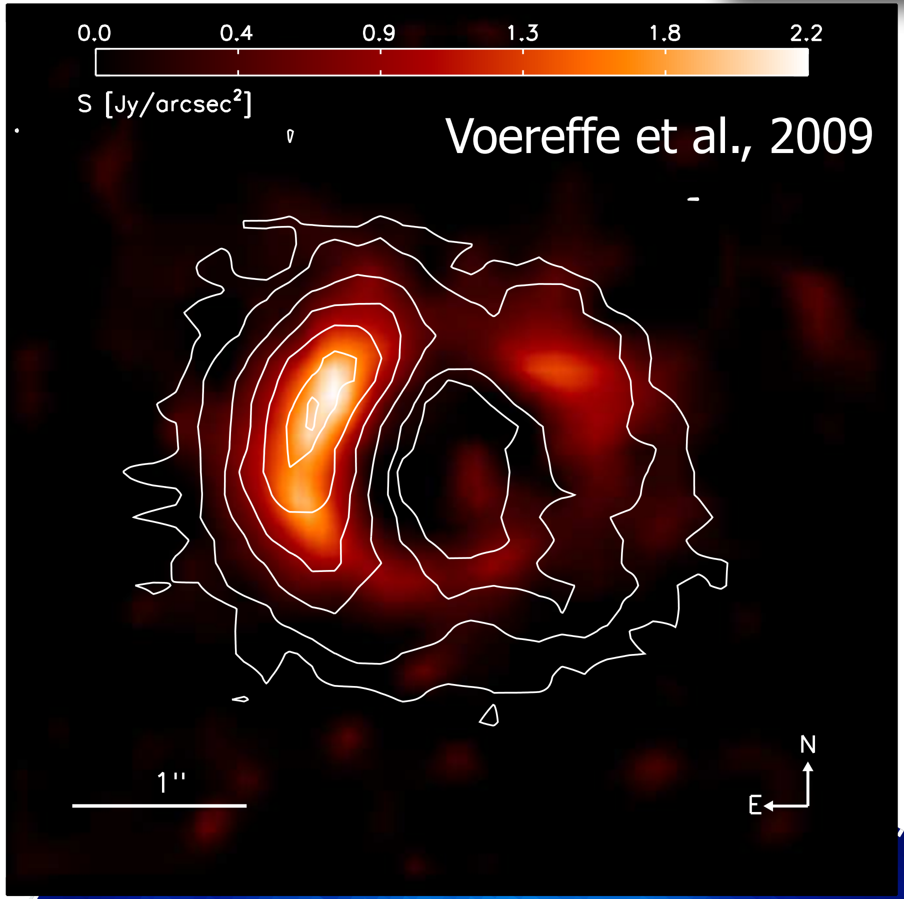
Van Der Marel et al., 2014

Imaging primordial disk with JWST

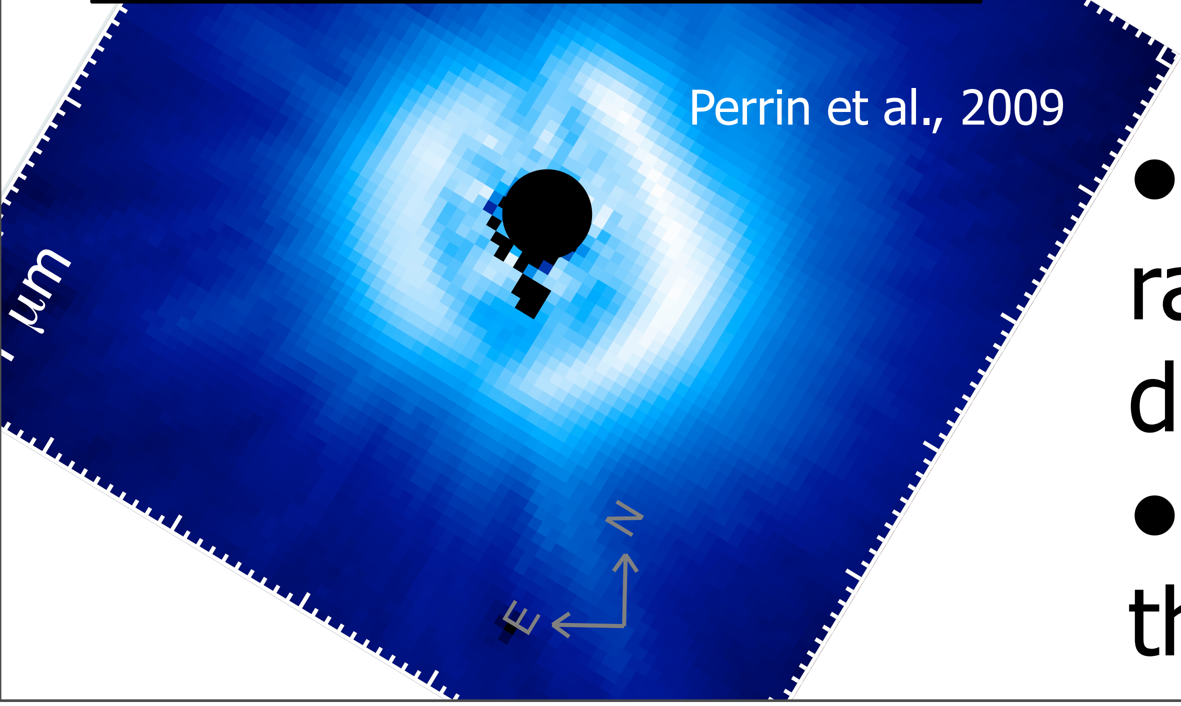
Resolution
Sensitivity
Stability

Same source in near and mid-IR

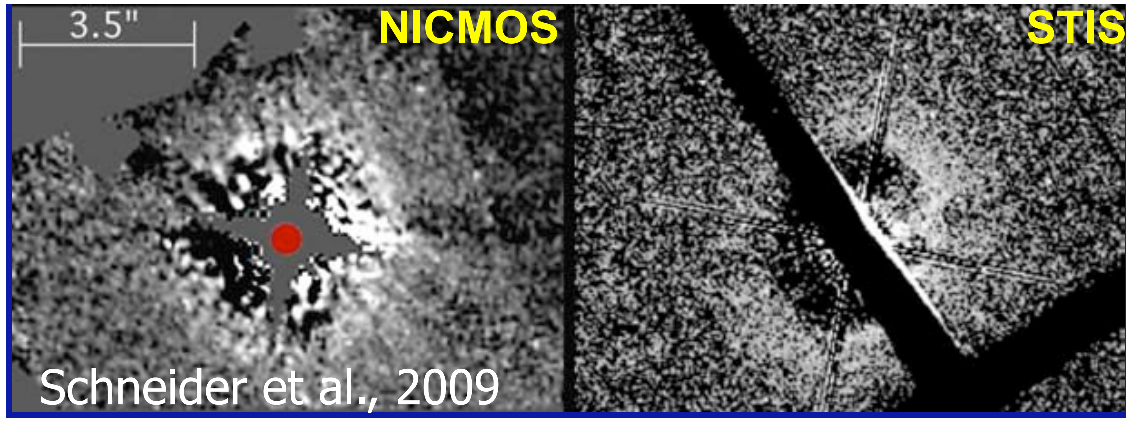
Fainter disks around T Tauri Stars



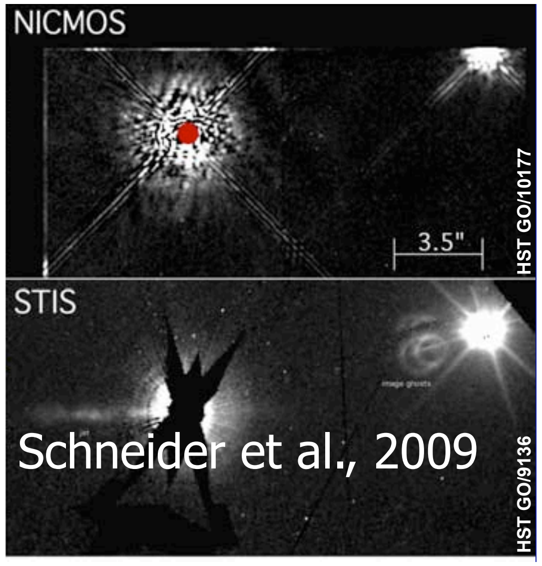
Voereffe et al., 2009



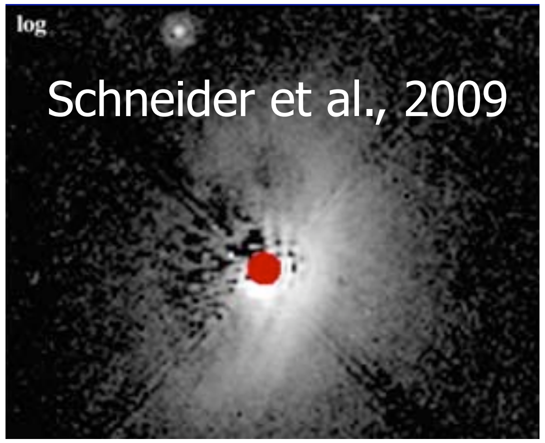
Perrin et al., 2009



Schneider et al., 2009



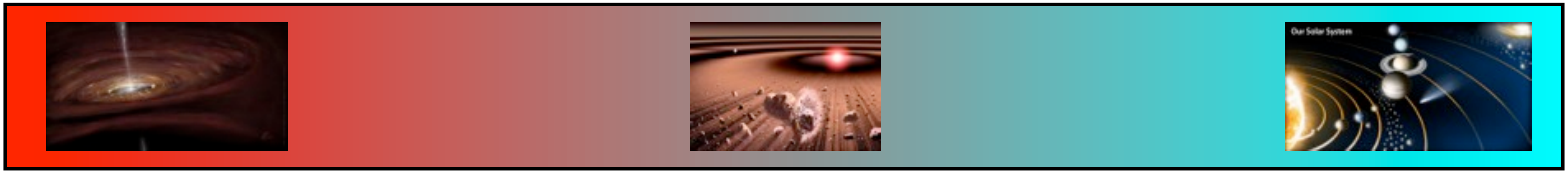
Schneider et al., 2009



Schneider et al., 2009

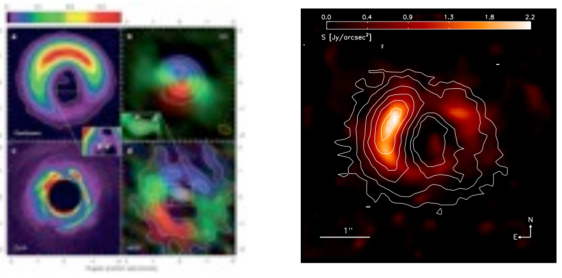
- JWST will characterize the mid-IR radiation and surface brightness of the dust, regardless of stellar mass.
- JWST spectroscopy will characterize the rich chemistry in these disk.

Age 1 Myrs 10 Myrs 100 Myrs 5 Gyrs

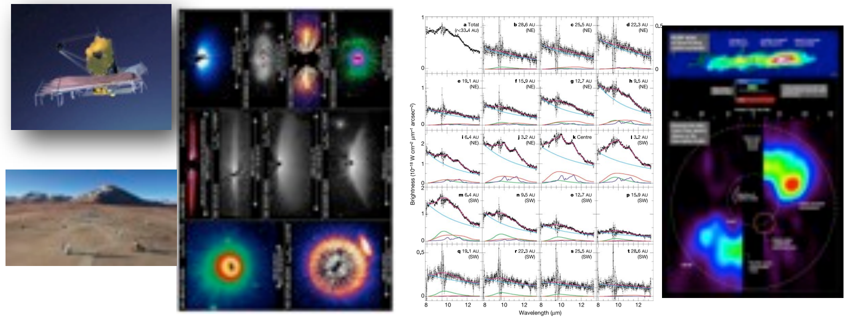


100+ pc 50 pc 10 pc

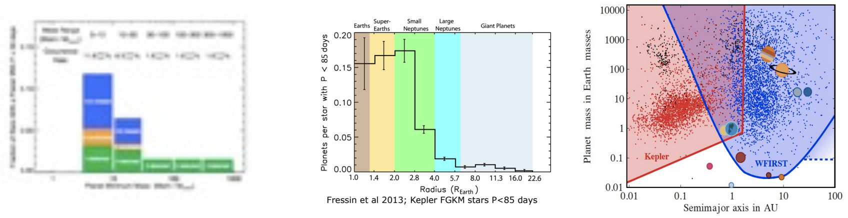
Primordial disk



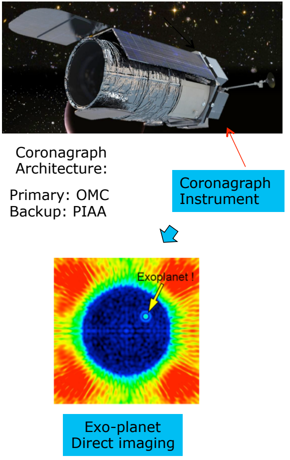
2nd generation Dust



Statistical distribution of mature planets



Characterization of nearby planets

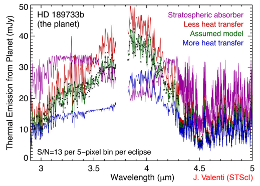

Coronagraph Architecture:

Primary: OMC
Backup: PIAA

Coronagraph Instrument

Exoplanet!

Exo-planet Direct imaging

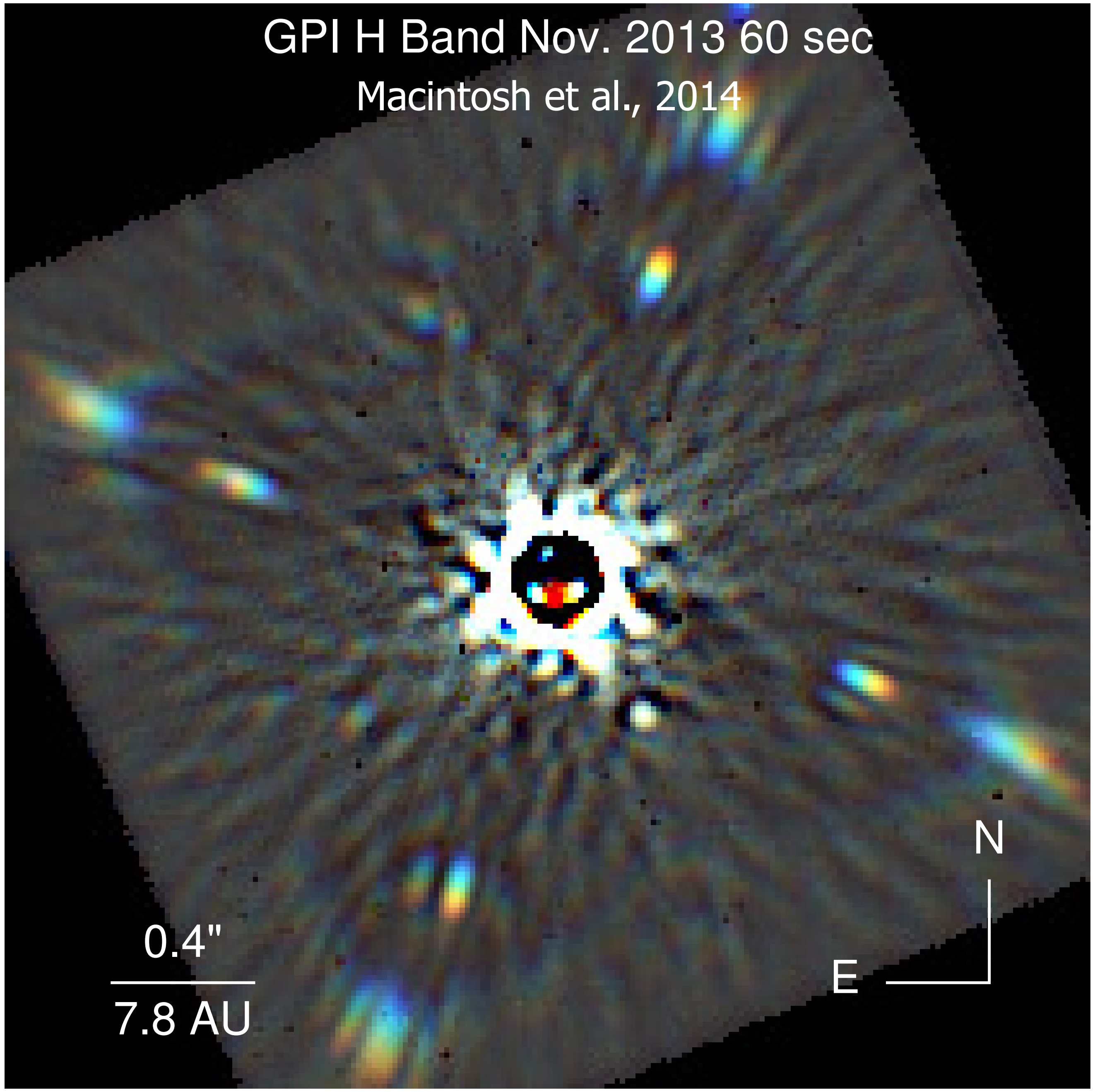


Characterizing adolescent planets.

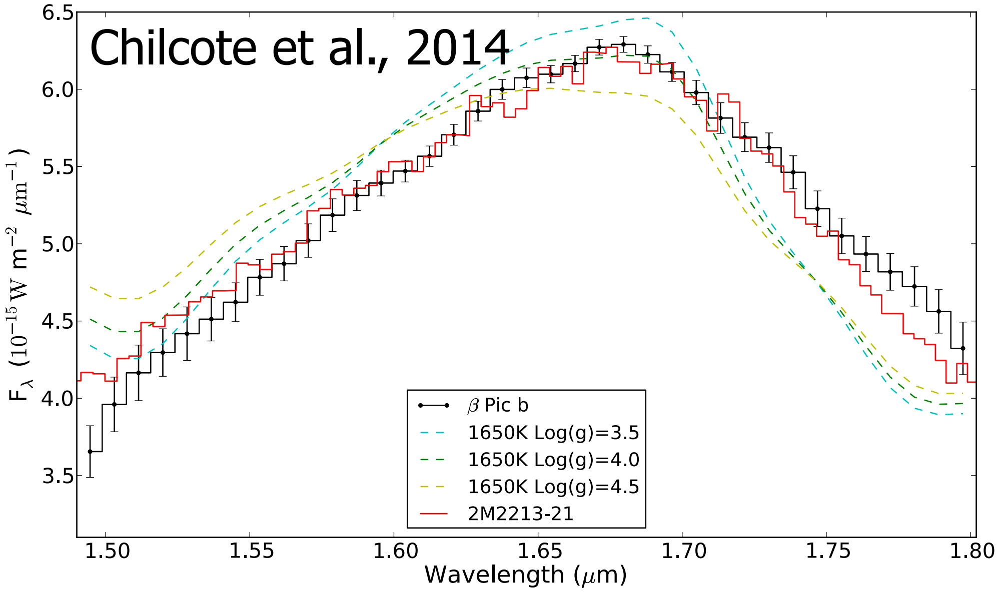
Resolution Contrast

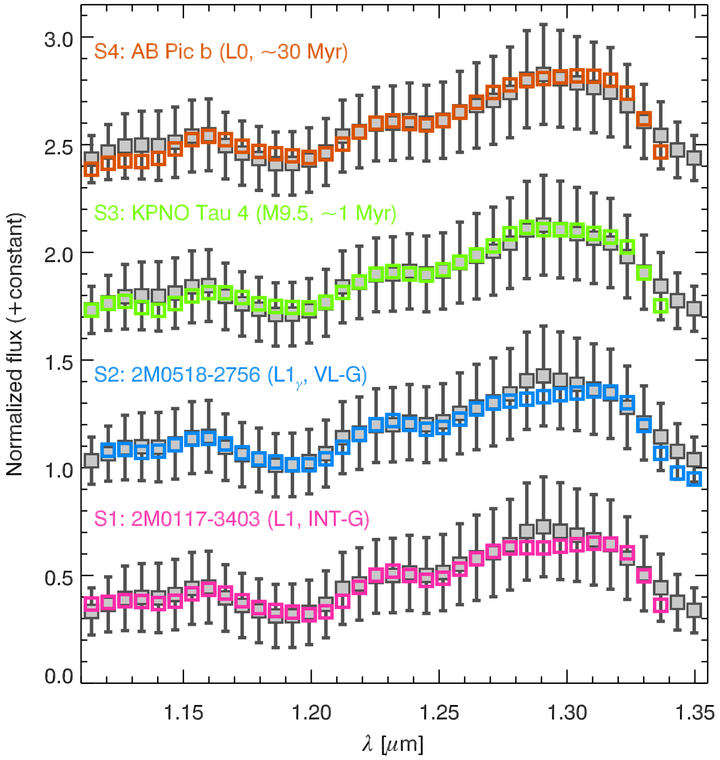
Extreme Adaptive Optics on 8 m telescopes will find a characterize adolescent planets around young nearby stars.

Near-IR Spectra


GPI H Band Nov. 2013 60 sec

Macintosh et al., 2014


Chilcote et al., 2014



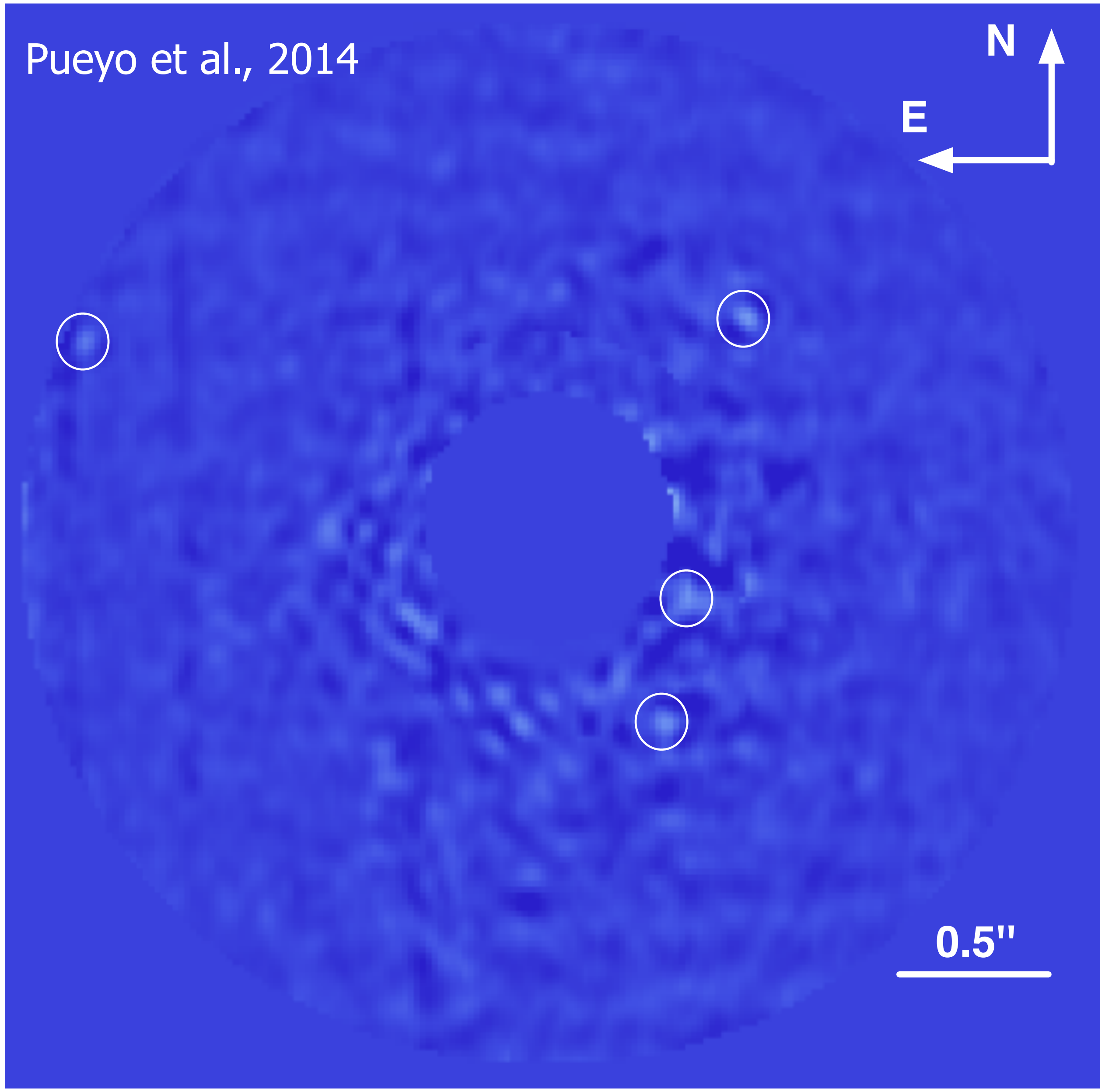
Bonnefoy et al., 2014

Characterizing adolescent planets.

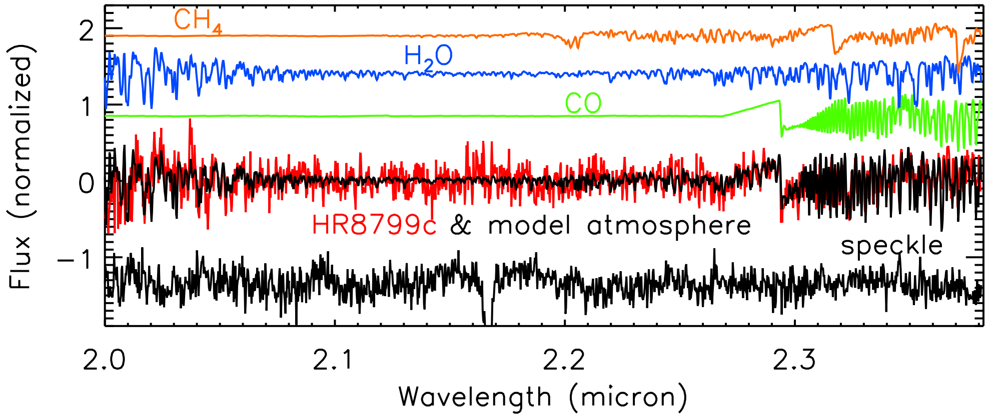
Resolution
Contrast

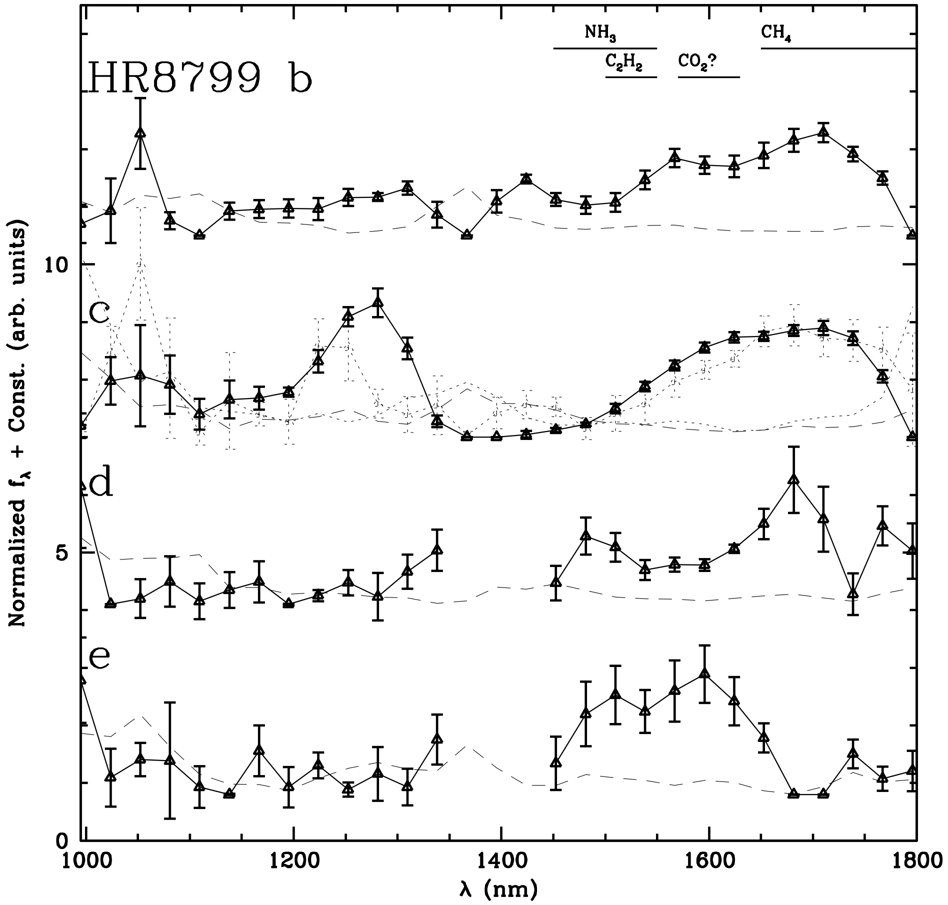
Extreme Adaptive Optics on 8 m telescopes will find a characterize adolescent planets around young nearby stars.

Near-IR Spectra


Pueyo et al., 2014

Konopacky et al., 2014





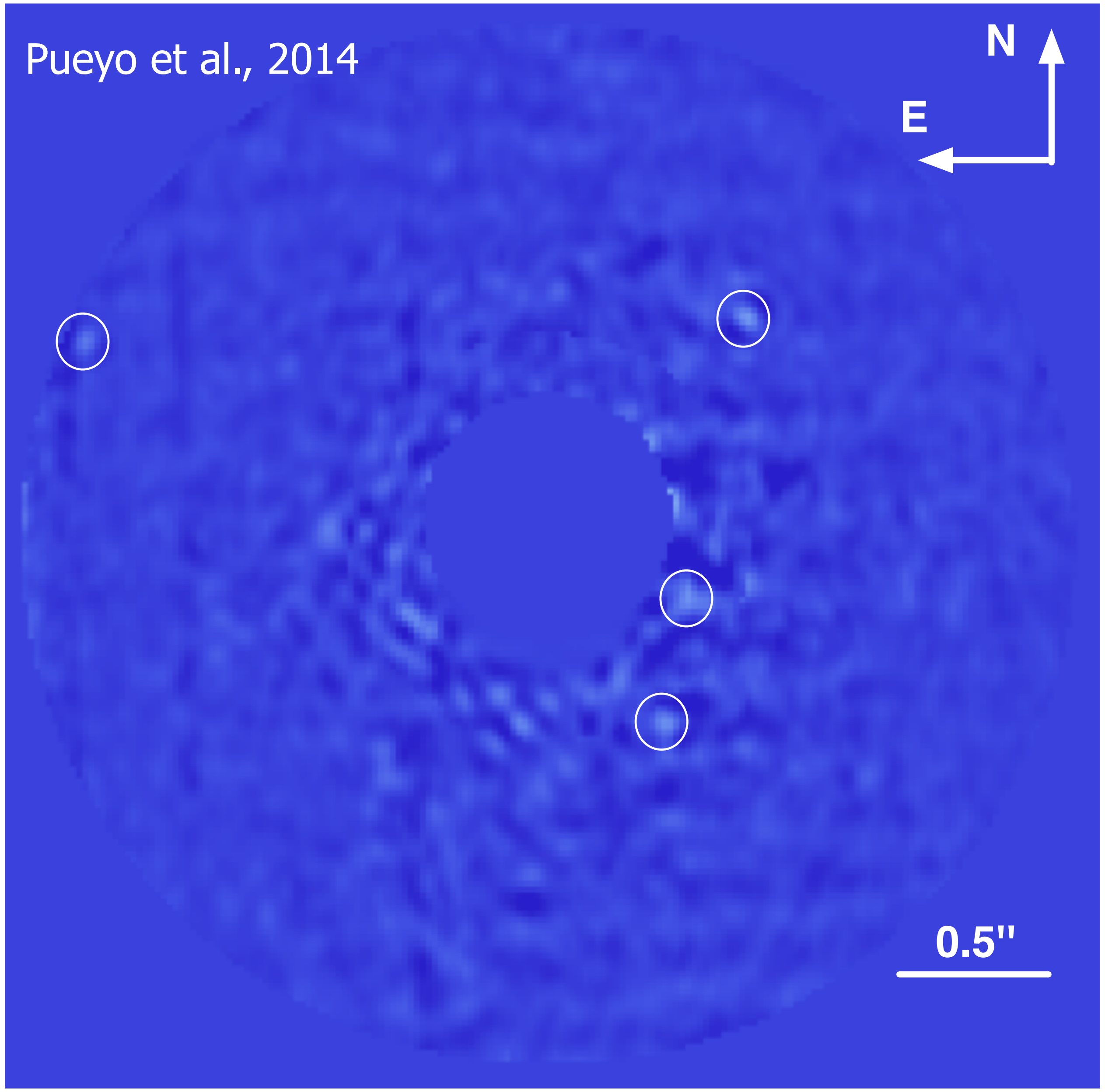
Oppenheimer et al., 2013

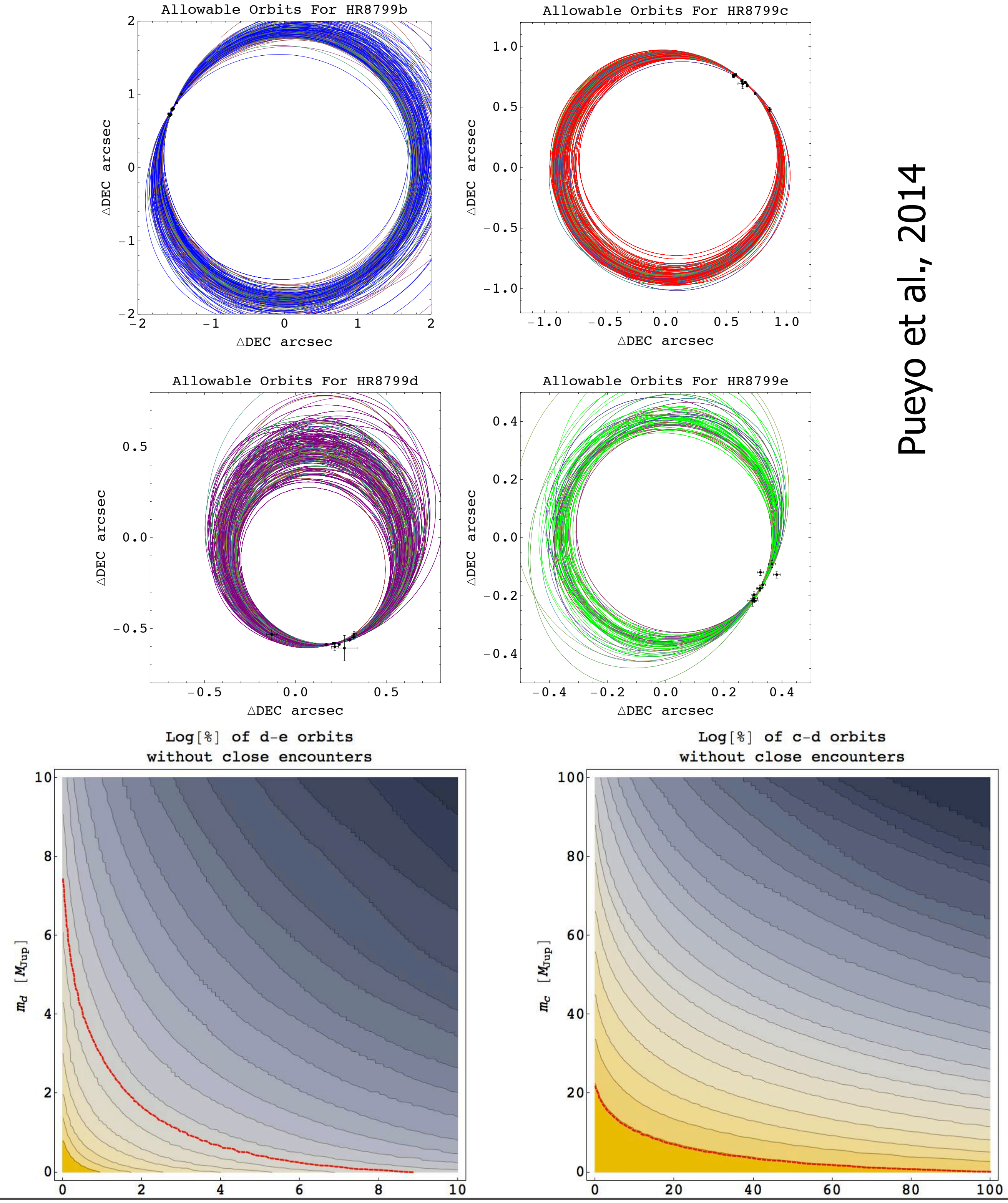
Characterizing adolescent planets.

Resolution Contrast

Extreme Adaptive Optics on 8 m telescopes will find a characterize adolescent planets around young nearby stars.

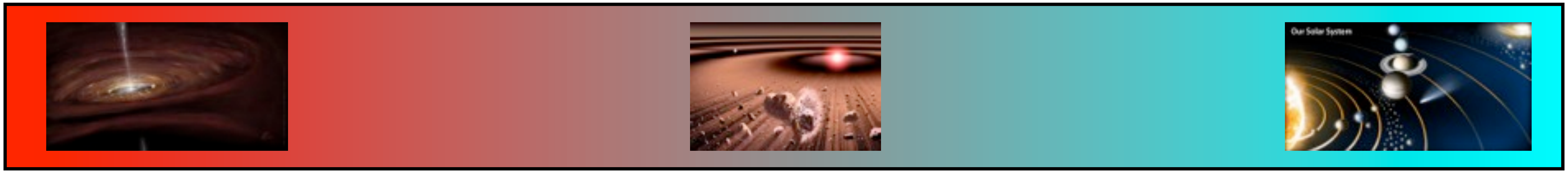
Orbits, dynamics





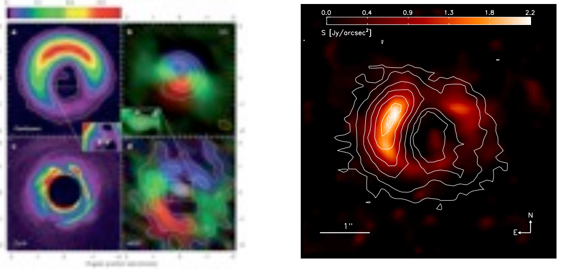
Pueyo et al., 2014

Age 1 Myrs 10 Myrs 100 Myrs 5 Gyrs

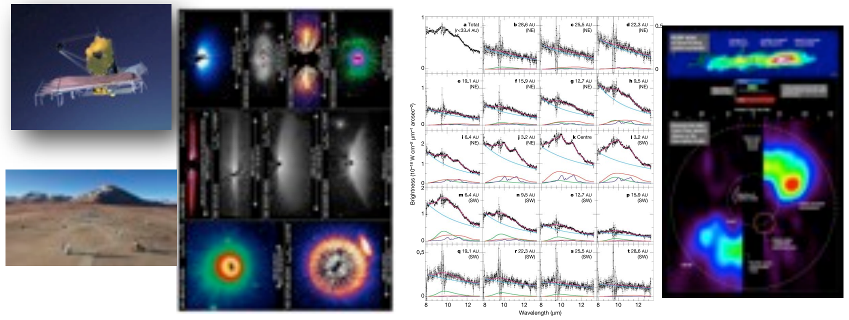


100+ pc 50 pc 10 pc

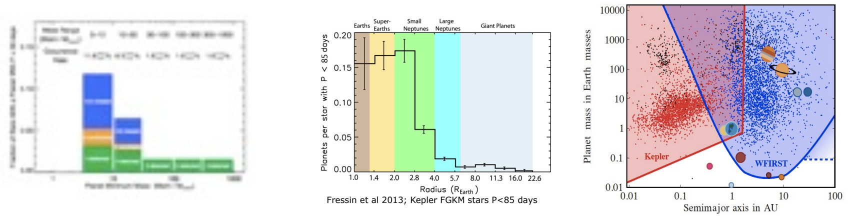
Primordial disk



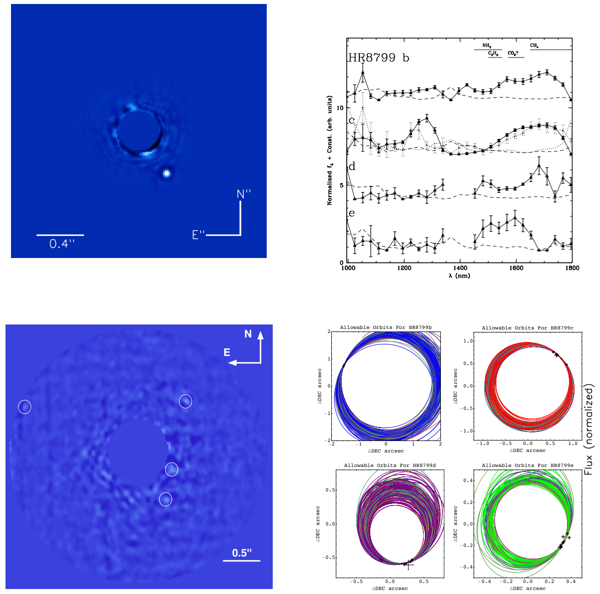
2nd generation Dust

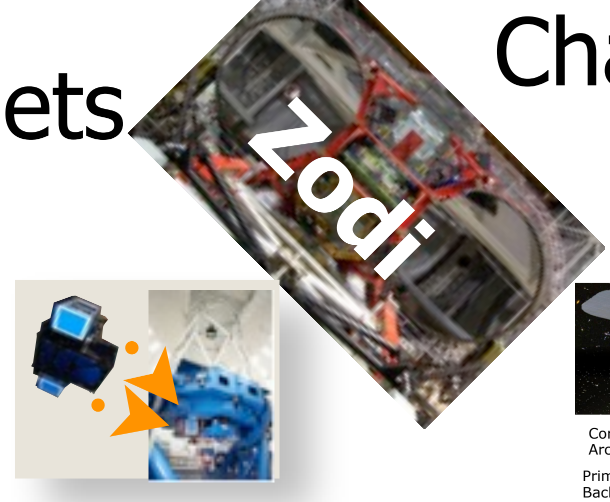


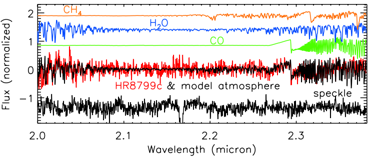
Statistical distribution of mature planets



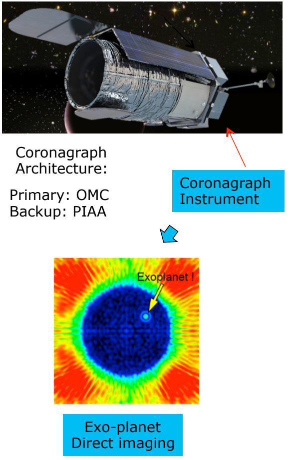
Adolescent Planets







Characterization of nearby planets

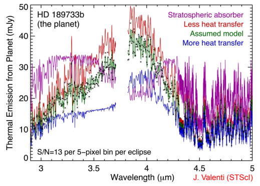


Coronagraph Architecture:

Primary: OMC
Backup: PIAA

Coronagraph Instrument

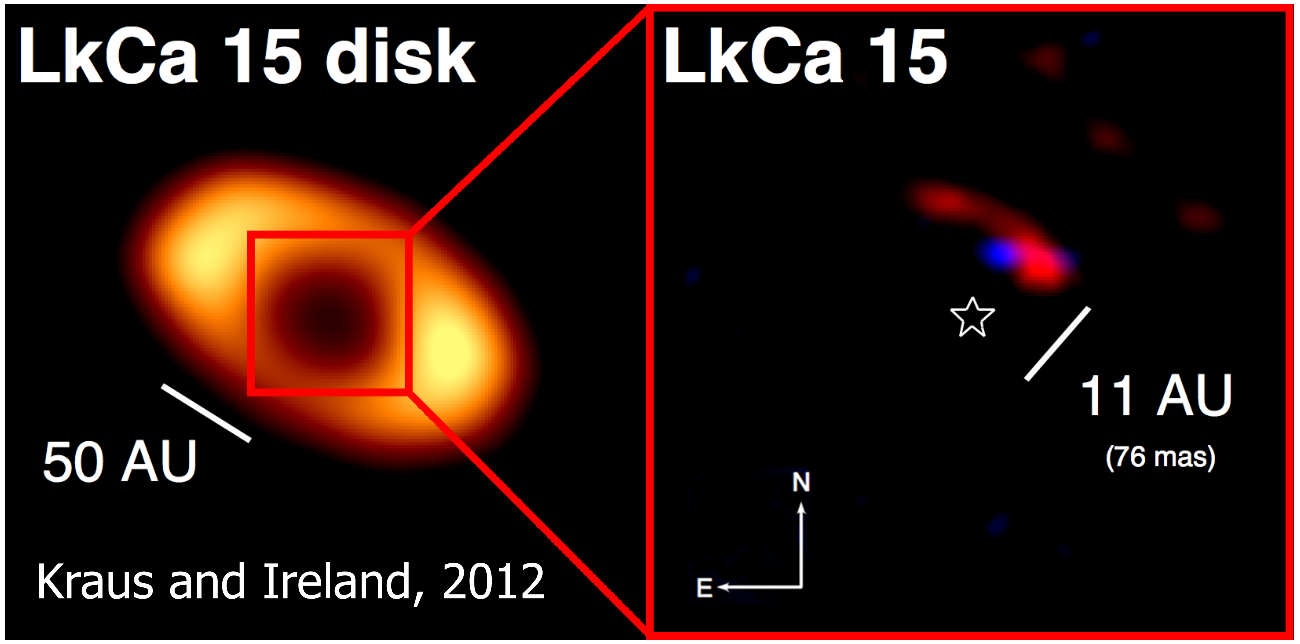
Exo-planet Direct imaging



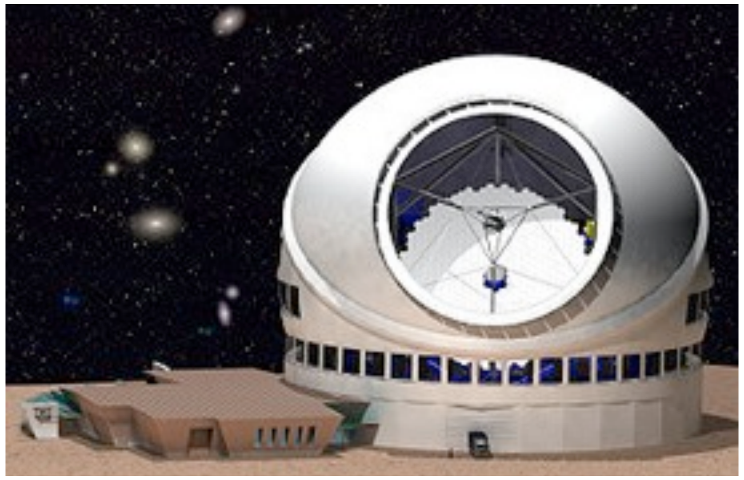
Planetary birth with ELTs

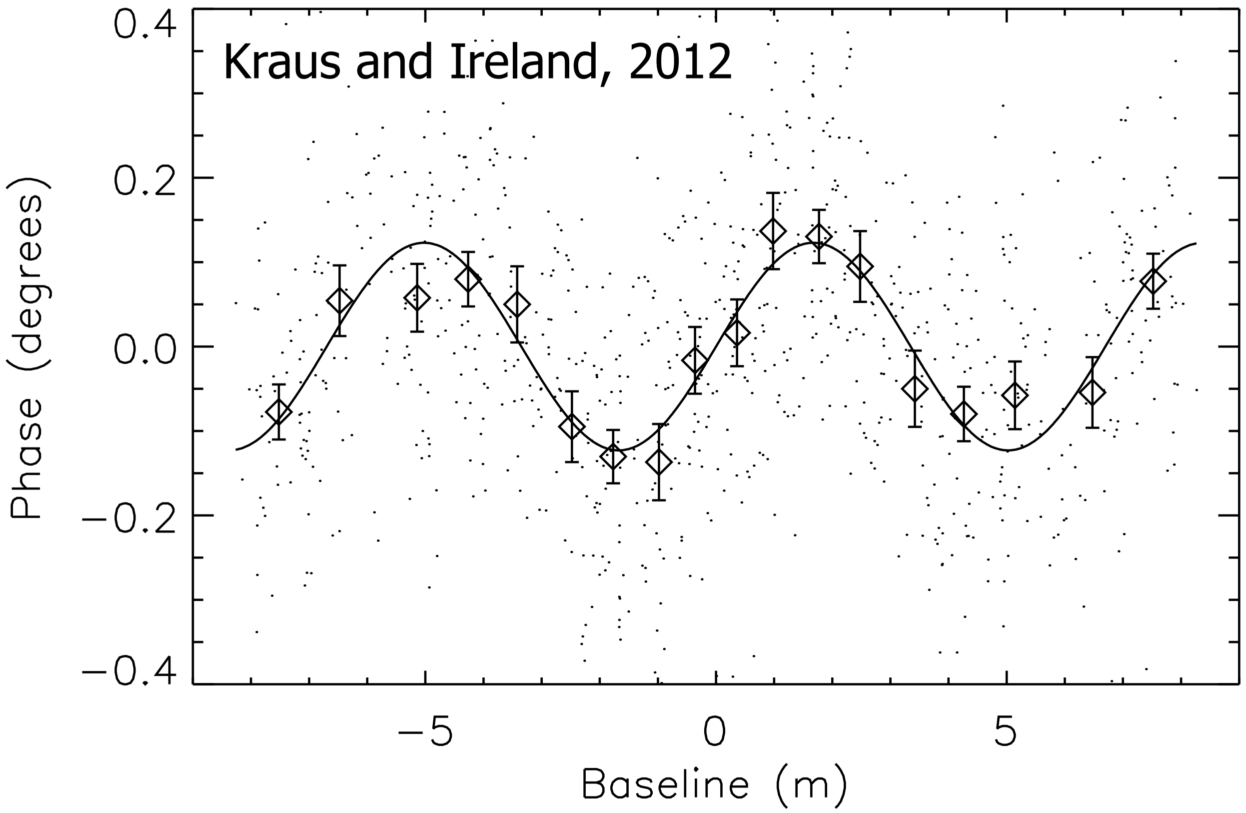
Resolution
Contrast
Sensitivity

10 AU in star forming regions < 100 mas.
Interferometric techniques on 8 m.

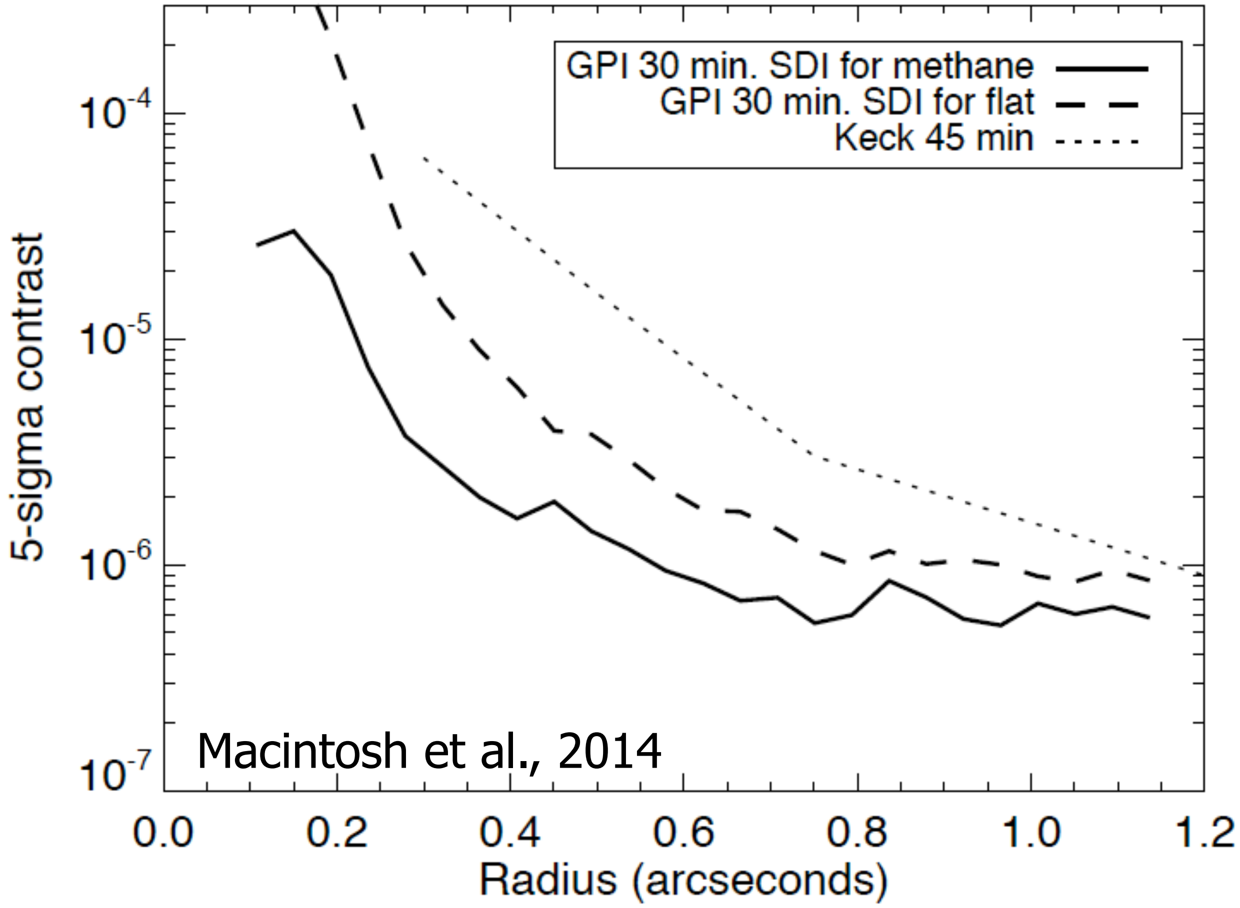


Kraus and Ireland, 2012





Kraus and Ireland, 2012



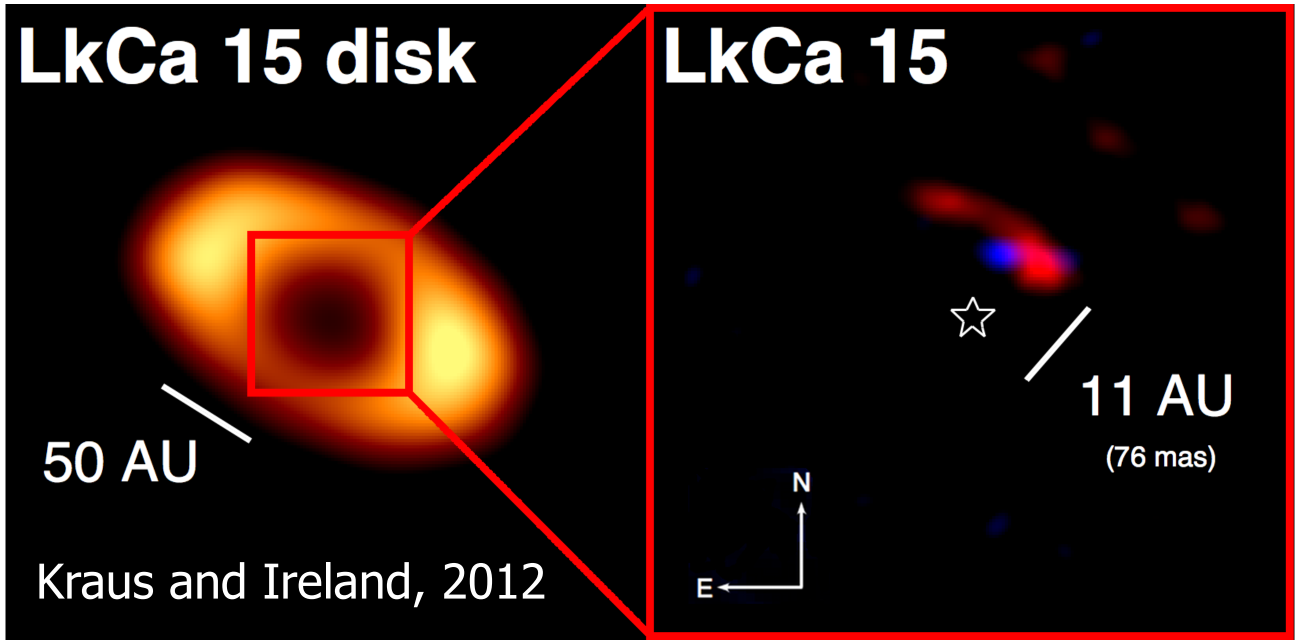
Macintosh et al., 2014

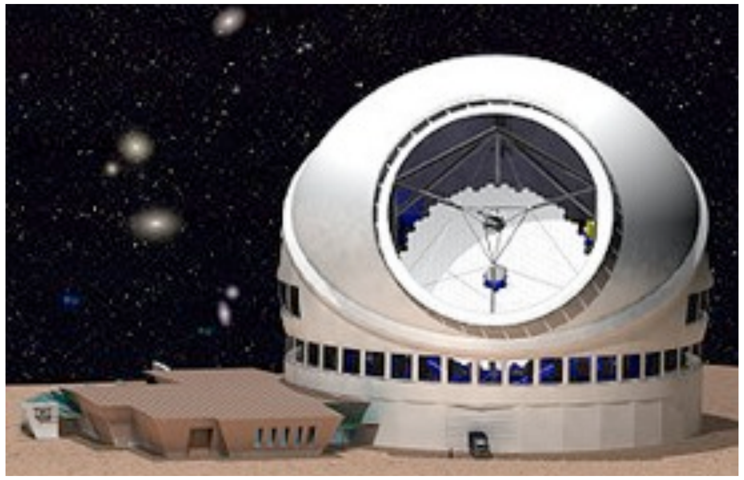
ELTs will image planetary birth in -situ.

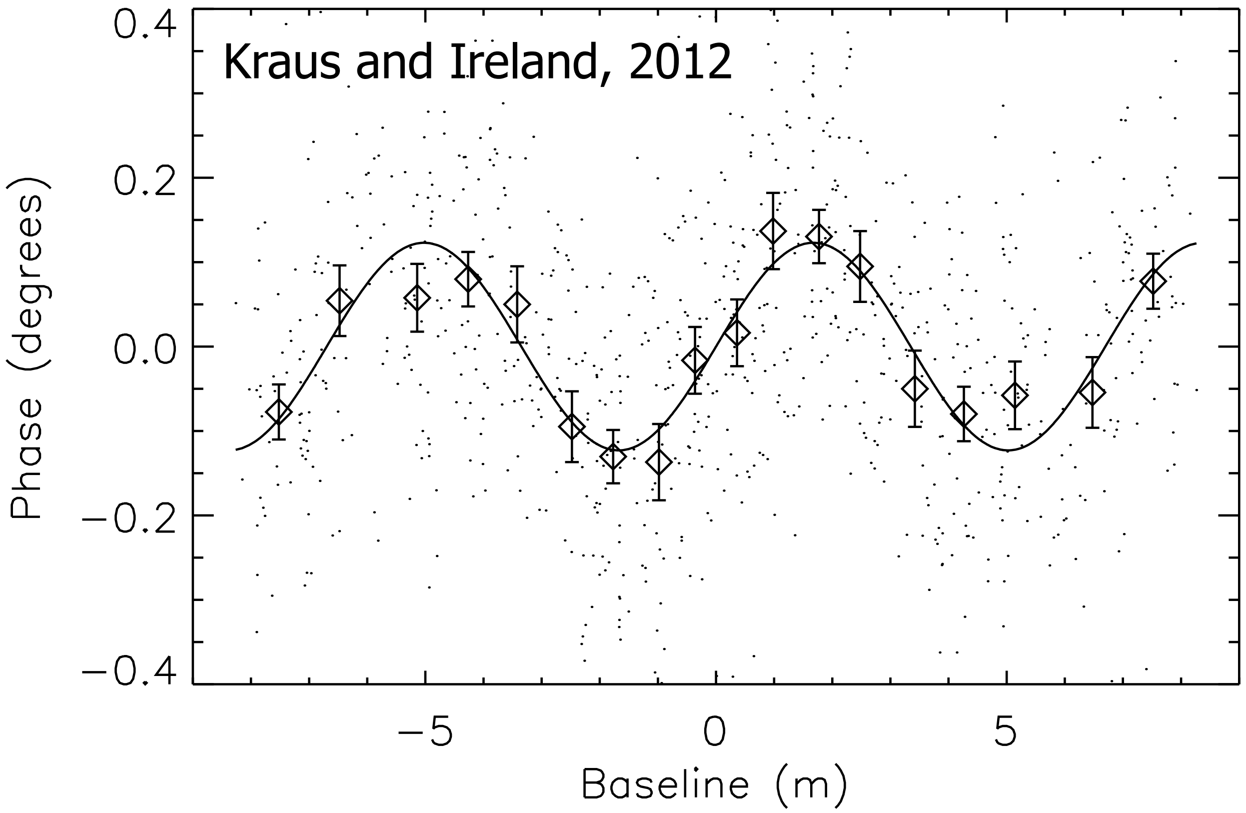
Planetary birth with ELTs

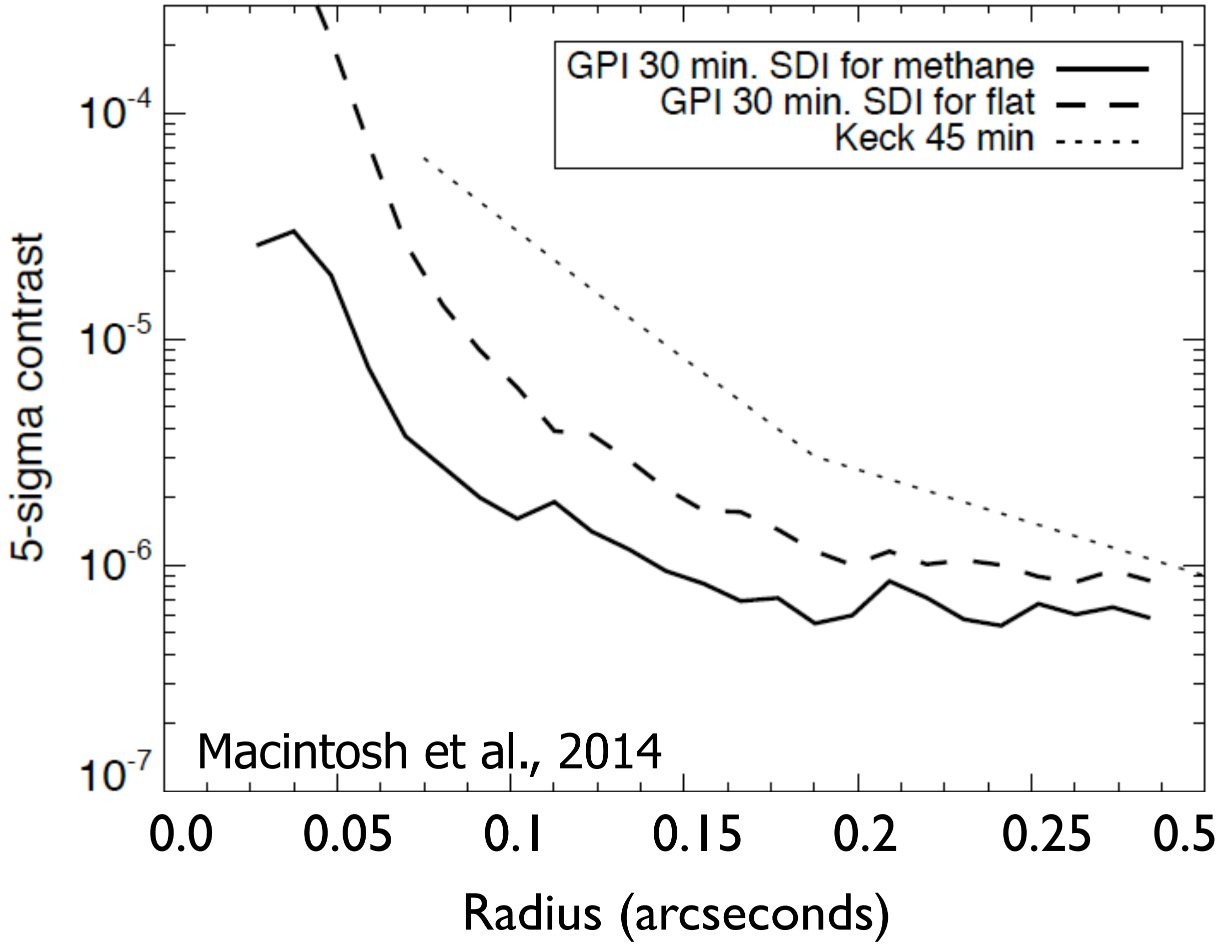
Resolution
Contrast
Sensitivity

10 AU in star forming regions < 100 mas.
Interferometric techniques on 8 m.



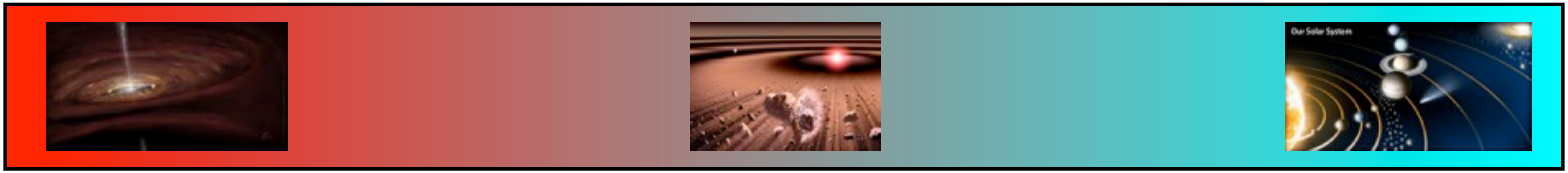






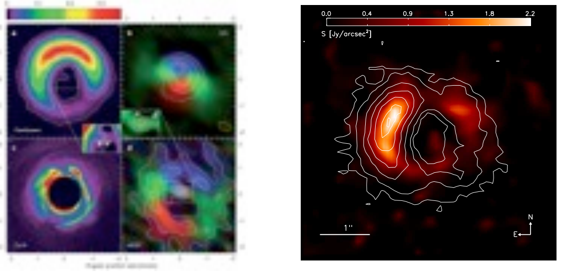
ELTs will image planetary birth at ~10 AU in situ.

Age 1 Myrs 10 Myrs 100 Myrs 5 Gyrs

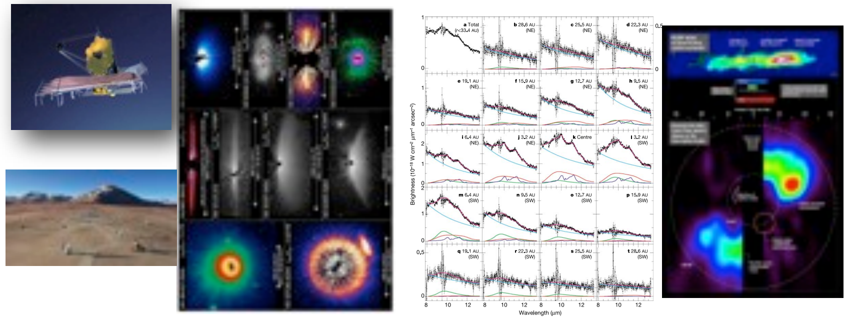


100+ pc 50 pc 10 pc

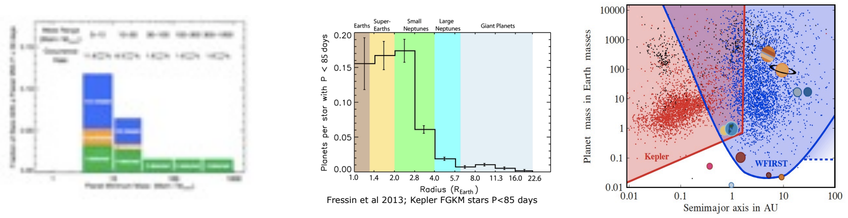
Primordial disk



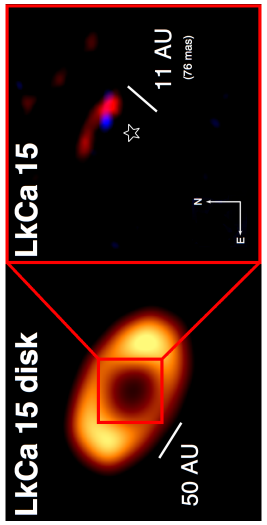
2nd generation Dust

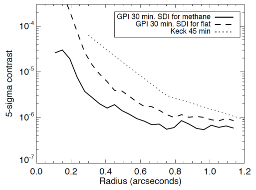


Statistical distribution of mature planets

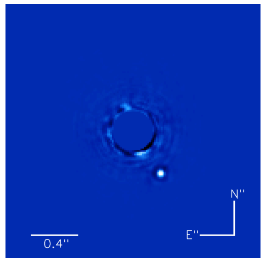


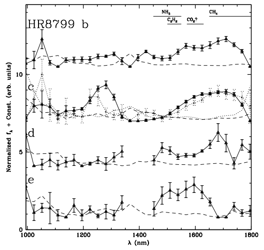
Planetary birth

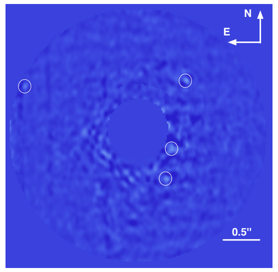


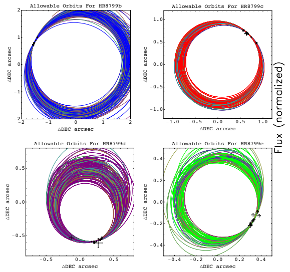


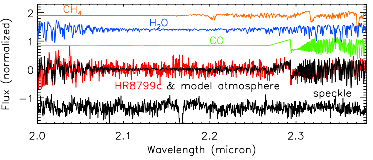
Adolescent Planets



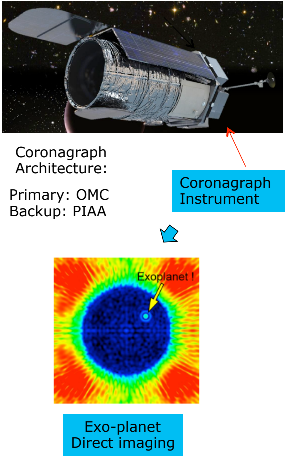


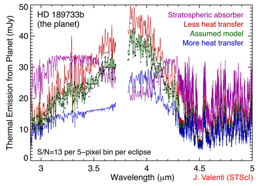




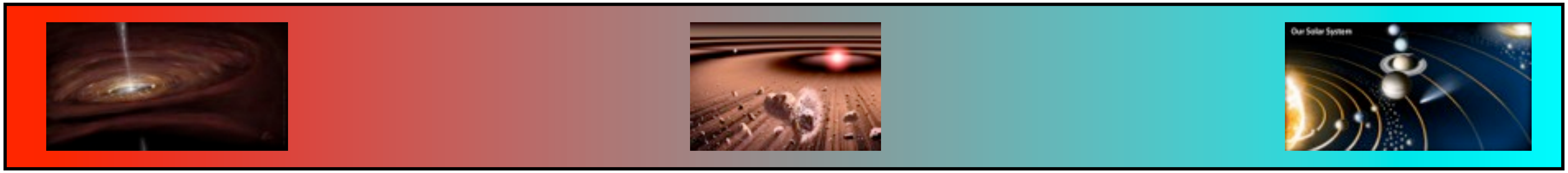


Characterization of nearby planets



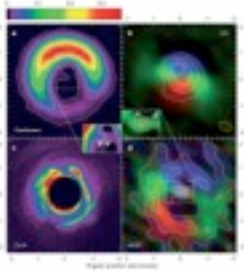
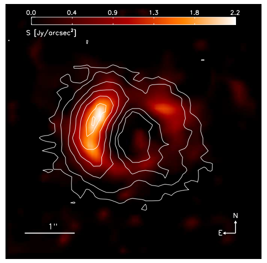


Age 1 Myrs 10 Myrs 100 Myrs 5 Gyrs

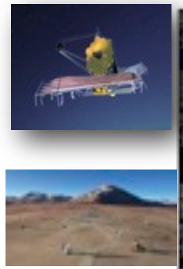


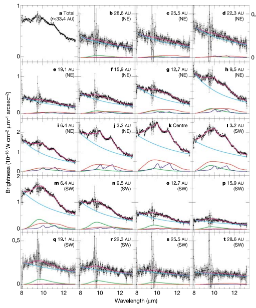
100+ pc 50 pc 10 pc

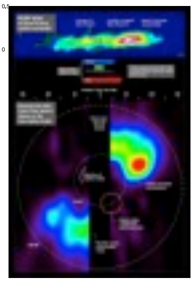
Primordial disk

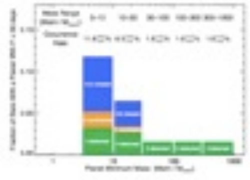
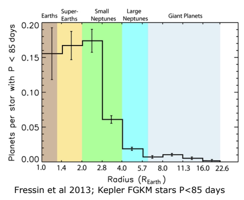
2nd generation Dust

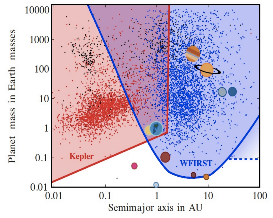






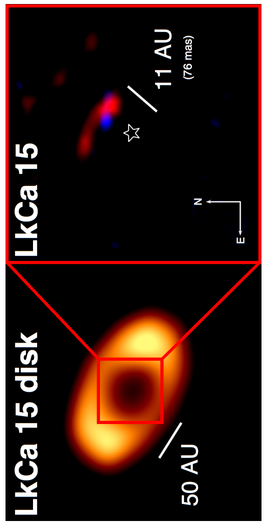
Statistical distribution of mature planets

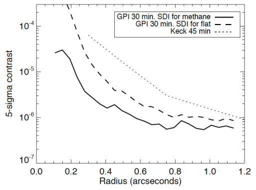





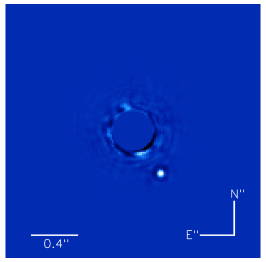
Characterization of nearby planets

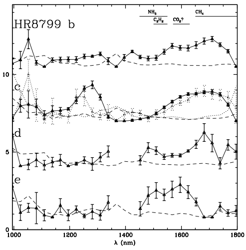
Planetary birth

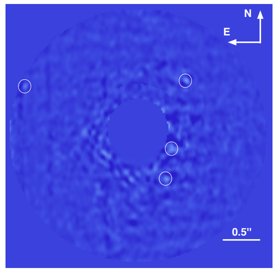


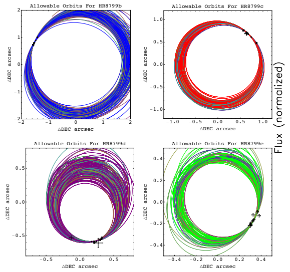



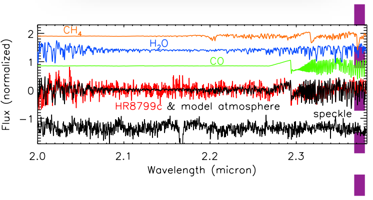
Adolescent Planets





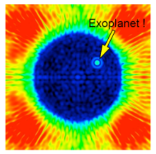




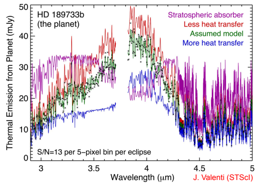
Coronagraph Architecture:

Primary: OMC
Backup: PIAA

Coronagraph Instrument



Exo-planet Direct imaging

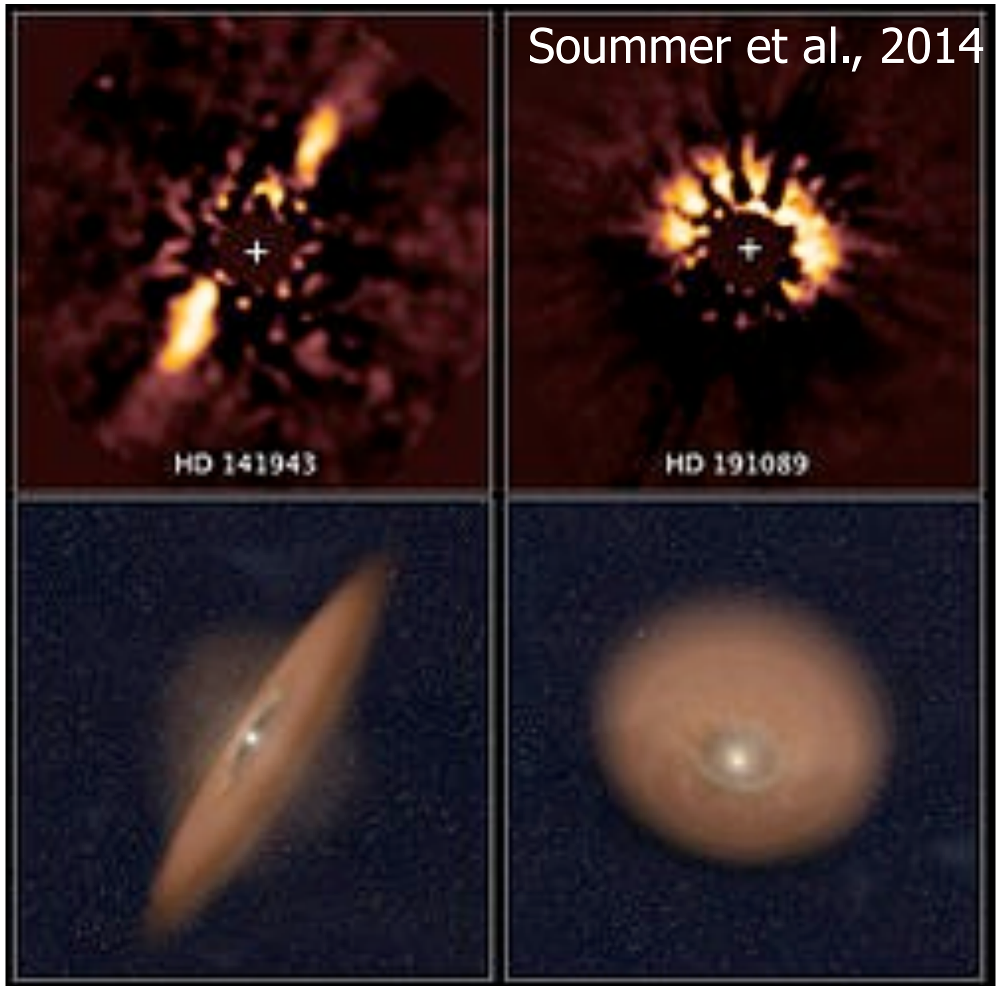



AFTA-WFIRST for planetary formation

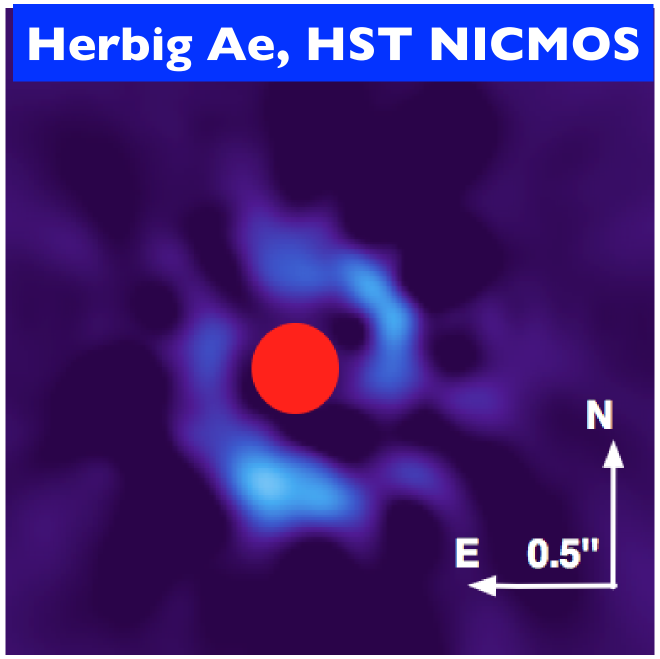
Contrast++ Sensitivity

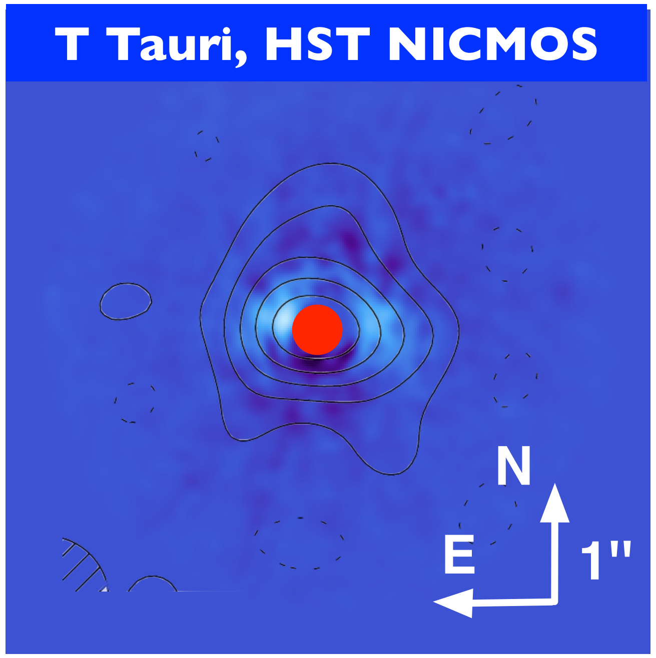
Debris Disks

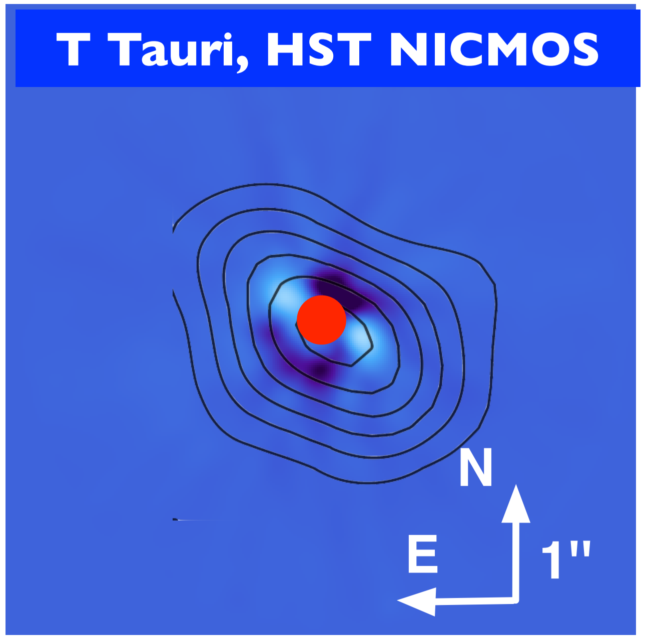
"....does not have any characteristics that distinguish it from the other stars so there is no clear explanation why more disks in our sample were not detected..."

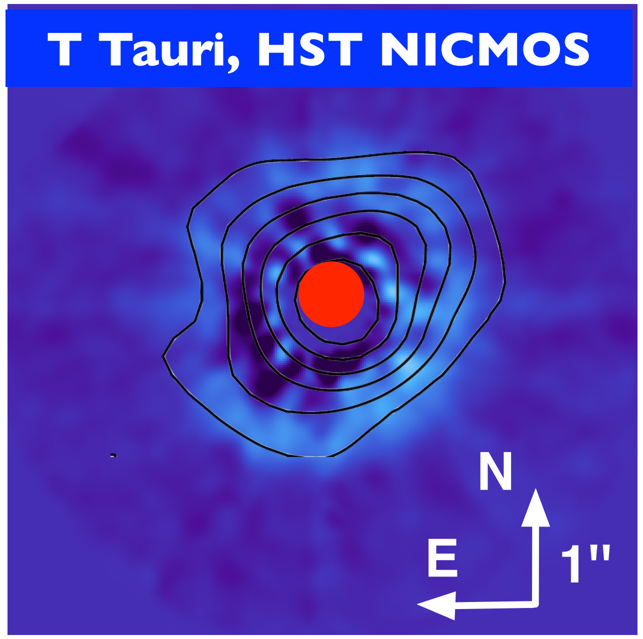

Soummer et al., 2014

Protoplanetary Disks







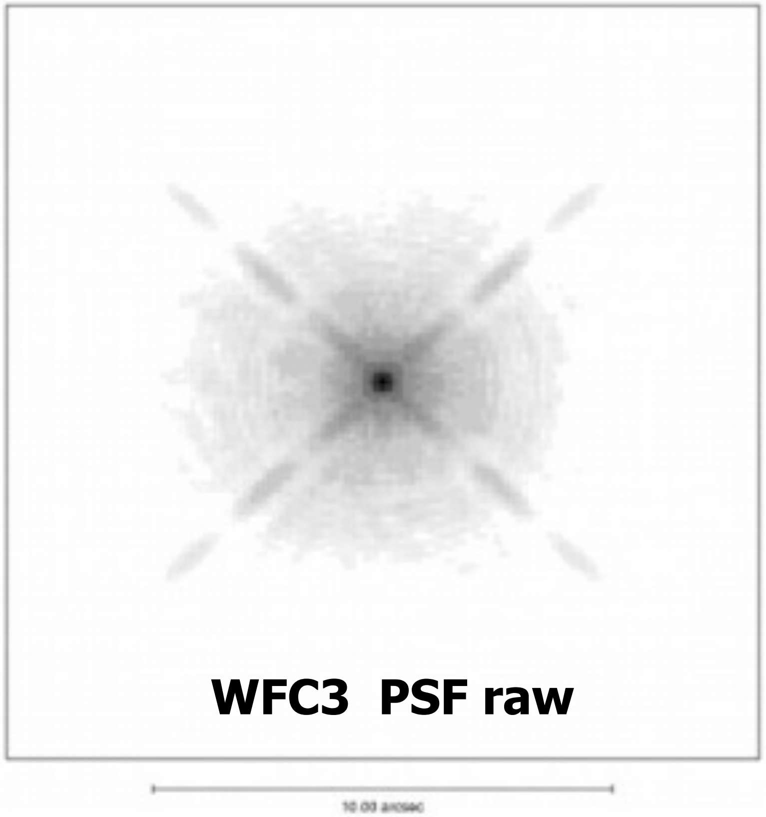


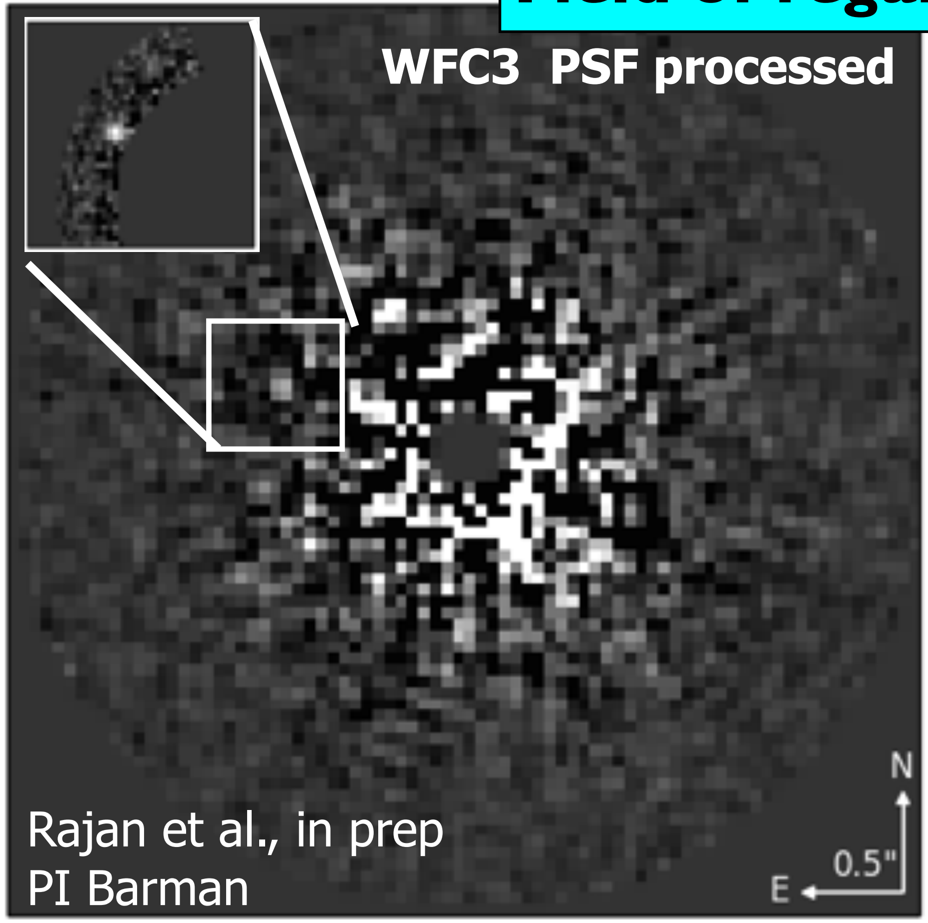
Imaging disk structures around faint stars (hard to do with Ex-AO)

AFTA-WFIRST for planetary formation

Contrast
Sensitivity
Field of regard

Planetary birth, Adolescent Planets
… “we need to be more efficient”

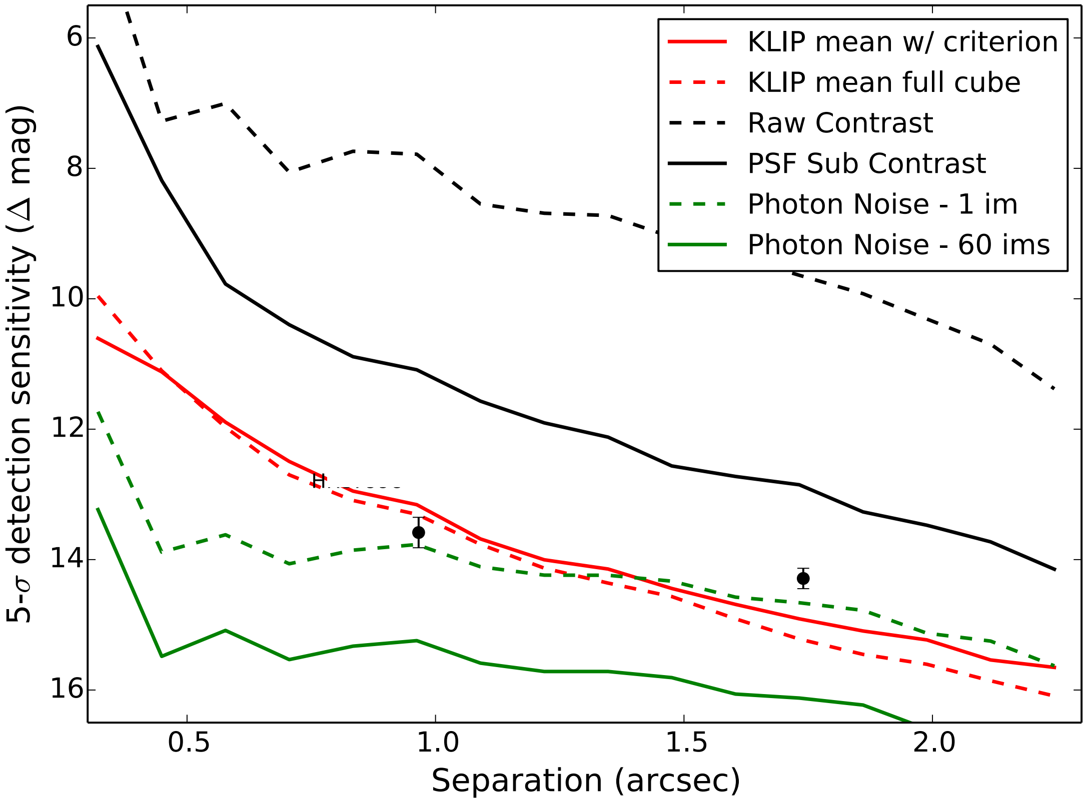

WFC3 PSF raw


WFC3 PSF processed

Rajan et al., in prep
PI Barman

Wide field camera for shallow surveys?

WFC3-IR: 0.13”/pix
AFTA-WFIRST: 0.11”/pix, 0.28 deg^2

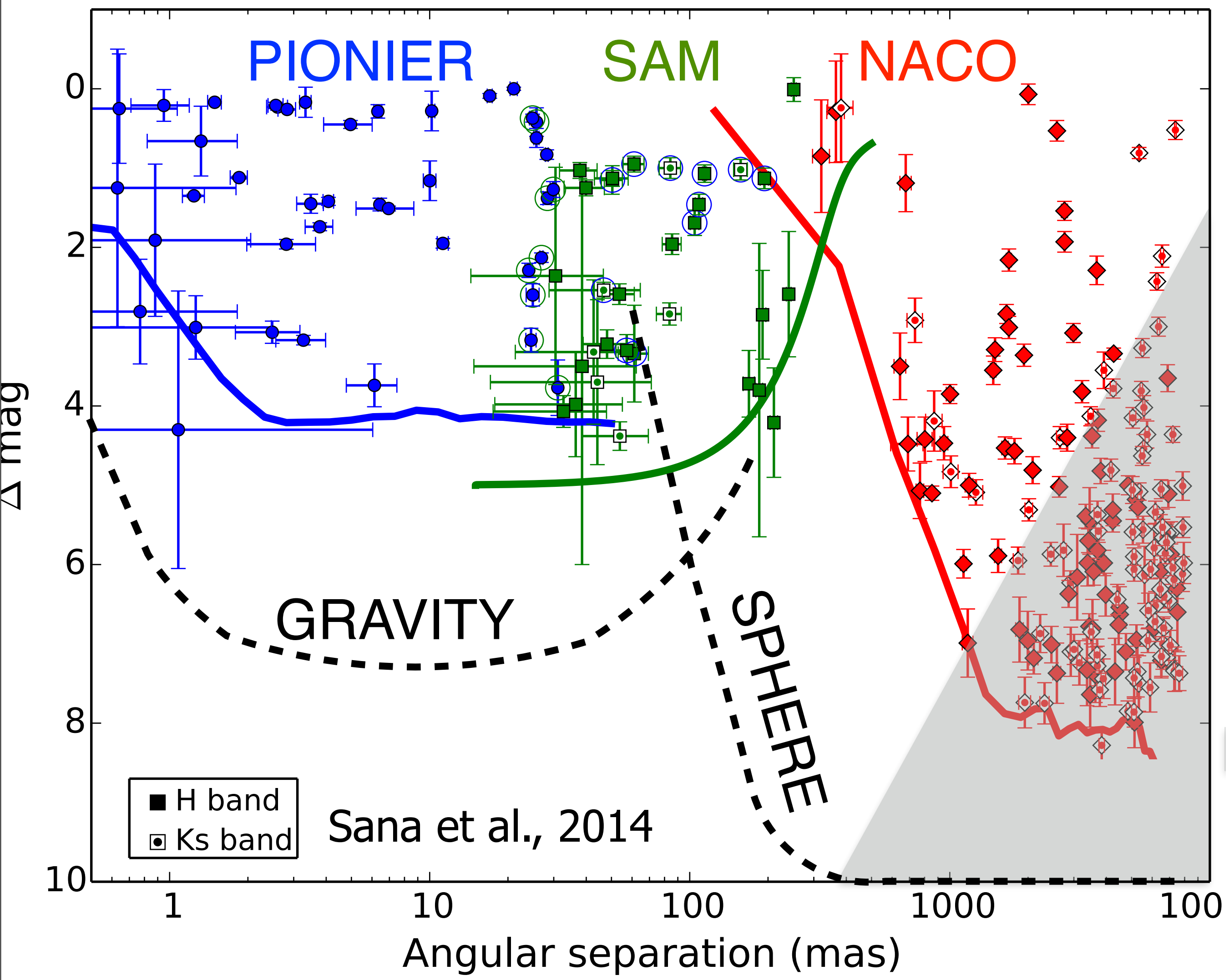


Massive stars and low mass stars

Massive Stars

Resolution
Contrast

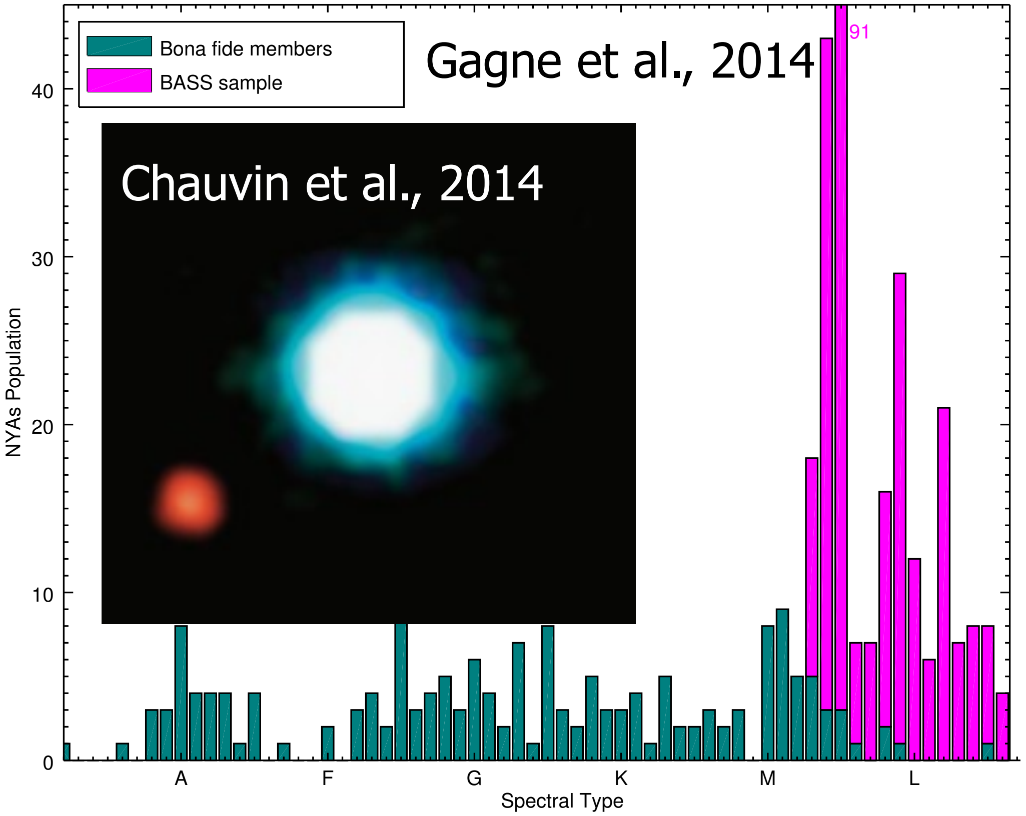
- Fraction of multiple systems around O star 91% +-3%
- Separation < 700 AU (0.2″)



Sana et al., 2014

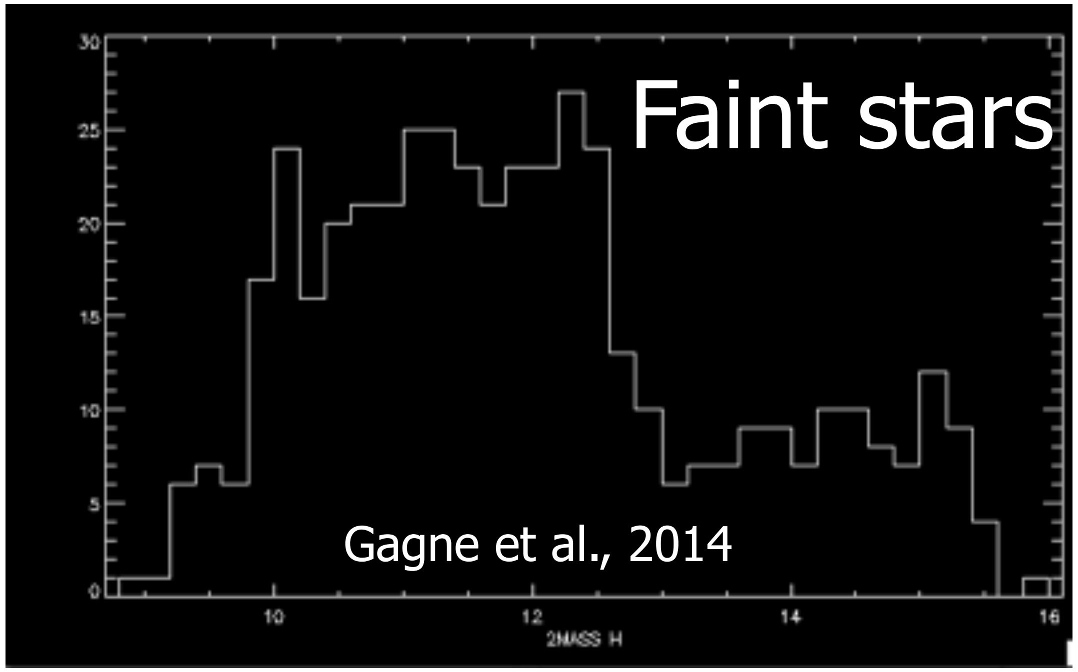
Low Mass Stars

Sensitivity
Contrast



Gagne et al., 2014

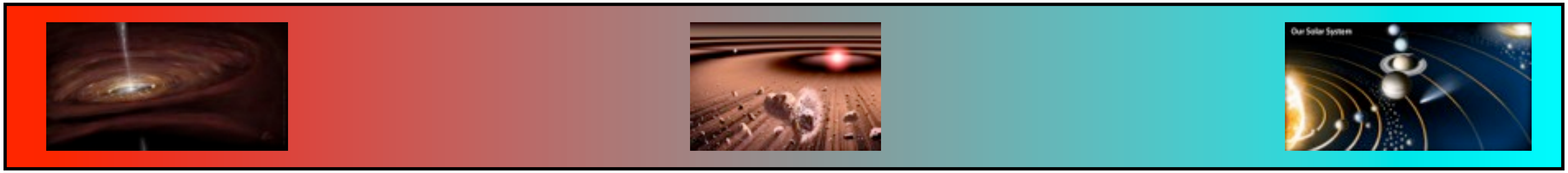
Chauvin et al., 2014



Faint stars

Gagne et al., 2014

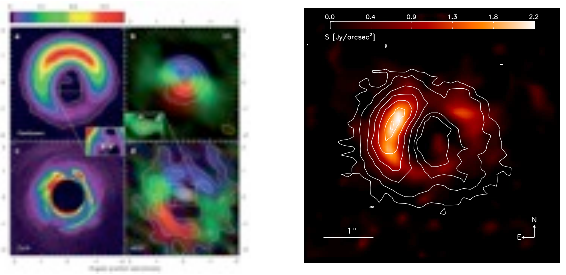
Age 1 Myrs 10 Myrs 100 Myrs 5 Gyrs



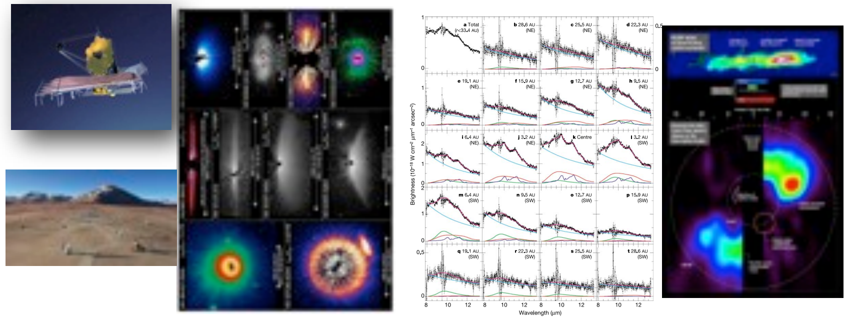
100+ pc 50 pc 10 pc

What can AFTA-WFIRST do for us?

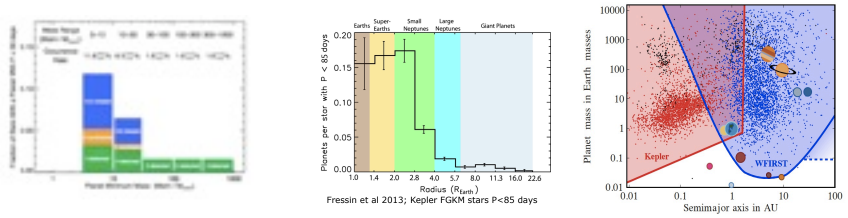
Primordial disk



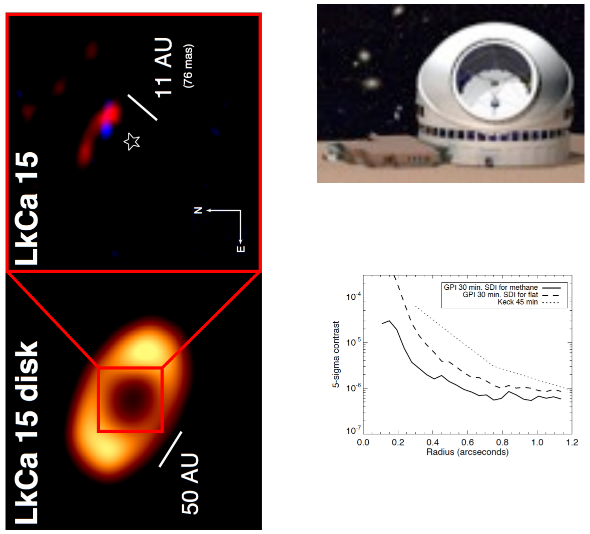
2nd generation Dust



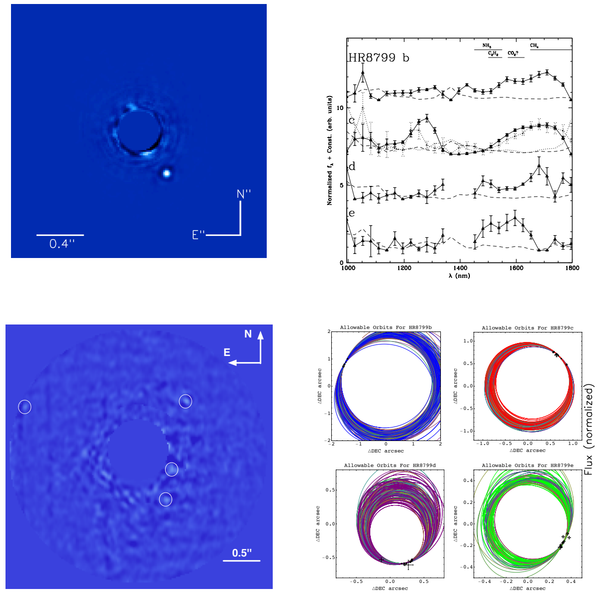
Statistical distribution of mature planets

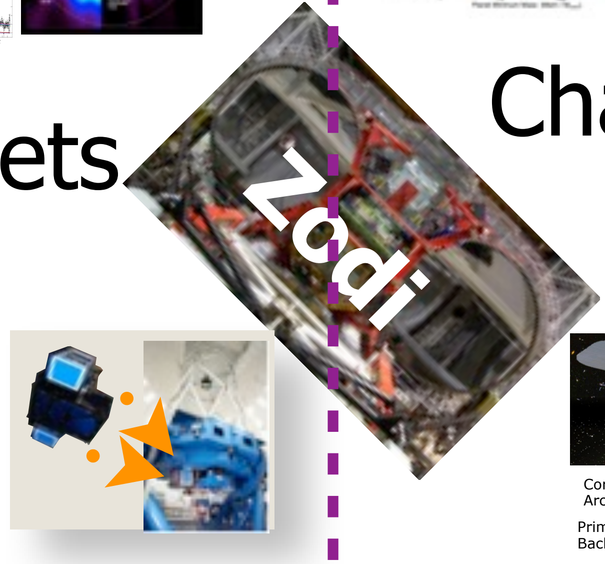


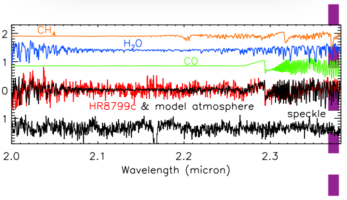
Planetary birth



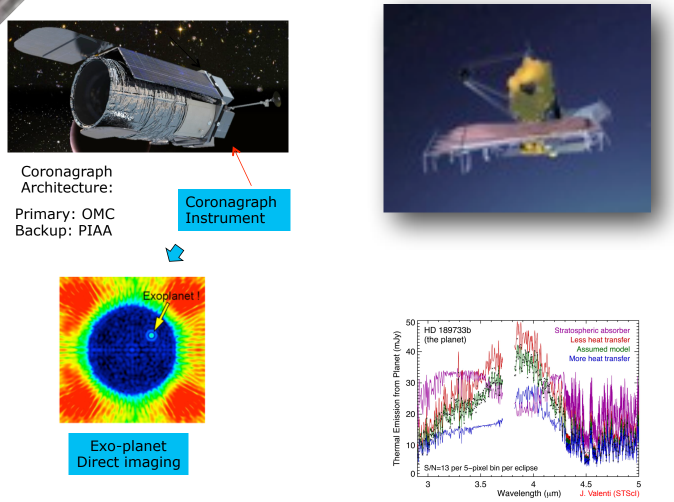
Adolescent Planets







Characterization of nearby planets


Coronagraph Architecture:

Primary: OMC
Backup: PIAA

Coronagraph Instrument

Exo-planet Direct imaging

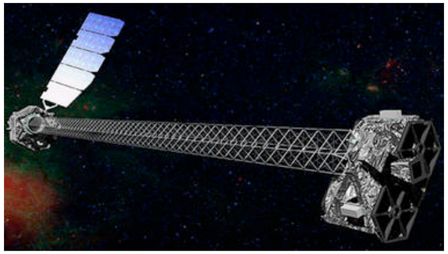
ASTRONOMY IN THE 2020'S: AN AGN ACCRETION PERSPECTIVE

Ashley L. King
University of Cambridge

2020's

- Age of Broad Band Studies
- Age of the Variable Universe
- High Energy Universe

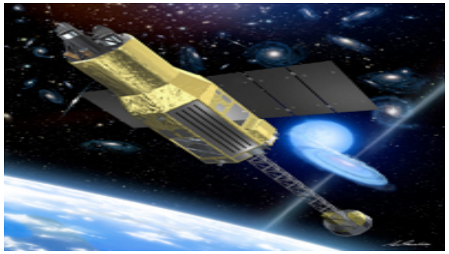
NuSTAR



Now

- 2 Wolter-I telescopes with CdZnTe detectors
- 3-79 keV
- 18'' FWHM
- 0.4 keV at 6 keV
- 0.1 msec
- ToO <24 Hrs

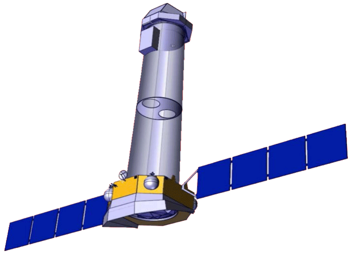
Astro-H



2016

- Soft X-ray Calorimeter Spectrometer
  - 0.3-10 keV, 7 eV
- Hard X-ray Imager
  - 5-80 keV, 60''
- Soft Gamma-ray Detector
  - Up to 300 keV
- Soft X-ray Imager

Athena+



2028

- Wide-Field Imager
  - 5'',150eV at 6 keV
- X-ray Integral Field Unit (TES Calorimeter)
  - 2.5 eV
- 50microsec
- ToO <8Hrs

How to Grow a Black Hole:

A. What is the seed for a supermassive black hole?
   - Massive Seed vs. Stellar-remnant
   - Are there “intermediate” mass black holes?

B. How does material reach a black hole?
   - Type of accretion disks

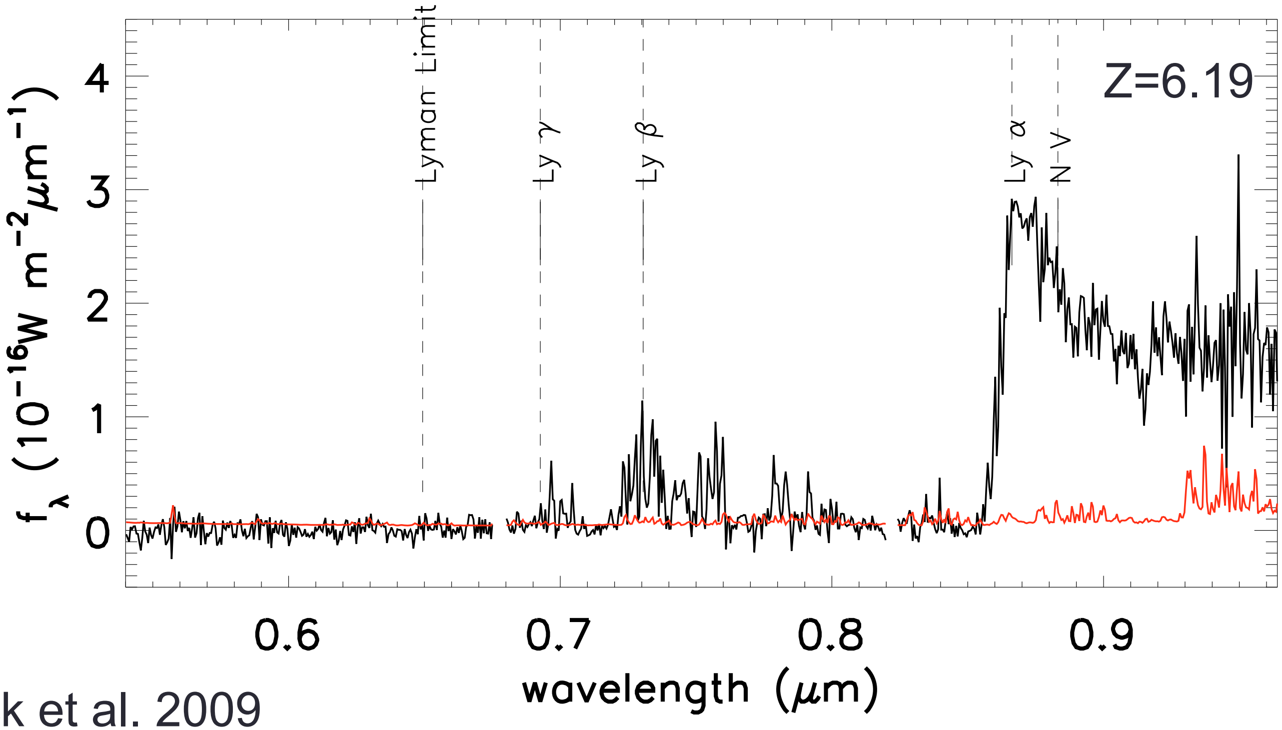
C. Feedback
   - How powerful are winds from black holes?

Supermassive Black Hole Seeds

- Identify Earliest Quasars (z>7?)
  - Need Accurate Mass Estimators
  - Identify Eddington Fractions

- WFIRST will be able to identify key emission lines in order to make these mass estimates

- Stellar-remnant
  - Pop III Stars
- Massive Seed
  - Direct collapse

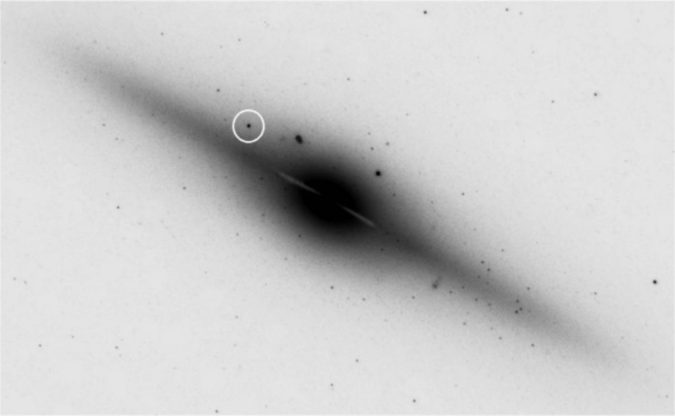


Mortlock et al. 2009

Intermediate Mass Black Hole

- Finding the Missing link?

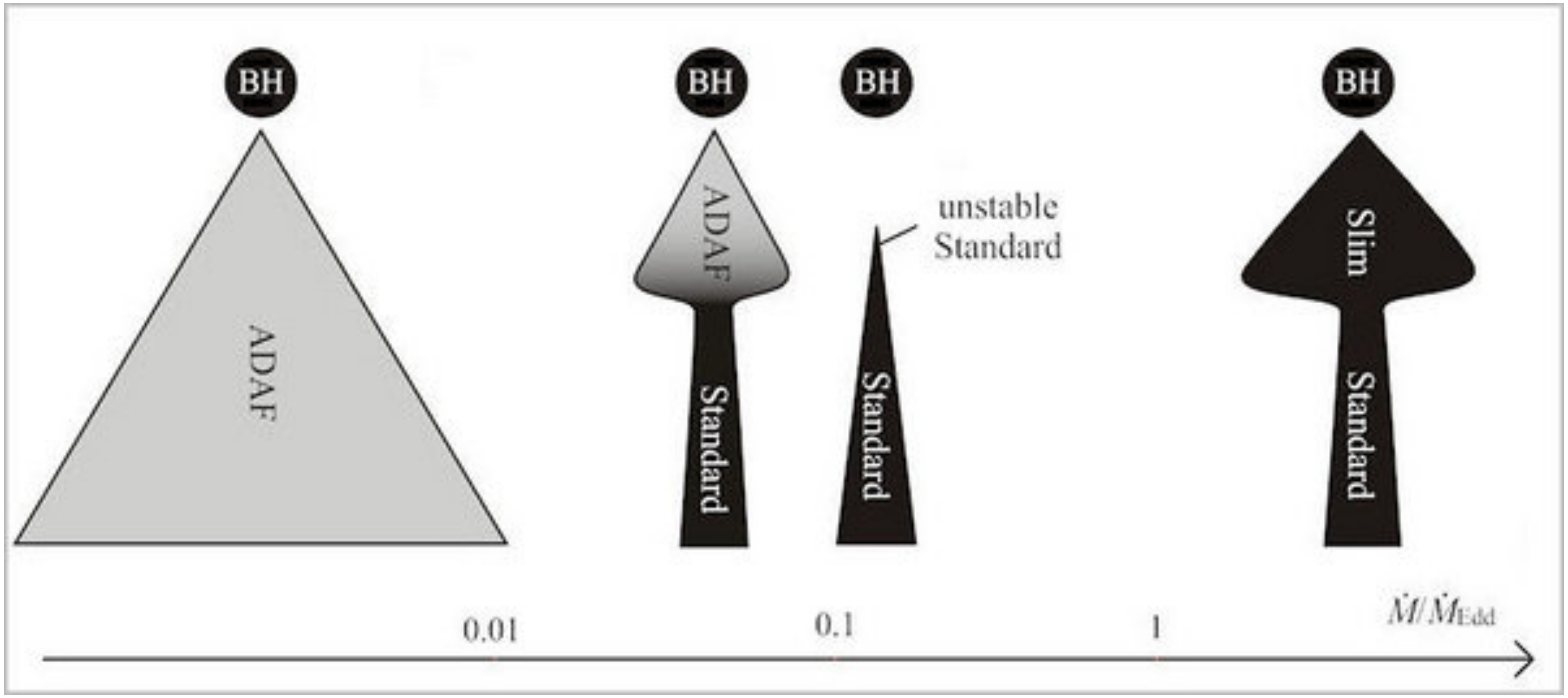
- Globular Clusters
- Dwarf Galaxies
- Ultra-Luminous X-ray sources (ULX)



Growing a Black Hole: Types of Accretion

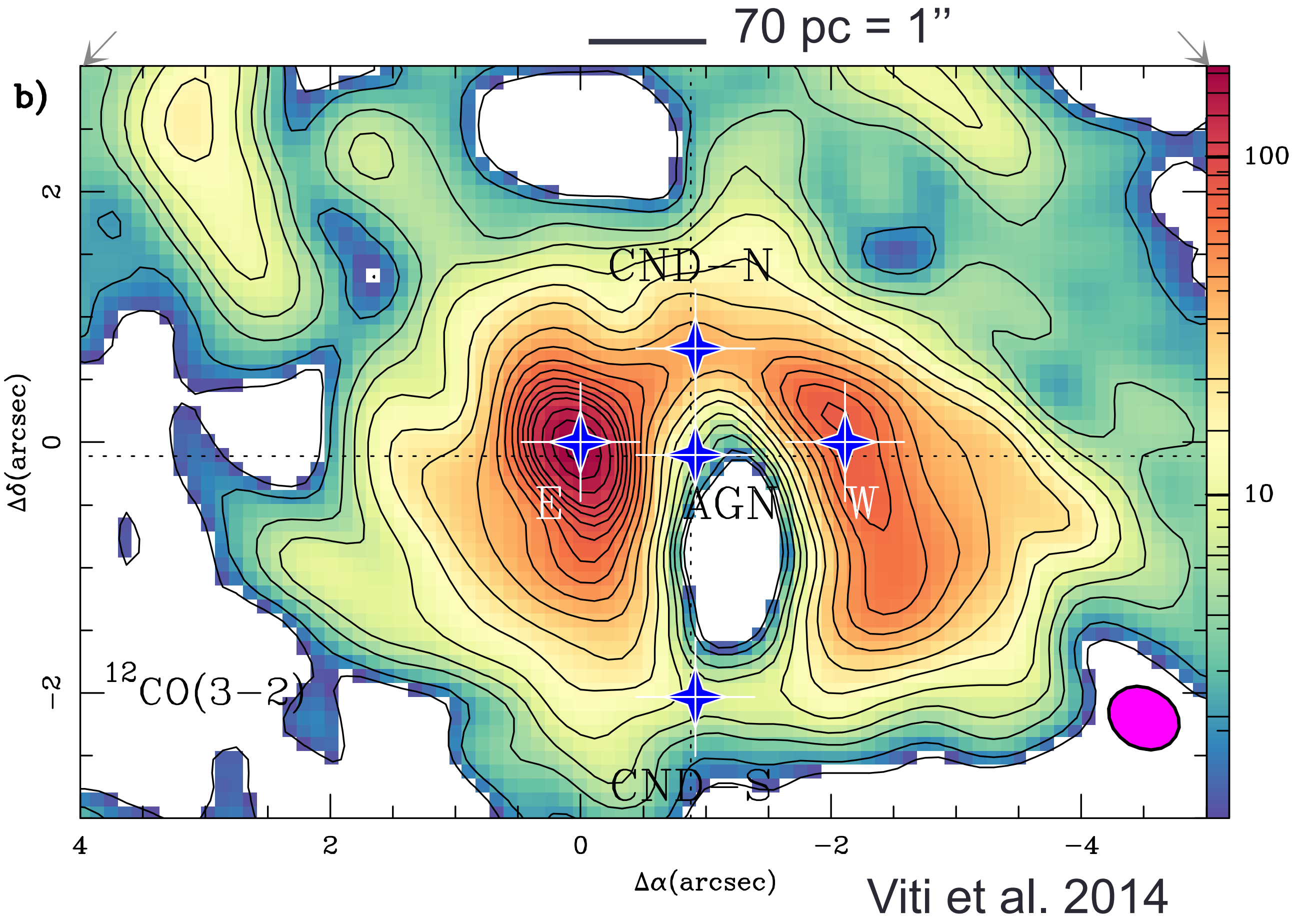
- How Does a Black Hole Accrete Material?
  - Thin Disk (Alpha Disk)
  - Advection Dominated Disk
  - Magnetically Arrested Disk

- Model lowest accretion regimes
  - Sgr A*,M87,etc
- Broadband SED are Key
- Variability studies



Imaging the Torus/Disk

- ALMA Circumnuclear Disk (200pc) of Seyfert NGC 1068

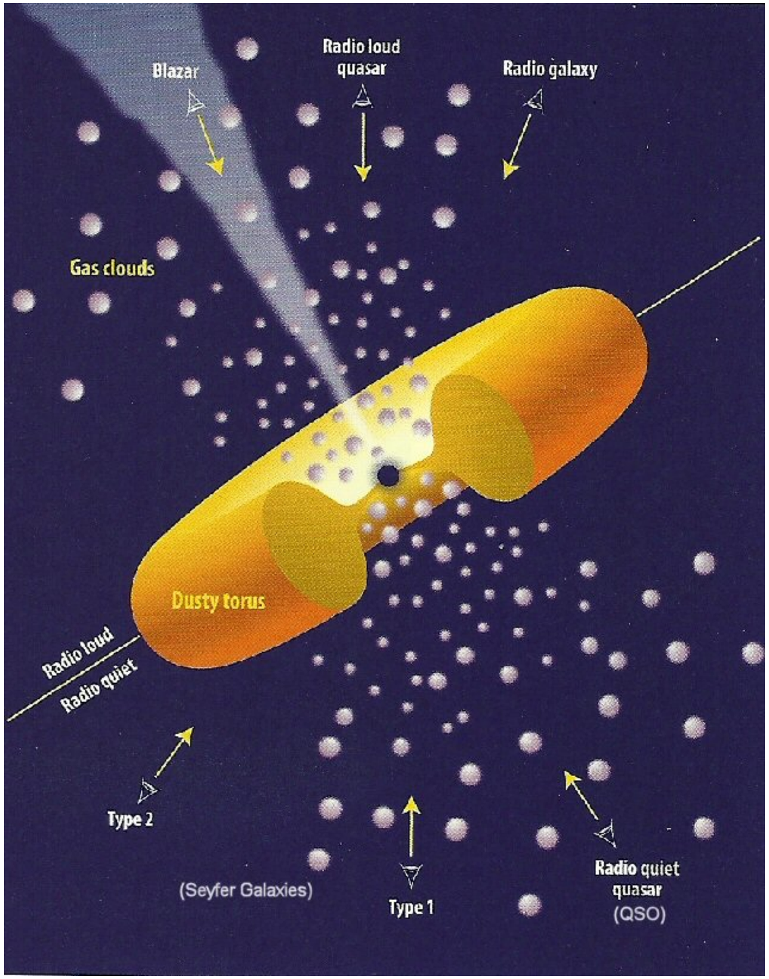


Viti et al. 2014

Types of Accretion: Imaging Torus/Disk

- Test the “Unified AGN Model”
  - Do all AGN have a torus?
  - What is the Structure of the torus?
  - Does the Torus depend on Mass or Accretion Rate?
- Quantify Obscured AGN Fraction
- Hard X-ray Selected Samples
  - Great way of finding AGN
  - Swift/BAT & NuSTAR
  - Does the amount of emission

we expect from X-ray absorption match IR observations?

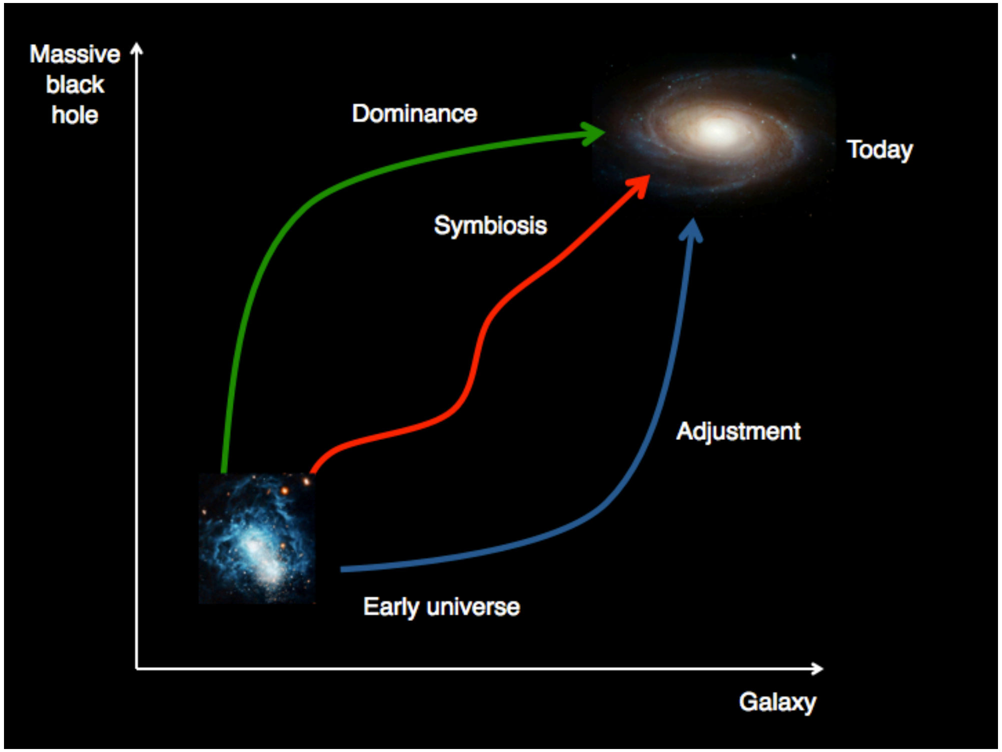


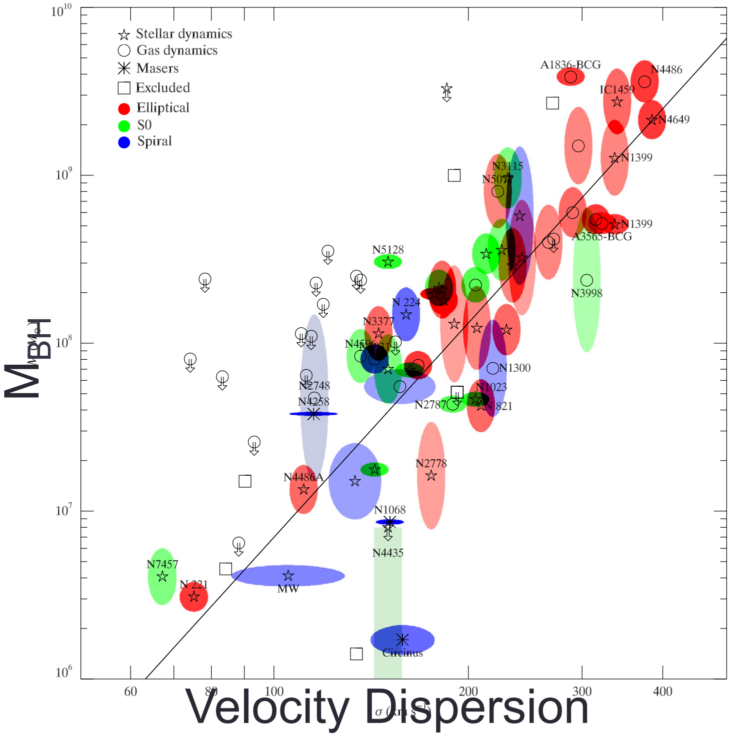
Feedback

- How do supermassive black holes evolve with their galaxies?

1. Black Holes Evolve First
2. Galaxies Evolve First
3. Co-evolve

- Volonteri, Gultekin et al. 2009



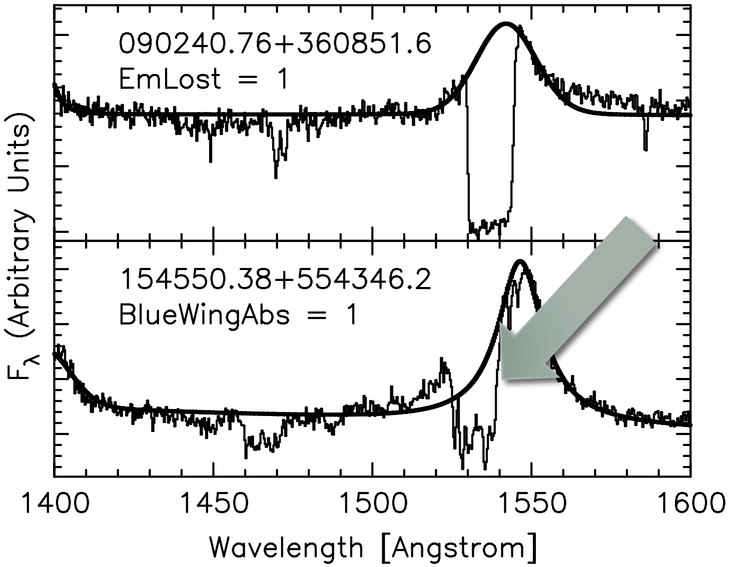


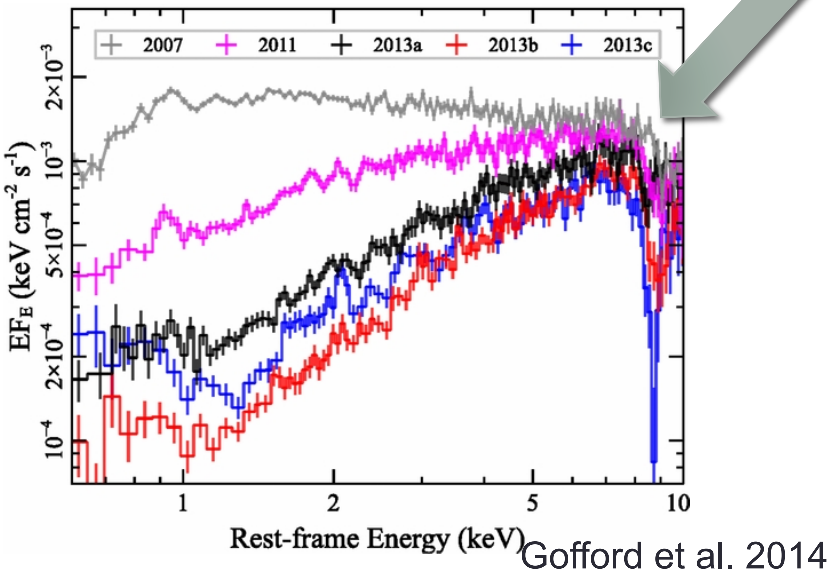
Feedback: Strong Winds

- Broad Absorption Line Quasars
  - >2000 km/s troughs
  - -25000 – 0 km/s outflows
  - Optical/UV
- Ultra-Fast Outflows
  - >3000 km/s
  - Highly Ionized
  - X-ray
- How do they relate to the jet cycle?
- What is the covering fraction, mass outflow rate, and power?

(King et al. 2013)

Gibson et al. 2009

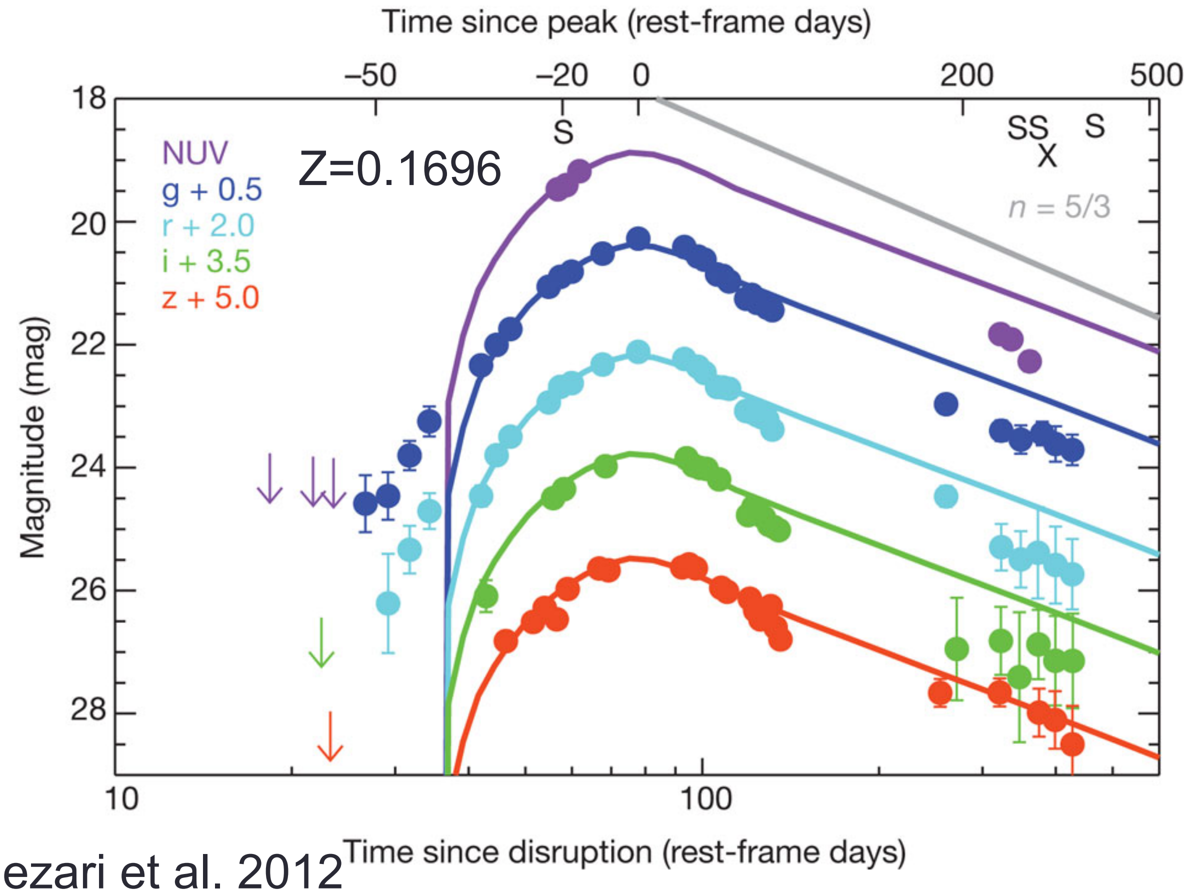




Gofford et al. 2014

Feedback: Serendipity is Key

- E.g., Tidal Disruptions
  - ~10^{-4} yr^{-1} $galaxy^{-1}$ (Stone & Metzger 2014)
- A new way to understand Accretion and Jet formation
- Will need Broad Band Coverage



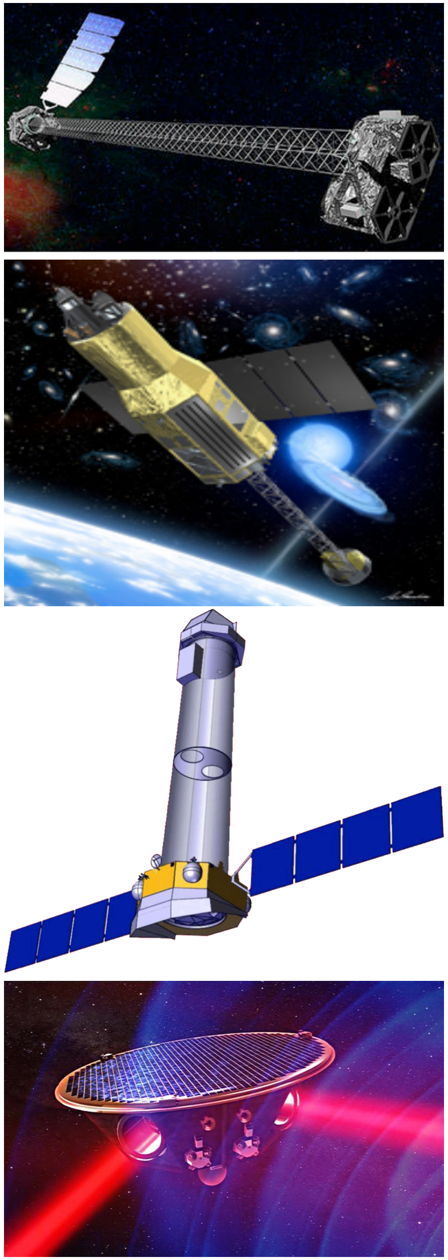
Gezari et al. 2012

Conclusions

- Age of Broadband, Simultaneous Studies and Fast Timing Analysis

- Goals from AGN Accretion Perspective
  - How to grow a Supermassive Black Hole
    - Seed Black Hole
    - Modes of Accretion
  - Feedback – Quantify Wind Power

  - High Energy Universe
    - Swift, XMM-Newton, Chandra, NuSTAR, NICER, eROSITA, Astro-H, Athena, LIGO, VIRGO, LISA



A Tale of Two Transients

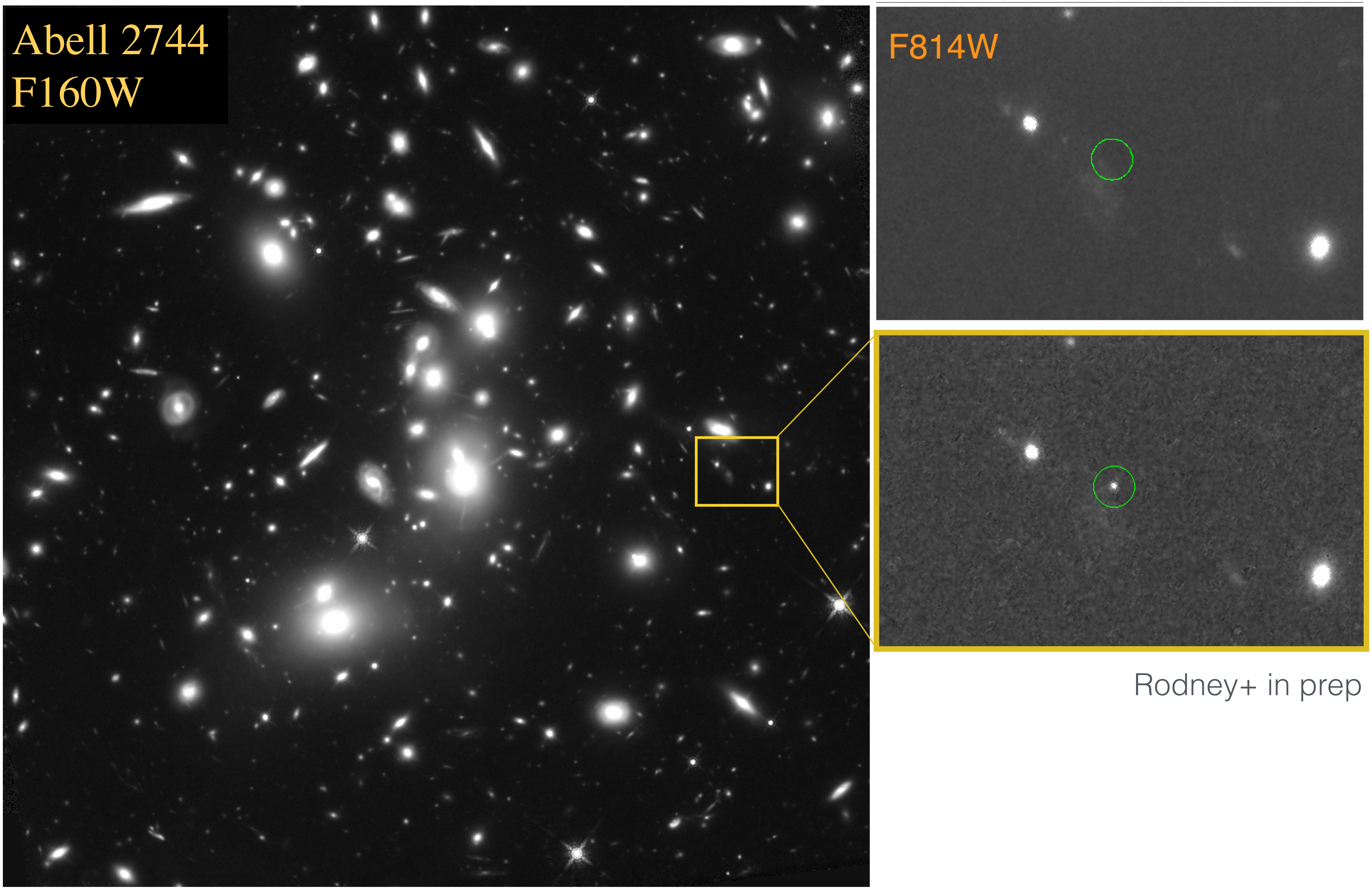
Steve Rodney
Johns Hopkins University

The Frontier Field Supernova Survey

Steve Rodney (JHU)

1. SN Tomas

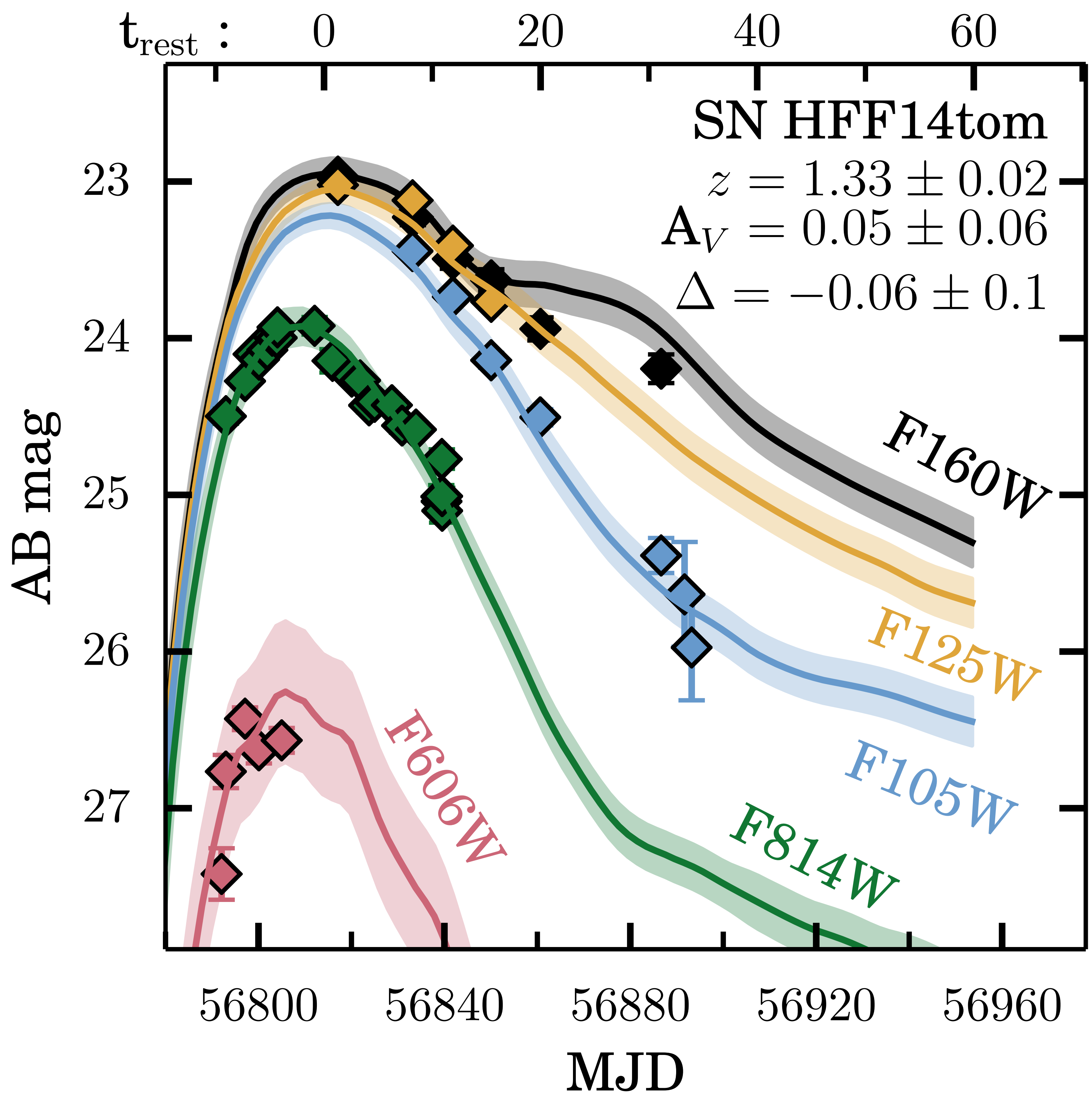
SN HFF14Tom behind Abell 2744



Rodney+ in prep

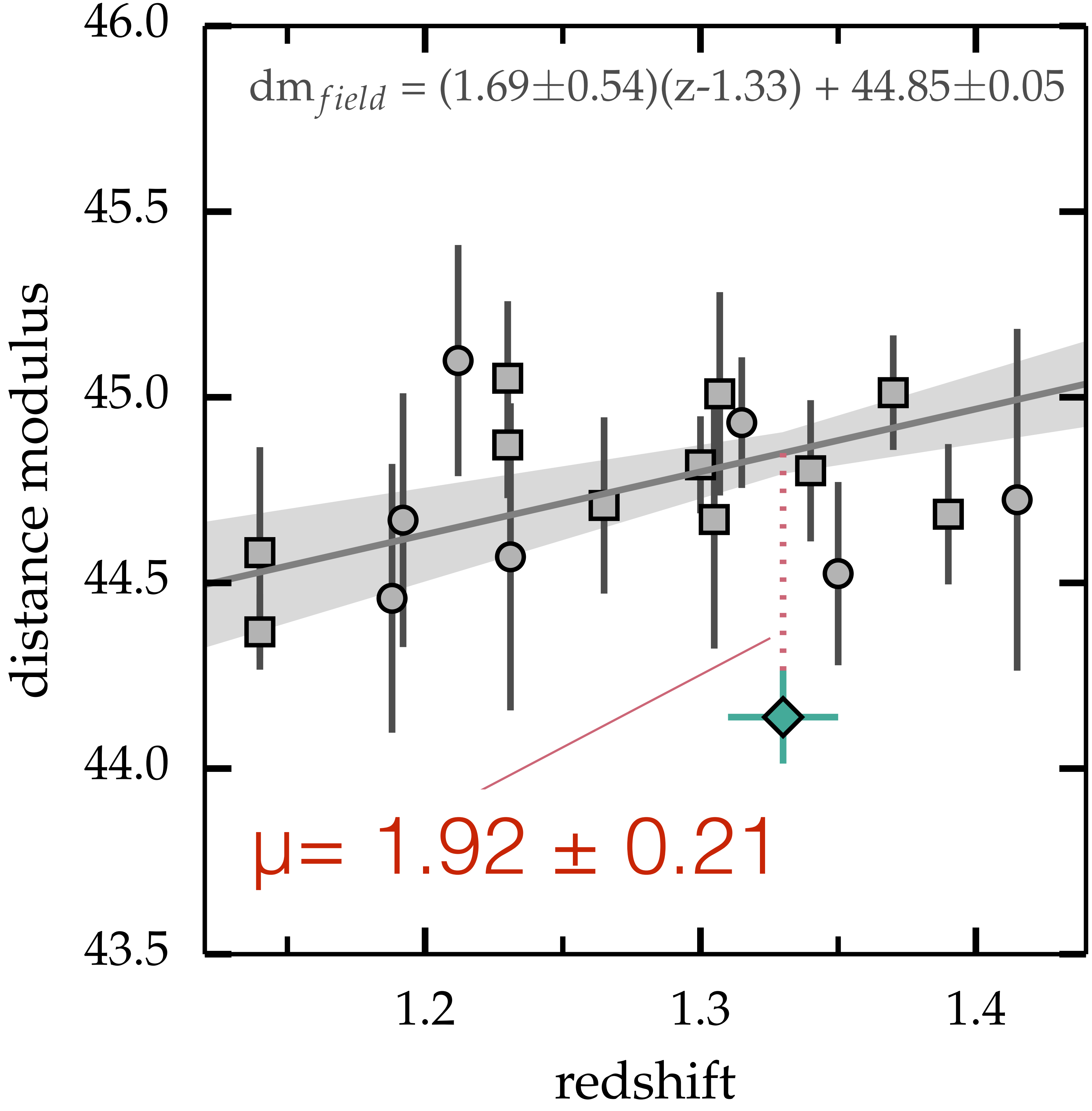
Steve Rodney (JHU)

Light Curve Fitting Provides Luminosity Distance



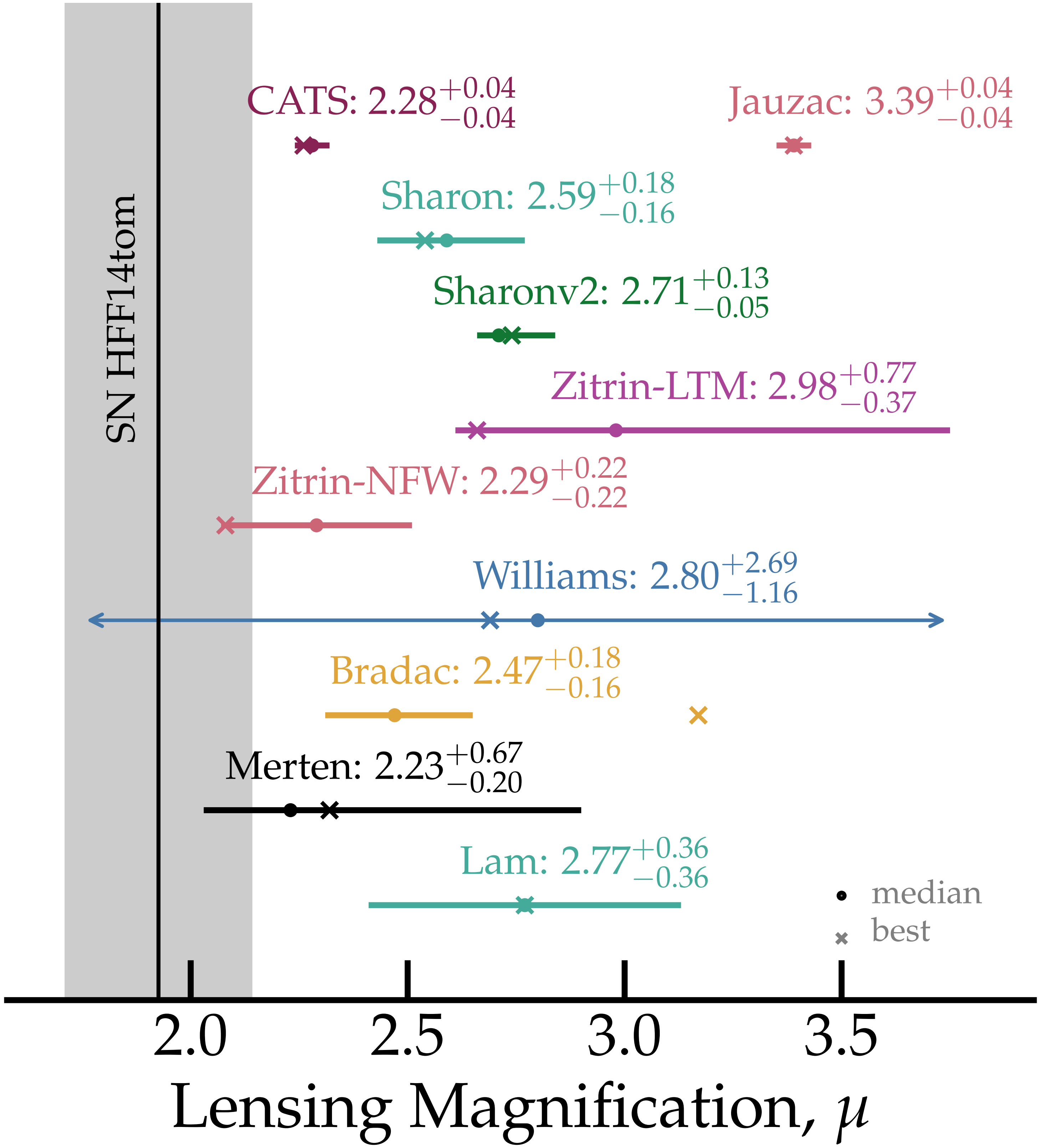
Steve Rodney (JHU)

Comparison to unlensed SN gives magnification



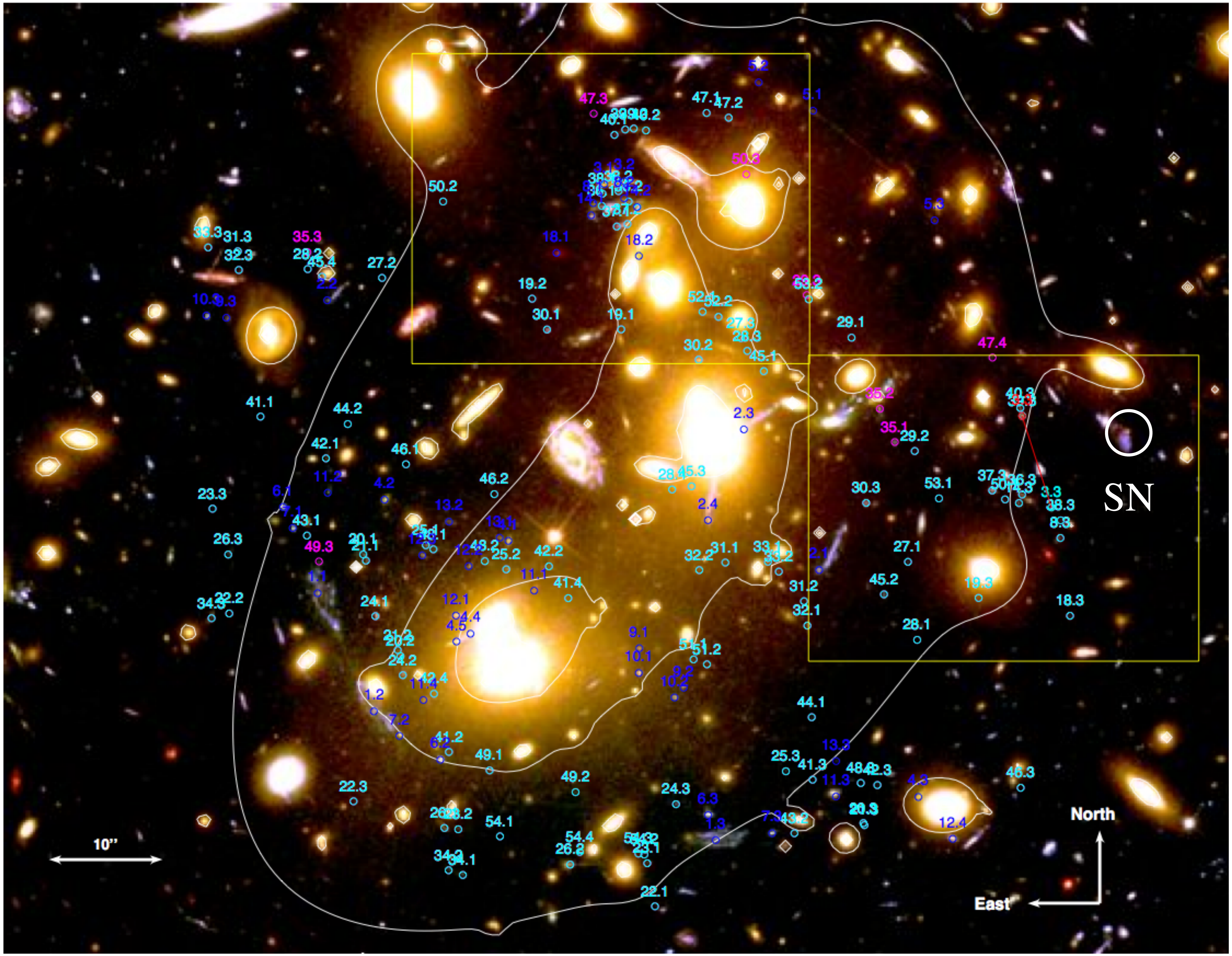
Steve Rodney

Cluster mass models ***systematically overpredict*** the magnification.



Steve Rodney (JHU

How can all the lens models be biased?



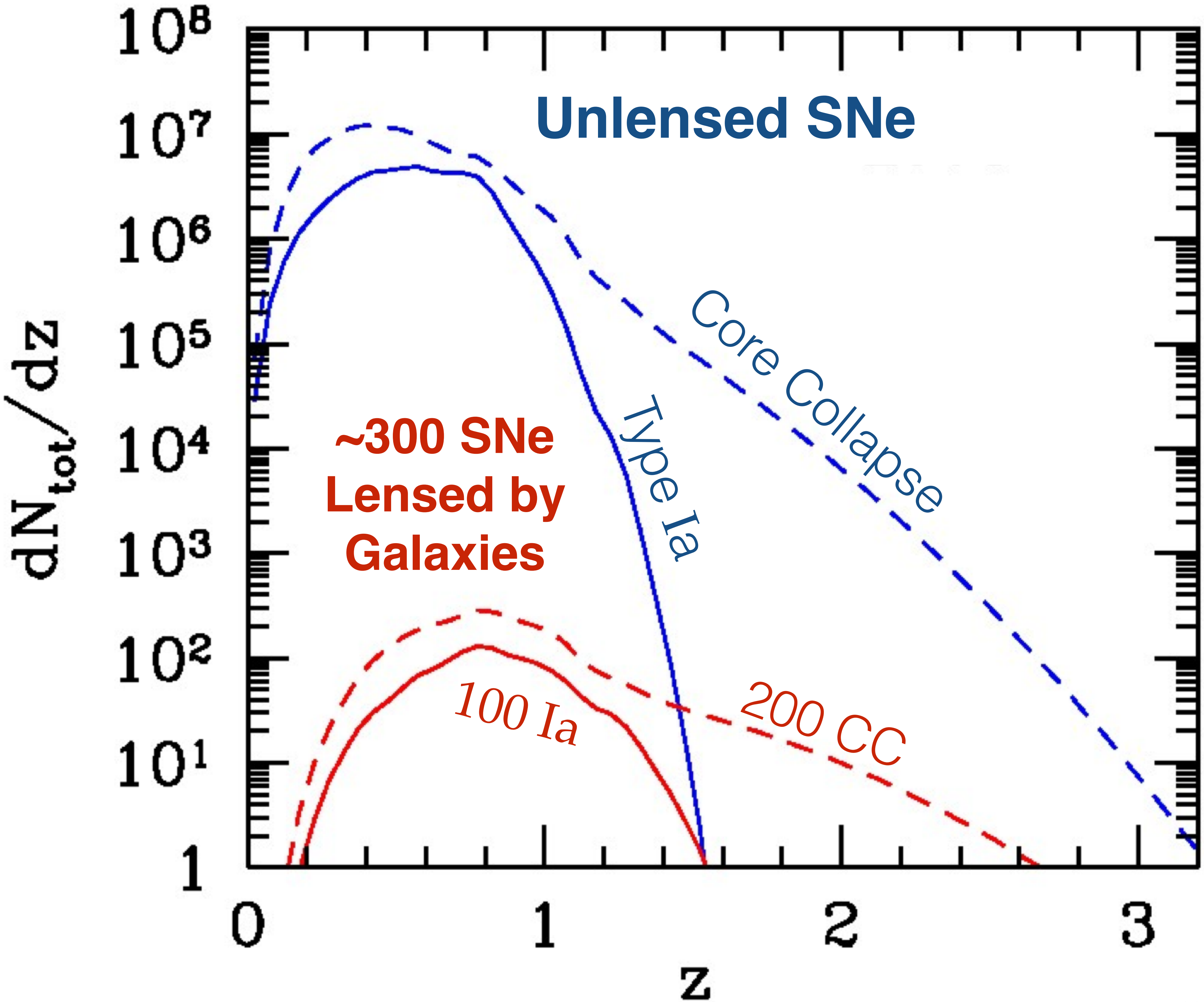
Jauzac+ 2014

2014 : A Lensed Type Ia SN at $z = 1.33$

2014 : A Lensed Type Ia
SN at z = 1.33

2024 : 500 Lensed Type Ia
SNe to z = 2.5

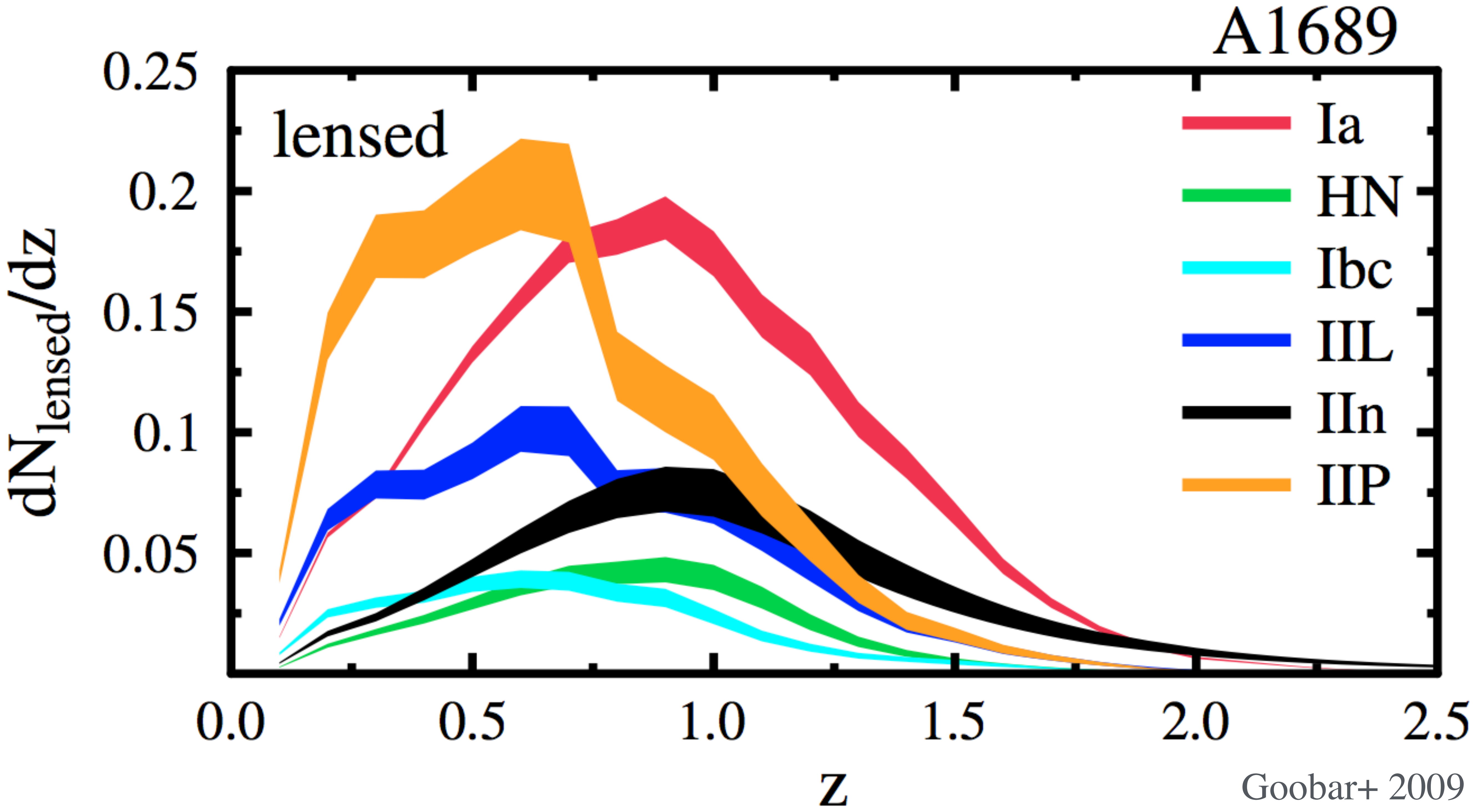
LSST will find ~300 SN strongly lensed by galaxies



Oguri & Marshall 2009

Steve Rodney (JHU)

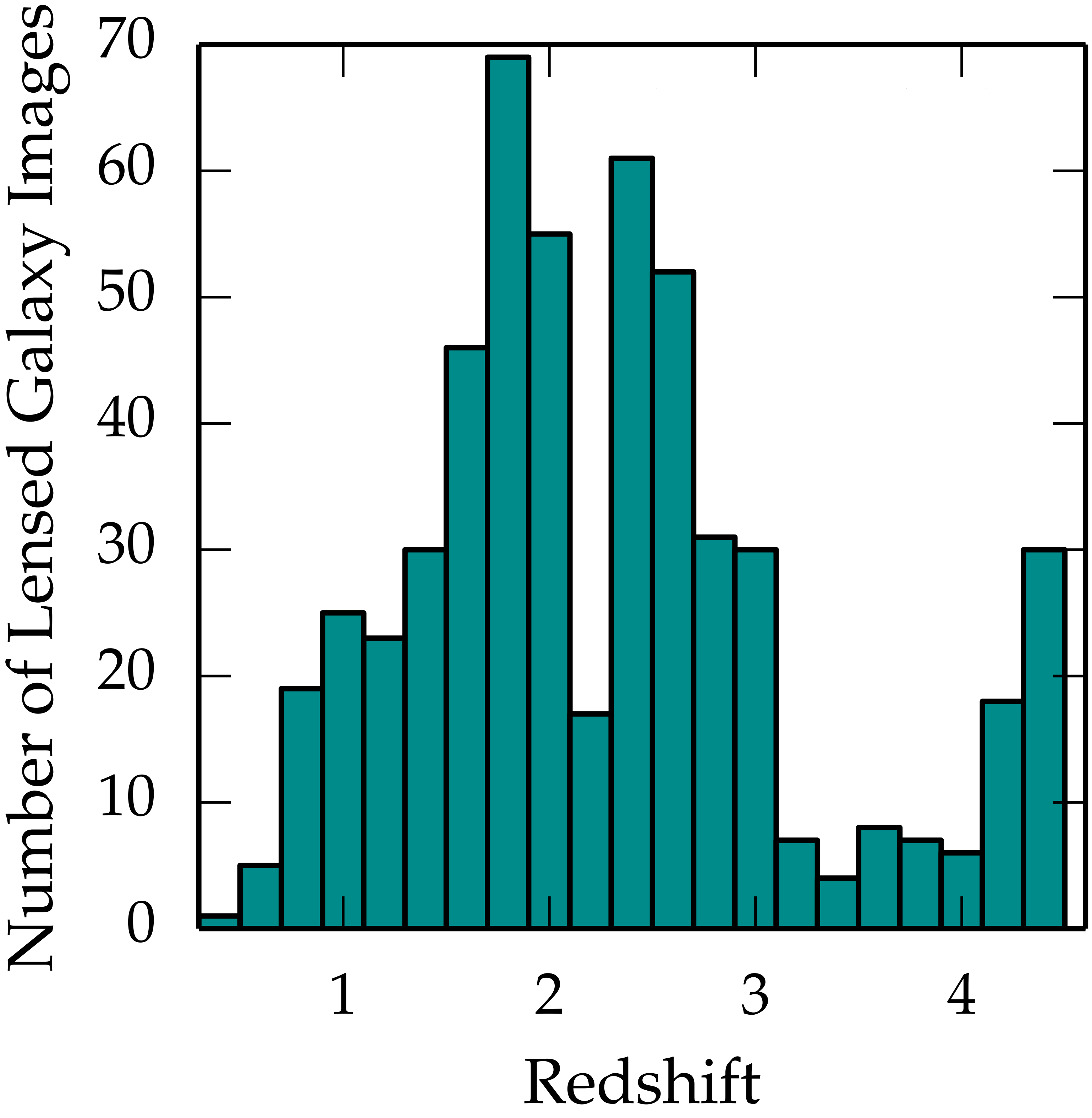
and ~100 SN behind strong-lensing clusters.



Goobar+ 2009

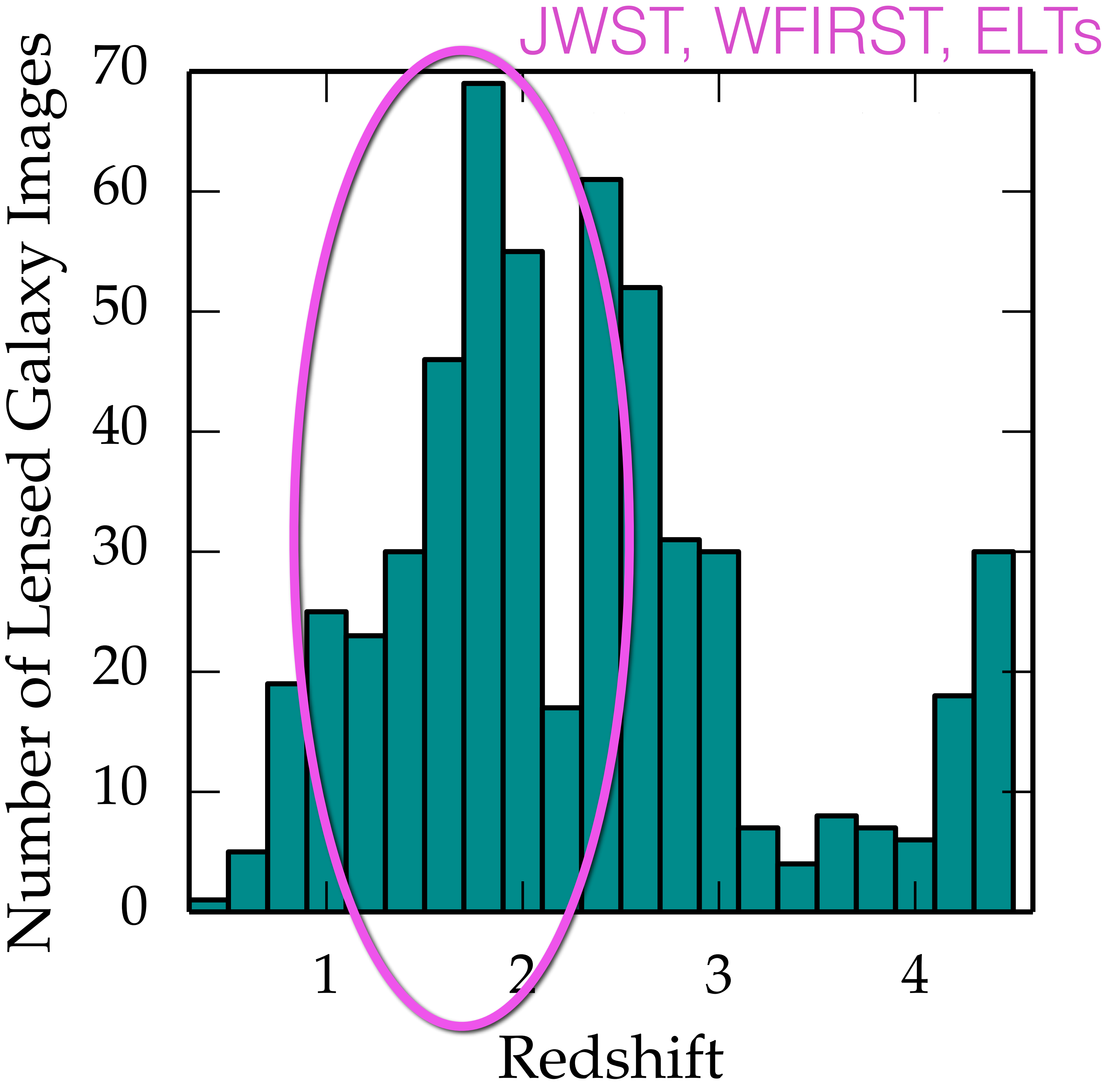
Steve Rodney (JHU)

Most cluster-lensed SN will need IR imaging + spectroscopy



Steve Rodney (JHU)

Most strongly-lensed SN will need IR imaging + spectroscopy



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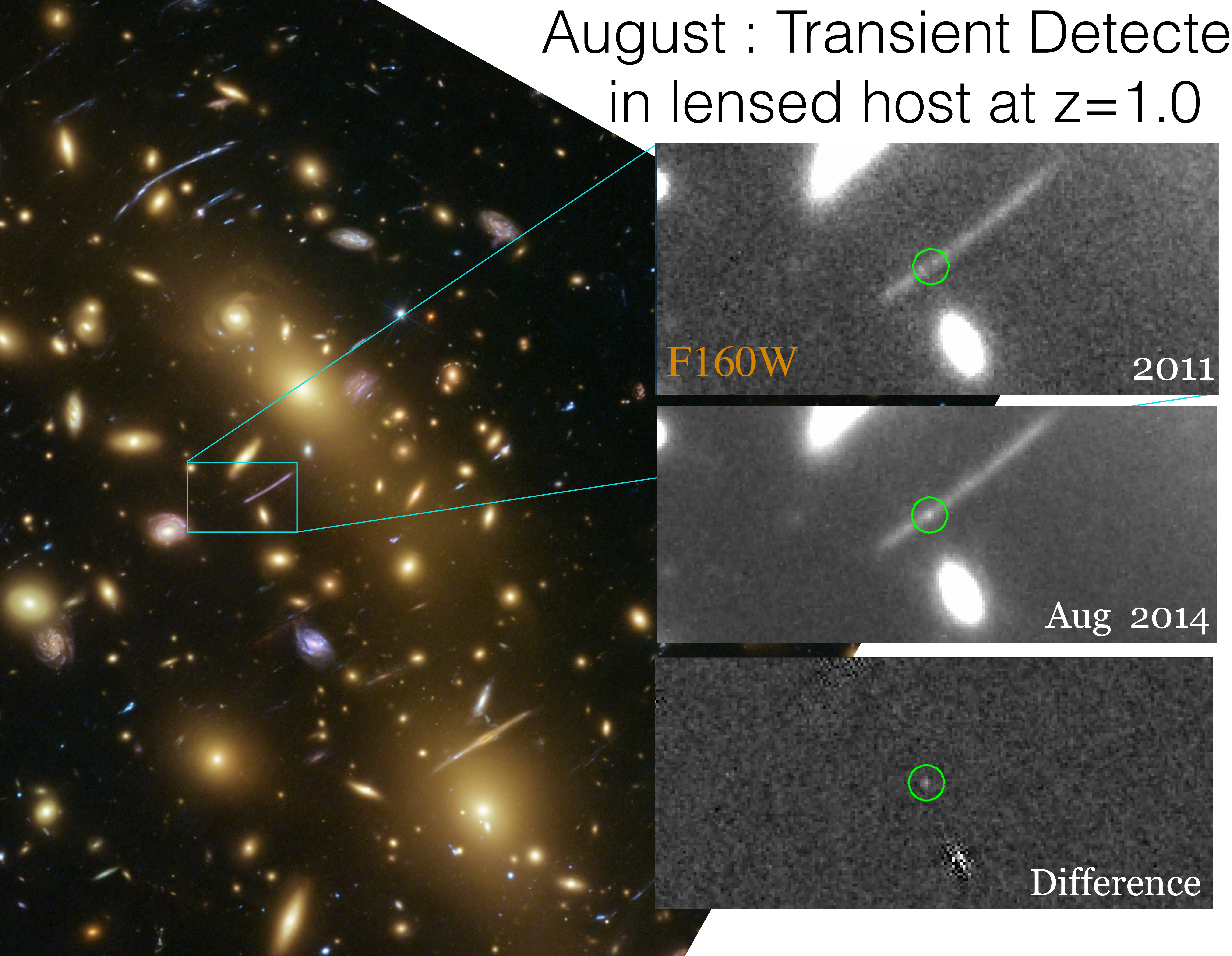
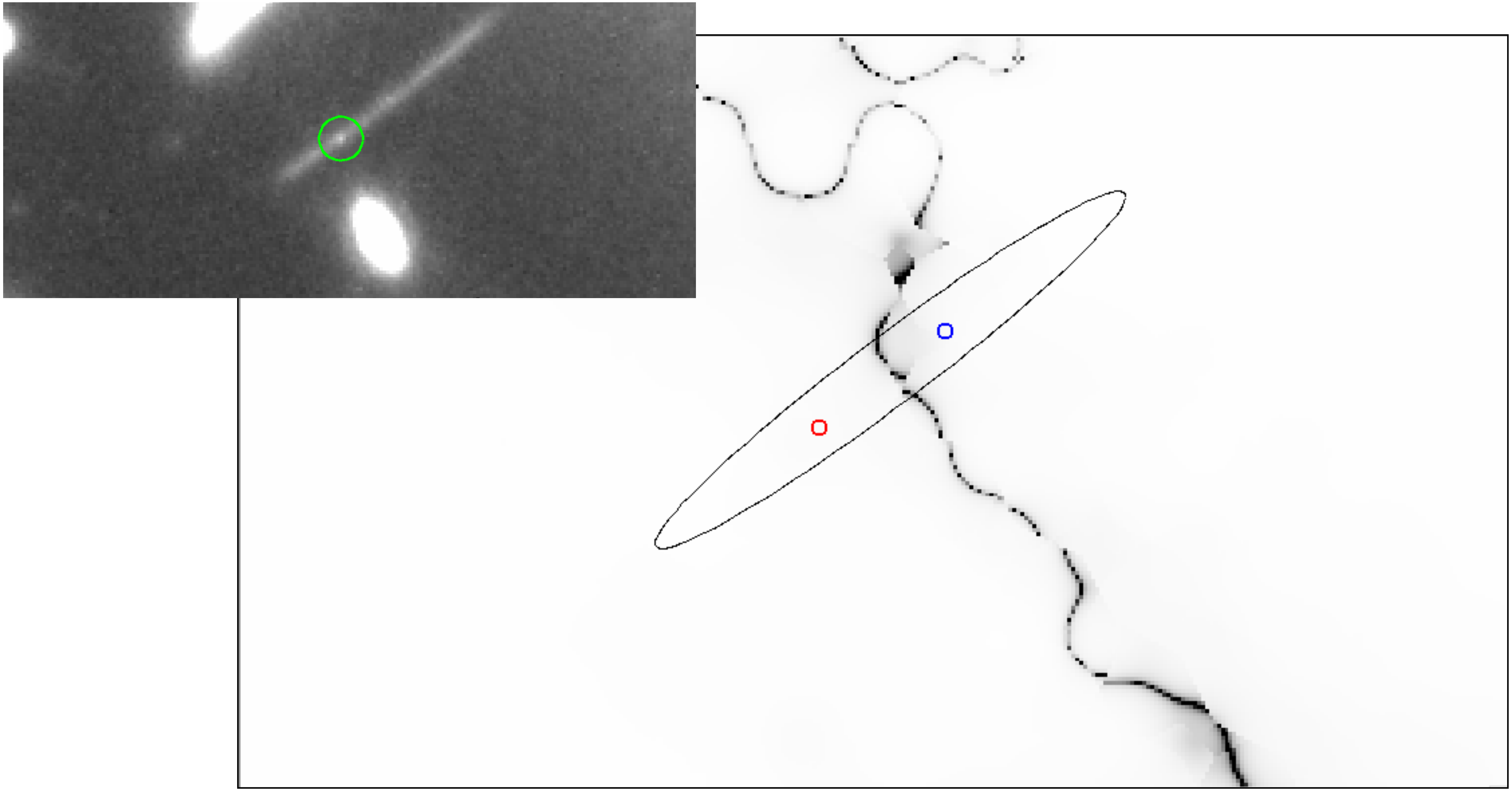
2. SN Spock

August : Transient Detected in lensed host at z=1.0

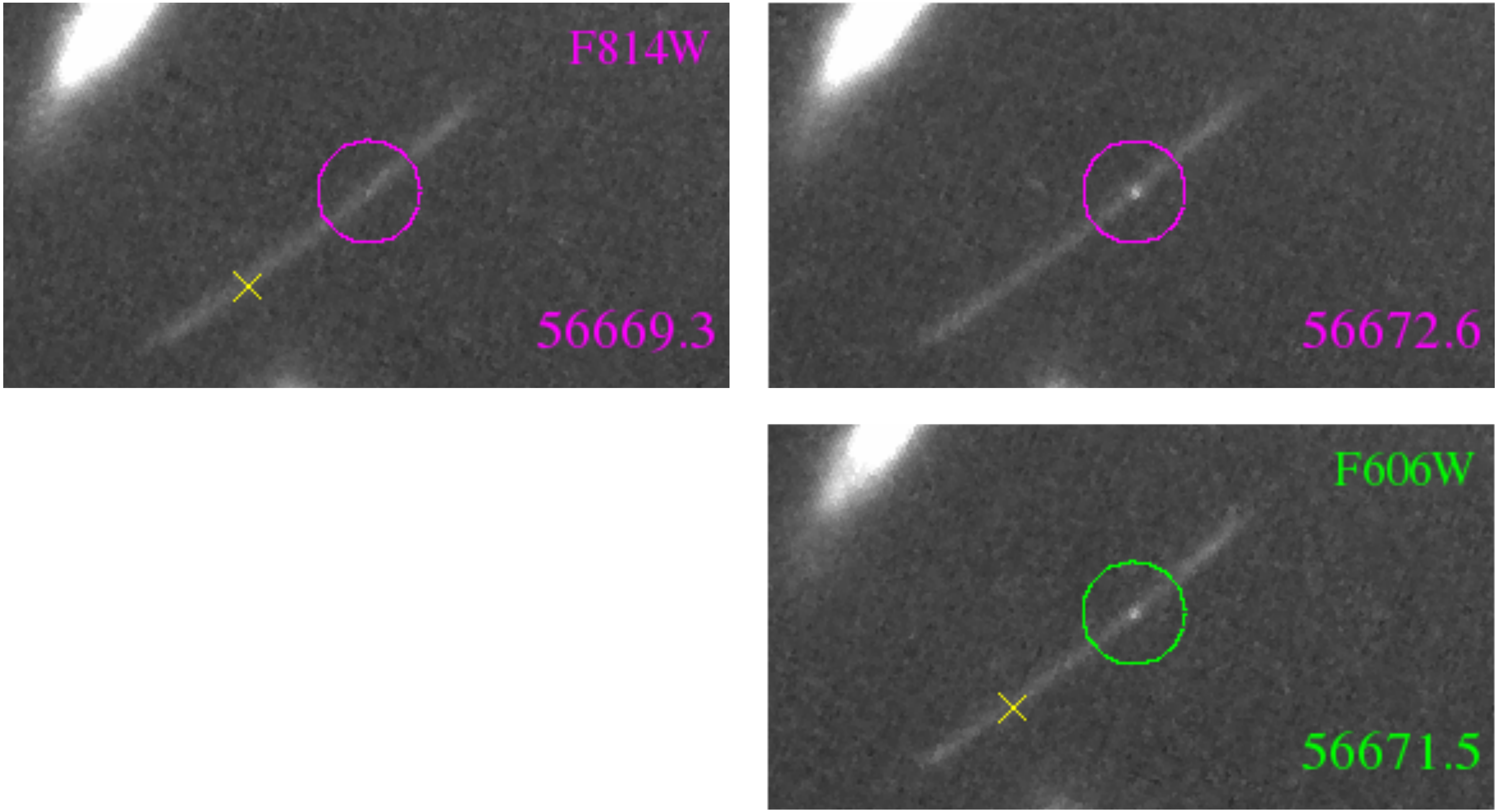


Lens model predicts another image



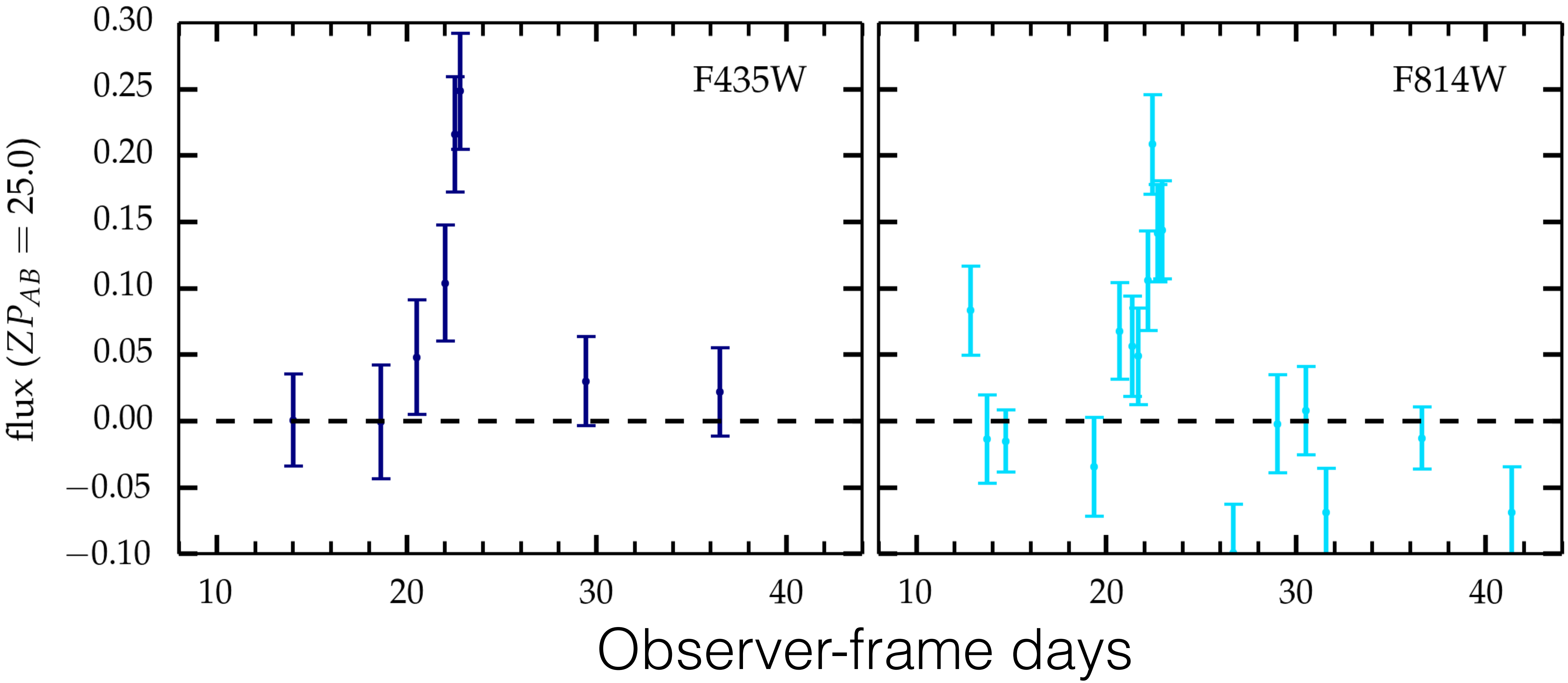
Bradac+ 2012

January : A prior detection!



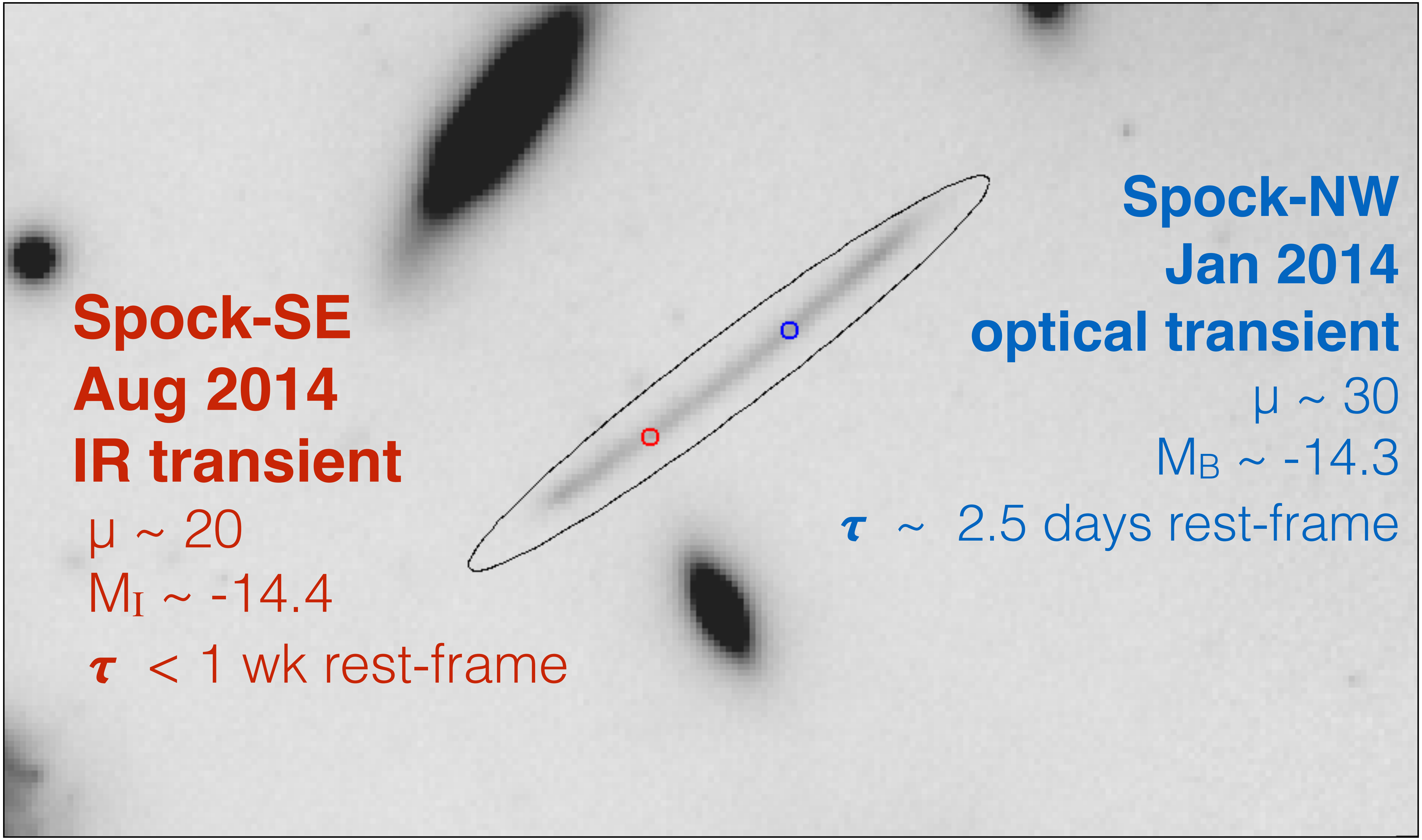
Steve Rodney (JHU)

But it lasted < 3 rest-frame days



Steve Rodney (JHU)

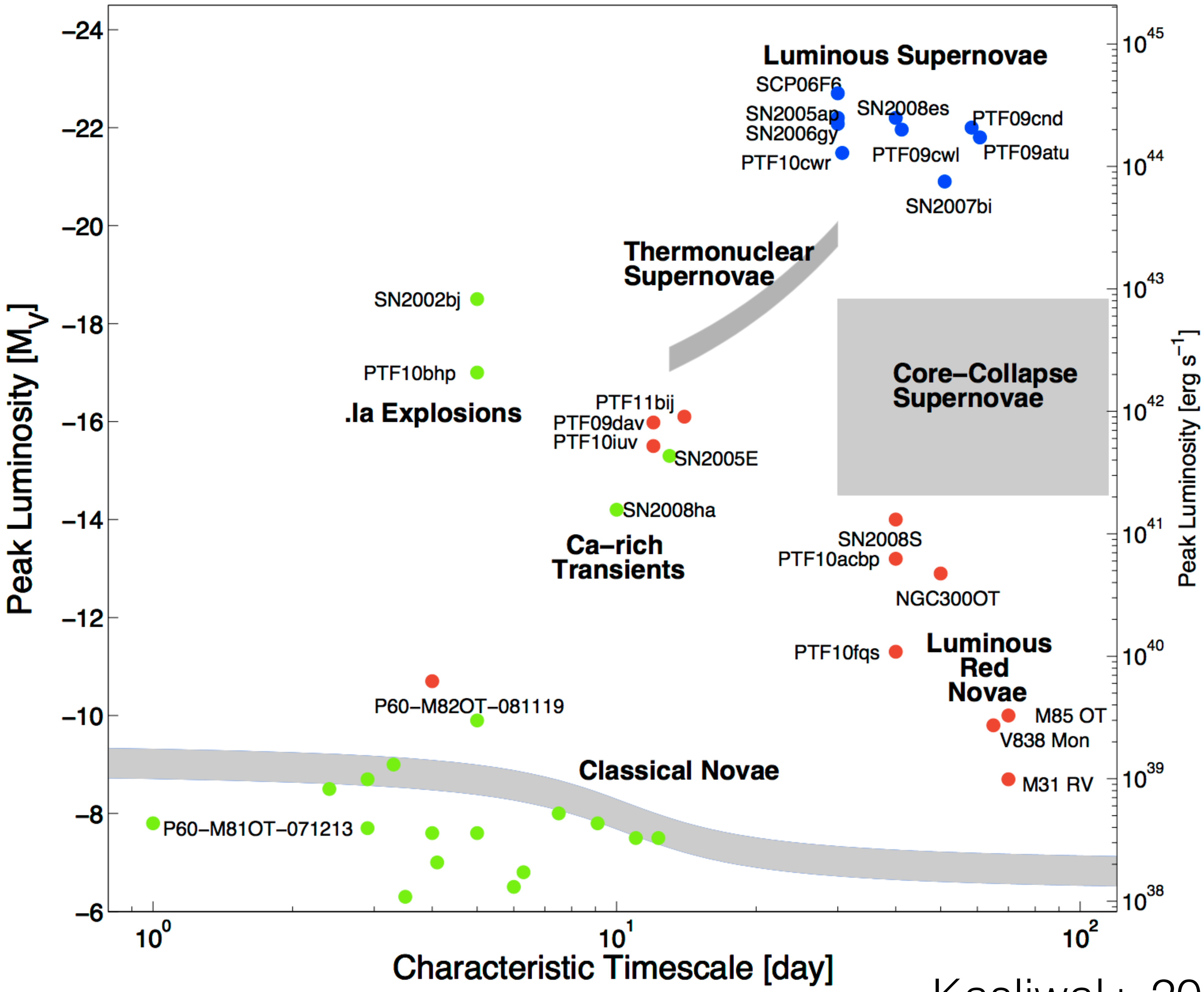
The peculiar "SN" Spock



Spock-SE
Aug 2014
IR transient
$\mu \sim 20$
$M_I \sim -14.4$
$\tau < 1$ wk rest-frame

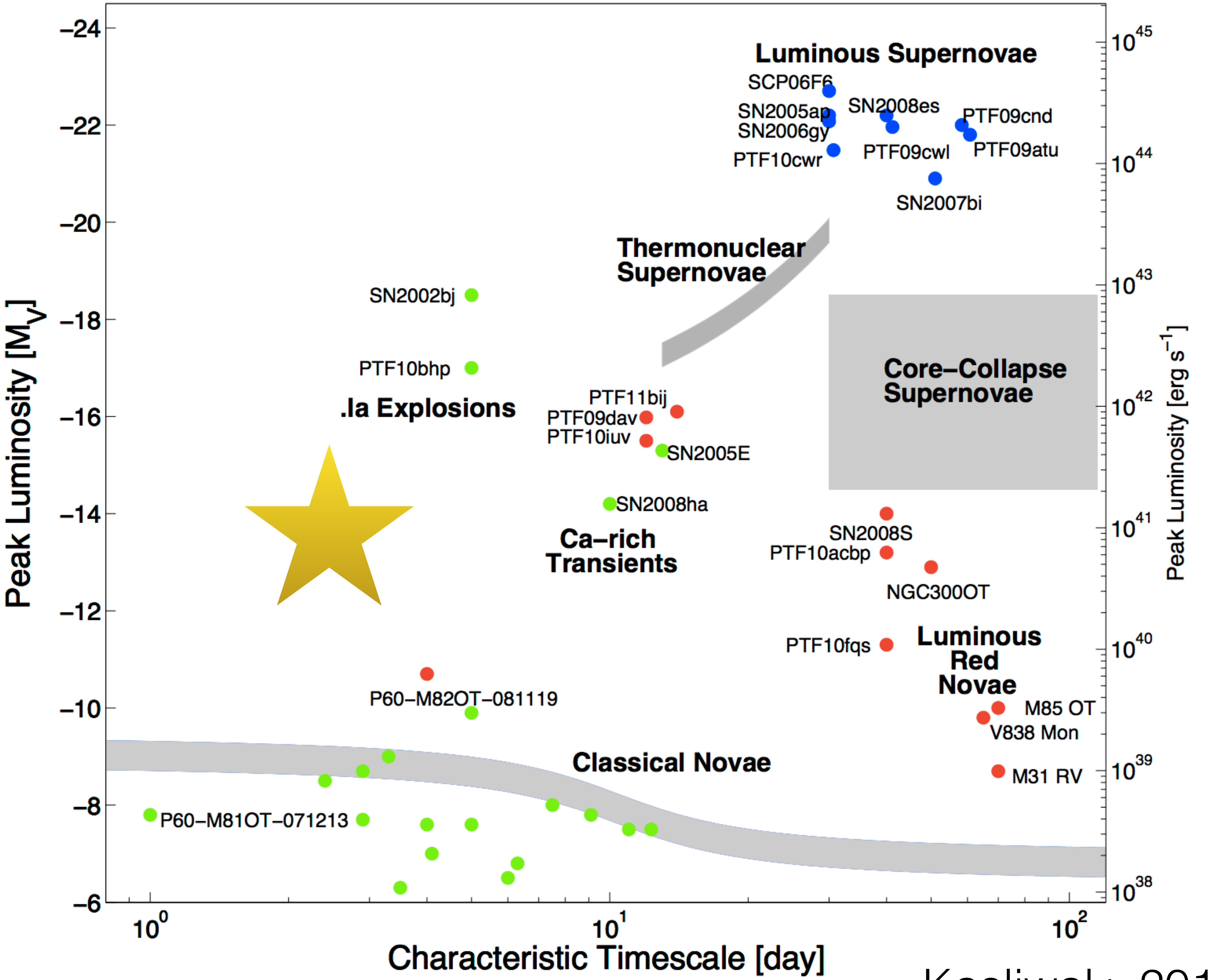
Spock-NW
Jan 2014
optical transient
$\mu \sim 30$
$M_B \sim -14.3$
$\tau \sim 2.5$ days rest-frame

Steve Rodney (JHU)



Kasliwal+ 2011

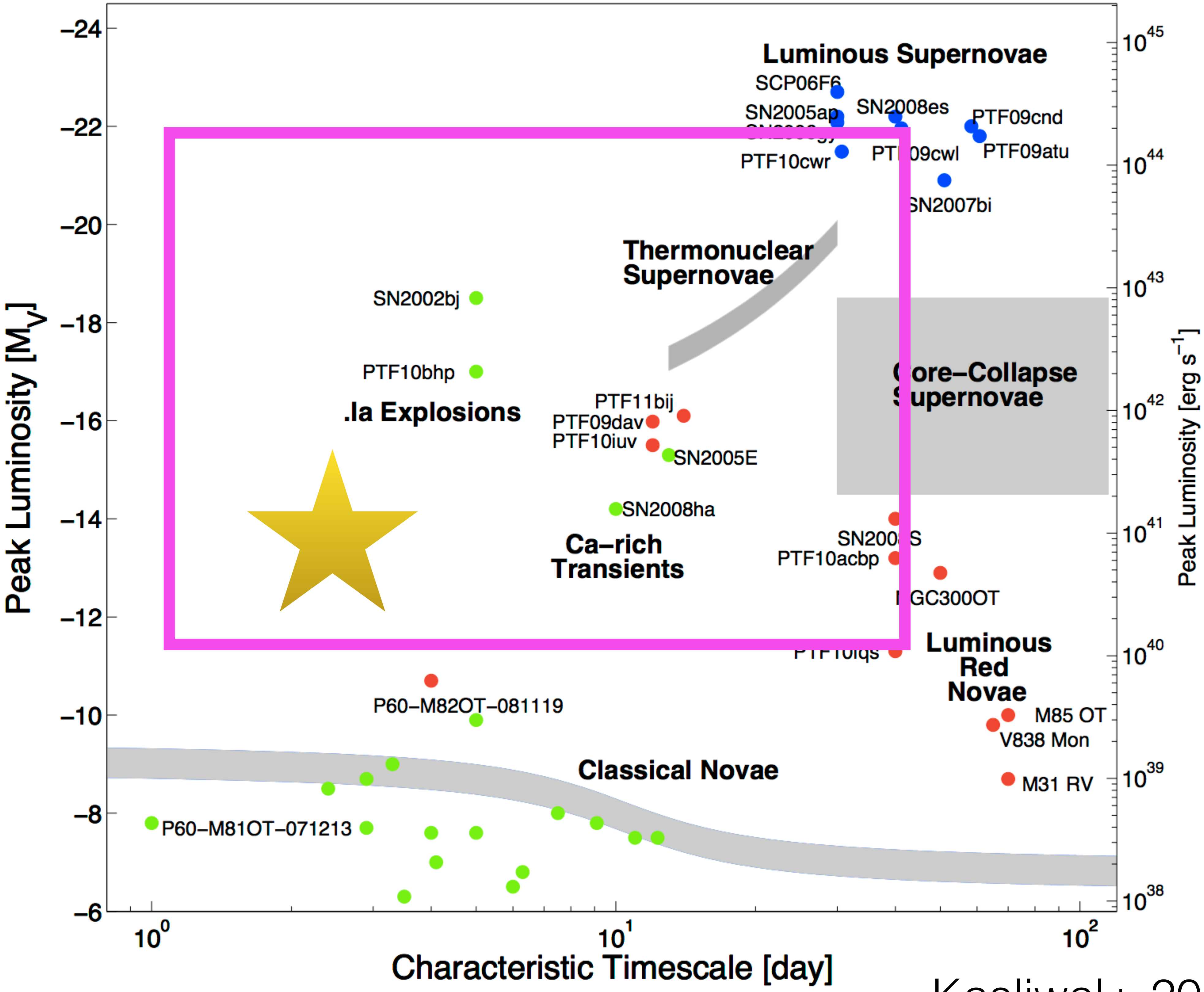
Too fast to be a SN or a .Ia



Kasliwal+ 2011

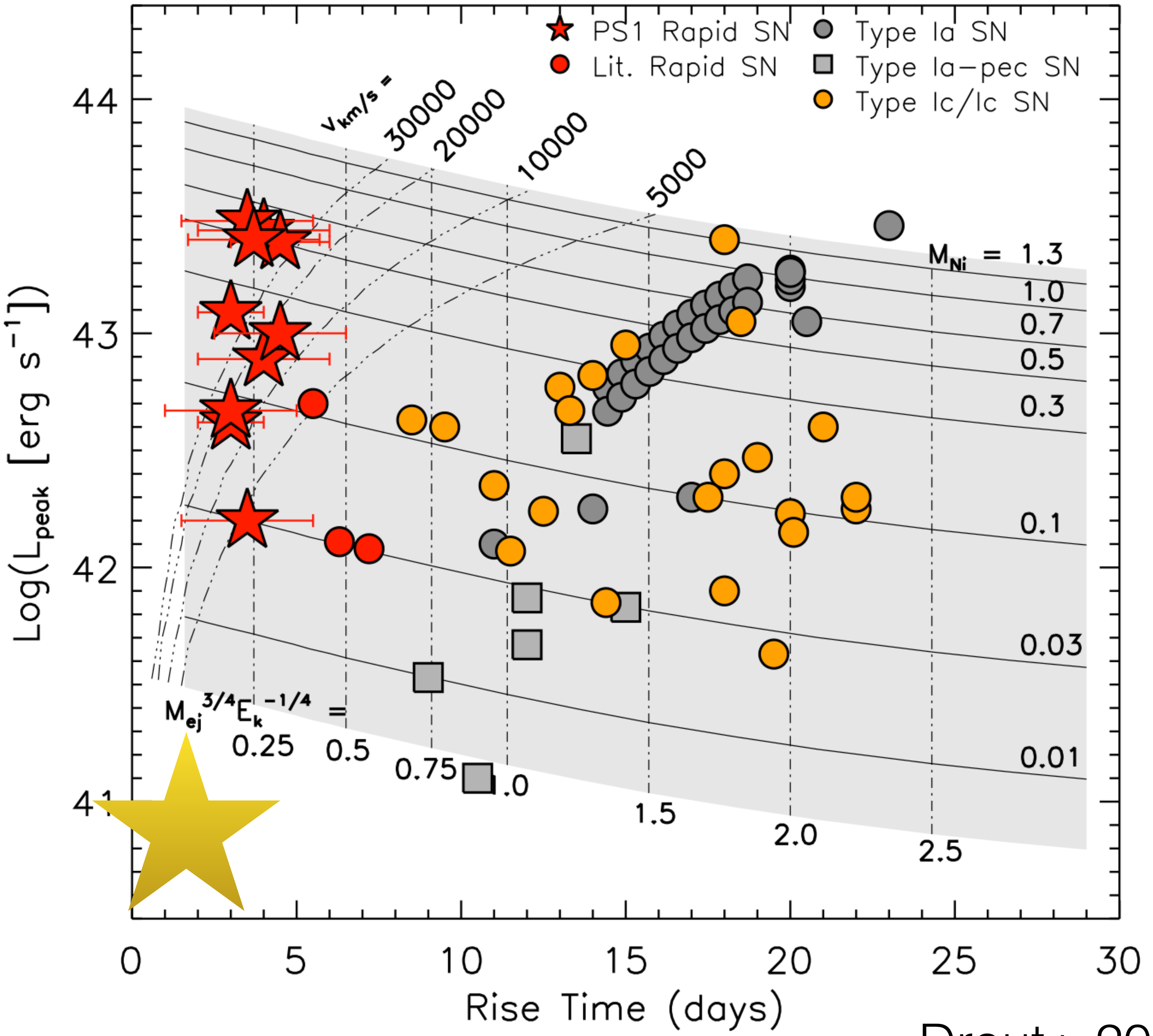
Steve Rodney (JHU)

Too fast to be a SN or a .Ia



Kasliwal+ 2011

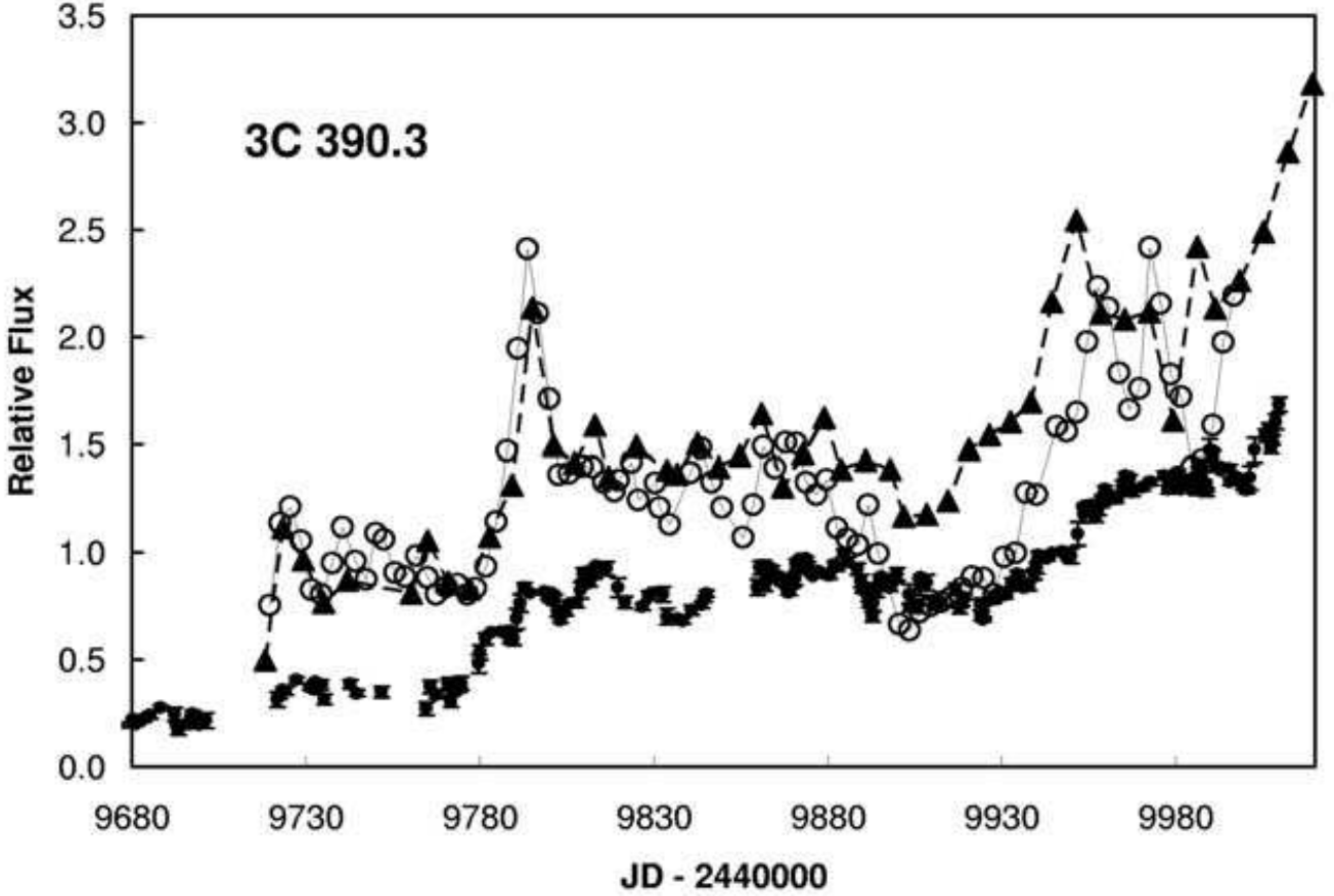
Fainter than known fast optical transients.



Drout+ 2014

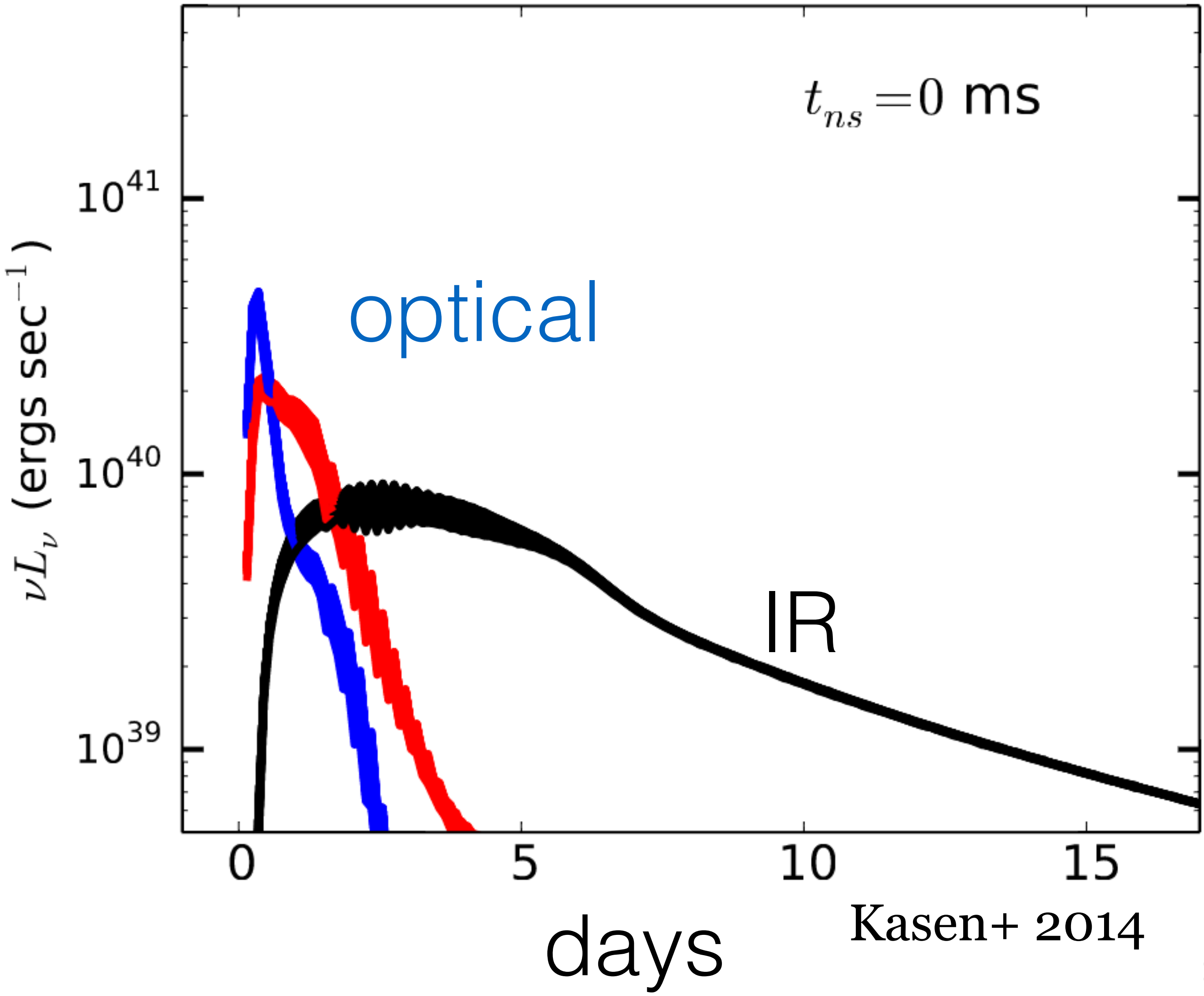
Steve Rodney (JHU)

Not an AGN…

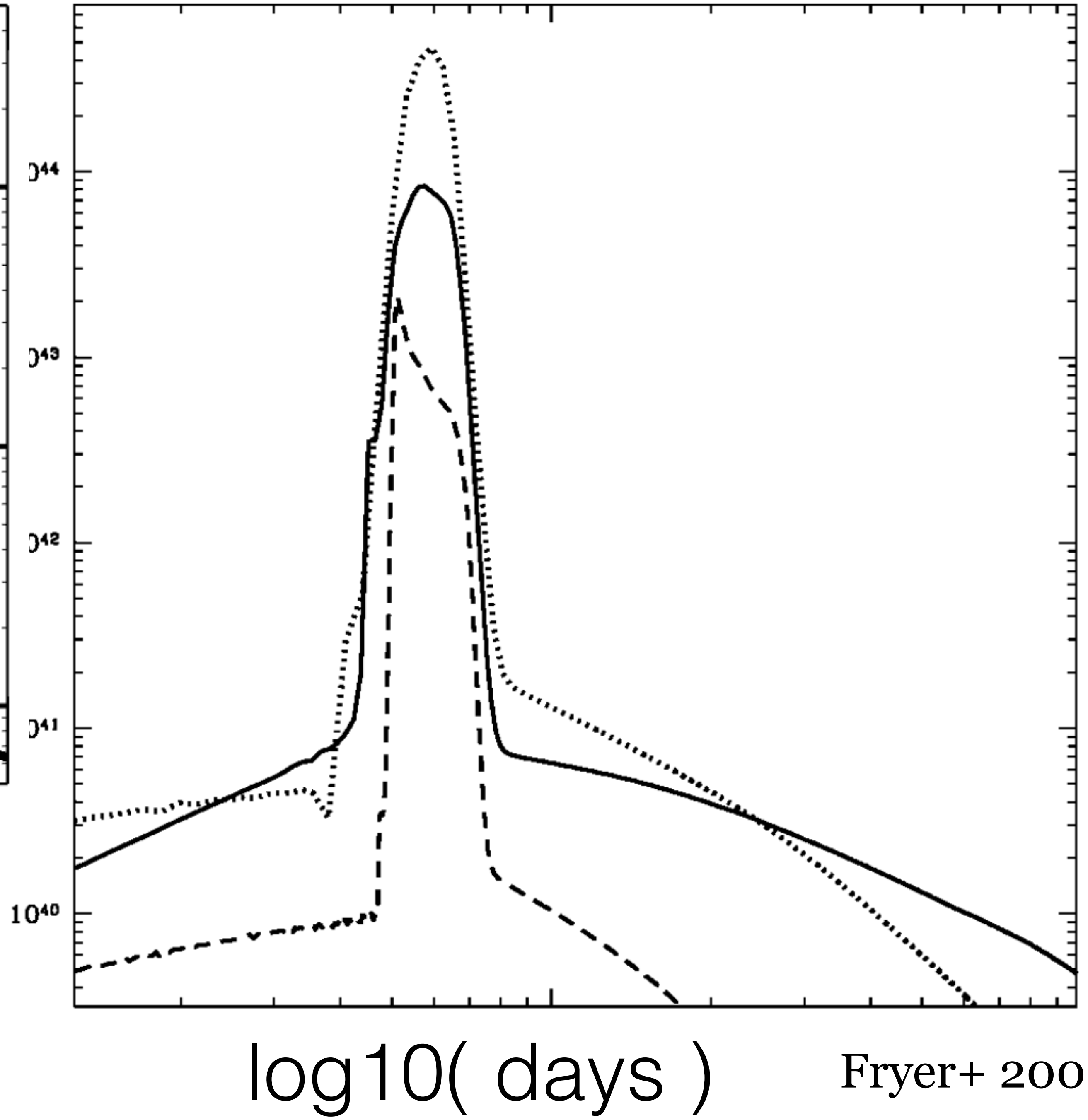


Gaskell+ 2006

Not a kilonova or fallback SN…

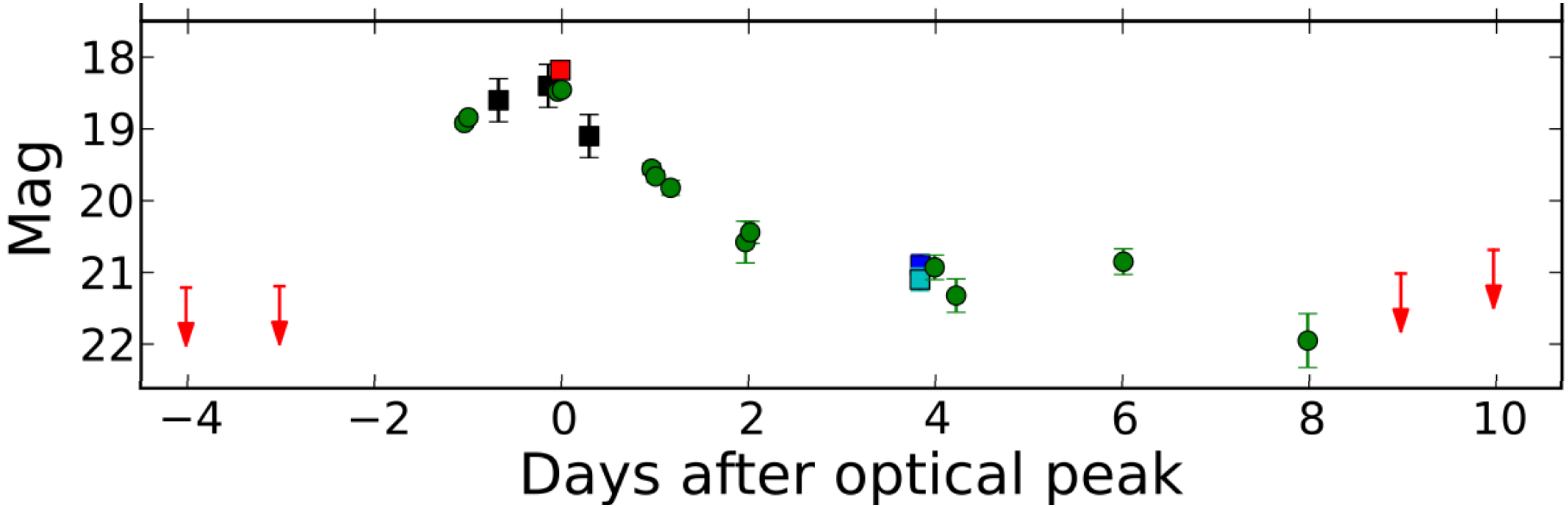


Kasen+ 2014



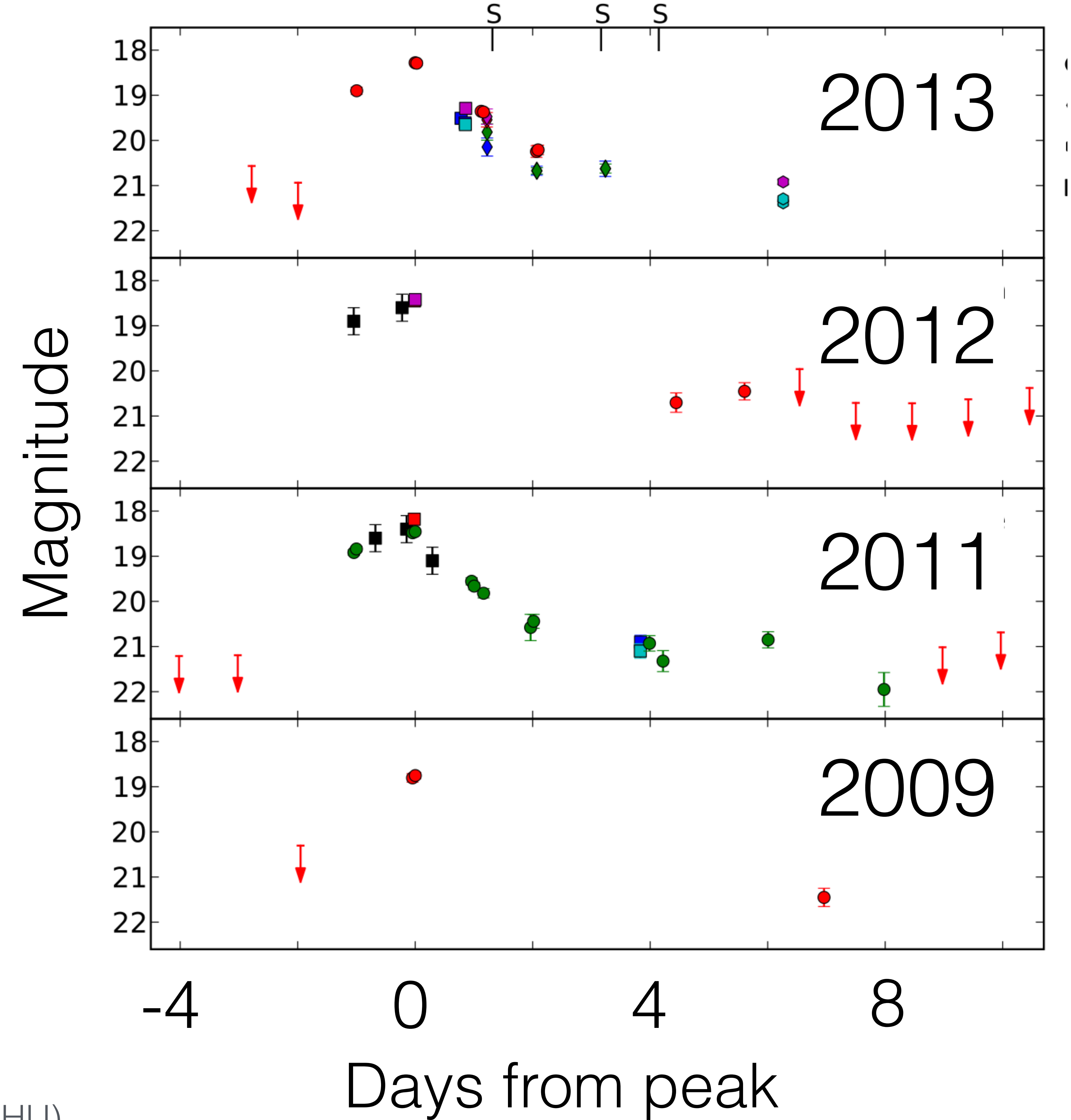
Fryer+ 2007

A rapid-recurrence nova?



Tang+ 2014

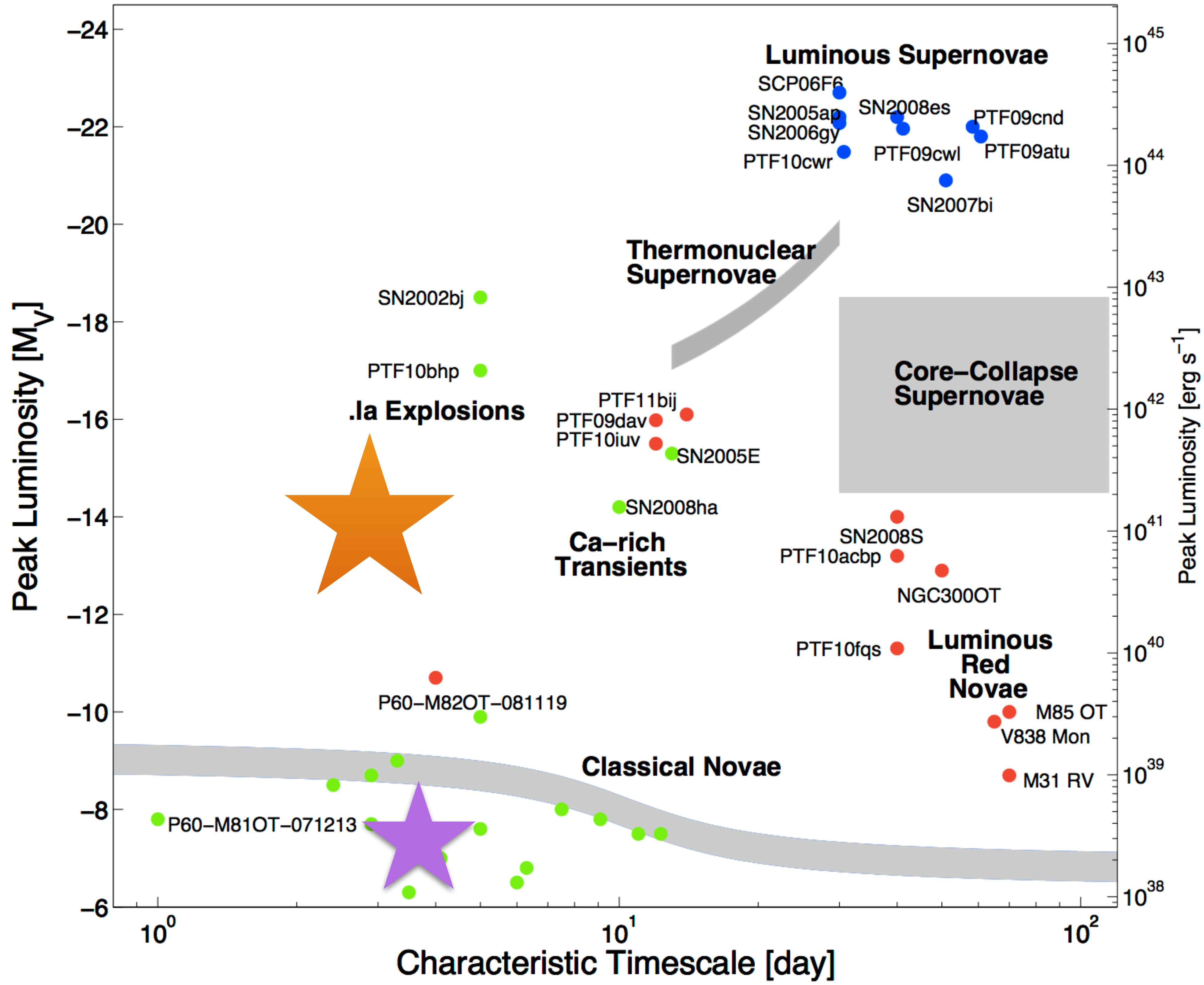
A rapid-recurrence nova?



Tang+ 2014

Steve Rodney (JHU)

A rapid-recurrence nova?



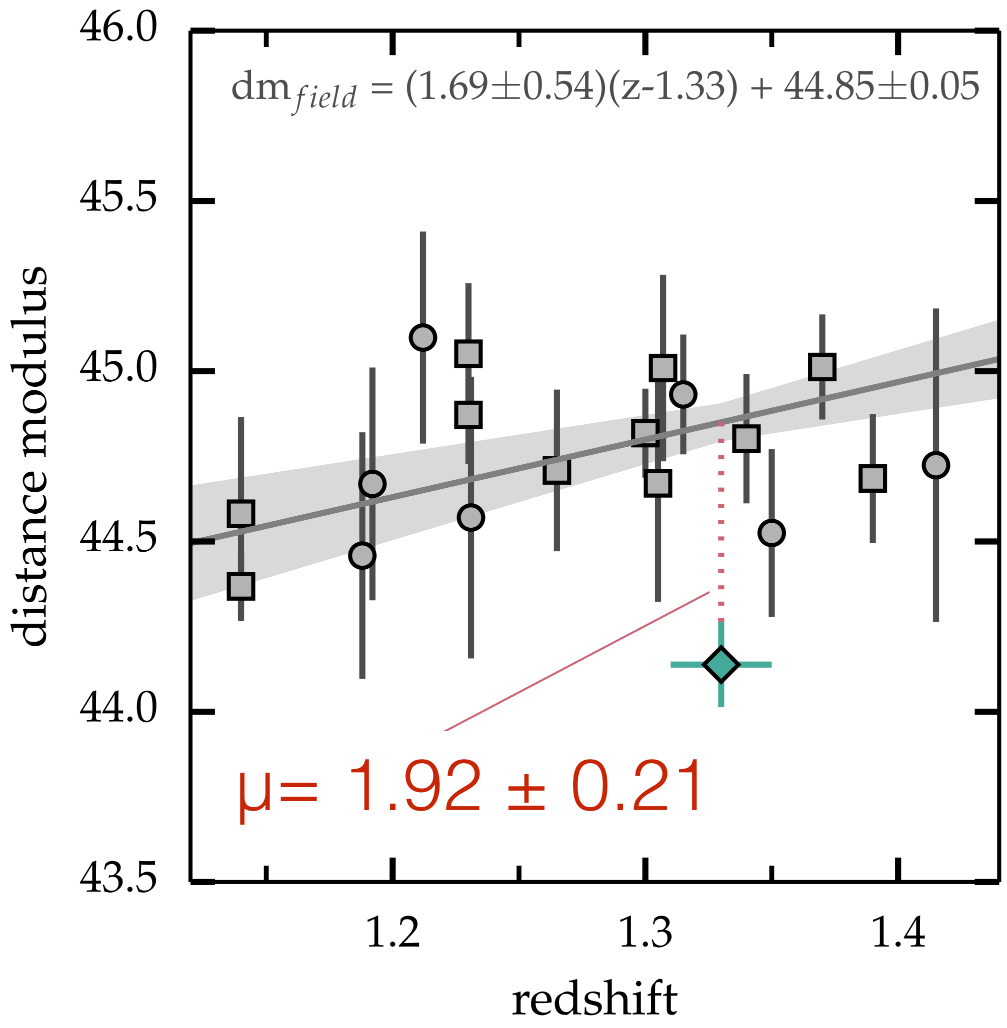
Steve Rodney (JHU)

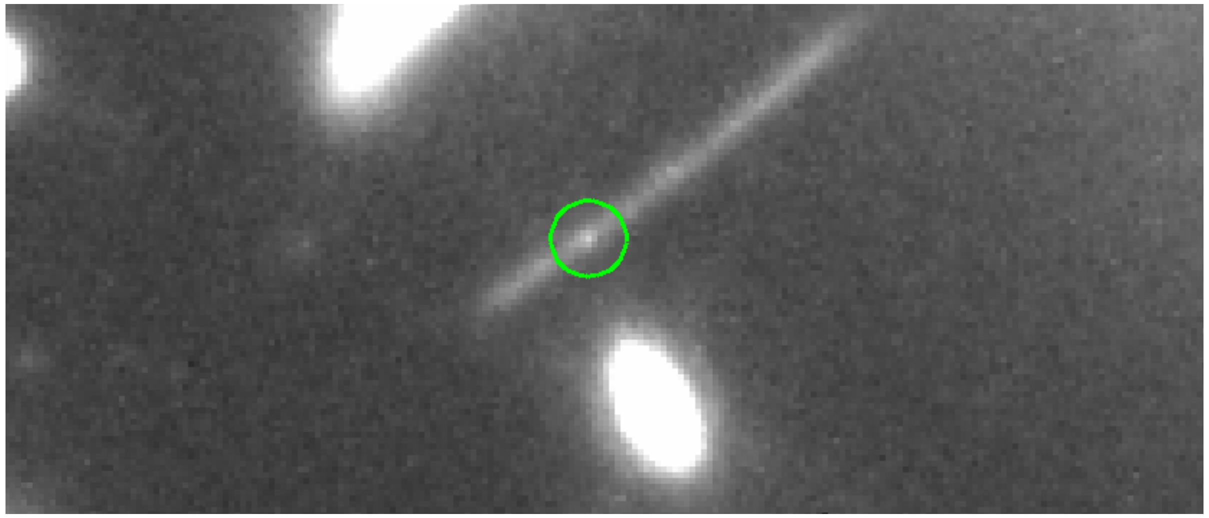
2014 : A Peculiar Multiply Imaged Transient

2014 : A Peculiar Multiply Imaged Transient

2024 : Nothing is peculiar anymore

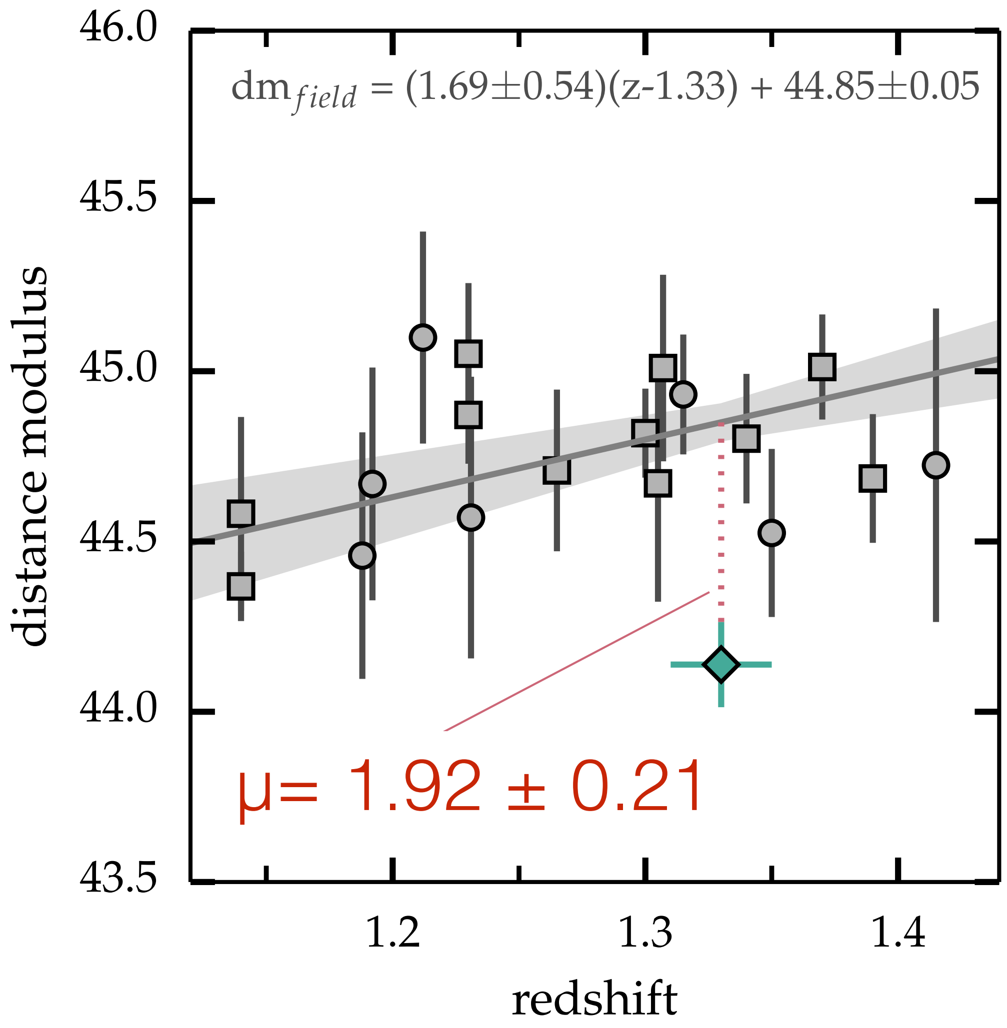
The Changing Transient Landscape

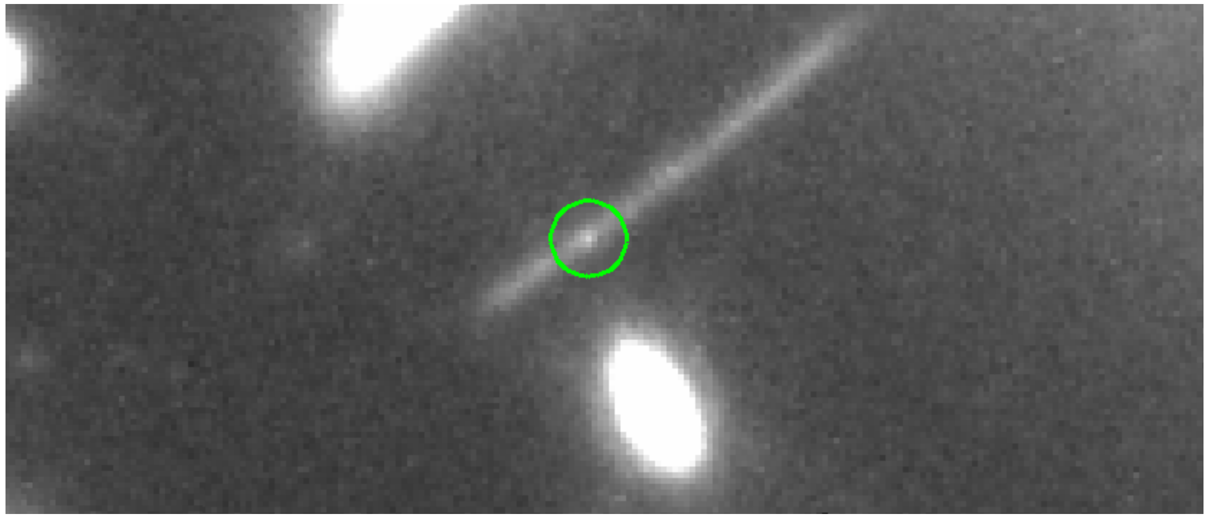




- As the rare become common, intersections are opportunities

The Changing Transient Landscape





- As the rare become common, intersections are opportunities

- Design for surprises :
  - cosmic telescopes
  - many cadences
  - rapid spectroscopic follow-up

Steve Rodney (JHU)