Finding the missed debris disks of the HST archive

An insight of the ALICE project

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The ALICE group at STScI:

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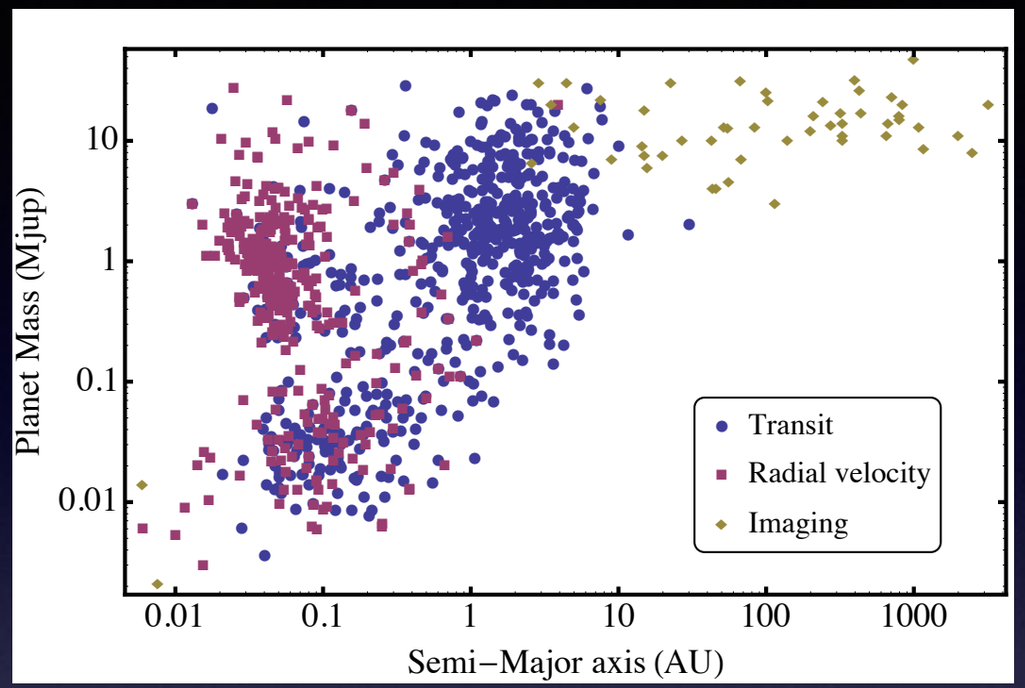
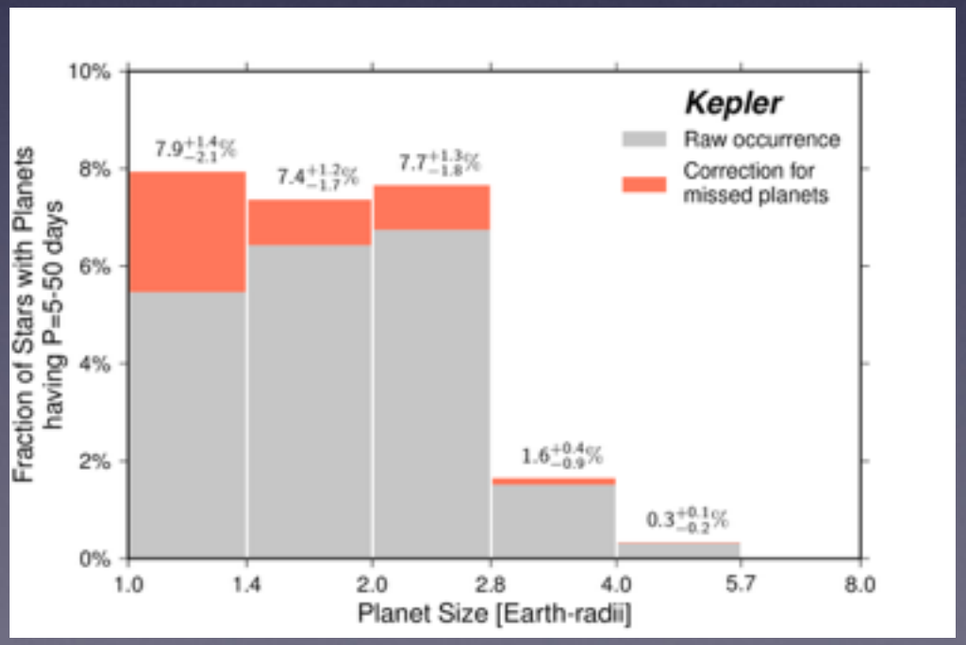
Planet formation:
Main questions

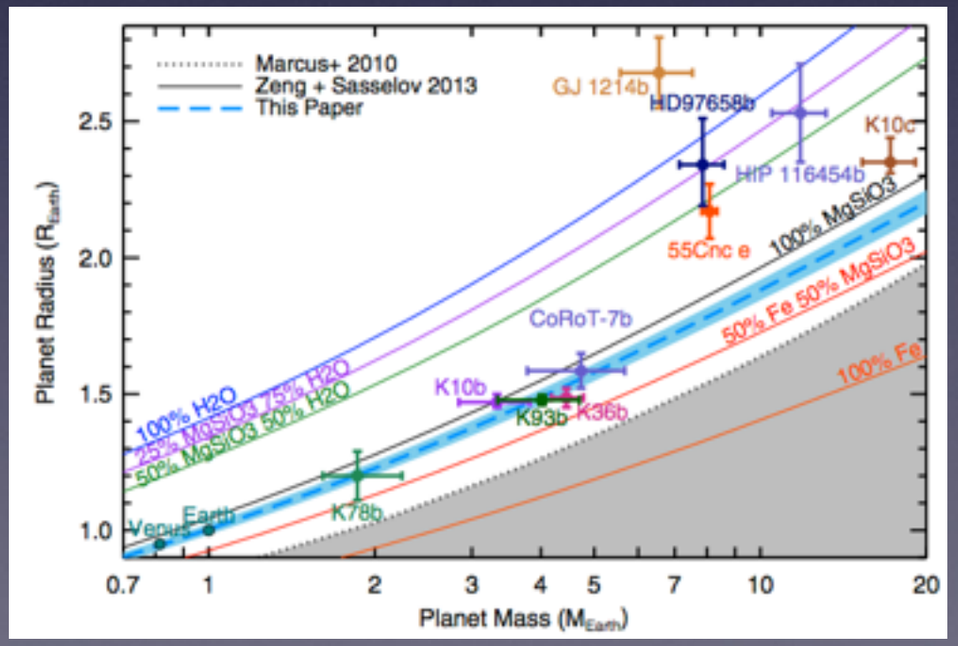
- How frequent are they?
- How diverse are they?
- What are they made of?
- How do they form?



exoplanet.eu



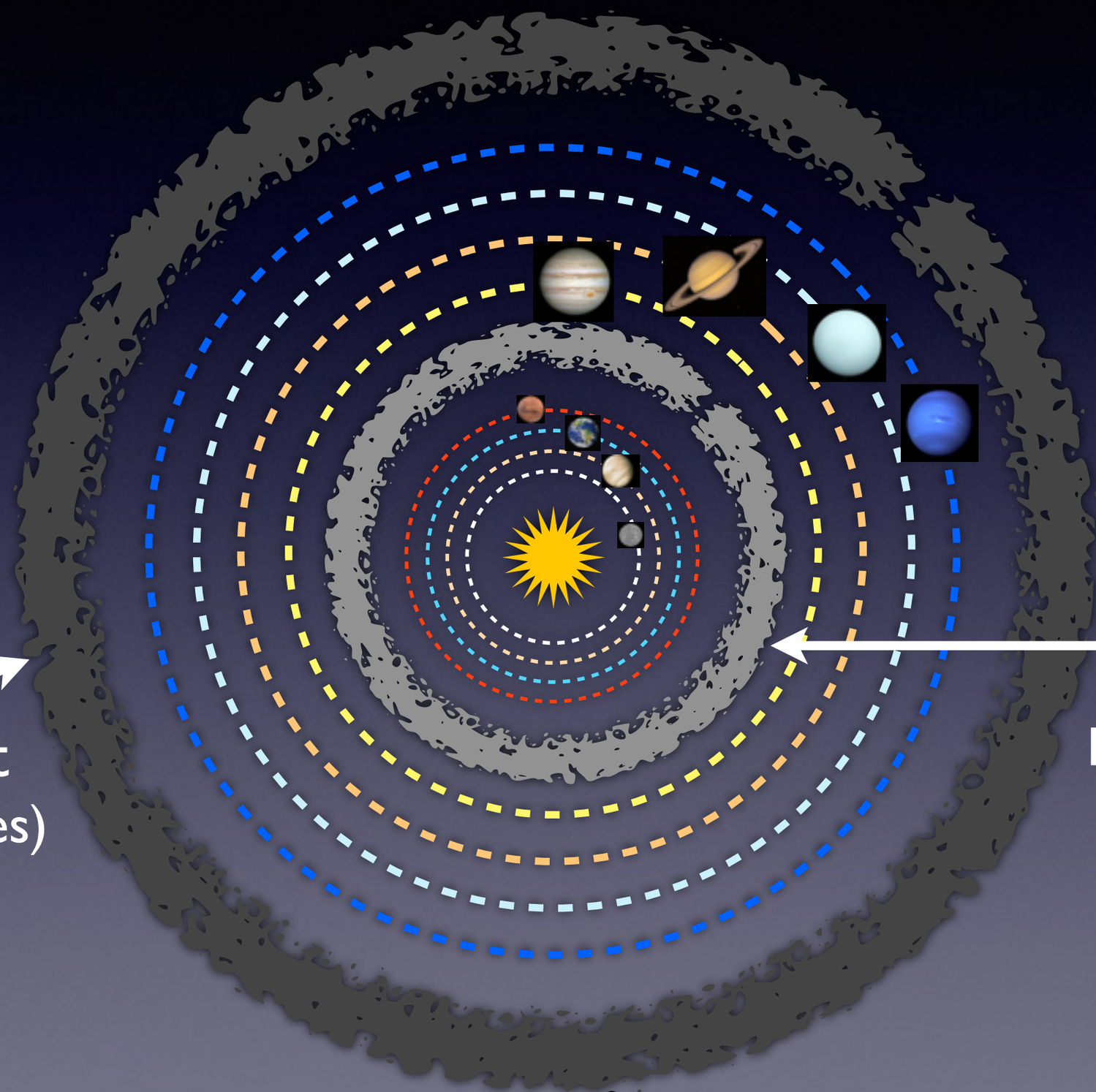
Petigura et al. 2013



Dressing et al. 2015

Debris disks:

Remnants of planet formation

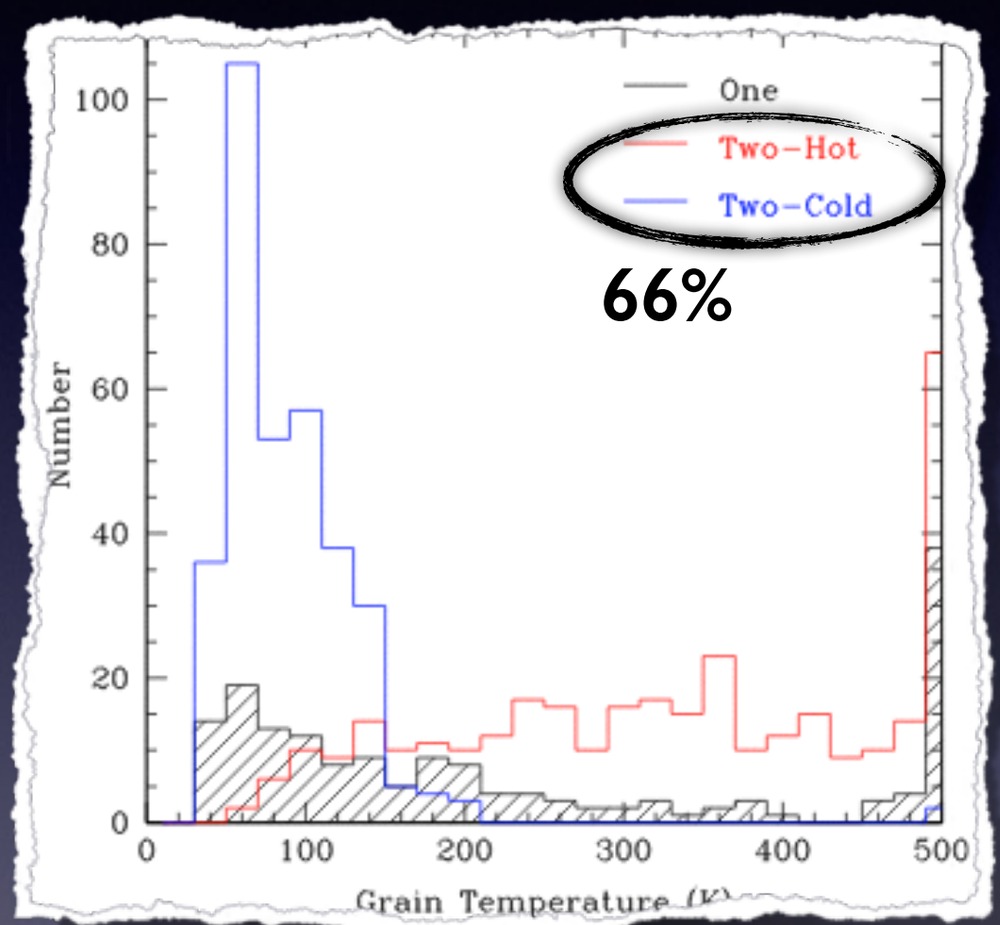


Asteroid belt
(Carbon-rich, Silicate-rich, and Metal-rich asteroids)

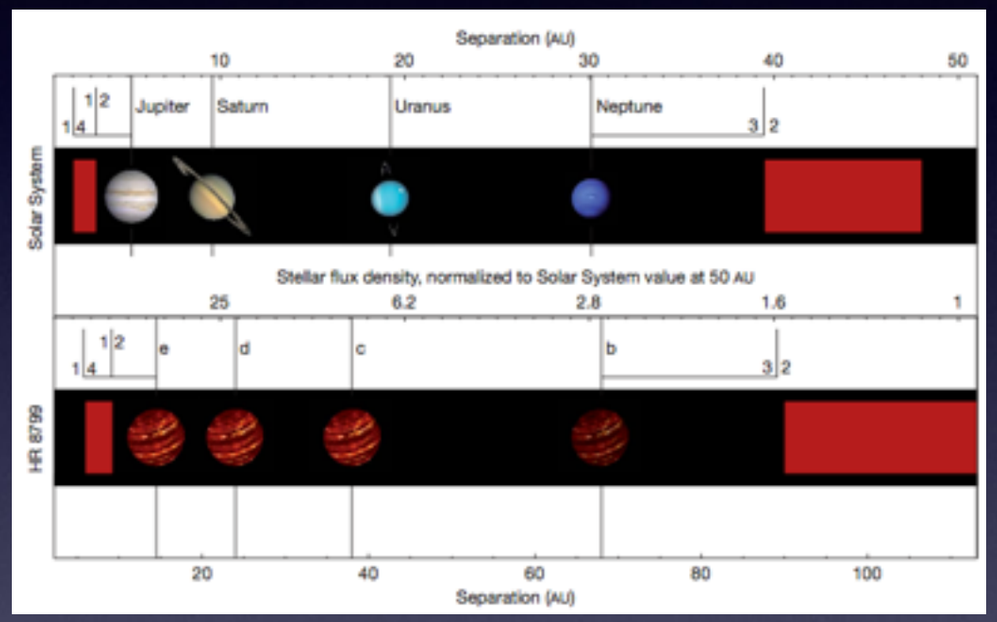
Kuiper belt
(mixture of ices)

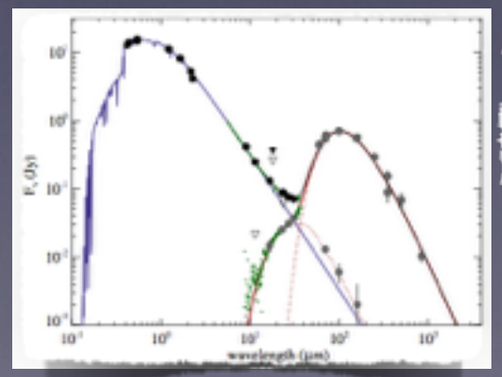
Debris disks:

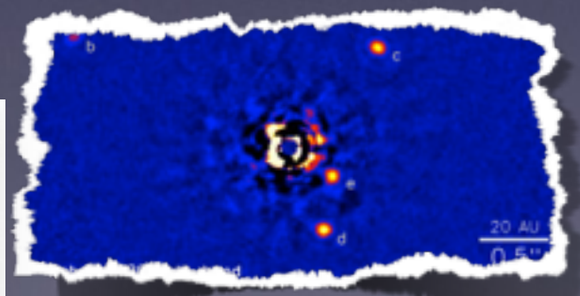
Remnants of planet formation

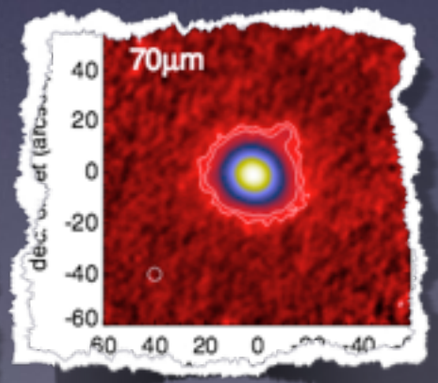


Chen et al. 2014





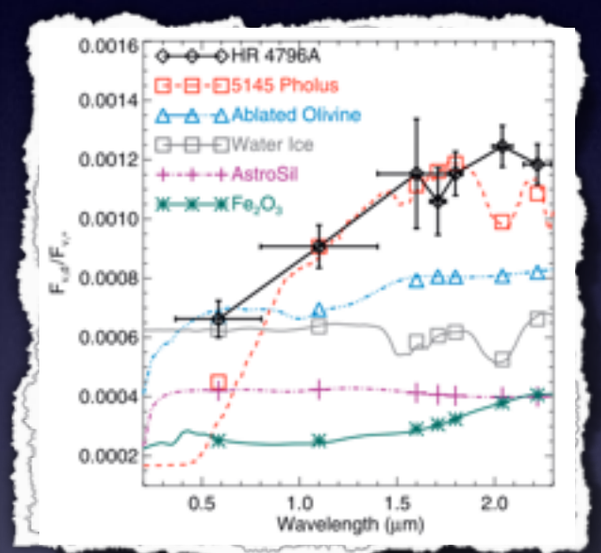




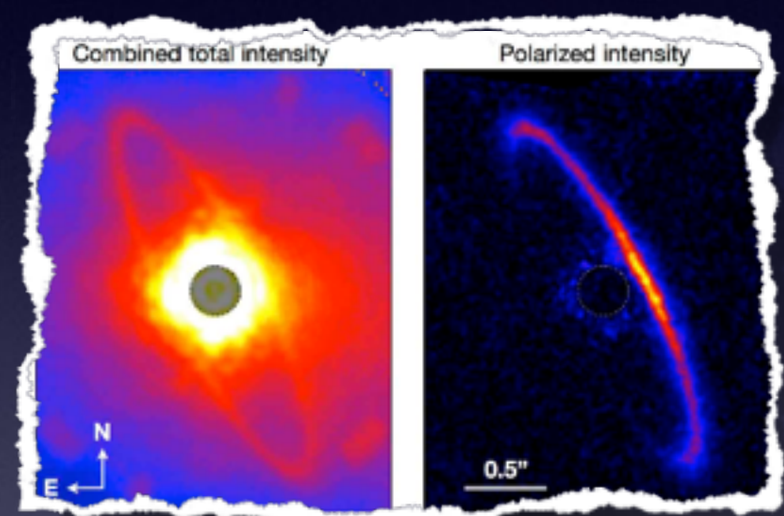
Marois et al. 2010
Matthews et al. 2014

Scattered light imaging:
Indirect studies of planets

Constraints on the disk composition



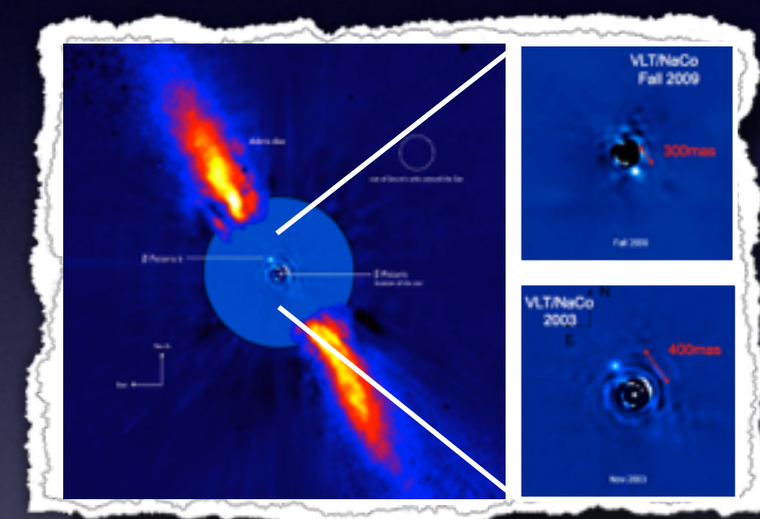
Debes et al. 2008



Perrin et al. 2014

- Albedo of the dust grains
- Color
- Polarized fraction of the dust

Signposts of planets



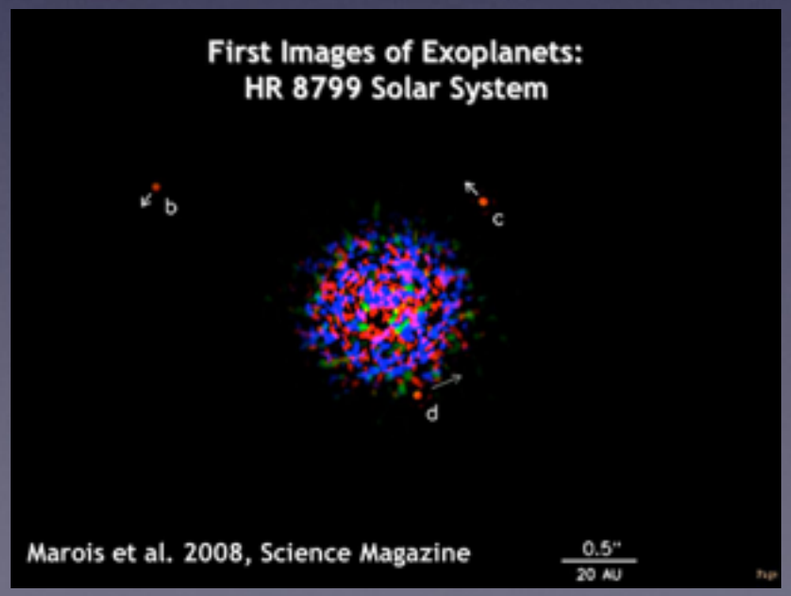
Lagrange et al. 2010

- Brightness asymmetries
- Disk offsets

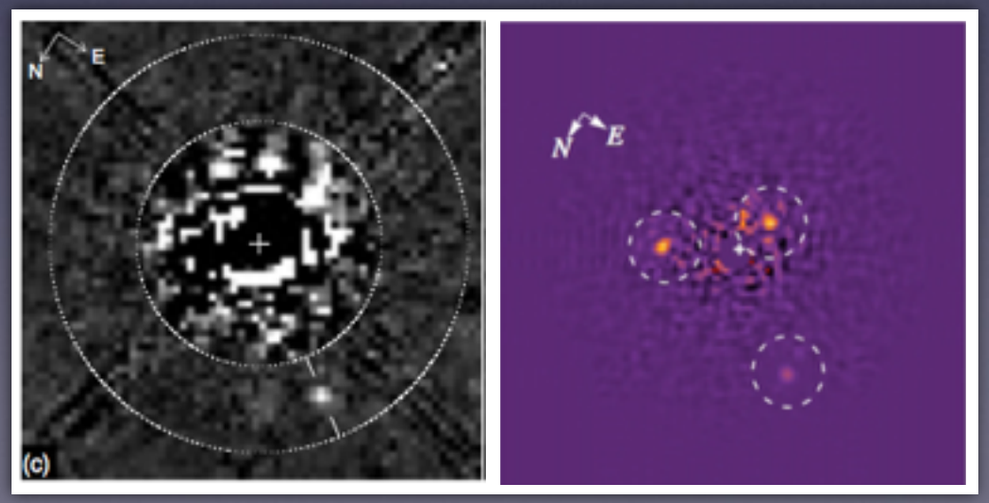
The ALICE project

Archival **L**egacy **I**nvestigations of **C**ircumstellar **E**nvironments

- **PI: Remi Soummer**
- **Goal:**
  Re-analyze the NICMOS coronagraphic archive with new post-processing algorithms
- **Motivation**:
  - Improve the detection limits on previous analyses
  - Detect circumstellar material missed by older methods



NICMOS data from 1998

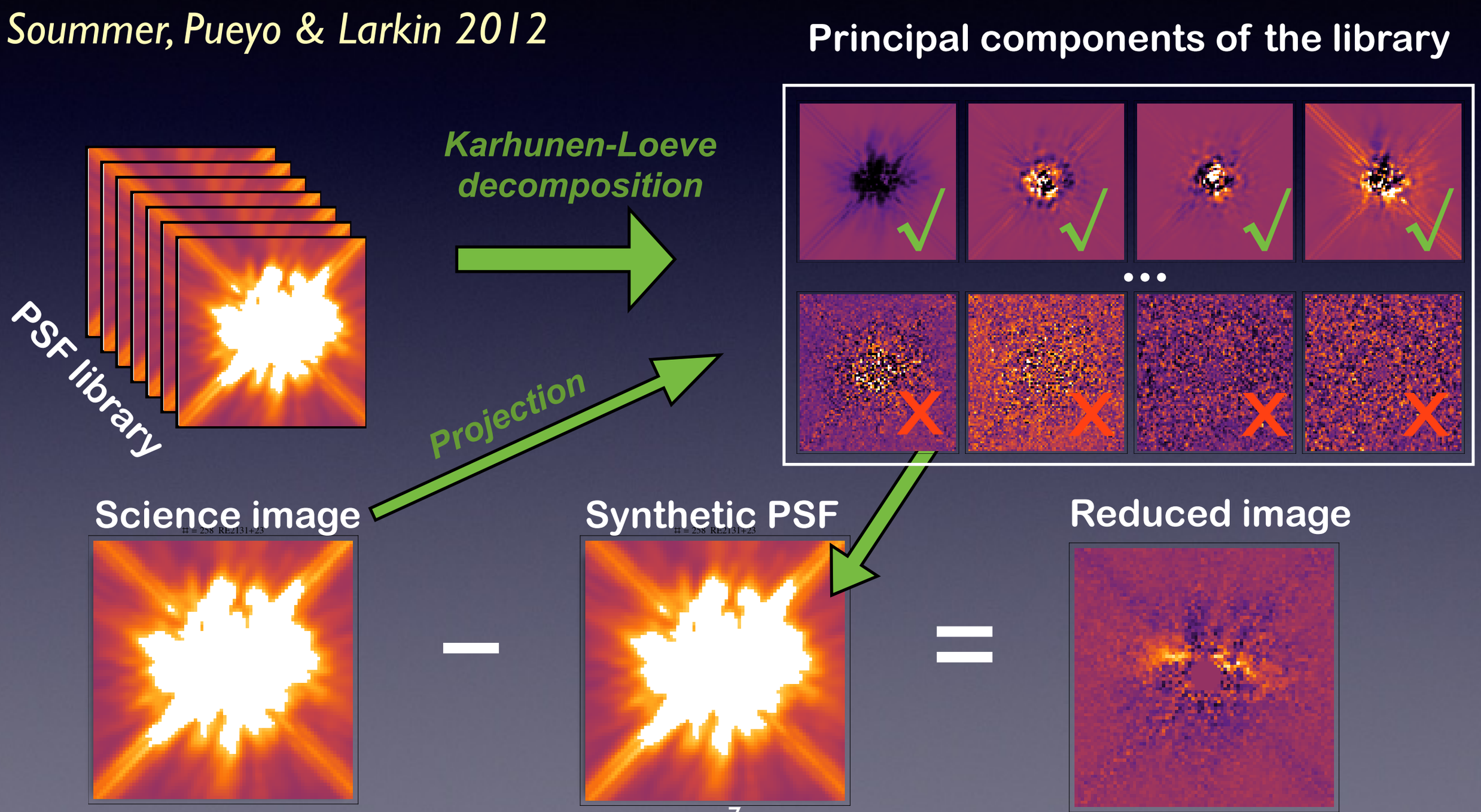


Lafreniere et al. 2009 Soummer et al. 2011

Postprocessing Method

The KLIP algorithm

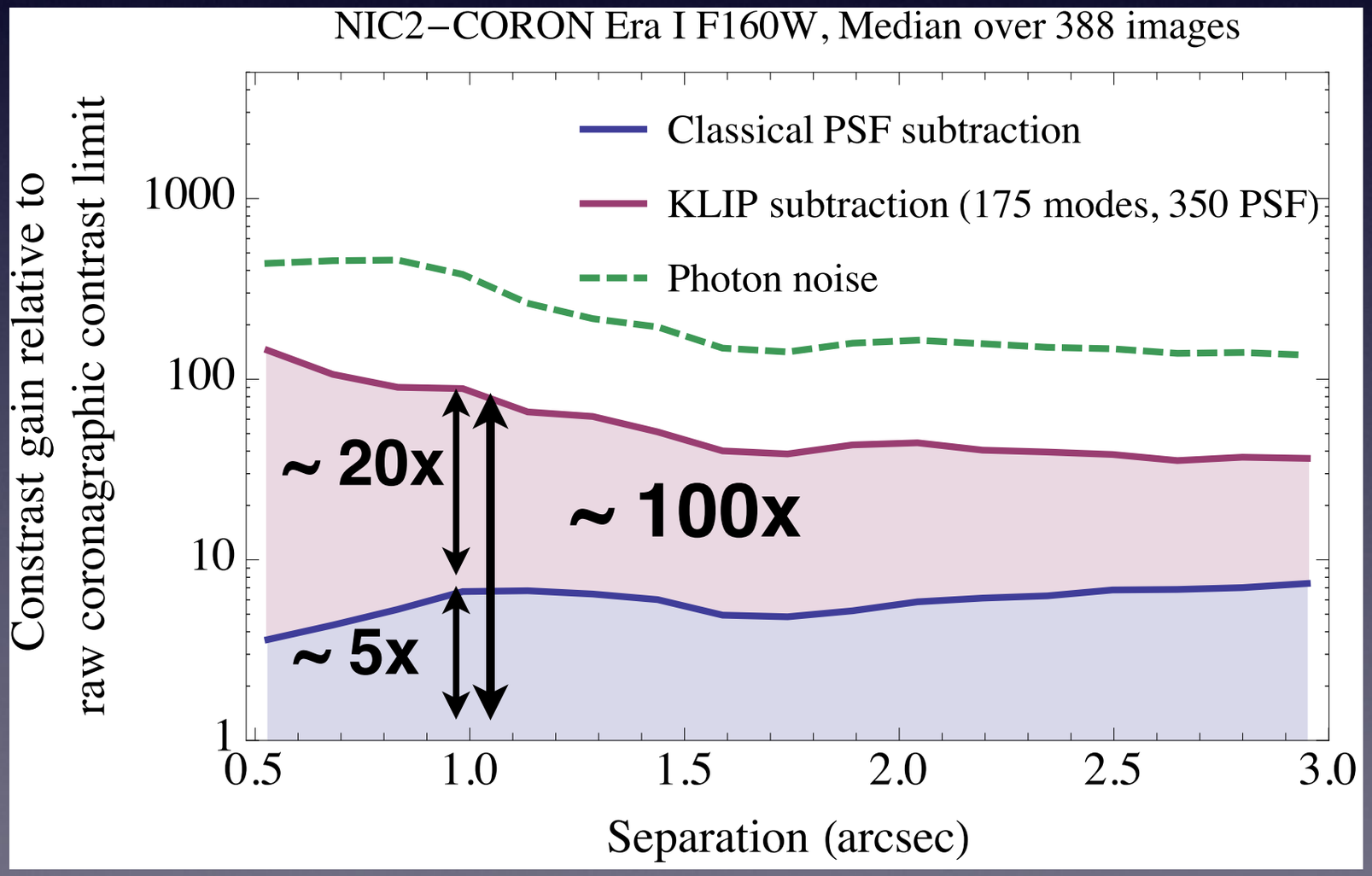
Soummer, Pueyo & Larkin 2012



Experience from the program

Contrast gain

- Mean gain over raw coronagraphic PSF: **~ 100x at 1”**
- Mean gain over classical PSF subtraction: **~ 20x at 1”**



The NICMOS archive

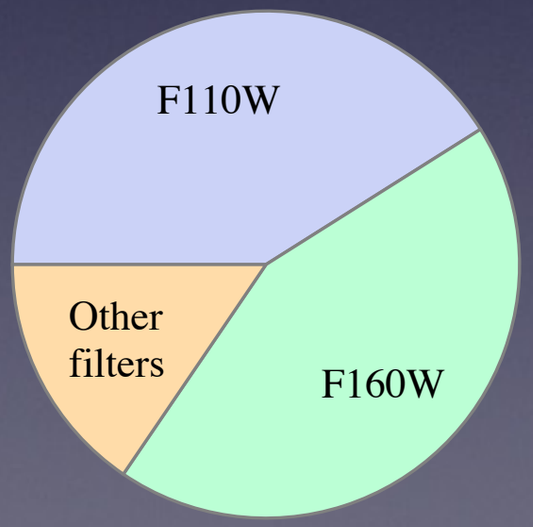
The ideal database PSF library

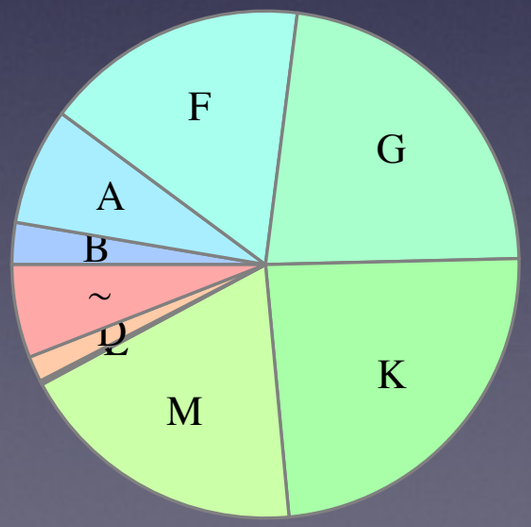
- ~5600 images
- All spectral types are present
- Stable instrument in space

Very large PSF libraries

No chromatic artifacts

Reproducible PSF variations

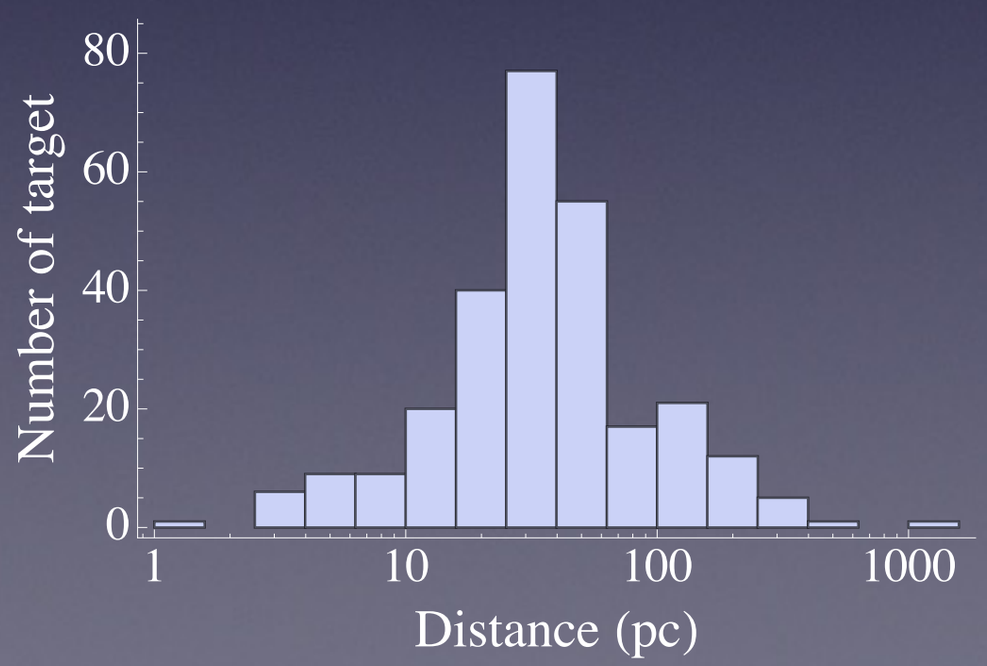




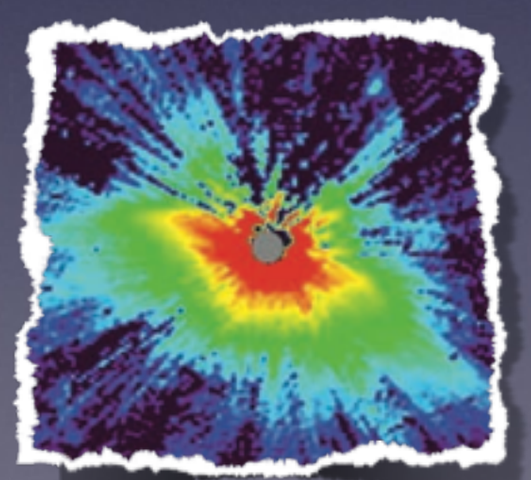
The NICMOS archive

The ideal science content

- 405 targets in the archive
- Mainly nearby star surveys for disks and planets
  - ~ 180 stars searched for planets
  - ~ 110 stars searched for debris disks
  - ~ 40 stars searched for protoplanetary disks

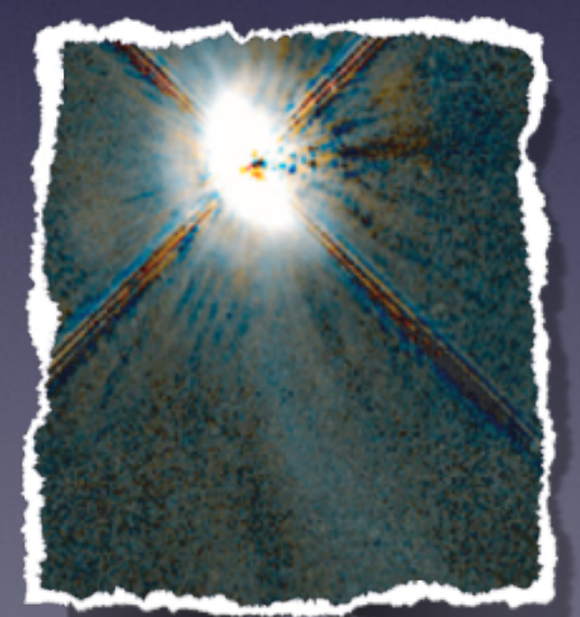


HD61005



Hines et al. 2007

GM-AURIGAE

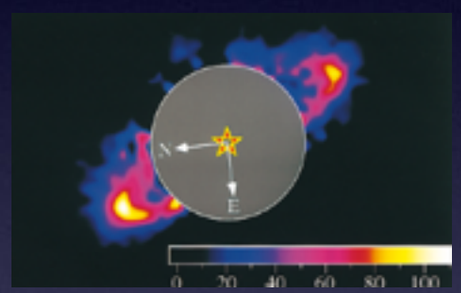


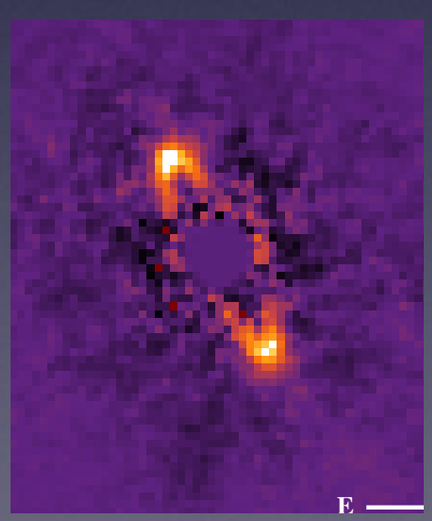
Schneider et al. 2003

ALICE results

Improved reduction of known disks

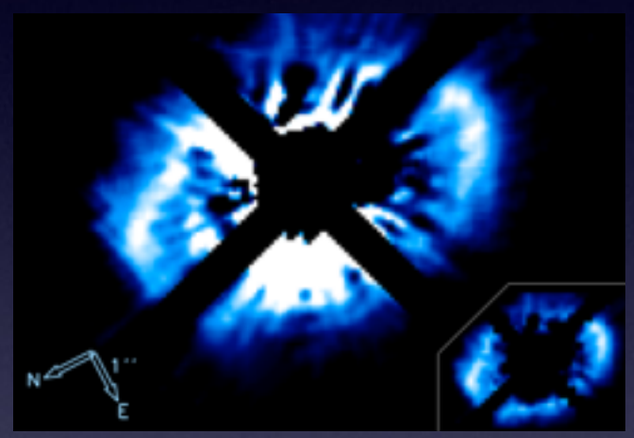
Schneider et al. 1999

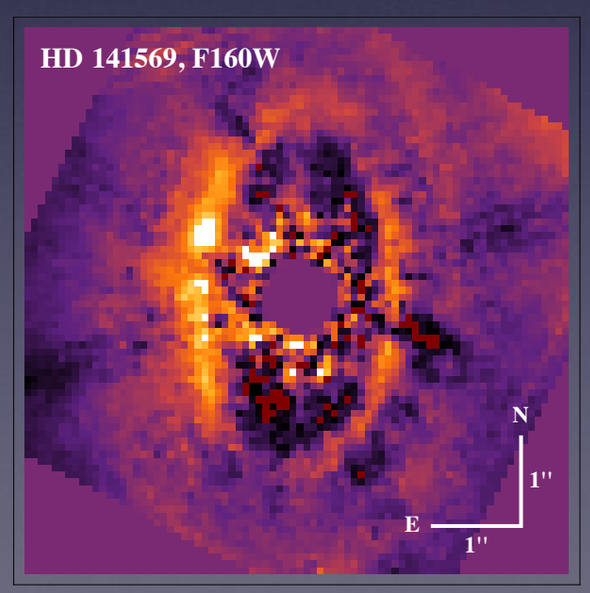




HR 4796A

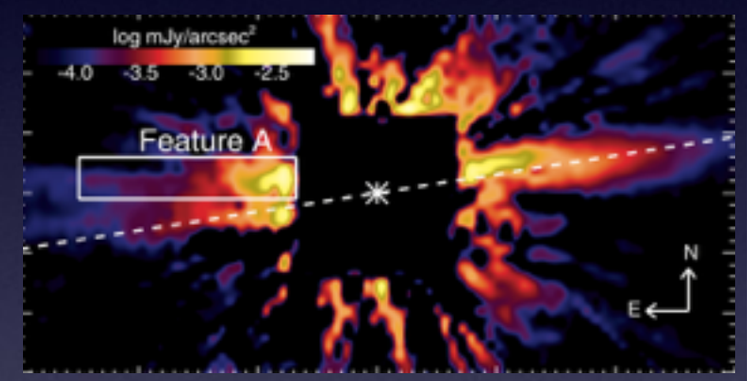
Augereau et al. 1999

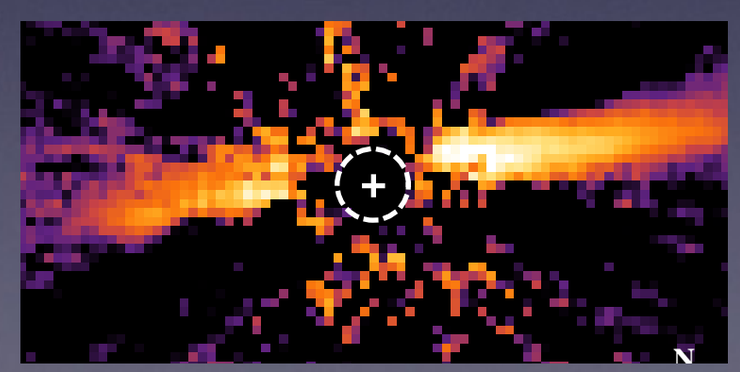




HD 141569

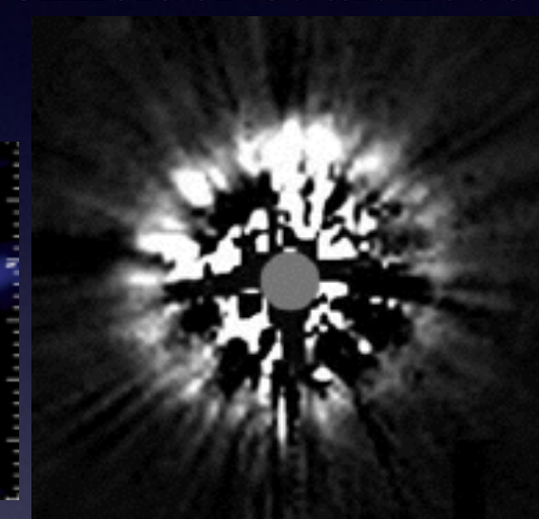
Debes et al. 2008

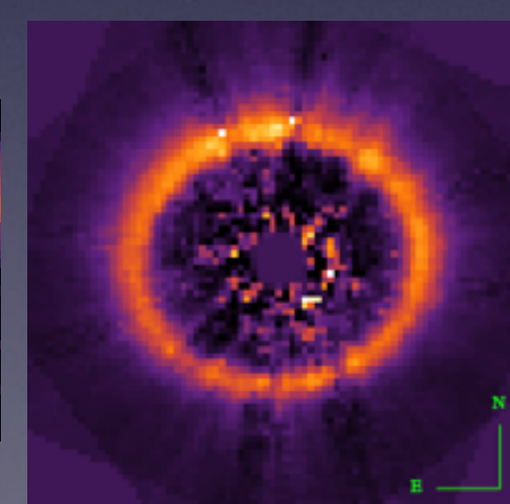




HD 15115

Schneider et al. 2006

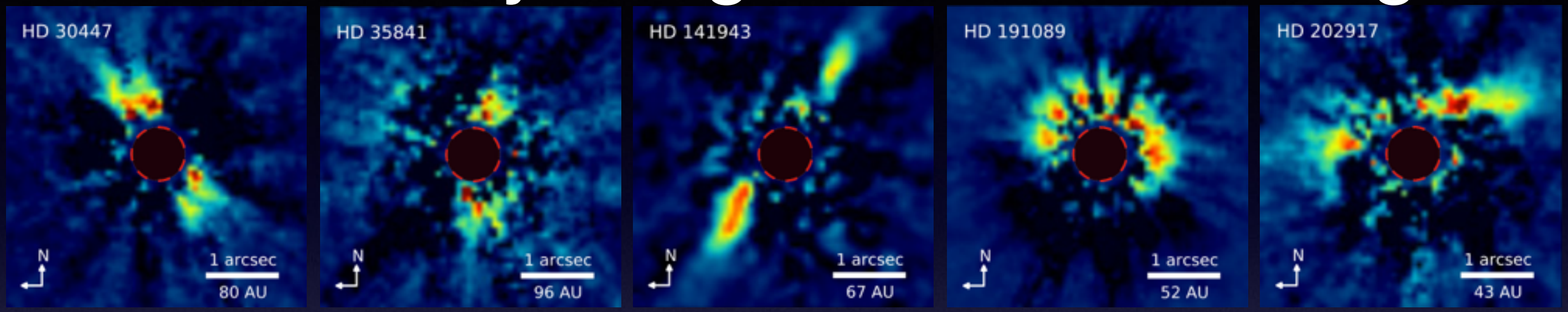


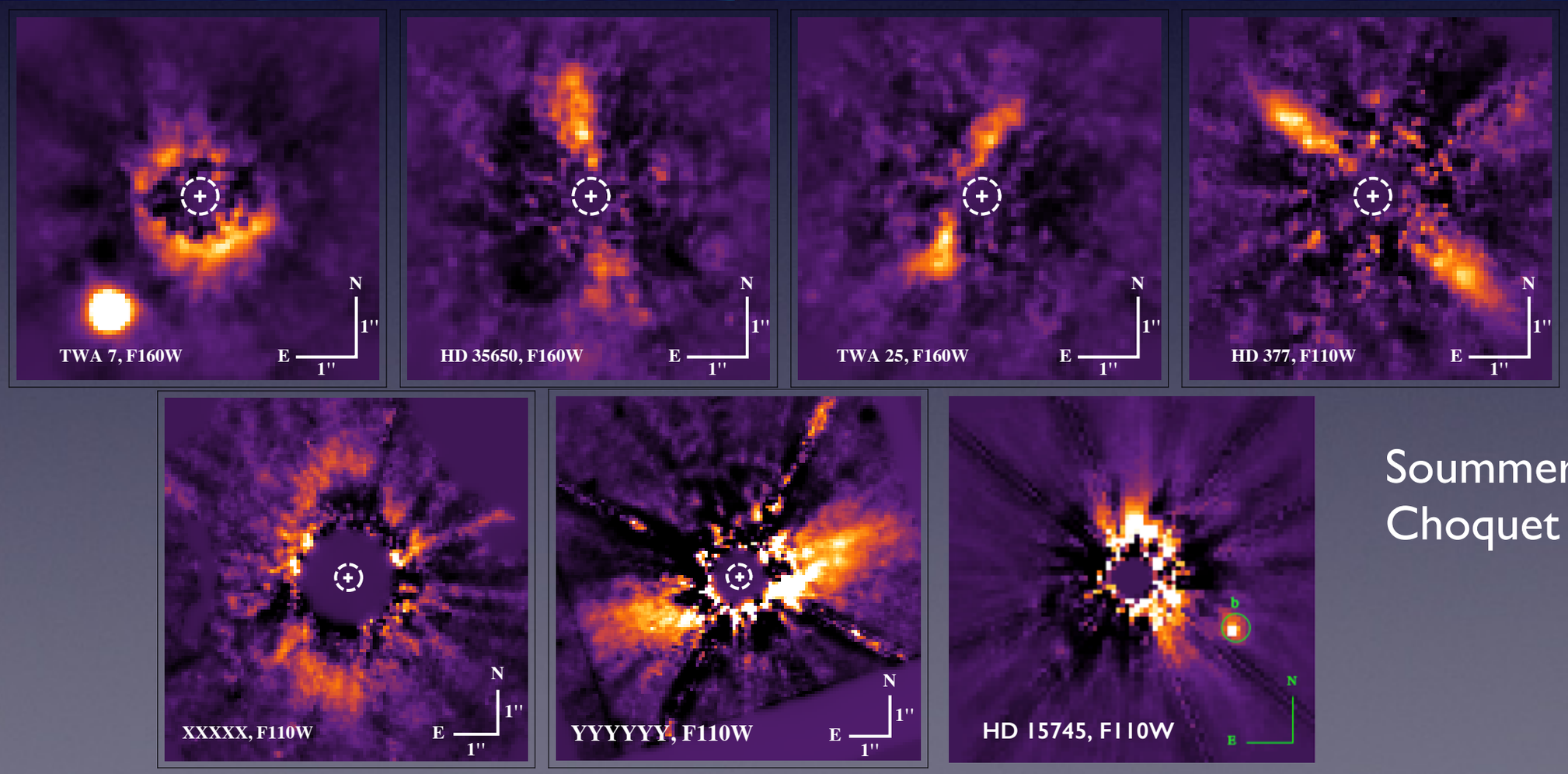


HD 181327

ALICE results

Disks newly imaged in scattered light

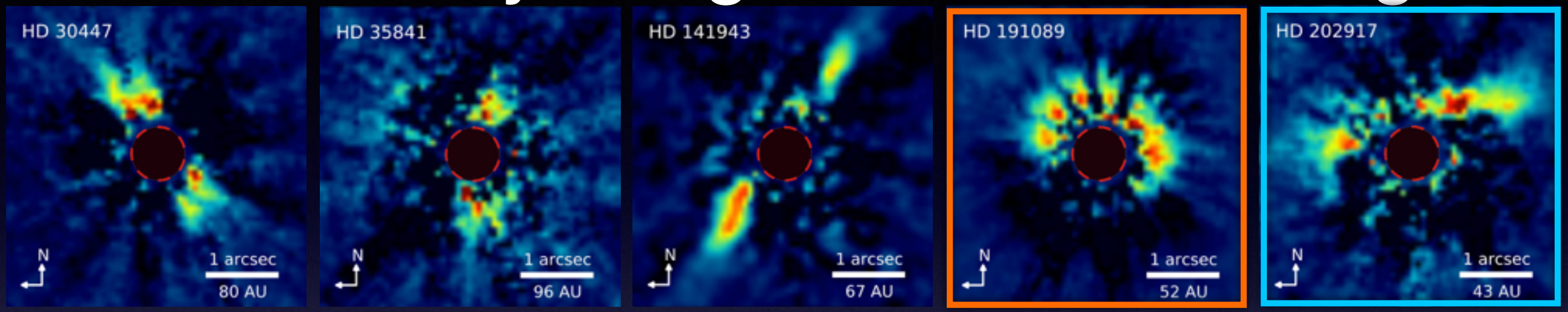


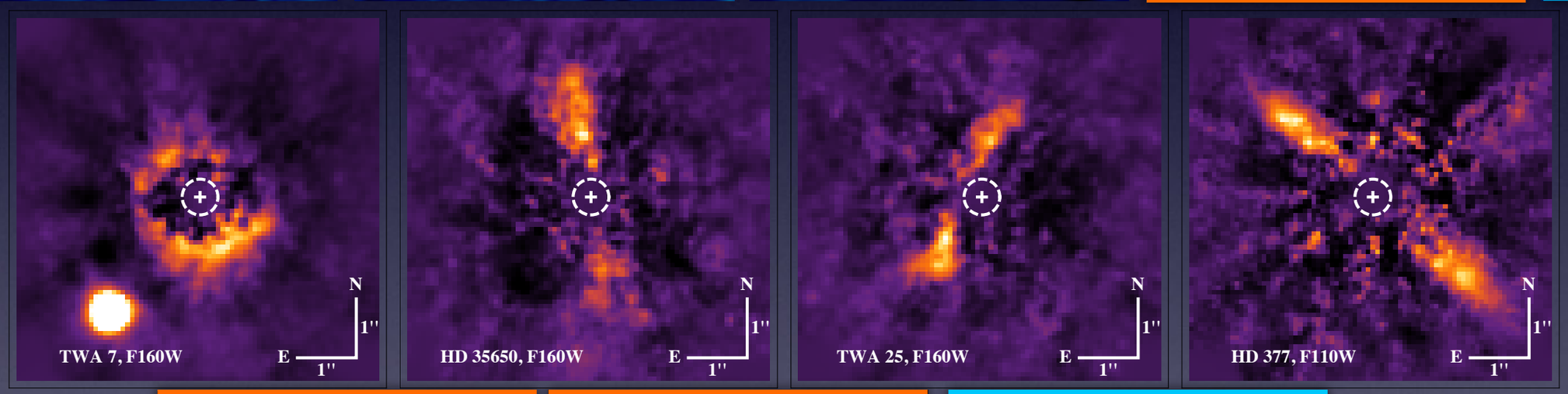


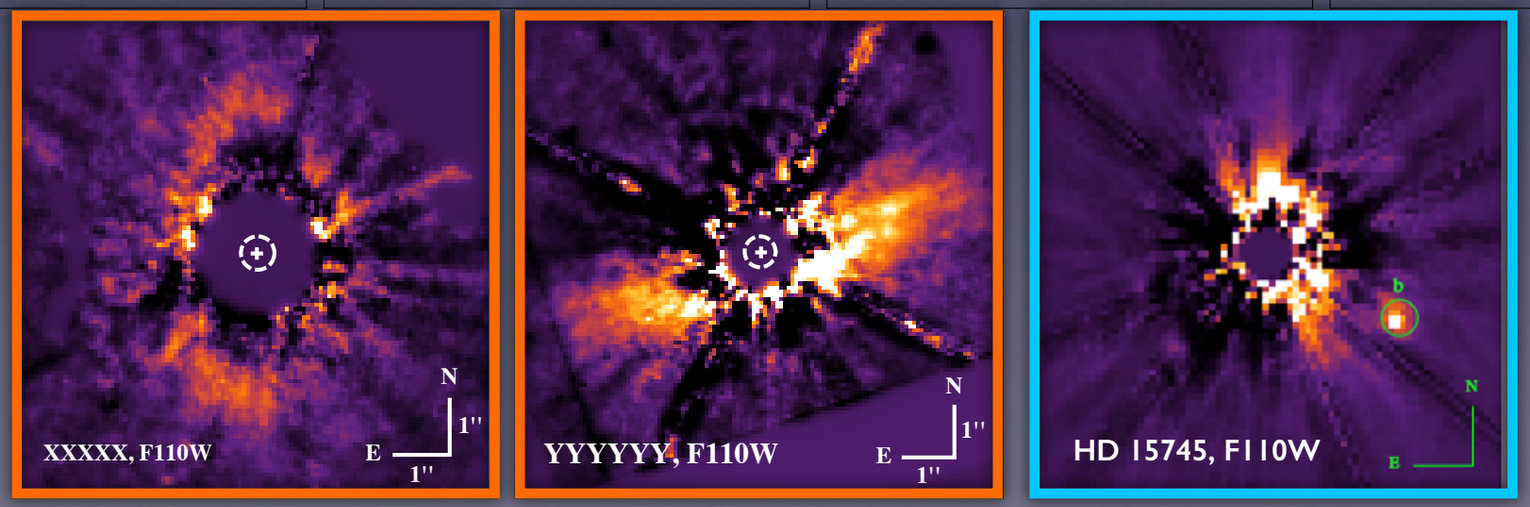
Soummer et al. 2014
Choquet et al 2016

ALICE results

Disks newly imaged in scattered light







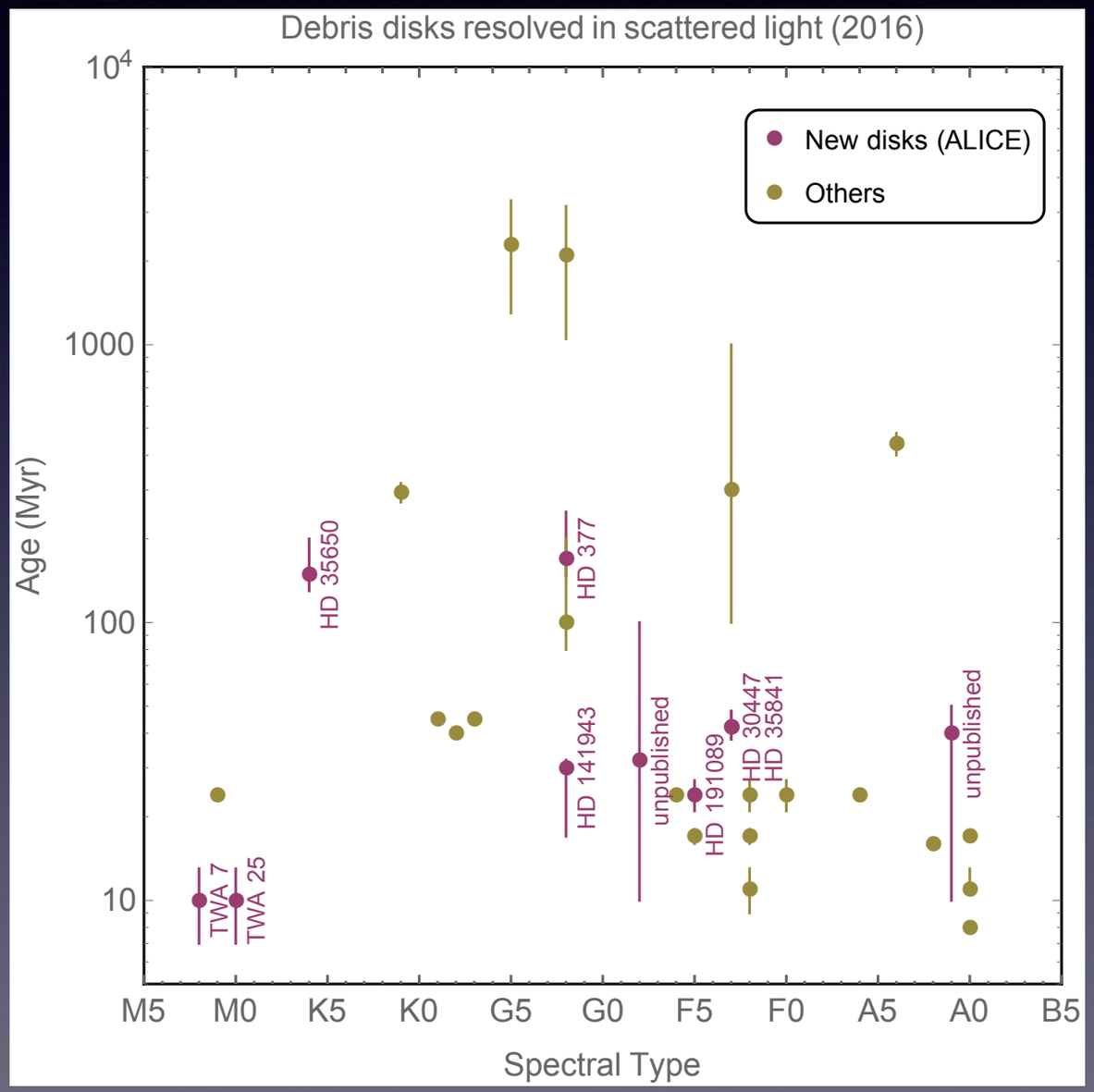
Soummer et al. 2014
Choquet et al 2016

+ Thermal emission image

+ other scattered light image

ALICE results

Resolved debris disks overview

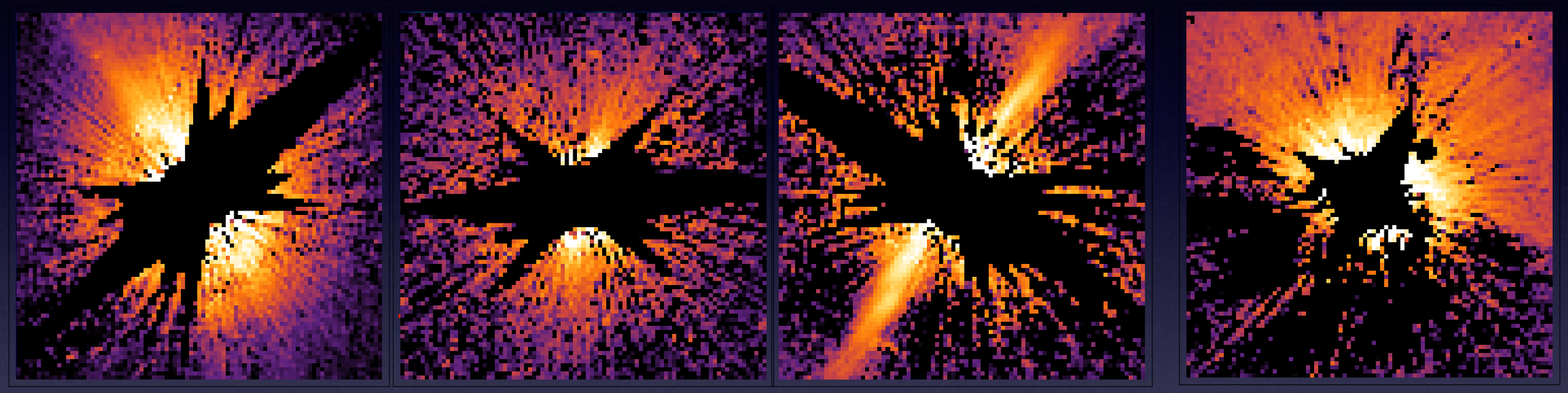


To date:

- 31 disks resolved in scattered light
- 32% from the ALICE project

ALICE results

Disks newly imaged in scattered light

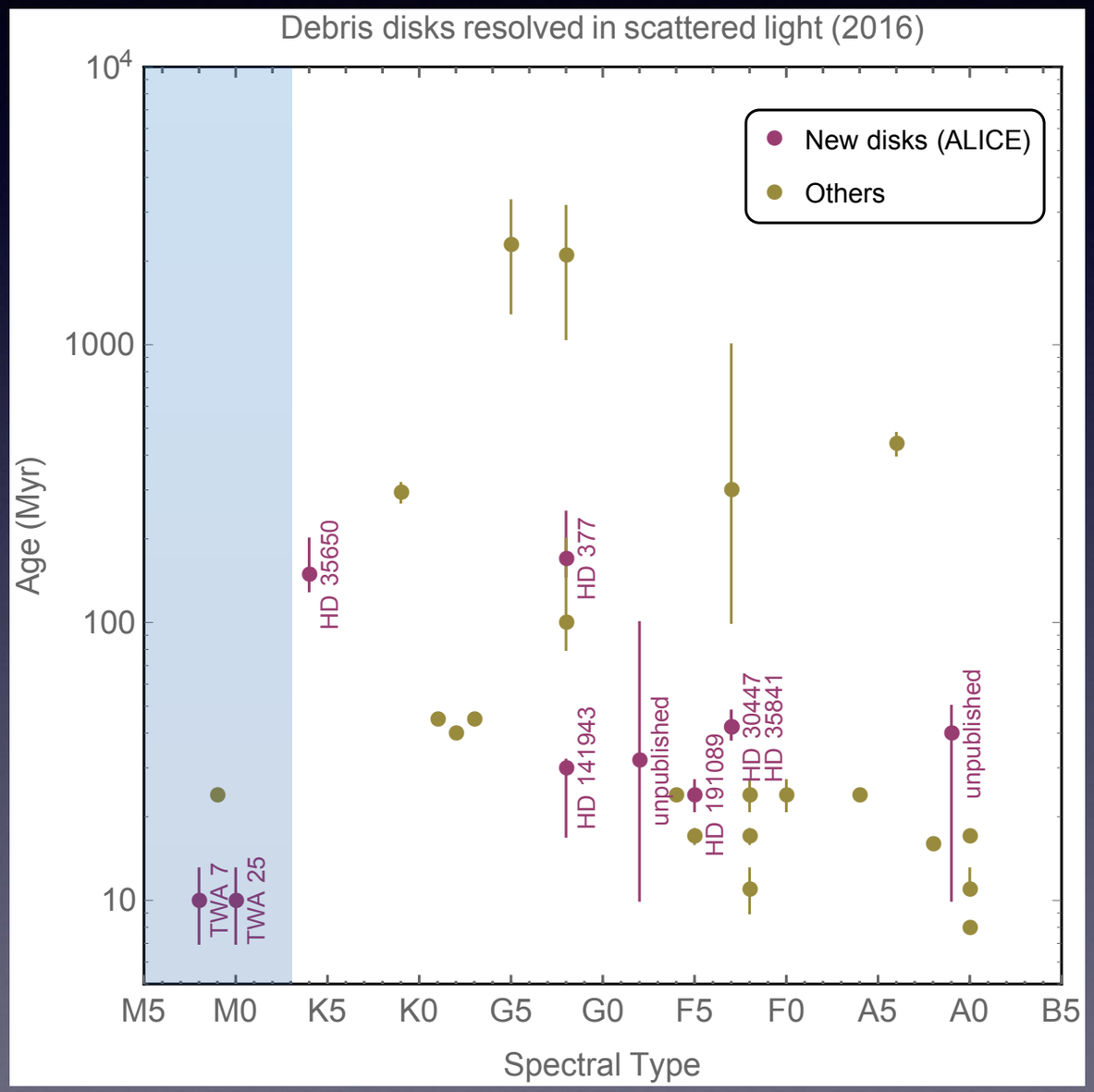


Perrin et al. in prep

- STIS follow-up observations
  - Visible images (color of the grains)
  - Better angular resolution

ALICE results

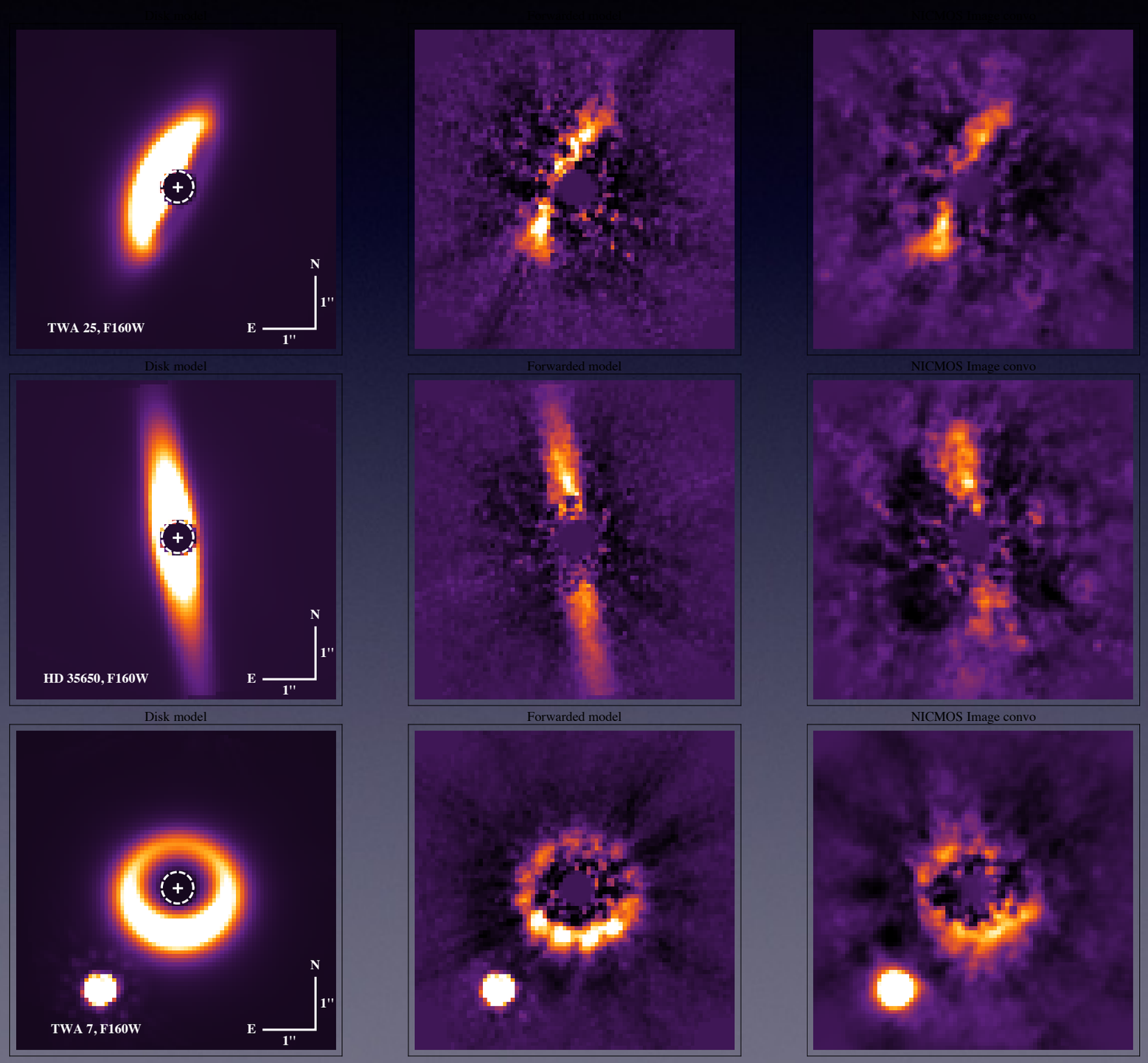
Where are the M dwarf disks?



- IR excess detection rates:
  - ~ 24% for A stars
  - ~ 20% for F, G, K stars
  - **~ 5% for M dwarfs**
- Below the detection limits?
- Less frequent?

ALICE results

Disks photometry



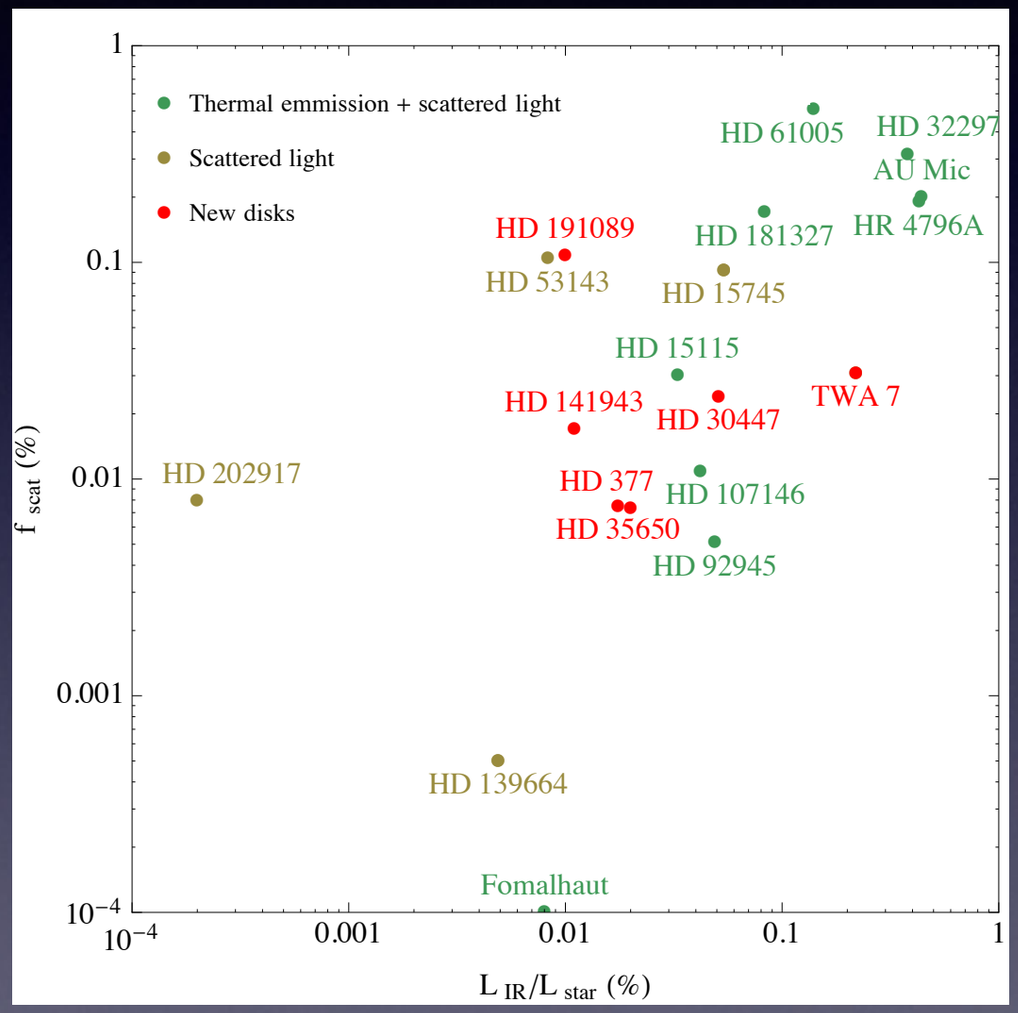
TWA 25	*f_scat:*
Spectral type:	M0.5
Distance:	54 pc
Age:	13 Myr
Association:	TWA
SB:	28 μJy/as^2

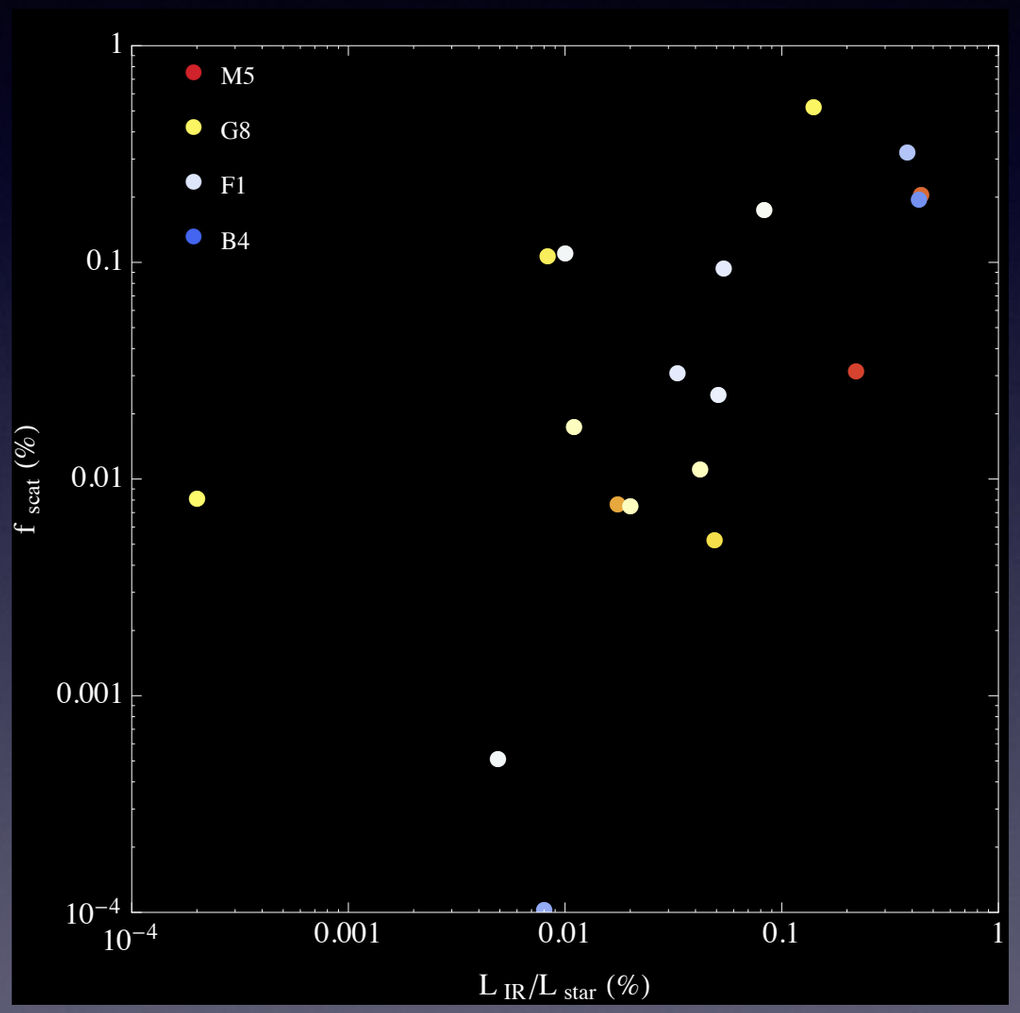
HD 35650	*f_scat:*
Spectral type:	K6
Distance:	18 pc
Age:	~80 Myr
Association:	AB Dor
SB:	56 μJy/as^2

TWA 7	*f_scat:*
Spectral type:	M3.2
Distance:	34 pc
Age:	4.4 Myr
Association:	TWA
SB:	78 μJy/as^2

ALICE results

Disks comparative study

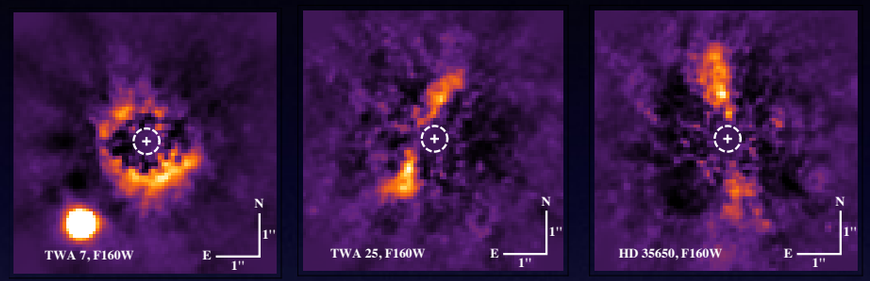




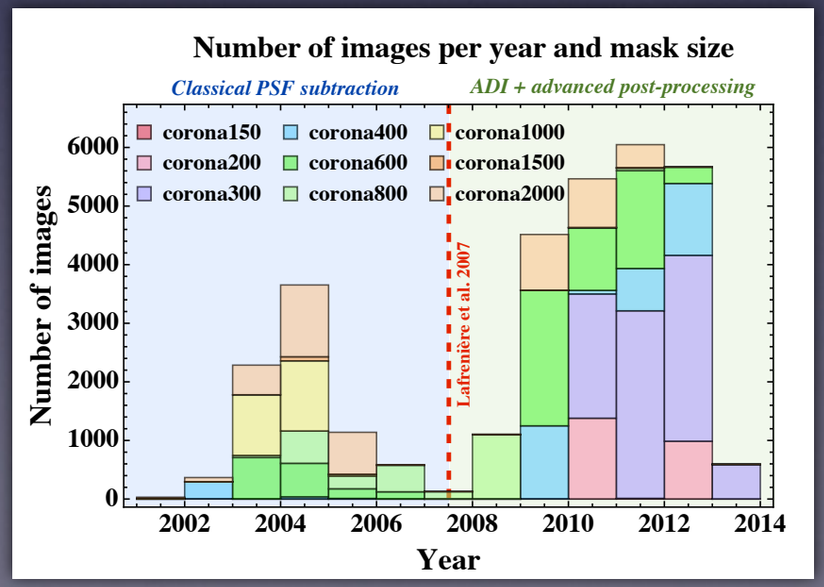
- Caveat: inconsistent dataset (different filters, different metrics)

Take-home messages & Prospects

- **ALICE status**
  - Archive reprocessing complete
  - 12 debris disks newly imaged
  - Detection of 3 disks around low-mass stars



Keck NIRC2 archive



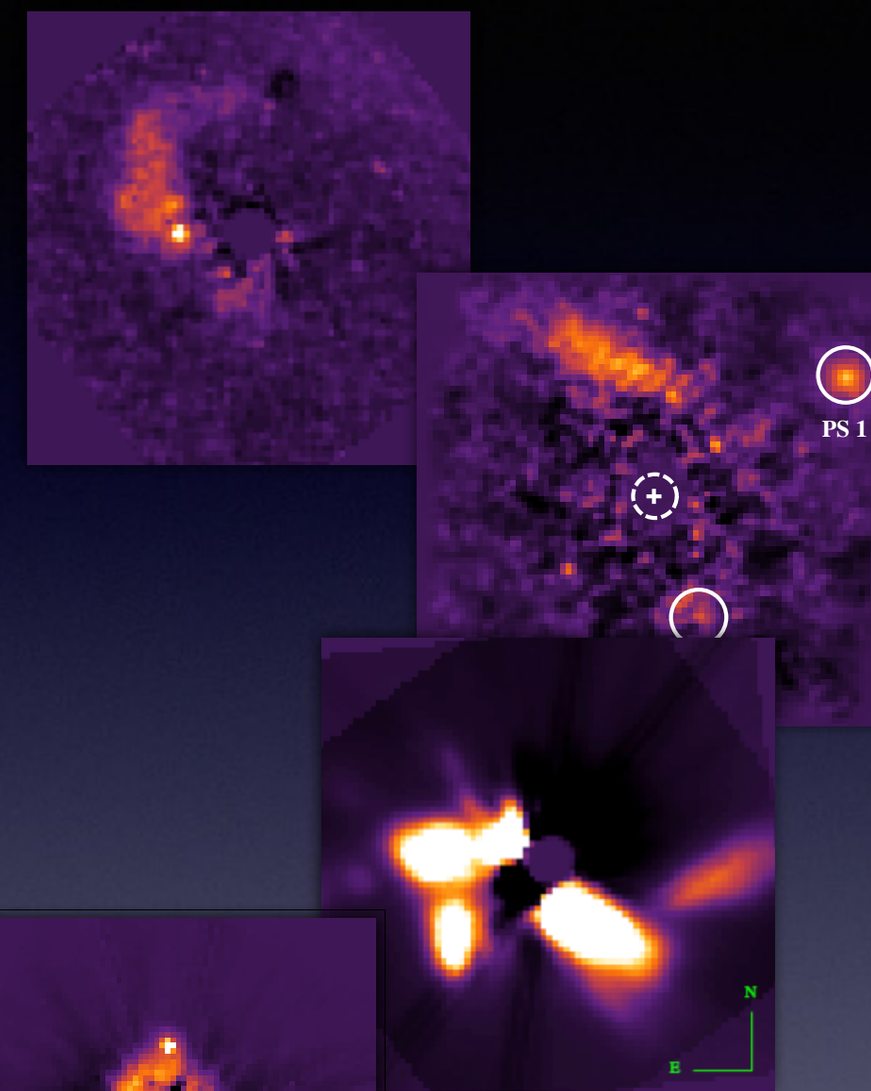
- **Prospects**
  - Follow up and modeling of the disks
  - Comparative study of debris disks
  - Analysis of the Keck archive

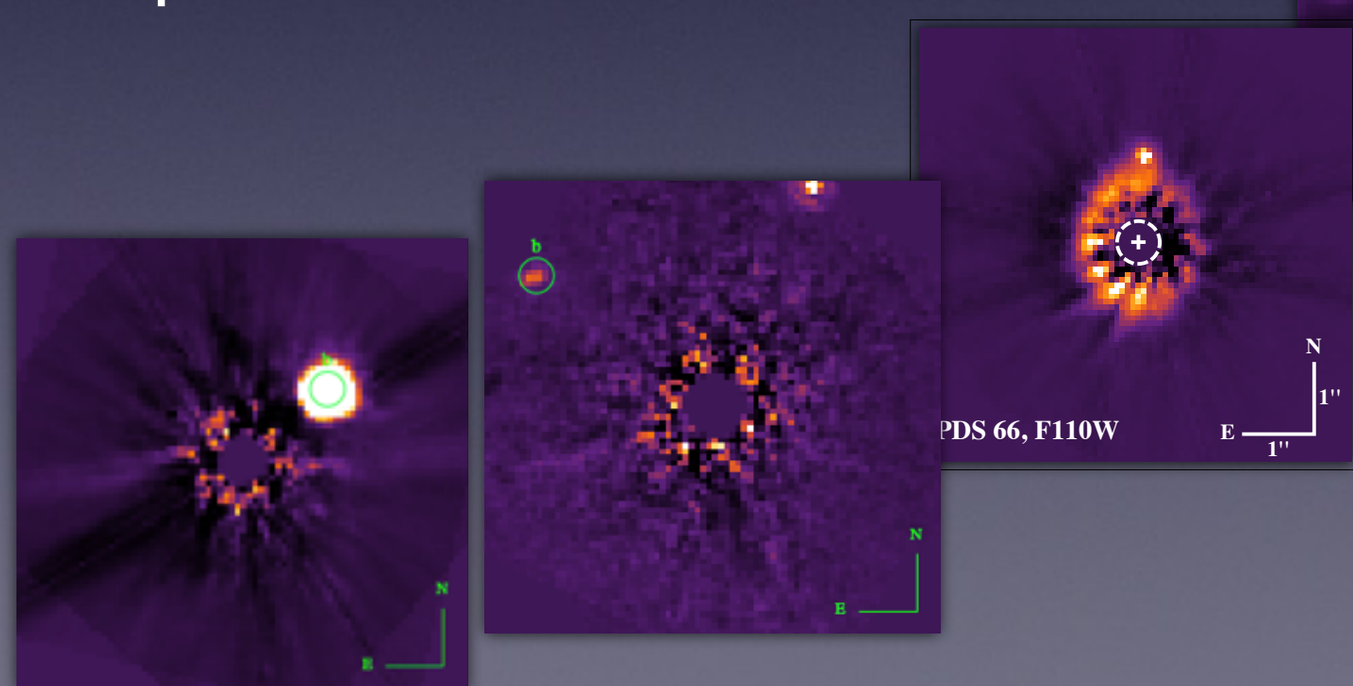
That’s it!

That’s it!

The one-slide summary
(including already known objects)

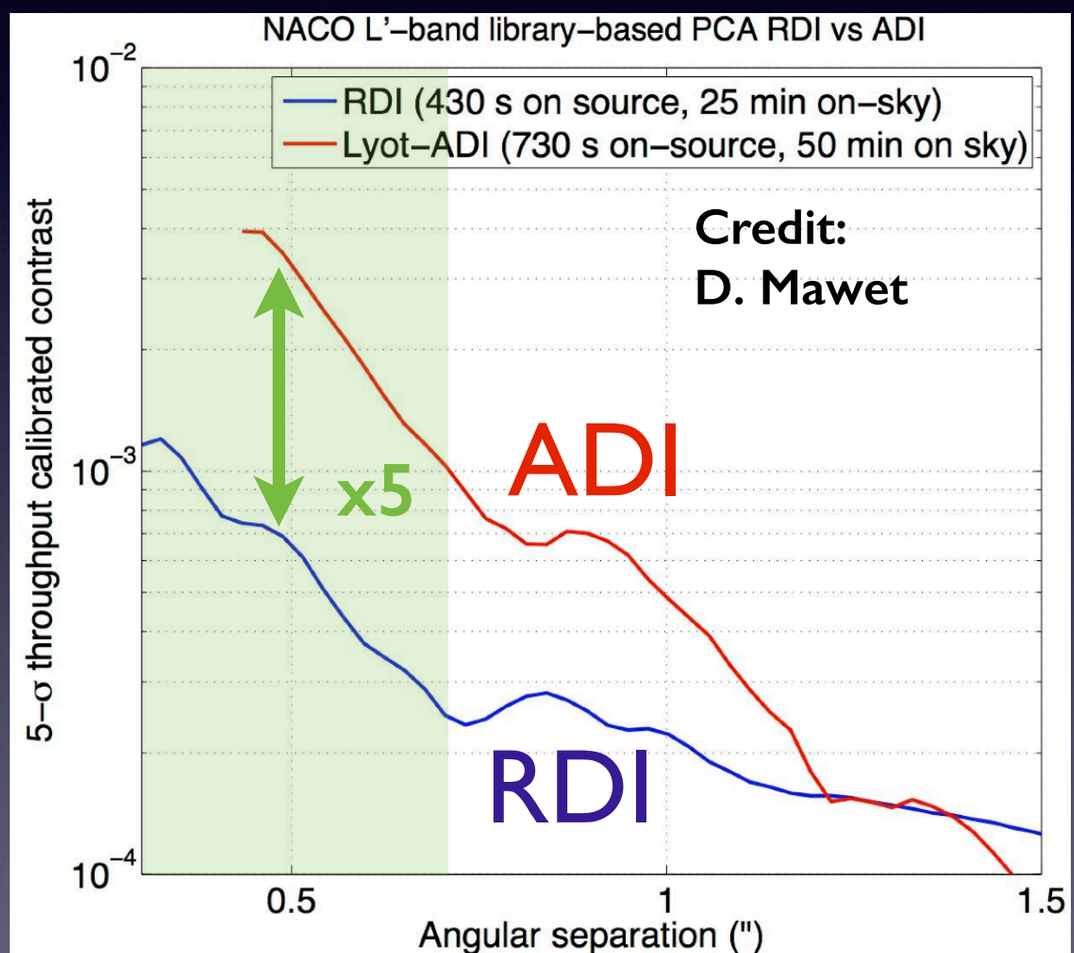
- Quasars / galaxies: 3
- Young stellar objects: 2
- Protoplanetary disks : 25
- Debris disks: 18
- Solid point sources: ~100



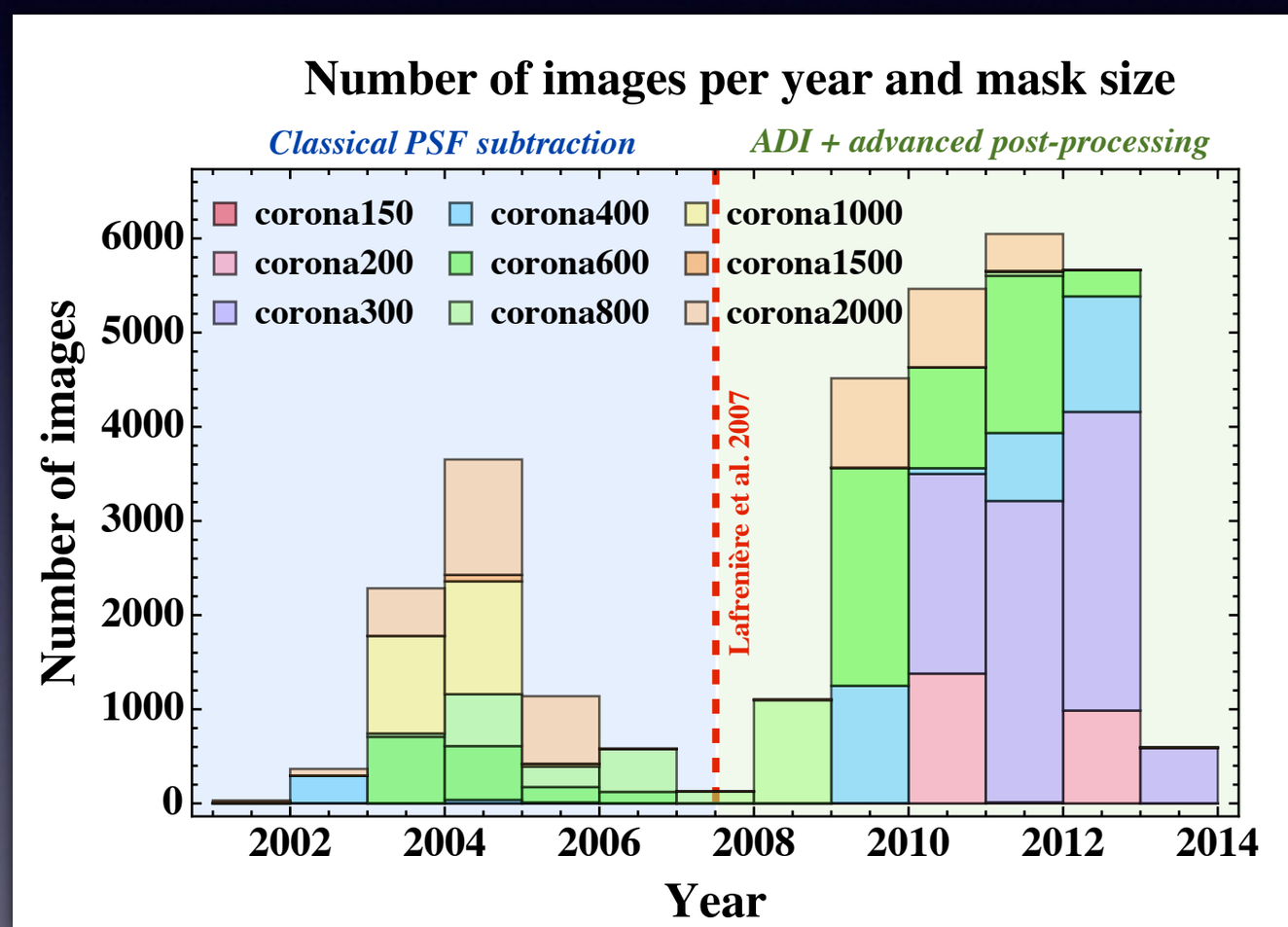


Prospects

Ground-base telescope archives

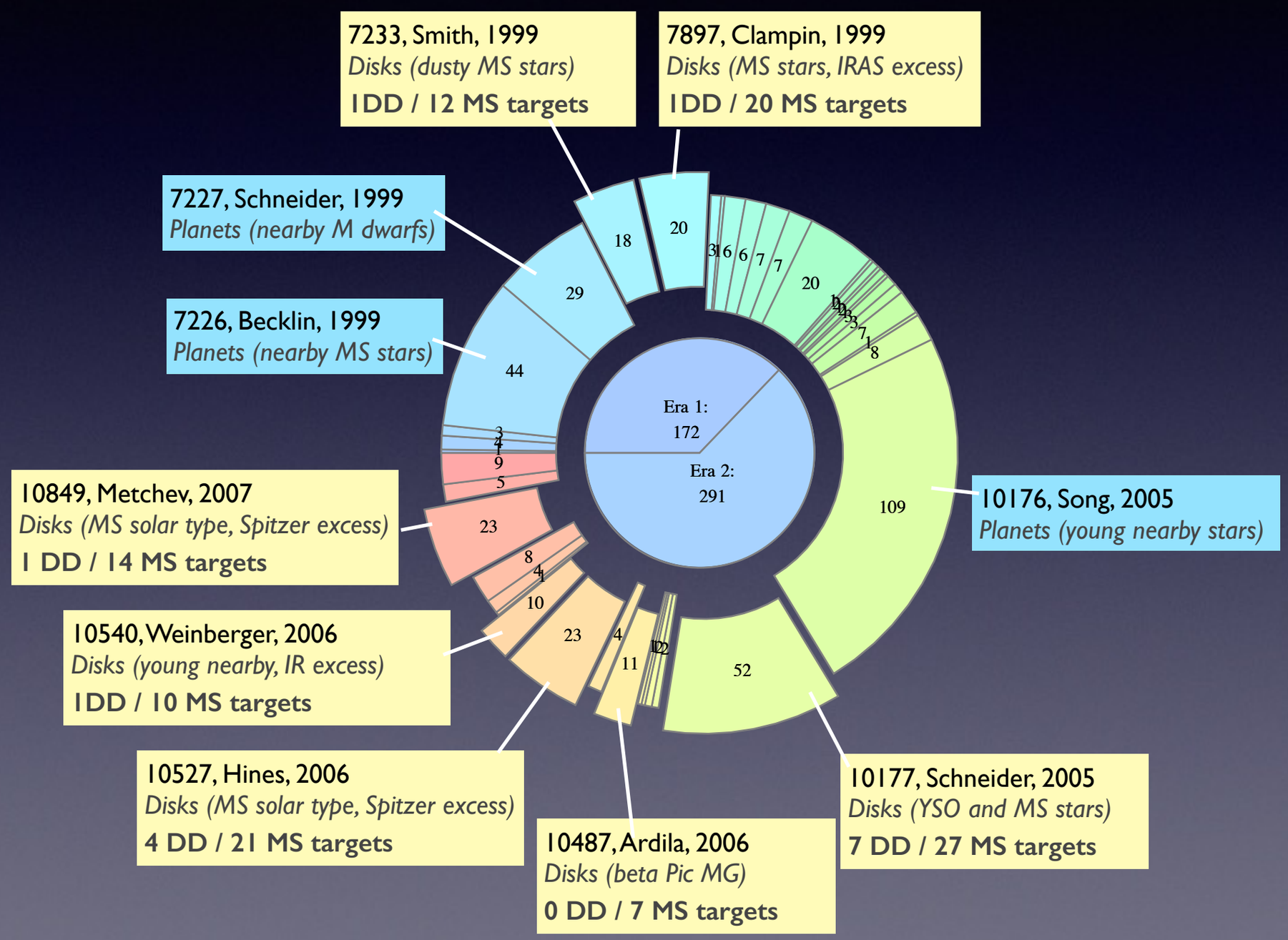


Keck NIRC2 archive

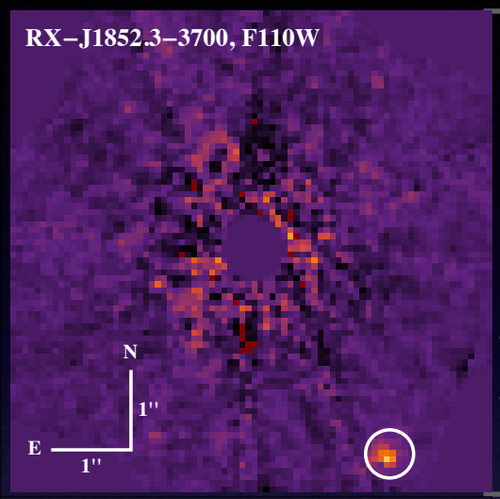


~ x10

~ x5

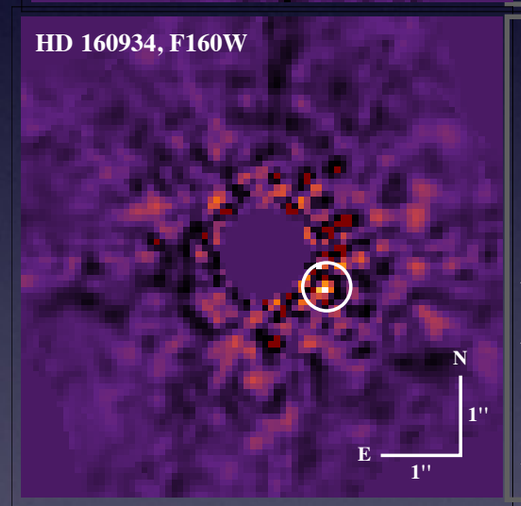

7233, Smith, 1999
Disks (dusty MS stars)
1DD / 12 MS targets
7897, Clampin, 1999
Disks (MS stars, IRAS excess)
1DD / 20 MS targets
7227, Schneider, 1999
Planets (nearby M dwarfs)
7226, Becklin, 1999
Planets (nearby MS stars)
10849, Metchev, 2007
Disks (MS solar type, Spitzer excess)
1 DD / 14 MS targets
10540, Weinberger, 2006
Disks (young nearby, IR excess)
1DD / 10 MS targets
10527, Hines, 2006
Disks (MS solar type, Spitzer excess)
4 DD / 21 MS targets
10487, Ardila, 2006
Disks (beta Pic MG)
0 DD / 7 MS targets
10177, Schneider, 2005
Disks (YSO and MS stars)
7 DD / 27 MS targets
10176, Song, 2005
Planets (young nearby stars)
Era 1:
172
Era 2:
291
18
20
29
44
23
10
23
11
52
109
20

Backup slides



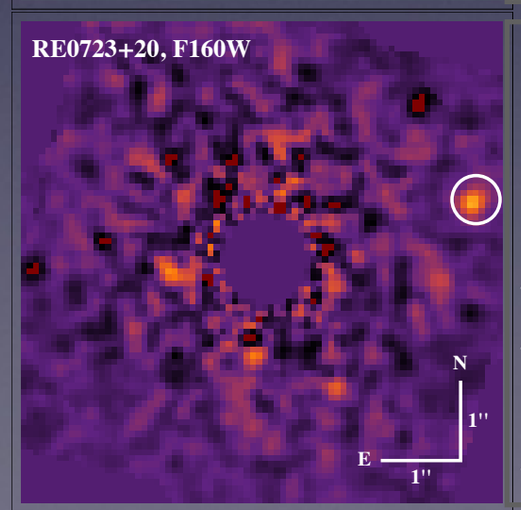
RX J1852.3-3700 ΔJ_{cand}:

Spectral type:	K3
Distance:	130 pc
Age:	3 Myr
Association:	Cha
J_{star}:	9.77



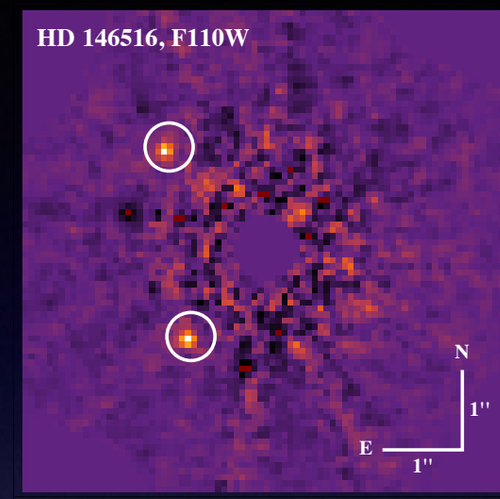
HD 160934

Spectral type:	K7Ve
Distance:	33 pc
Age:	100
Association:	Myr
H_{star}:	AB Dor
ΔH_{cand}:	7.00



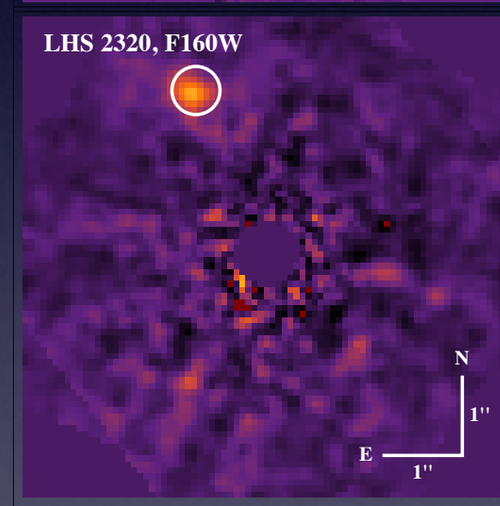
RE0723+20

Spectral type:	K5Ve
Distance:	25 pc
Age:	100
Association:	Myr
H_{star}:	AB Dor
ΔH_{cand}:	7.03



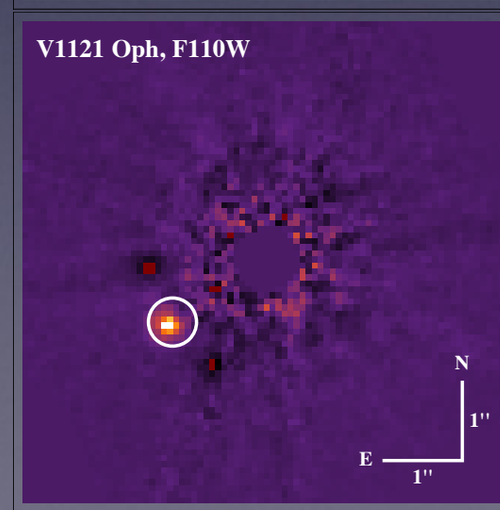
HD 146516

Spectral type:	G7V
Distance:	120 pc
Age:	10 Myr
Association:	Up
J_{star}:	Sco
ΔJ_{cand}:	8.51



LHS 2320

Spectral type:	M5.0V
Distance:	22 pc
Age:	100
Association:	Myr
H_{star}:	-
ΔH_{cand}:	9.28



V1121 Oph

Spectral type:	K4Ve
Distance:	125 pc
Age:	1 Myr
Association:	ρ Oph
J_{star}:	8.30
ΔJ_{cand}:	8.6