VLTI in the 2020s

J.-P. Berger (VLTI Programme Scientist)

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Discussions with many colleagues in/out the room:

O. Chesneau, A. Chiavassa, G. Duvert, C. Hummel, S. Hoenig, W. Jaffe, P. Kervella, S. Kraus, T. Lanz, J. B. Lebouquin, A. Merand, J. Monnier, D. Mourard, C. Paladini, J.U. Pott., R. Petrov, F. Soulez, P. Stee, M. Wittkowski, J. Woillez

Future of interferometry in Europe WG(JU Pott chair)

Science case for interferometry in the visible (P. Stee chair)

GRAVITY & MATISSE science wg

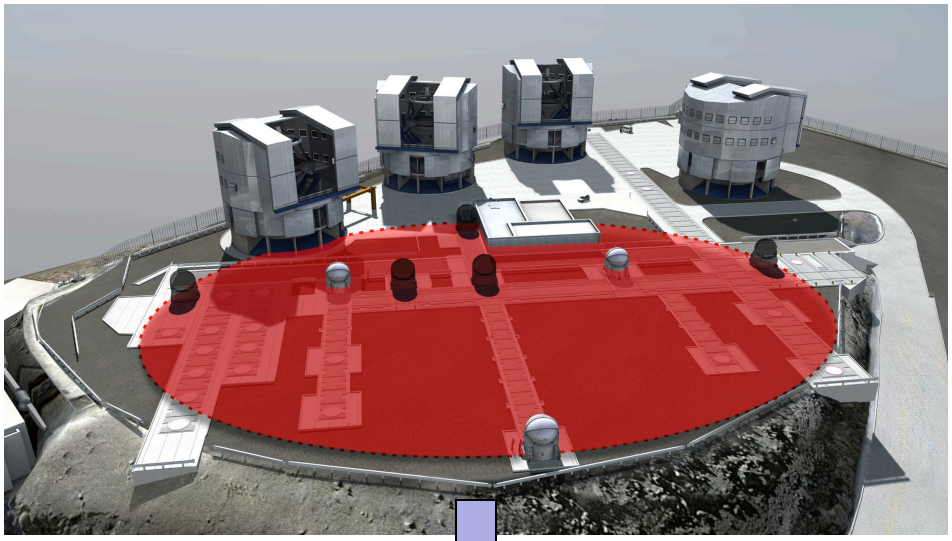
VLTI community days (ESO-EII: June 22nd 2015 EWASS)

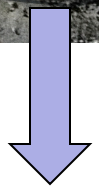
Recent conferences

The VLTI

AMBER
MIDI
PIONIER

AMBER
GRAVITY
MATISSE
PIONIER





- Imaging (parametric, true)
- Narrow Angle Astrometry

Fully operational

- Tech downtime: 5%
- Science time: 75%
- Integrated in LSP CfP
- First surveys (> 100 objects):2014
- Community support

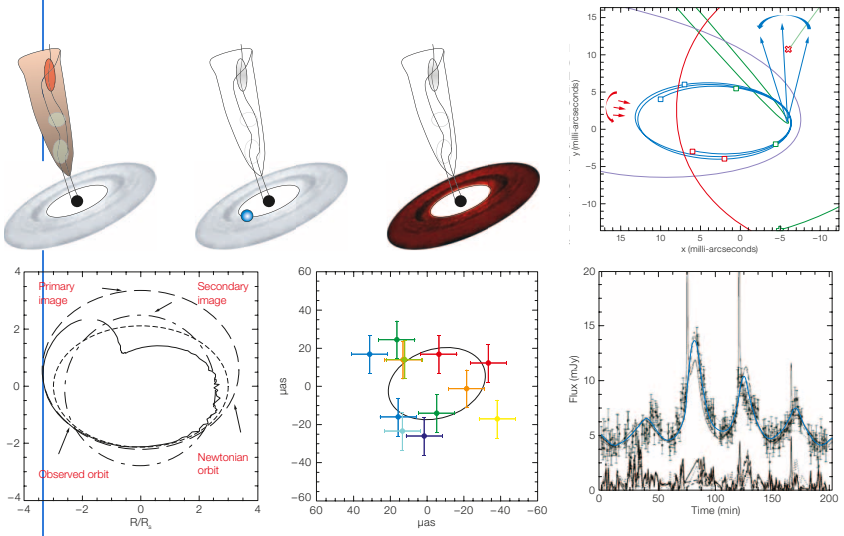
Difficulties:

- 2T/3T limitations
- Sensitivity (Phasing)
- PRIMA-Astrometry
- “expert” facility

Second generation instruments

GRAVITY

4 telescopes (UT-AT), K band,
Rspec up to 4000: Imaging & NA.
Astrometry

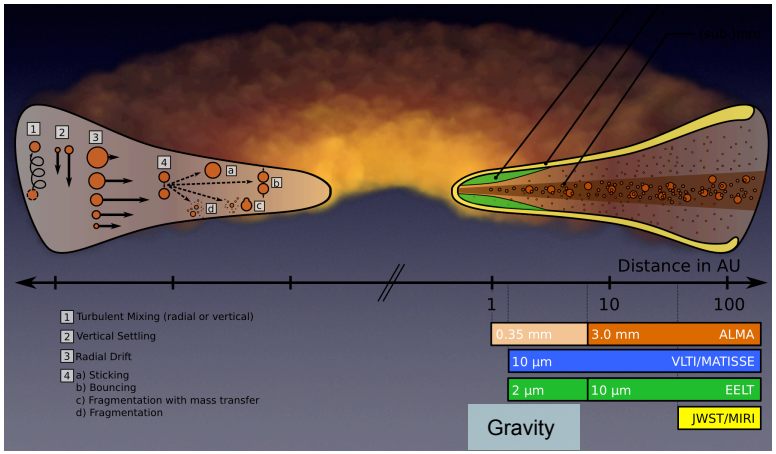


Angular resolution: ~ 2 mas @ K

PI: F. Eisenhauer- MPE

MATISSE

4 telescopes (UT-AT), L-M-N band,
Rspec up to 5000 (L)



Angular resolution: ~ 10 mas @ N

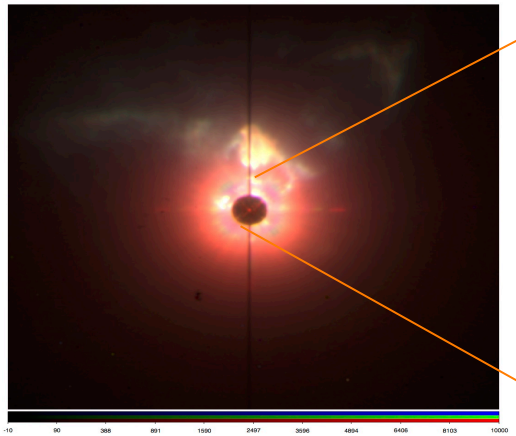
PI: B. Lopez – Lagrange/OCA

VLTI as a phased array

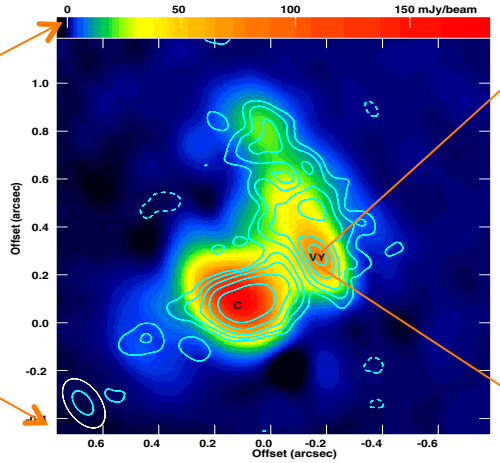
VLTI in the 2020s

- Wide variety of stellar physics/AGN pending questions
- Connecting astrophysical scales (Instrumental synergies)
- Developing surveys
- Expand User base

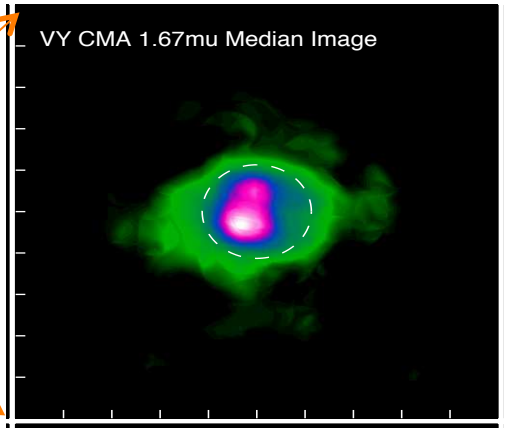
SPHERE



ALMA



VLTI - PIONIER



Siebenmorgen ++ SVT 2015

Monnier ++ 2014

VLTI in the 2020s

- Epoch I (2004-2015): MIDI and AMBER
- Epoch II (2017-2030): Exploiting the instruments:

  GRAVITY, MATISSE, PIONIER
- Epoch III (2025?..) : Third generation instrument
- Epoch IV: Evolution of the infrastructure (?)

Keywords from previous days

Bizarro, Alibert, Longmore, Chabrier, Humphreys, Eisenhauer,Hoenig, Richards

Star/planet formation

- High mass star formation
- Low-mass star formation
- Disk
- Exoplanet
- Mass loss (outflows wind, jets)
- Dust processing
- Accretion-ejection

Stellar physics:

- Fundamental parameters
- Rotation/Convection/Pulsation

Evolved stars:

- Dust production
- Pulsation/Convection/Shocks
- Winds
- Chemistry

Milky way:

- Black hole
- Accretion disk
- Star formation

Extragalactic

- Distance scale
- Black hole
- BLR
- Outflows
- Dust (torus)

Questions tackled by VLTI/Interferometers

- Do we understand stars?
- How do planetary systems form?
- How do massive stars form and interact with their environment?
- How do stars enrich galaxies?
- Unveil the nature of exoplanets
- Understand SMBH interaction with host galaxy?
- How do progenitors of supernovae work?
- Understand Gravity

Fundamental stellar parameters

Gaia FGK Benchmark Stars and their reference parameters

Paula Jofré[1,2] *, Ulrike Heiter[3†], Sergi Blanco-Cuaresma[2] and Caroline Soubiran[2]

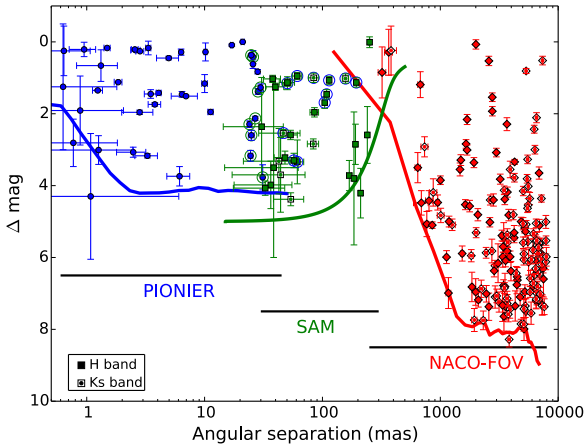
Jofré++ 2014

$$F_{bol} = \sigma(0.5\theta_{LD})^2 T_{eff}^4$$

The key aspect of the Gaia Benchmark Stars is that the stellar parameters T_{eff} and logg are determined using fundamental relations, that means, independently from the spectra…

About 70% of the stars have a direct measurement of their radius via in- terferometry, while the rest has radii using calibrations, such as infrared spectrophotometry and photometric surface-brightness relations.

Sana++ 2014



VLTI in the 2020s:

- Homogeneous FGK benchmarks
- GRAVITY: Brown dwarf
- GRAVITY: Metal poor giants in neighbouring glob clusters
- GRAVITY/Matisse binaries: Evolutionary tracks calibration

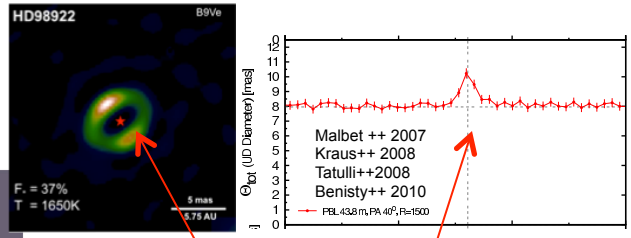
Going forward:

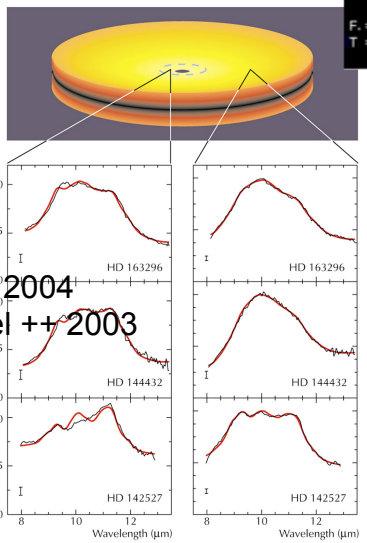
- G. Chabrier's talk
- Synergy with asteroseismology
- CHEOPS/PLATO
- Age determination
- Instrumentation performance probably too limited for real breakthrough

Star/planet formation

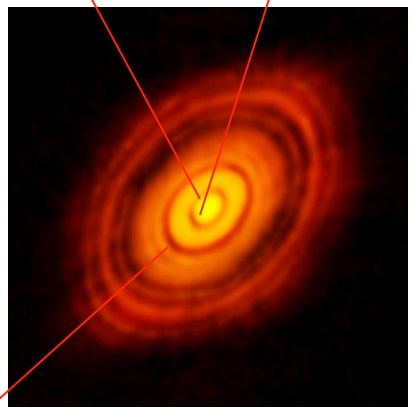
Inner rim- Dust sublimation

Disk structure
Dust processing

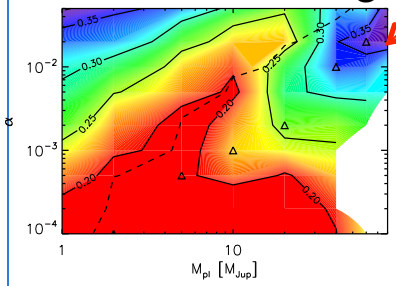




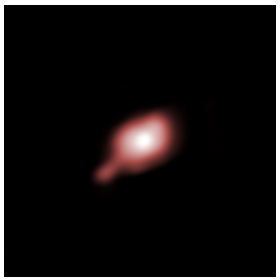
Leinert ++ 2004
Van Boekel ++ 2003



Planet formation signposts



Mulders ++ 2014



Kraus++ 200
Boley++ 2013

Winds/Accretion

VLTI in the 2020s:

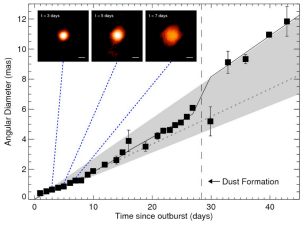
- Generalizing the studies of disks with AU resolution (morphology, kinematics constraints)
- GRAVITY: resolving the structure of wind, jets;
- MATISSE:
  - dust distribution, processing
  - Solid: Silicate, PAHs, H2O(ice)
  - hot disk gas kinematics (CO, Bralpha,Pfd,Pfg, H20)
  - planet formation signposts
- MATISSE + GRAVITY: structure of the dusty disk – wind disk connection – Multiplicity – Massive star formation

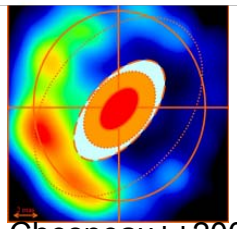
<u>Going forward:</u>

- VLTI imaging power interesting but limited to the 2020s (angular resolution)
- Resolving planets forming in disks: PLANET FORMATION IMAGER

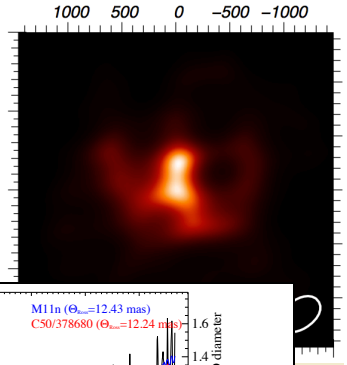
Evolved stars

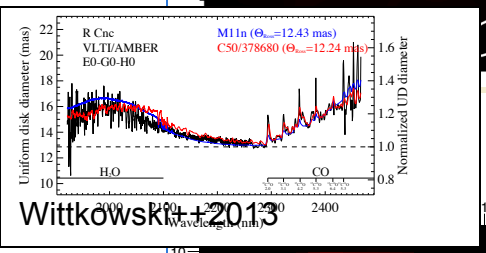
Schaefer++2014





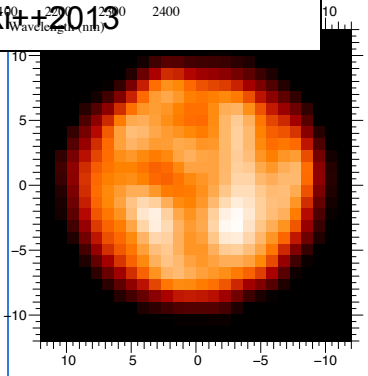
Chesneau++2007



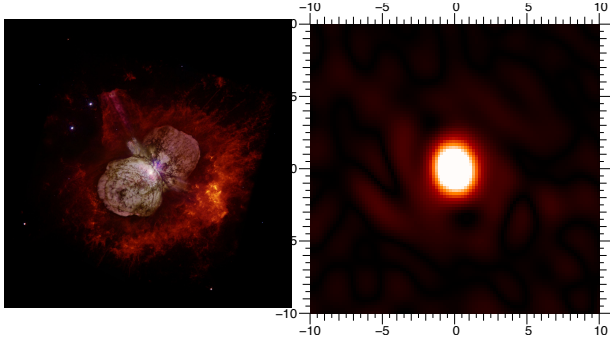


Wittkowski++2013

Freytag 2014



Paladini in prep



Groh in prep

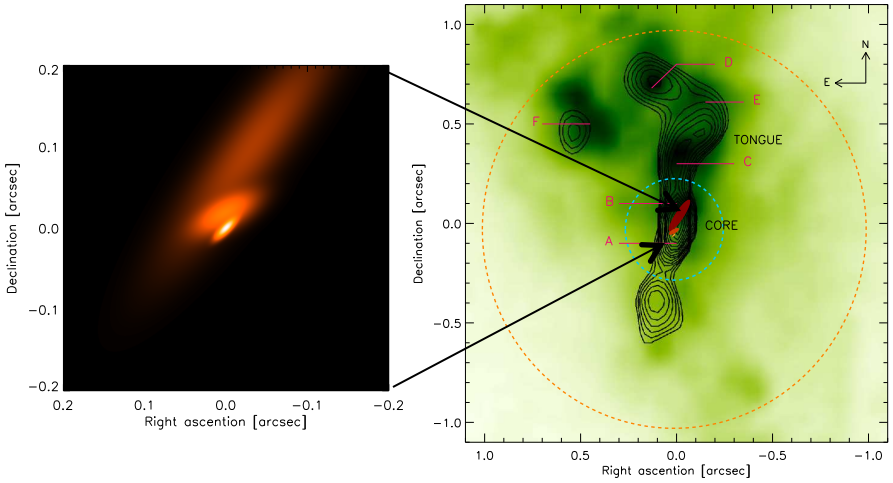
VLTI in the 2020s:

- Main application of image reconstruction
- Disentangling molecular lines, continuum (high spectral resolution)
- Temporal evolution: kinematic processes
- Novae monitoring fireball expansion – shocks – dust formation
- Dust/photosphere connexion (mid-IR => visible)
- Connecting spatial scales
- Challenging 3D hydrodynamics modelling

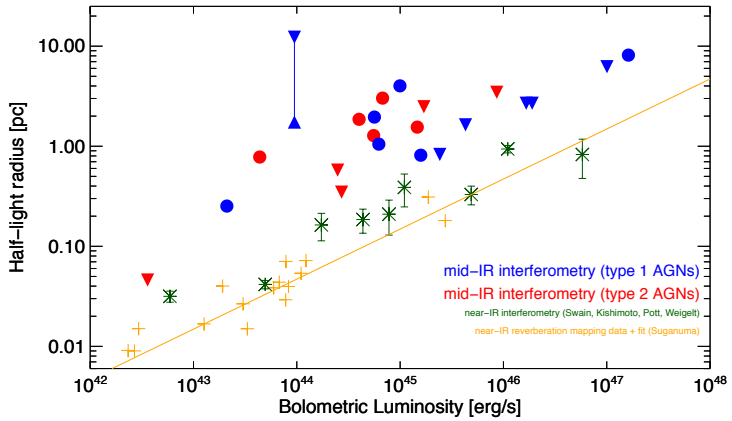
<u>Going forward:</u>

- Increasing imaging capability
- Increasing spectral resolution (> 30000)
- Going to the visible

AGN



Lopez-Gonzaga++ 2014



Burtscher++2013

Jaffe ++ 2004
Meisenheimer++2007
Tristram 2007, 2013
Hönig++ 2012/2013

VLTI in the 2020s:

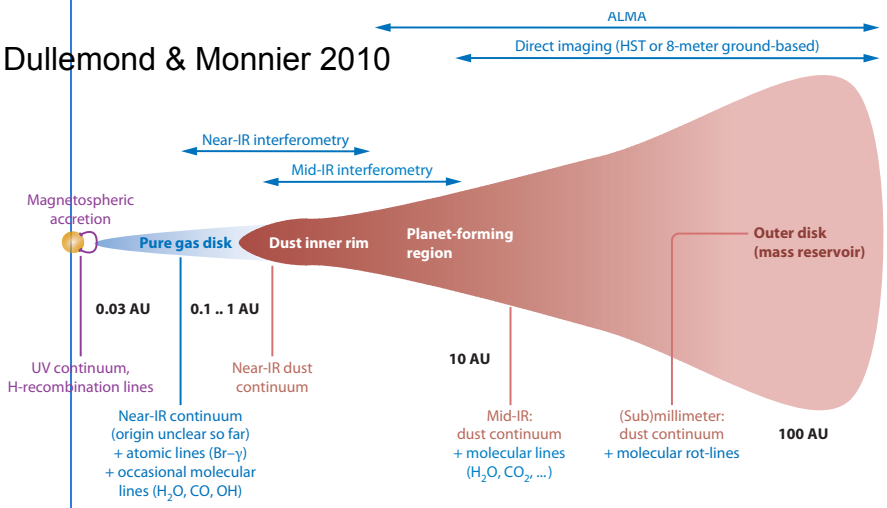
Understand the complexity of the inner parsecs (e.g near-nucleus/ nucleus symetries)

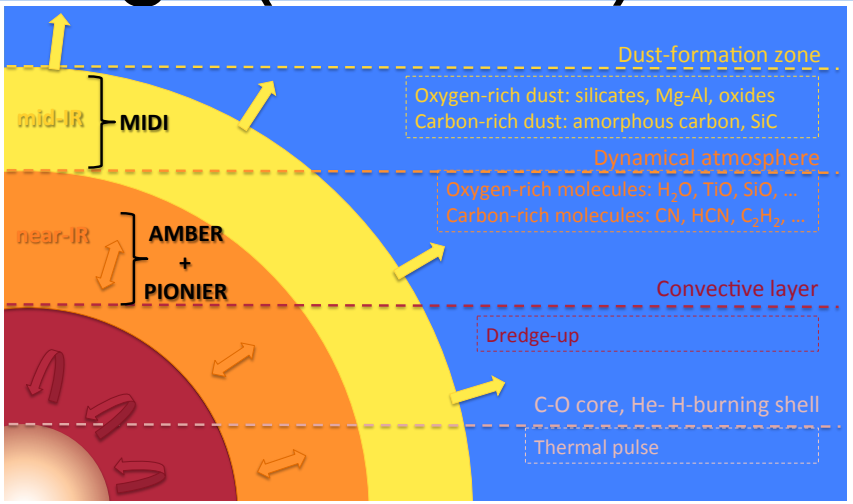
MATISSE + GRAVITY:

- Test unified model
- Confirm S2 (MIDI) have strong bipolar dust emission.
- Why S1 diverse (MIDI)
- How UV/X flux are intercepted (energy balance)?
- Exploit L bands lines (C0, Br alpha): turbulence/shocks – ionisation radiation
- Connecting the 100 pc – 10 pc scales (inflows/outflows)
- Structure of BLR (Br alpha, Br gamma)
- Mineralogy (dust processing) - Polarimetry

The case for simultaneous multi-wavelength coverage (iShooter)

Dullemond & Monnier 2010

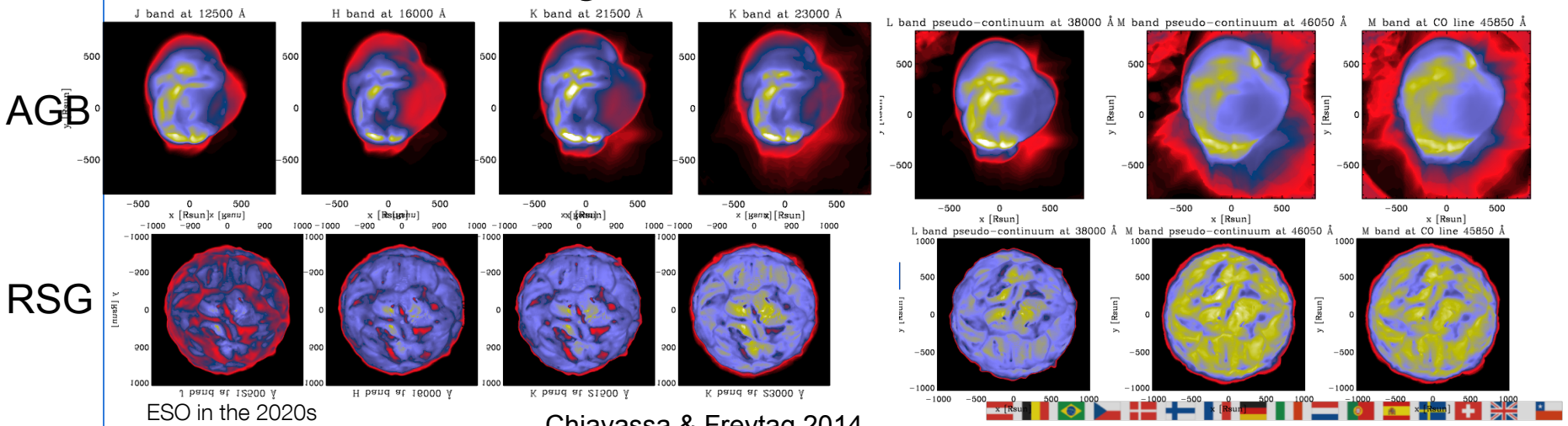




Courtesy C. Paladini

From photosphere to dust processing: simultaneously

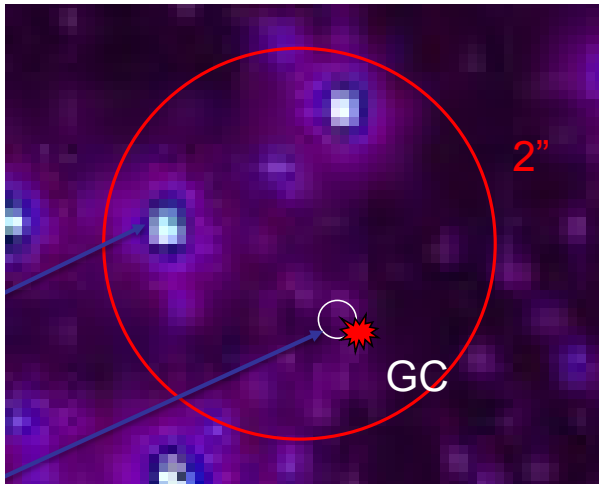
J ← N



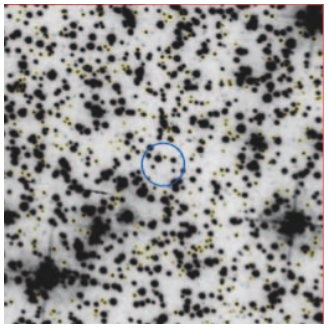
ESO in the 2020s

Chiavassa & Freytag 2014

Gravity - Astrometry

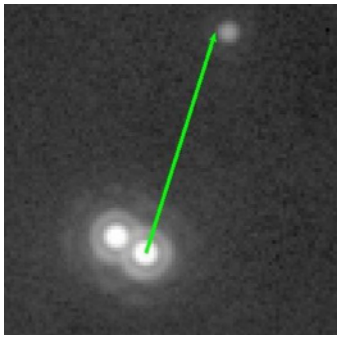


Off axis fringe tracking



Deep integrations: e.g globular cluster

Astrometry



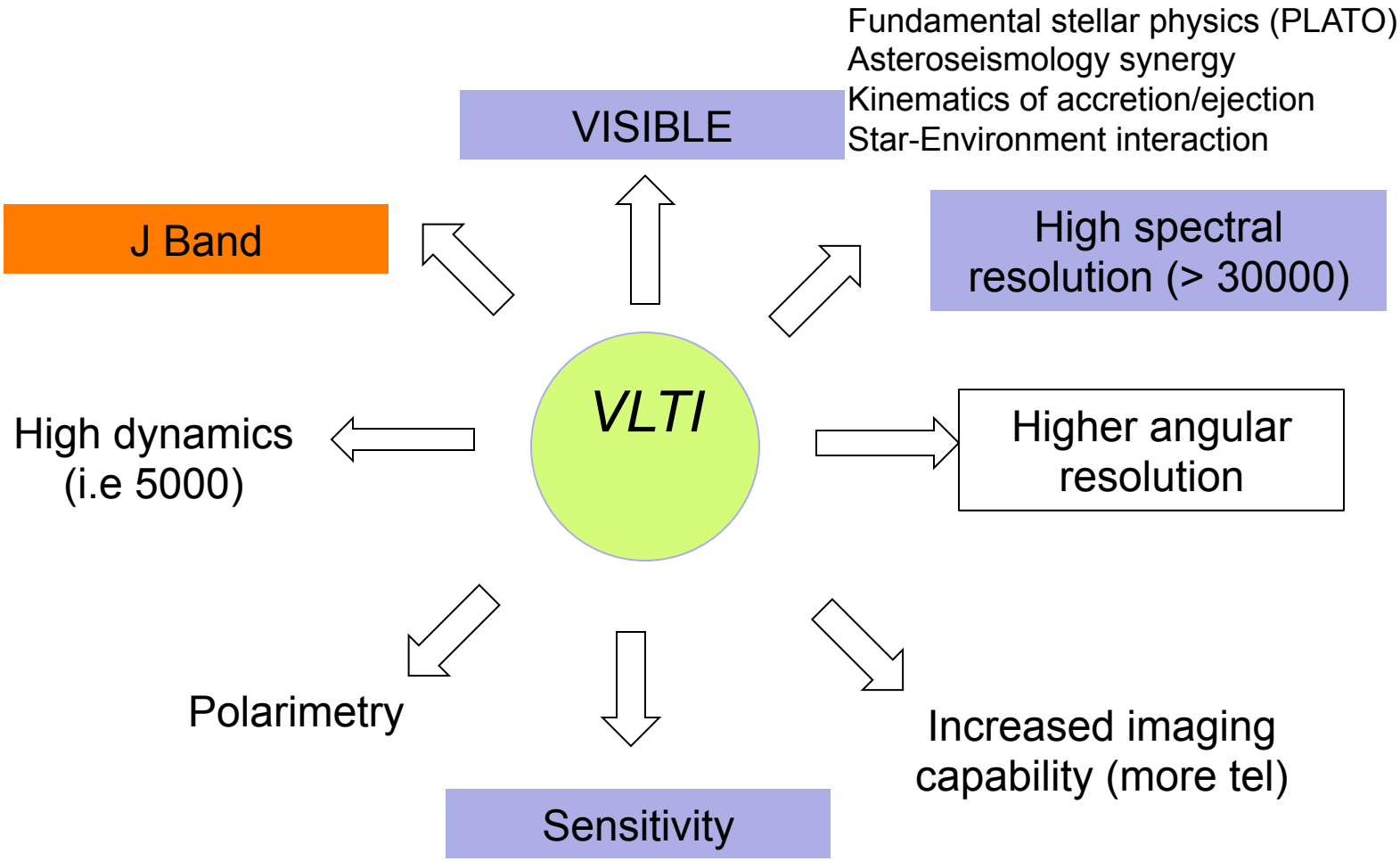
Planets in multiple systems – Long period planets

VLTI Expertise center(s)

- Provide astronomers with assistance with their VLTI data processing, analysis and image reconstruction

Epoch III (third generation instrument)

Prerequisite: VLTI phasing

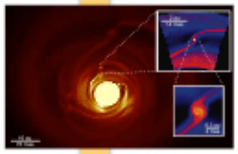


Visitor vs. Facility ?

VLTI Future directions

Other initiatives

	Spectro-Imaging	Astrometry
Epoch I 2004-2017	MIDI-AMBER	PRIMA
Epoch II 2017-2030	iSHOOTER K: GRAVITY-Imaging L-N: MATISSE H (J): PIONIER ++ VLTI-Expertise center Visitor Focus CHARA synergy	GRAVITY-Astrometry
Epoch III 2025 - ...	Visible - High spectral resolution VLTI-NTelescopes	GRAVITY "Wide field"



Coordinated by EII: Future of interferometry working group

PFI* VisI

*Planet Formation Imager