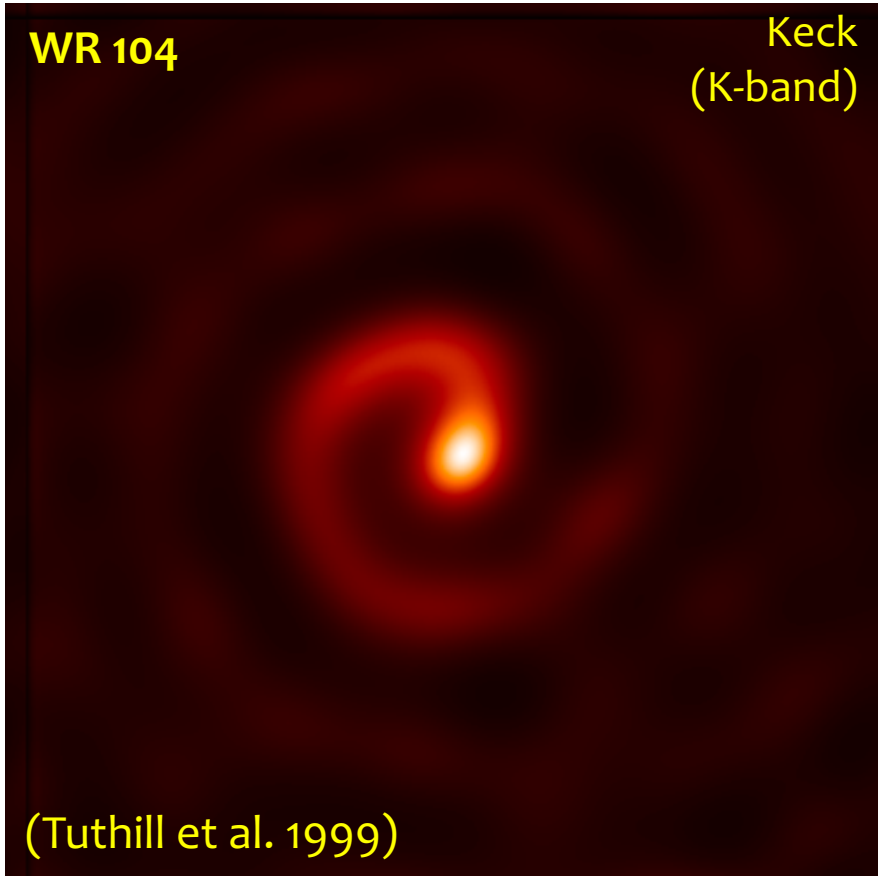
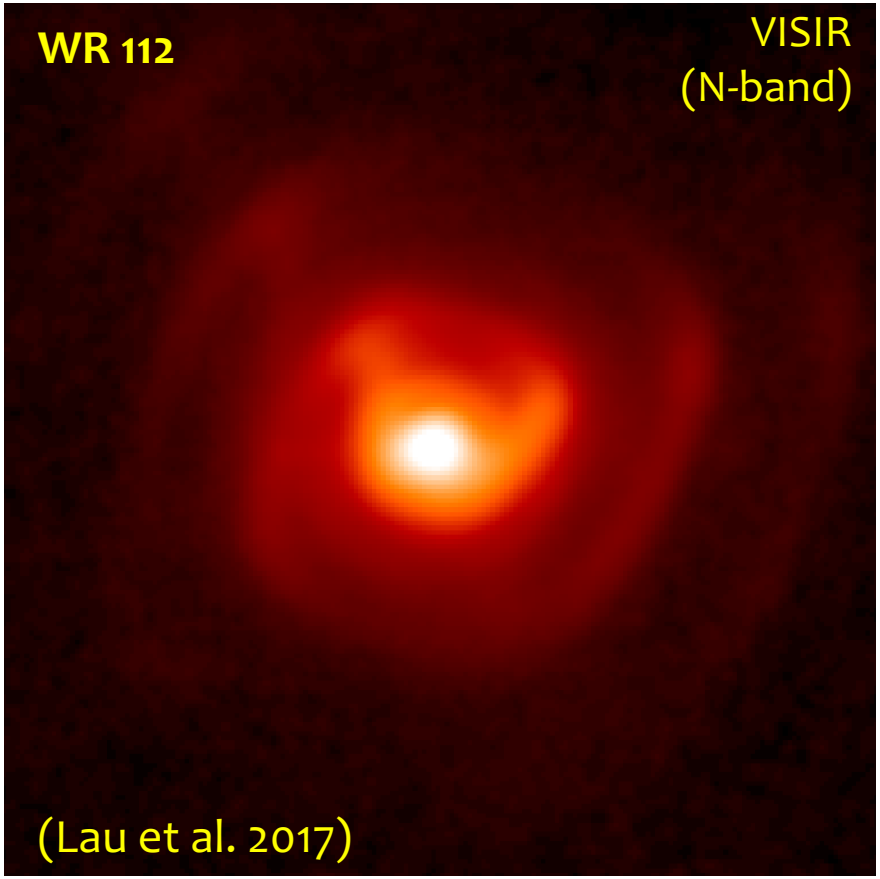
WR DustERS: a JWST-ERS program to resolve the nature of dust in Wolf-Rayet winds





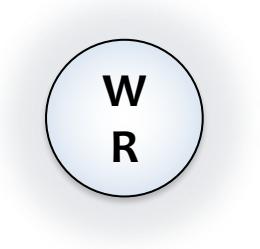
Ryan M. Lau ***JAXA ITYF Fellow, Institute of Space and Astronautical Science***

Collaborators: M. Hankins (Caltech), I. Sakon (U Tokyo), Astrid Lamberts (OCA), JJ Eldridge (Auckland), P. Williams (ROE), and the WR DustERS Team

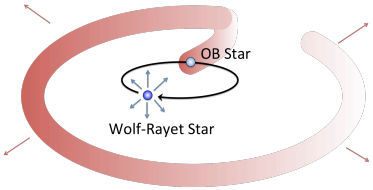
COPAG Splinter
Honolulu, HI
Jan 4, 2020

Talk Outline

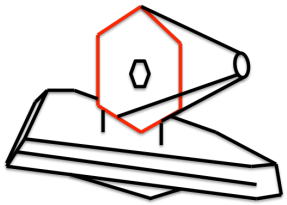
- **Background:**
  Wolf-**R**ayet (WR) stars and dust formation

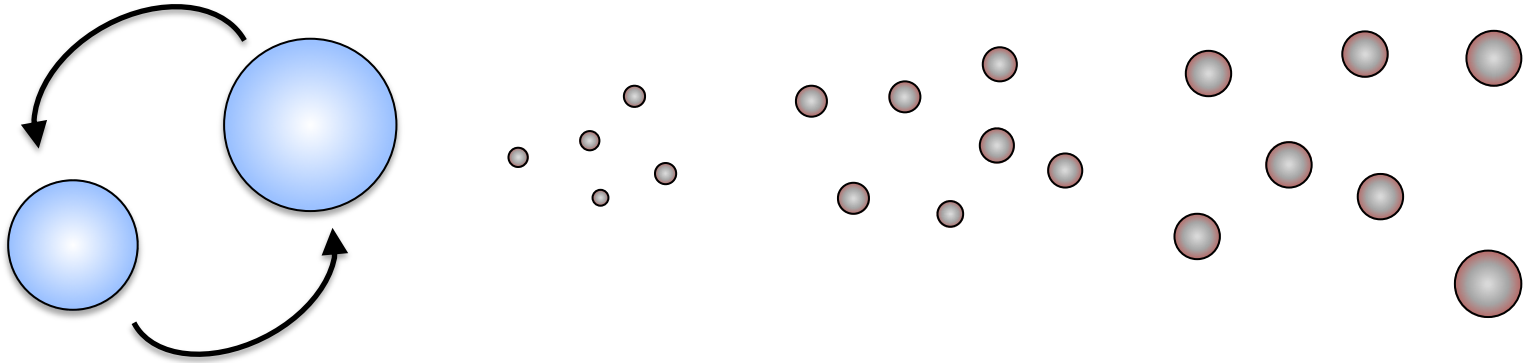


- **Science Focus:**
  Revisiting WR dust input and their impact on galactic dust budgets



- **Early Science with JWST:**
  The *WR DustERS* Program





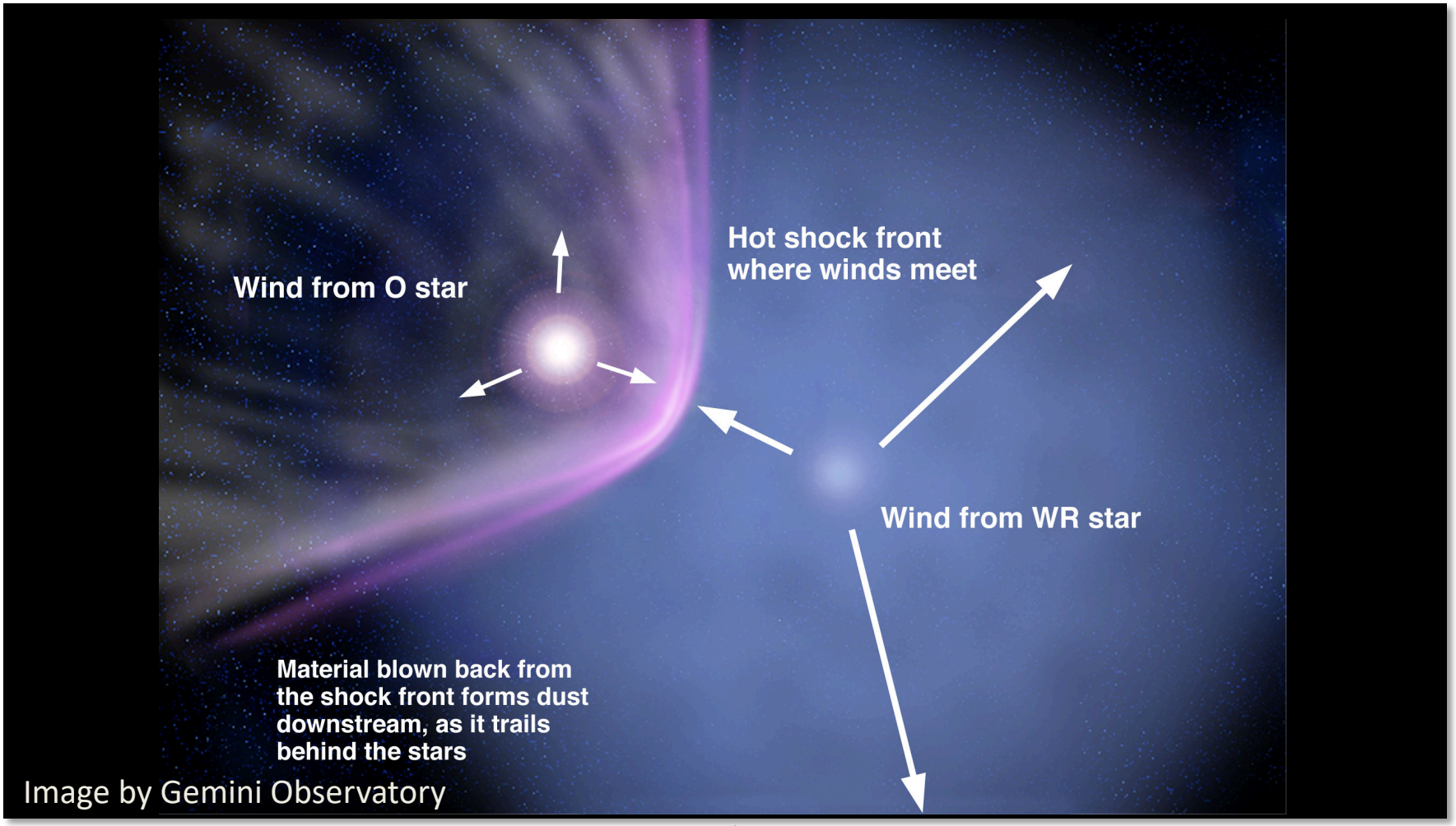
Wolf-**R**ayet stars and how they form dust

Wolf Rayet (WR) Star: descendent of a massive O-star

- Luminous (**>10^5 L_{sun}**)
- Hot (**>40,000 K**)
- Strong winds (**>1000 km/s**)
- High mass-loss (**~10^{-5} M_{sun}/yr**)

WR

Dust Formation in WR Binaries



(Williams+ 1990; Usov+1991)

Dusty outflow and orbital motion form a "Pinwheel"

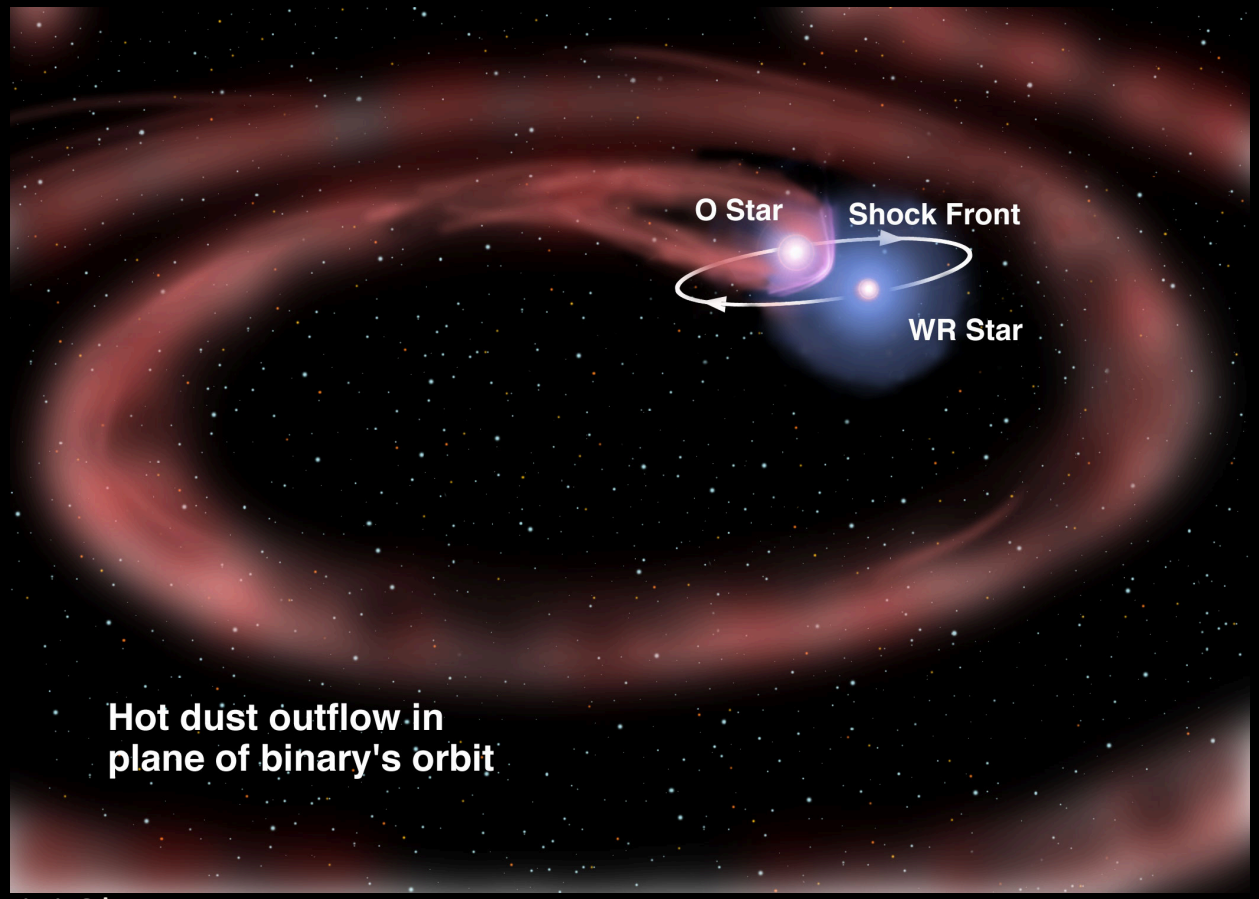
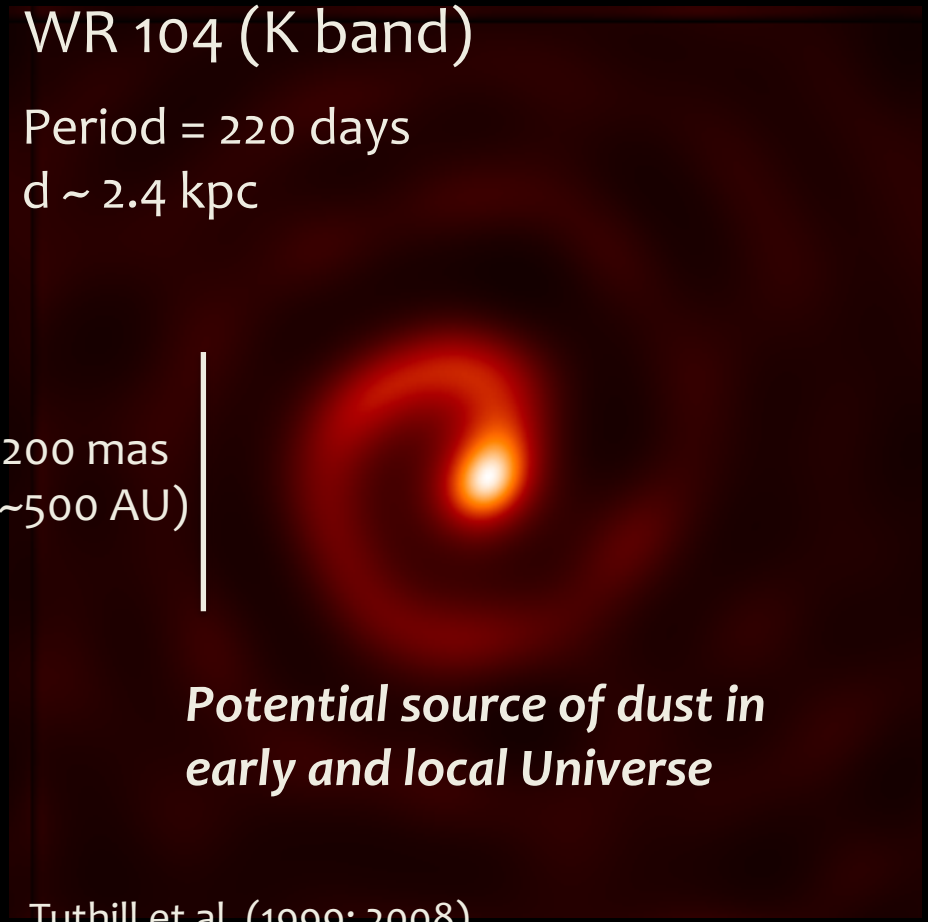


Image by Gemini Observatory

A Dusty WR "Pinwheel" Nebula!



Dust Sources in the LMC

Dust Source	Number	Total DPR ($M_\odot$ yr^{-1})
AGB	20000	1.4×10^{-5}
RSG	4000	1.4×10^{-6}
CCSNe	4 per 10^3 yr	$\sim 4 \times 10^{-4}$

Riebel et al. (2012), Temim et al. (2015), Srinivasan et al. (2016)

Dust Sources in the LMC

Dust Source	Number	Total DPR ($M_\odot$ yr^{-1})
AGB	20000	1.4×10^{-5}
RSG	4000	1.4×10^{-6}
CCSNe	4 per 10^3 yr	$\sim 4 \times 10^{-4}$
CCSNe ***Dest.***	”	**- $\sim 6 \times 10^{-3}$**

Riebel et al. (2012), Temim et al. (2015), Srinivasan et al. (2016)

Dust Sources in the LMC

Dust Source	Number	Total DPR ($M_\odot$ yr^{-1})
AGB	20000	1.4×10^{-5}
RSG	4000	1.4×10^{-6}
CCSNe	4 per 10^3 yr	$\sim 4 \times 10^{-4}$
CCSNe ***Dest.***	”	**- $\sim 6 \times 10^{-3}$**

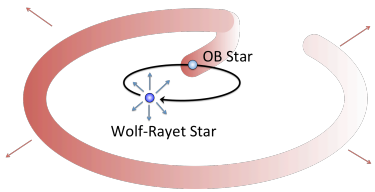
Riebel et al. (2012), Temim et al. (2015), Srinivasan et al. (2016)

A dusty WR binary => $\sim 10^{-10} - 10^{-5}$ M_{Sun} yr^{-1}

Lau et al. (Submitted)

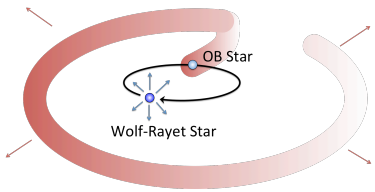
Implications and big questions…

Implications: WR Binaries should be an important source of dust

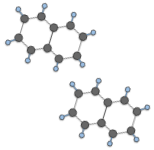


Implications and big questions…

Implications: WR Binaries should be an important source of dust



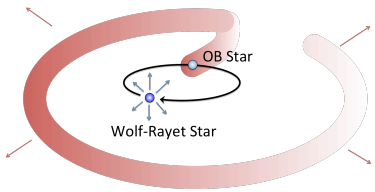
<u>Further questions…</u>



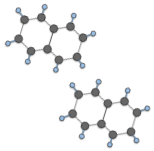
WR dust chemistry: *What are the molecular precursors of the carbon dust?*

Implications and big questions…

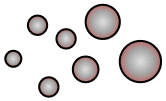
Implications: WR Binaries should be an important source of dust



<u>Further questions…</u>



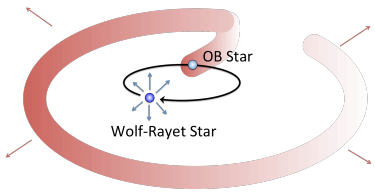
WR dust chemistry: *What are the molecular precursors of the carbon dust?*



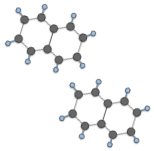
Dust formation: *How does dust form in such a hostile environment?*

Implications and big questions…

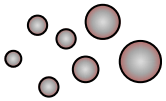
Implications: WR Binaries should be an important source of dust



<u>Further questions…</u>

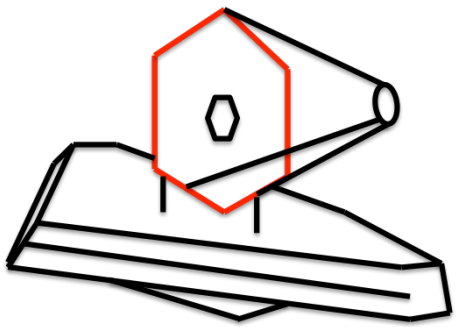


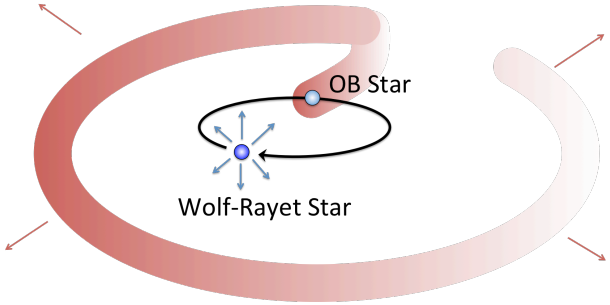
WR dust chemistry: *What are the molecular precursors of the carbon dust?*



Dust formation: *How does dust form in such a hostile environment?*

Dust Survival: *Does dust survive as it incorporates into the ISM?*



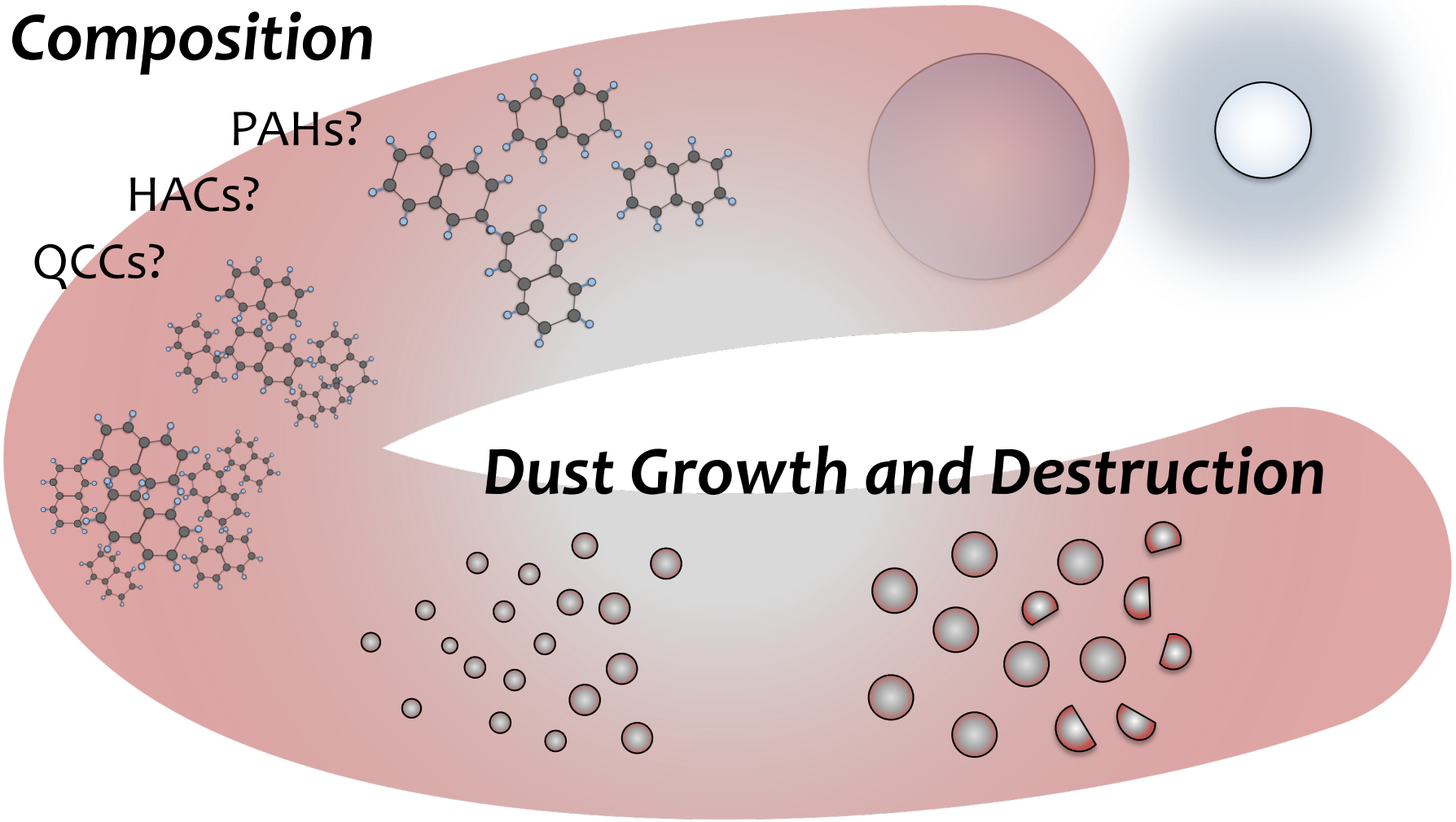


Early Science with JWST!
Dust Formation from Wolf-Rayet binaries

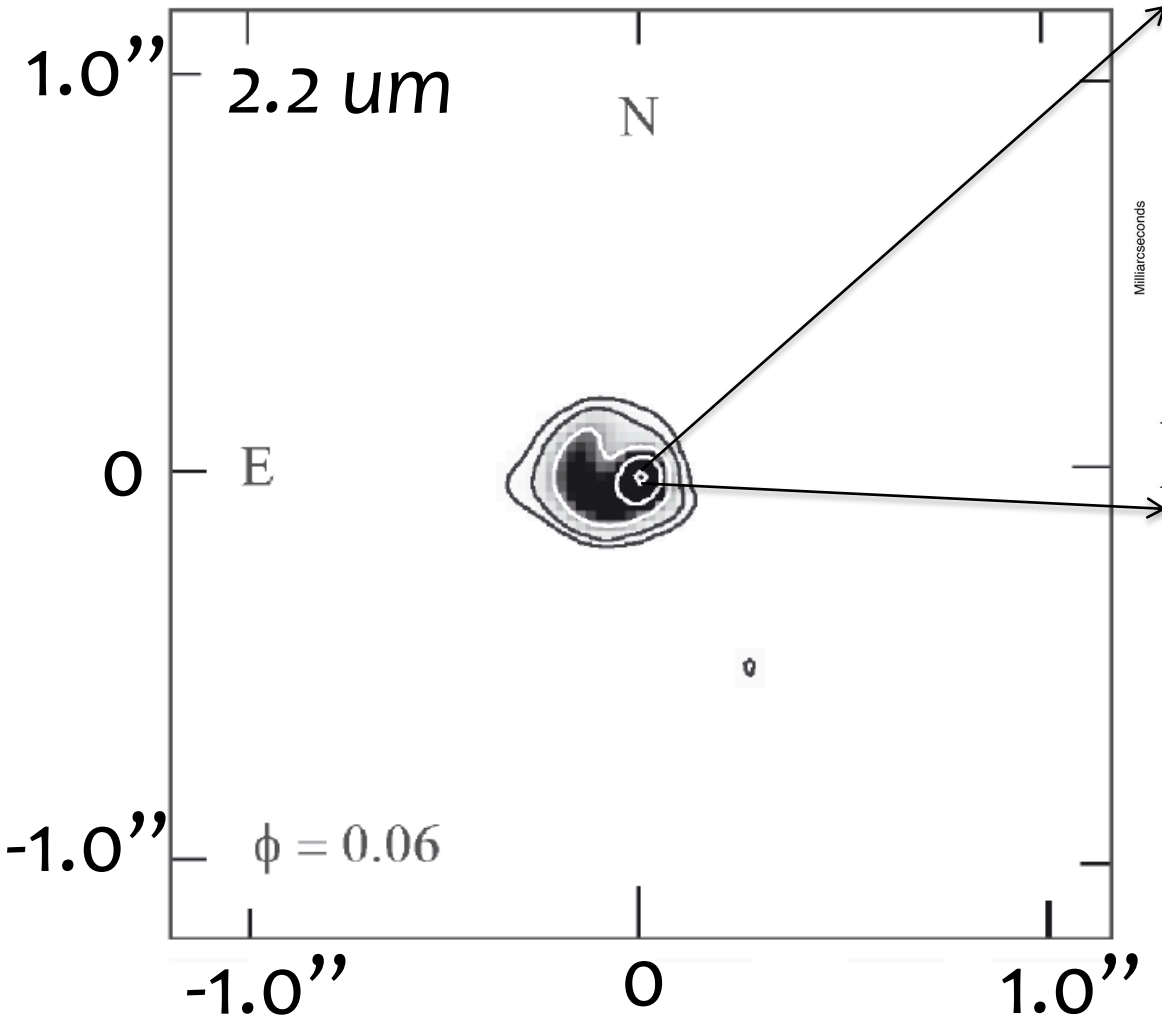
WR DustERS Team

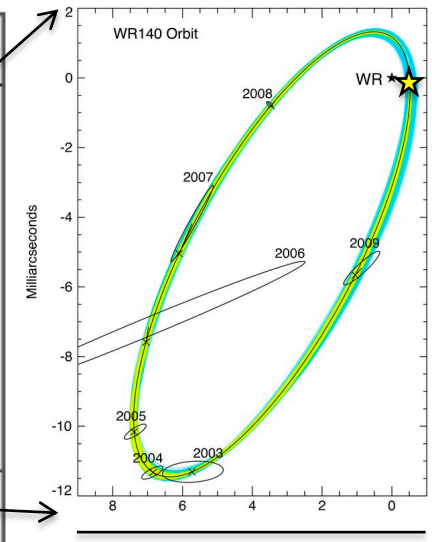
Ryan Lau (PI - ISAS/JAXA)
Matthew Hankins (Caltech)
Anand Sivaramakrishnan (STScI)
Deepashri Thatte (STScI)
Astrid Lamberts (OCA)
Joel Sanchez-Bermudez (UNAM)
Christopher Russell (Pontificia Universidad Católica de Chile)
Mansi Kasliwal (Caltech)
Michael Ressler (JPL)
Mike Corcoran (GSFC)
Izumi Endo (University of Tokyo)
Ori Fox (STScI)
Alexandra Greenbaum (U. Mich)
Ted Gull (GSFC)
Kenji Hamaguchi (GSFC)
Jamie Lomax (University of Washington)
Sergey Marchenko (SSA Inc.)
Tom Madura (San Jose State University)
Florentin Millour (Cote d'Azur Observatory)
Elisabeth Mills (Brandeis University)
Tony Moffat (Université de Montréal)
Mark Morris (UCLA)
Noel Richardson (University of Toledo)
Itsuki Sakon (University of Tokyo)
Nathan Smith (Steward Observatory)
Peter Tuthill (University of Sydney)
Takehiko Wada (ISAS/JAXA)
Gerd Weigelt (MPIfR)
Peredur Williams (University of Edinburgh)
Kevin Volk (STScI)
Andy Pollock (University of Sheffield)
Ed Young (UCLA)
Alexandra Schneider (UCLA)
Diego Calderon (Pontificia Universidad Católica de Chile)
Anthony Soulain (Cote d'Azur Observatory)
Olivia Jones (ROE)
Alistair Glasse (ROE)
JJ Eldridge (University of Auckland)
Macarena Garcia Marin (ESA)
Pat Morris (Caltech/IPAC)
Ian Stevens (University of Birmingham)

WR DustERS Science Goals



ERS Target: Wolf-Rayet (WR) 140





O-star

10 mas

Episodic Dust-Formation in WR140

WC7 + O5 (d = 1.6 kpc)

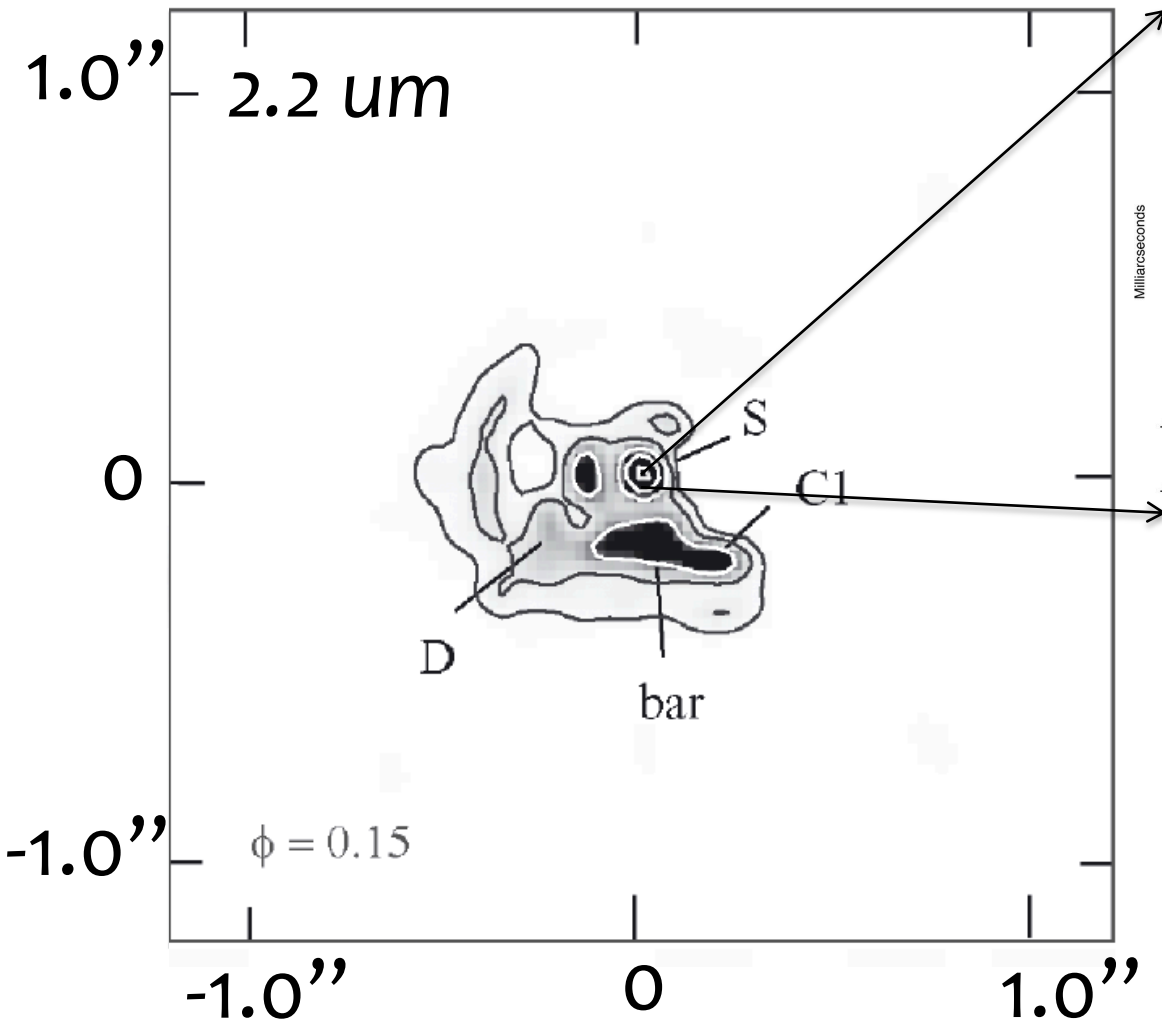
P = 7.94 yr

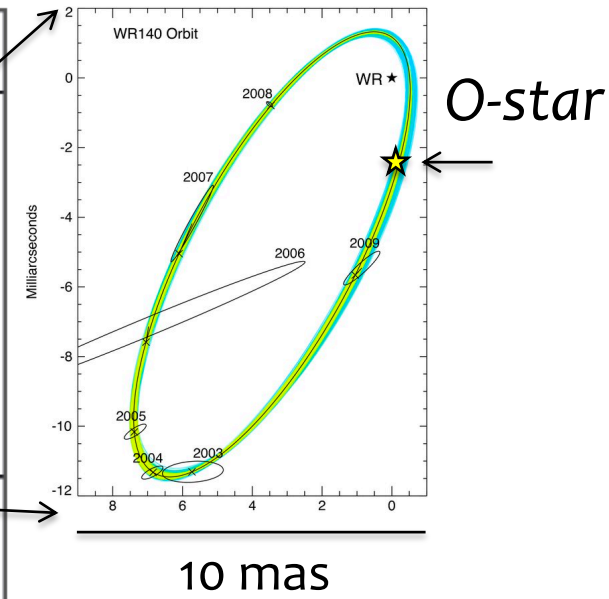
e = 0.9

i = 120°

Williams et al. (2009), Monnier et al. (2011)

ERS Target: Wolf-Rayet (WR) 140





Episodic Dust-Formation in WR140

WC7 + O5 (d = 1.6 kpc)

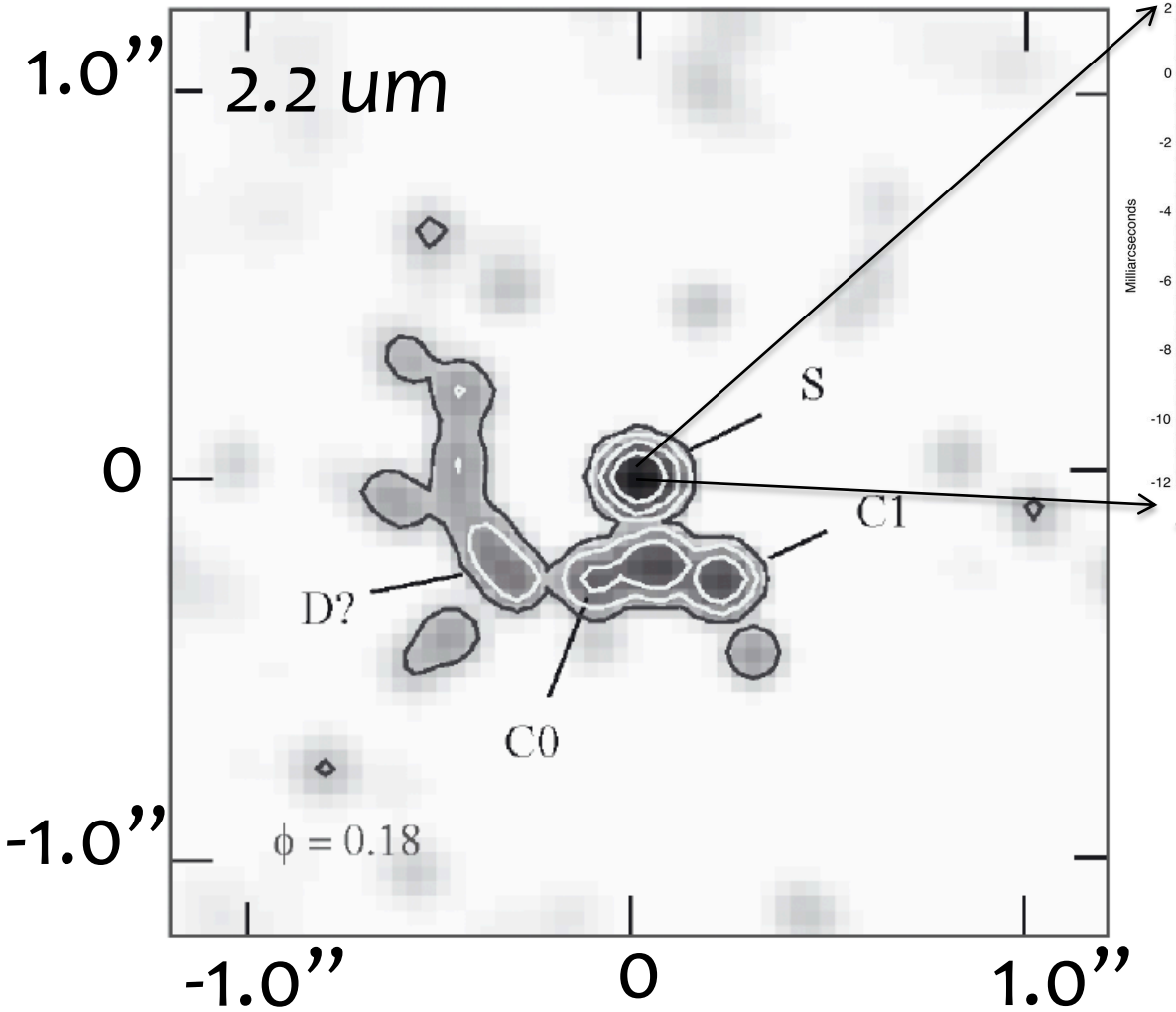
P = 7.94 yr

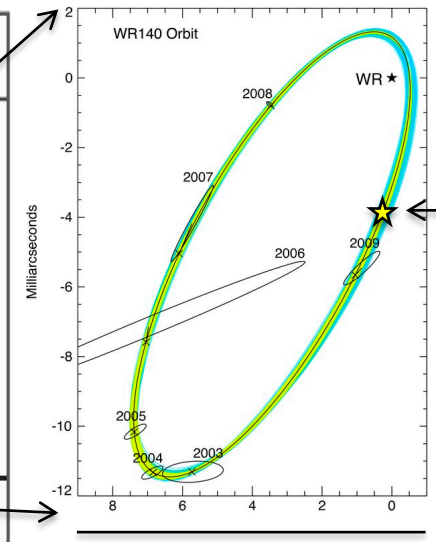
e = 0.9

i = 120°

Williams et al. (2009), Monnier et al. (2011)

ERS Target: Wolf-Rayet (WR) 140





O-star

Episodic Dust-Formation in WR140

WC7 + O5 (d = 1.6 kpc)

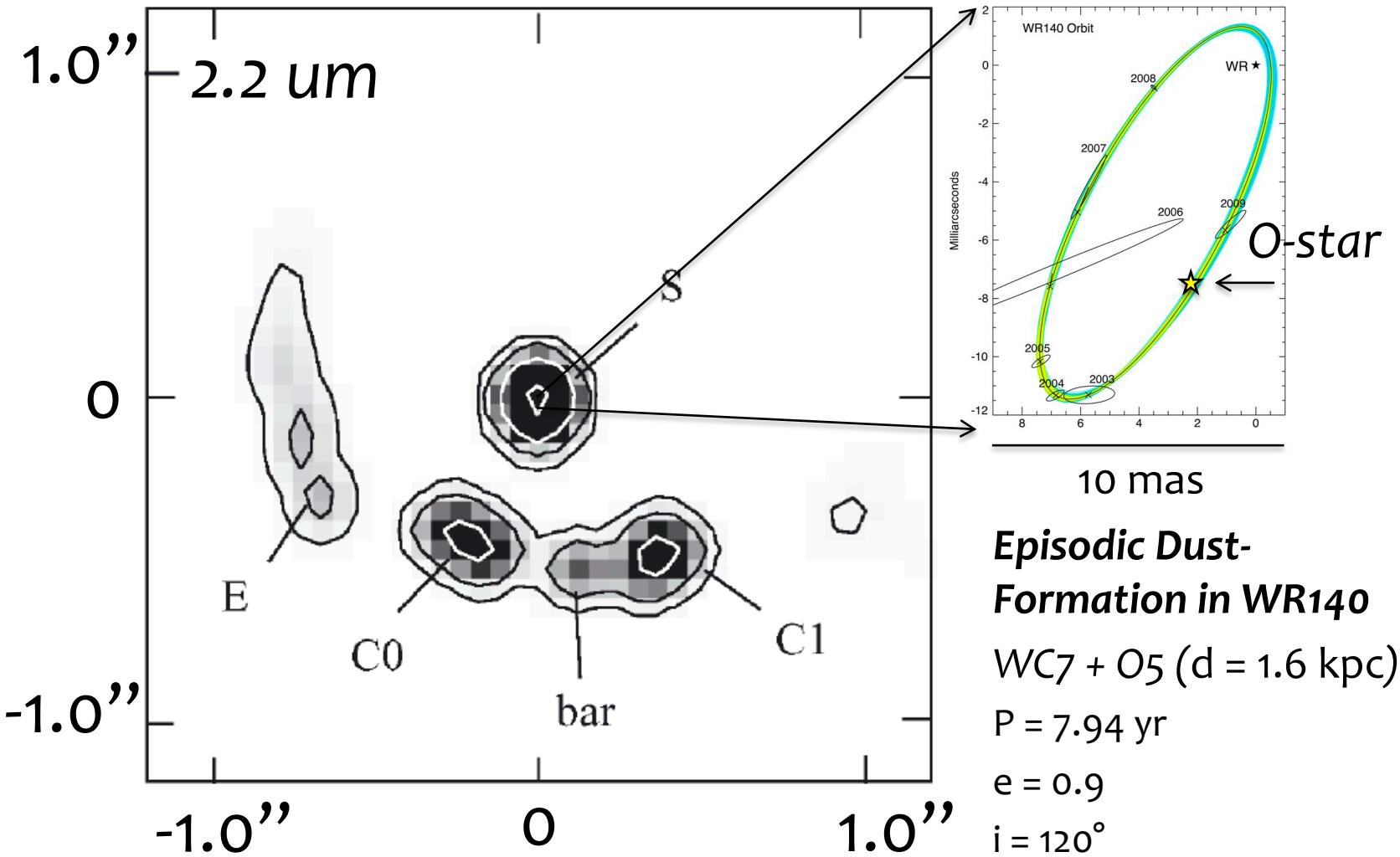
P = 7.94 yr

e = 0.9

i = 120°

Williams et al. (2009), Monnier et al. (2011)

ERS Target: Wolf-Rayet (WR) 140



Episodic Dust-Formation in WR140

WC7 + O5 (d = 1.6 kpc)

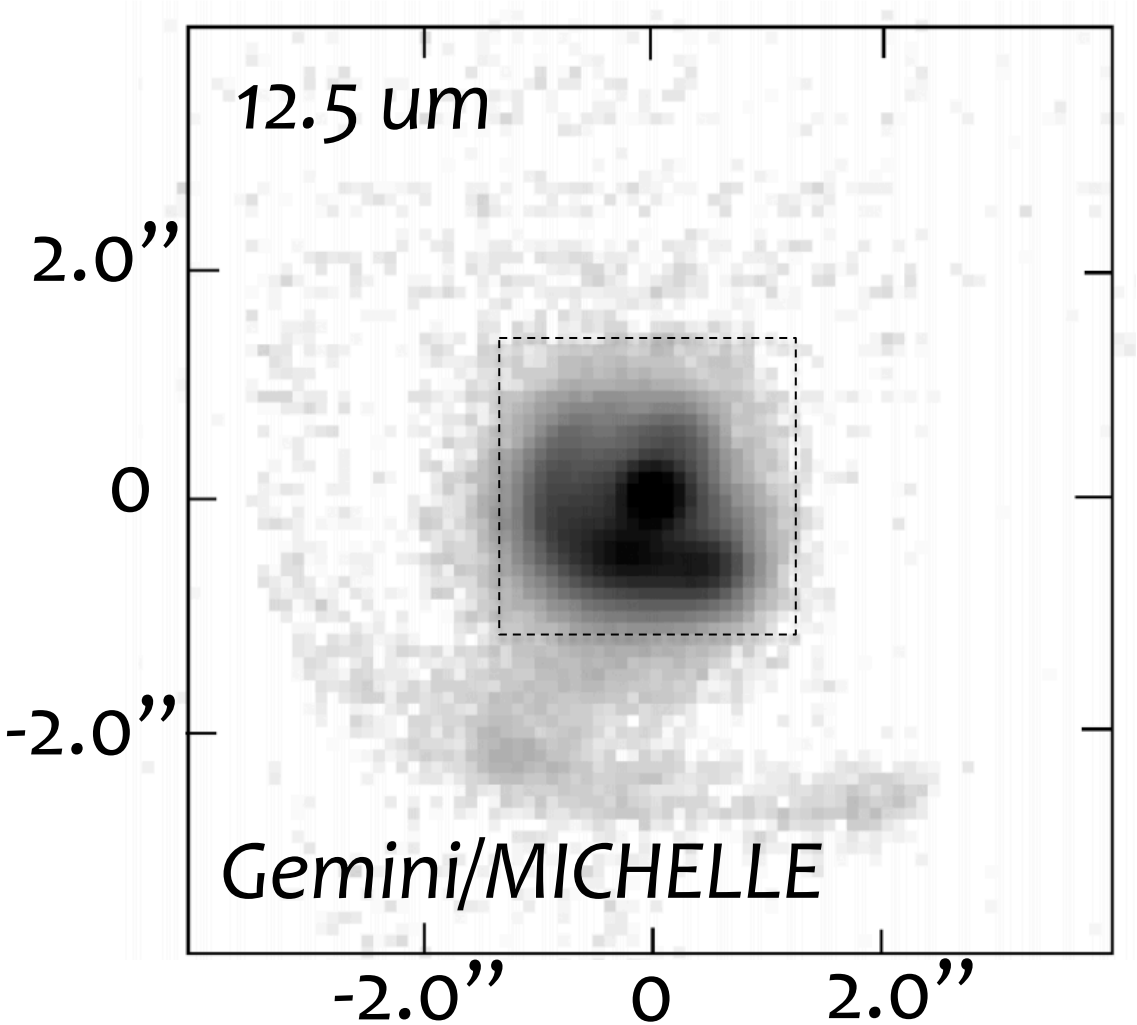
P = 7.94 yr

e = 0.9

i = 120°

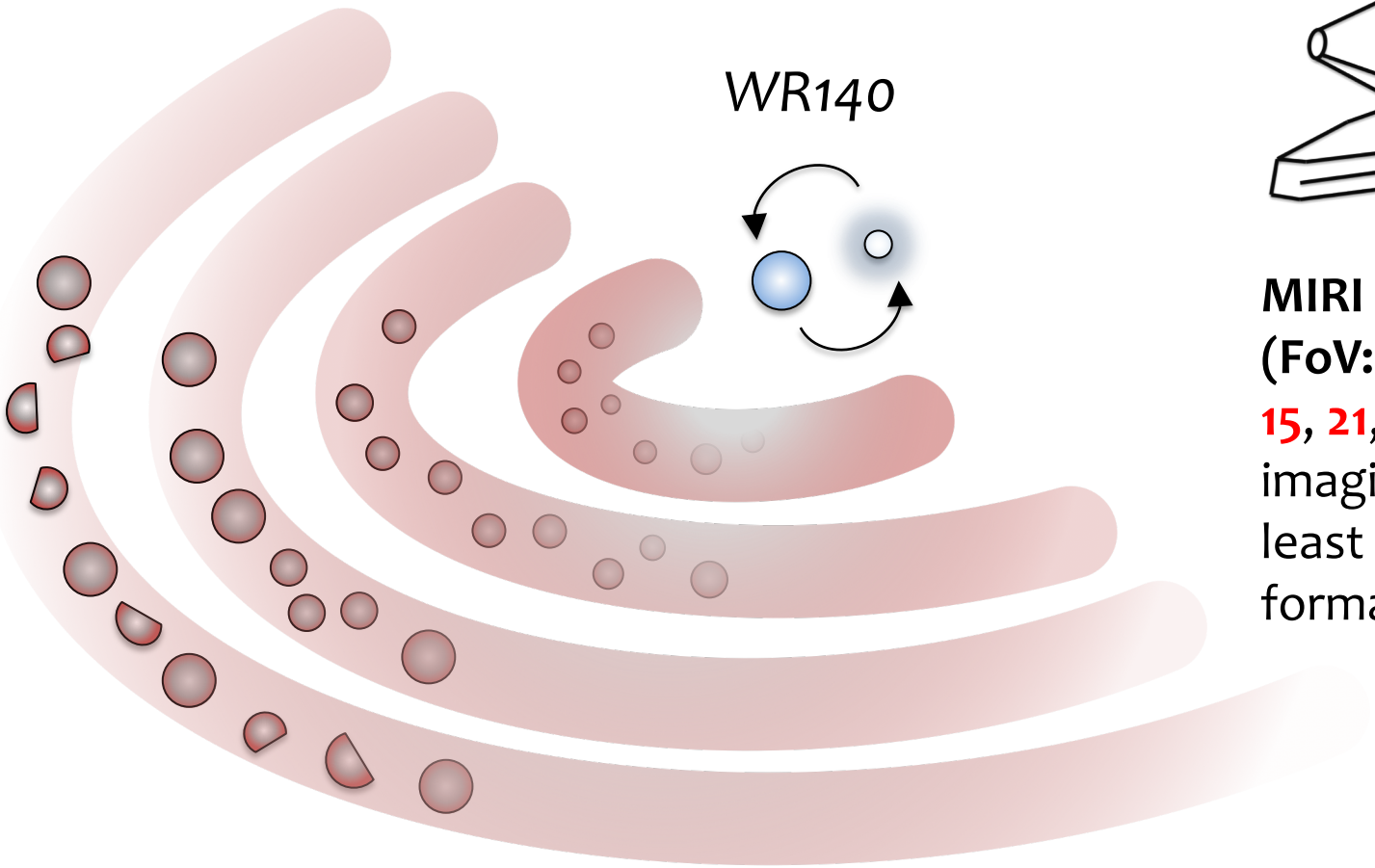
Williams et al. (2009), Monnier et al. (2011)

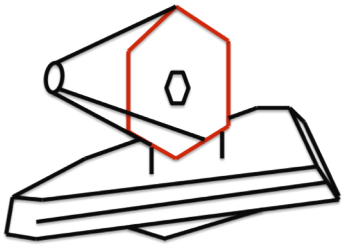
ERS Target: Wolf-Rayet (WR) 140



Williams+ (2009)

WR DustERS – JWST Observing Modes: *MIRI Im*, MIRI IFU, NIRISS AMI

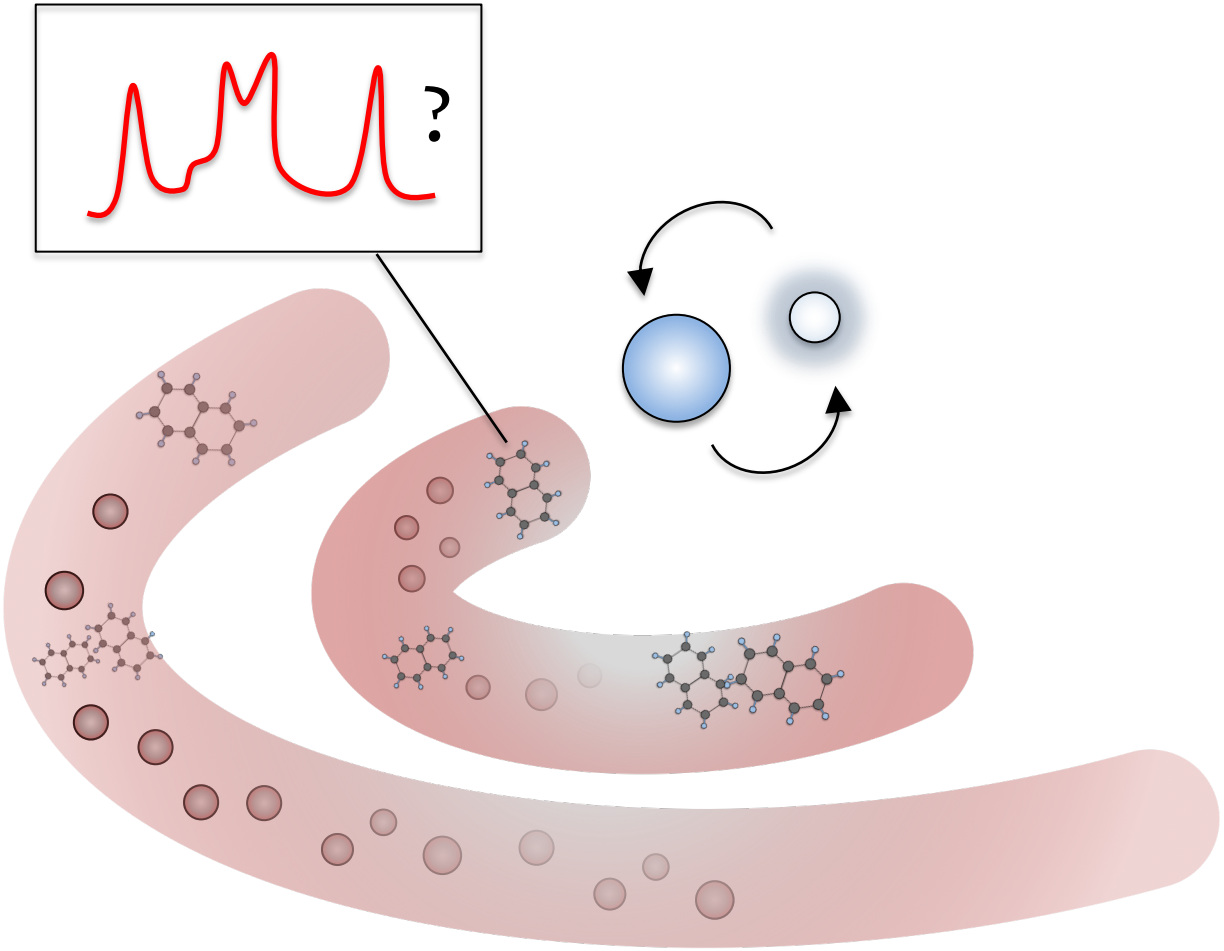


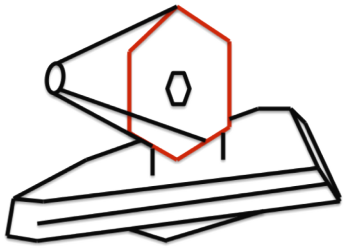


MIRI Imaging (FoV: ~1 x 2')

15, 21, and 25 μm imaging to detect at least 8 past dust formation episodes

WR DustERS – JWST Observing Modes: MIRI Im, *MIRI IFU*, *NIRISS AMI*

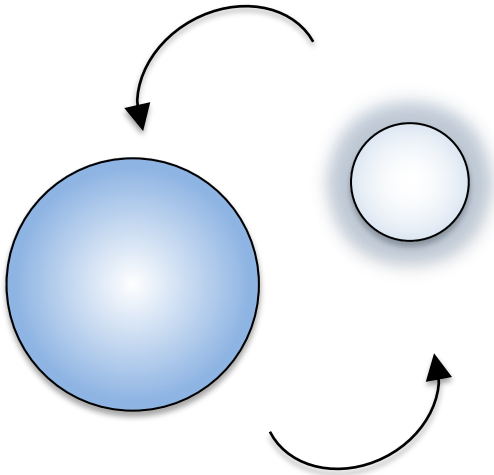


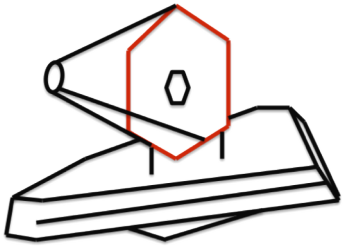


MIRI Integral Field Spectroscopy (FoV ~ 4 – 8”)

5 - 28 μm R ~ 2000 IFU spectroscopy to detect molecular precursors to WR dust

WR DustERS – JWST Observing Modes: MIRI Im, *MIRI IFU*, *NIRISS AMI*



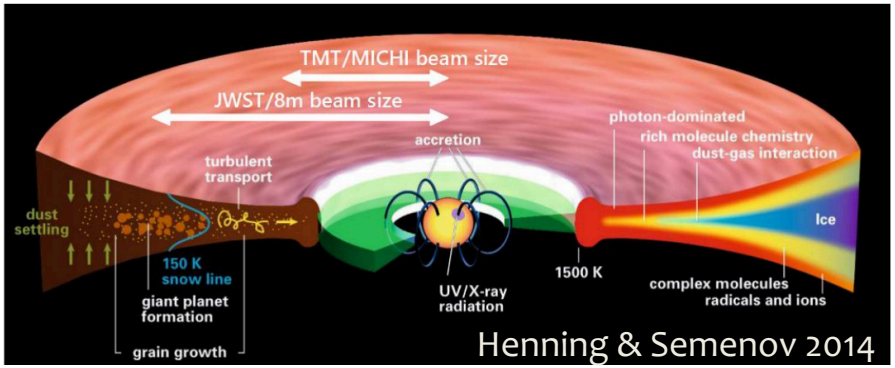


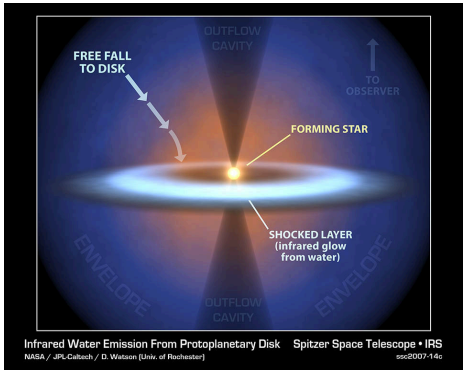
NIRISS Aperture Masking Interferometry (Resolution ~ 65 mas)
3.8 & 4.8 μm high contrast observations of hot inner dust to resolve morphology

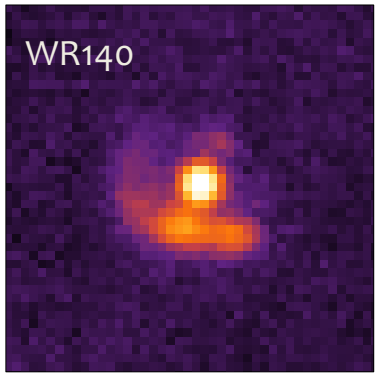
A natural synergy: NIRISS probes hot dust at finer spatial scales, while MIRI probes warm extended dust.

WR DustERS - Technical Goals

- *Many people want to point JWST at IR bright sources…*
  - E.g. AGN tori, protoplanetary disks, massive star ejecta



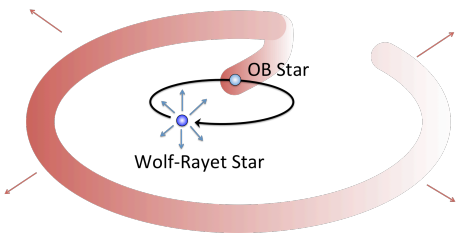




- ***How well can we detect faint extended emission around bright sources with JWST?***
  - Dealing with bright source artifacts for MIRI/MRS and NIRISS/AMI (e.g. persistence, row/column scattering and pull-up/down)
  - *How close to a bright source can we detect faint extended emission? (with bright source correction and PSF subtraction)*

Summary

Dusty WR Binaries

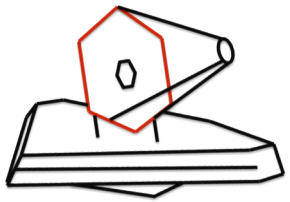


WR+OB binaries form dust via colliding winds

WR binaries should be important source of dust

Composition, formation, and survival of WR dust still unclear

JWST Early Science: WR DustERS



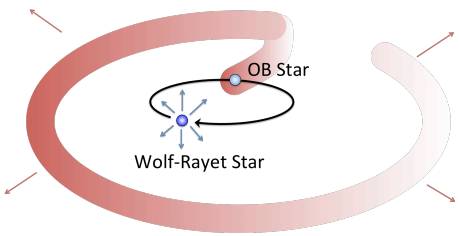
JWST – Enables high spatial resolution and sensitivity in mid-IR

WR DustERS – Investigating dust composition, growth and destruction from ***WR140***

On-going work – ground-based mid-IR survey w/ Subaru of WR binaries

Summary – Thanks!

Dusty WR Binaries

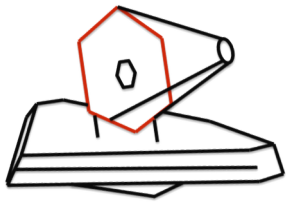


WR+OB binaries form dust via colliding winds

WR binaries should be important source of dust

Composition, formation, and survival of WR dust still unclear

JWST Early Science: WR DustERS



JWST – Enables high spatial resolution and sensitivity in mid-IR

WR DustERS – Investigating dust composition, growth and destruction from ***WR140***

On-going work – ground-based mid-IR survey w/ Subaru of WR binaries