MODELING IONIZED GAS AT LOW METALLICITIES: THE WOLF-RAYET EMISSION NEBULA N76

IR STIG AAS239 Session

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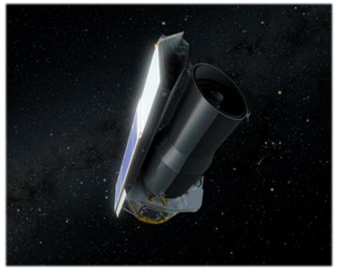
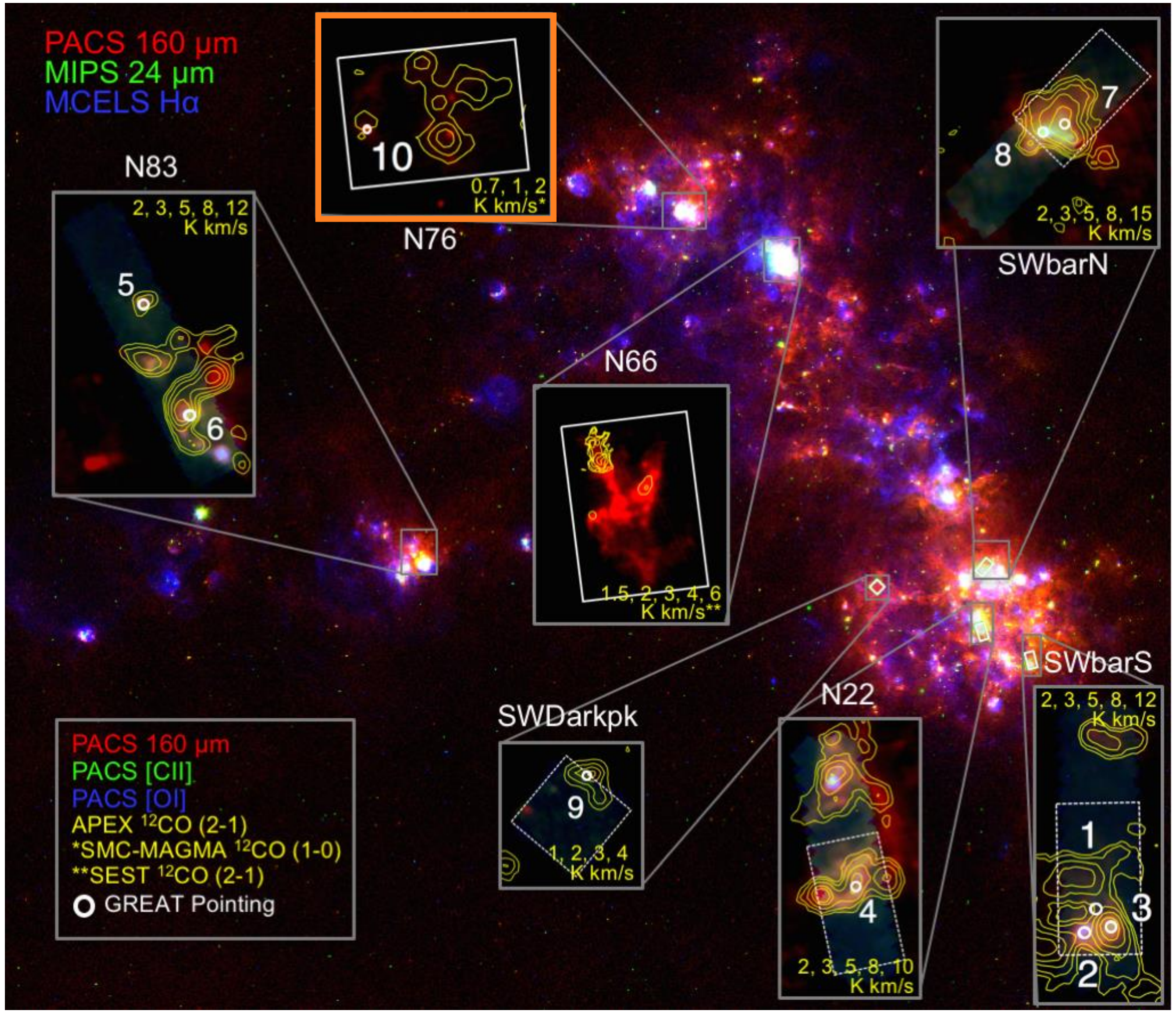


Ionized Gas Properties at Low Metallicities

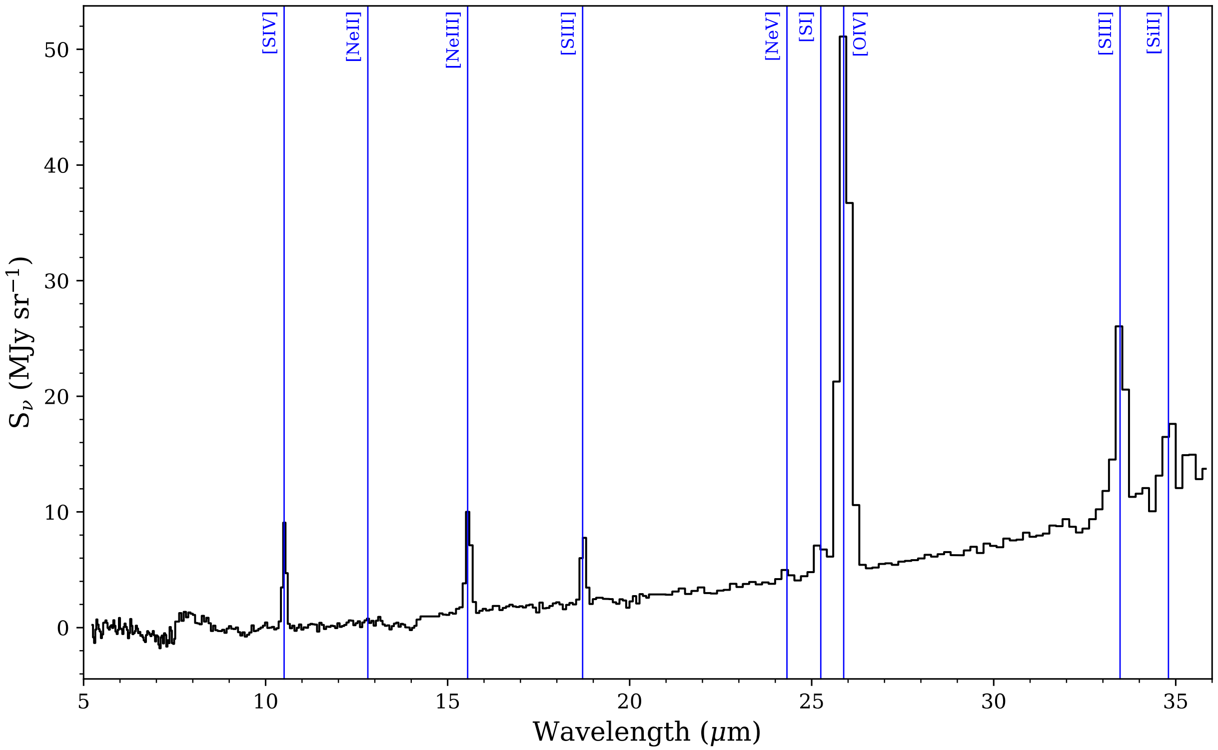
- IR observations allow an extinction-free measurement of ISM properties
- Understanding effect of metallicity is **crucial**
- Observations of mostly unresolved low metallicity dwarf galaxies show (Hunt et al. 2010; Cormier et al 2015, 2019; Polles et al. 2019):
  - Harder radiation fields
  - Bright, extended [OIII] emission
  - Porous structure

Our approach: use the Small Magellanic Cloud (1/5 $Z_{\odot}$) to determine the **resolved** properties of the ionized gas



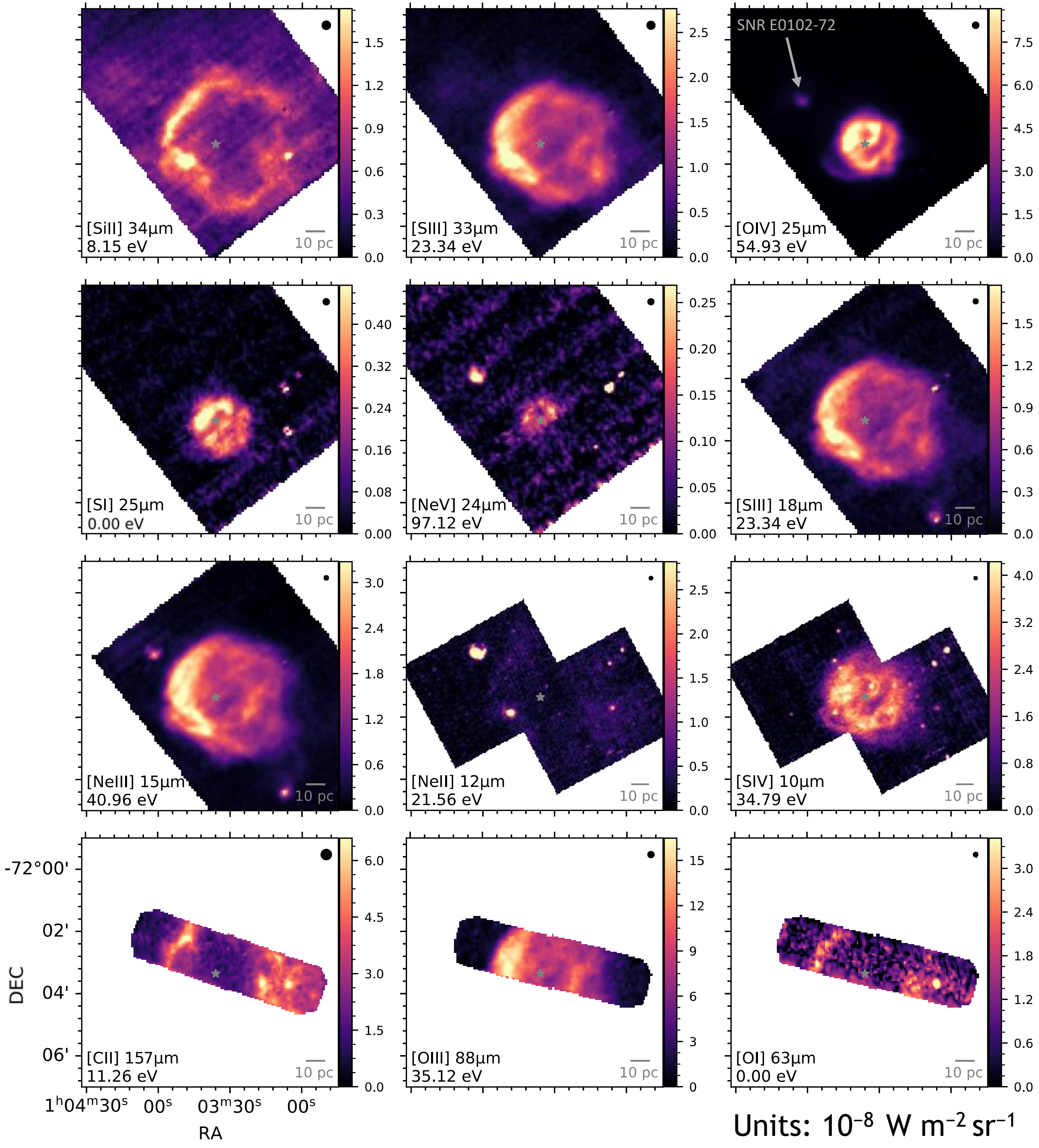
The N76 Wolf-Rayet Emission Nebula

- Simplest region in sample: roughly spherically symmetric with a single ionization source
- AB7: a WN4 + O6 binary (Shenar+ 2016)
  - T_* = 105,000 K
  - L = $10^{6.1}$ $L_\odot$
- Similar environment in young starbursts
- *Herschel*/PACS and *Spitzer*/IRS data
  - ≈2-3 pc resolution
- Photoionization modeling using Cloudy (Ferland+ 2017) to measure the physical conditions in N76

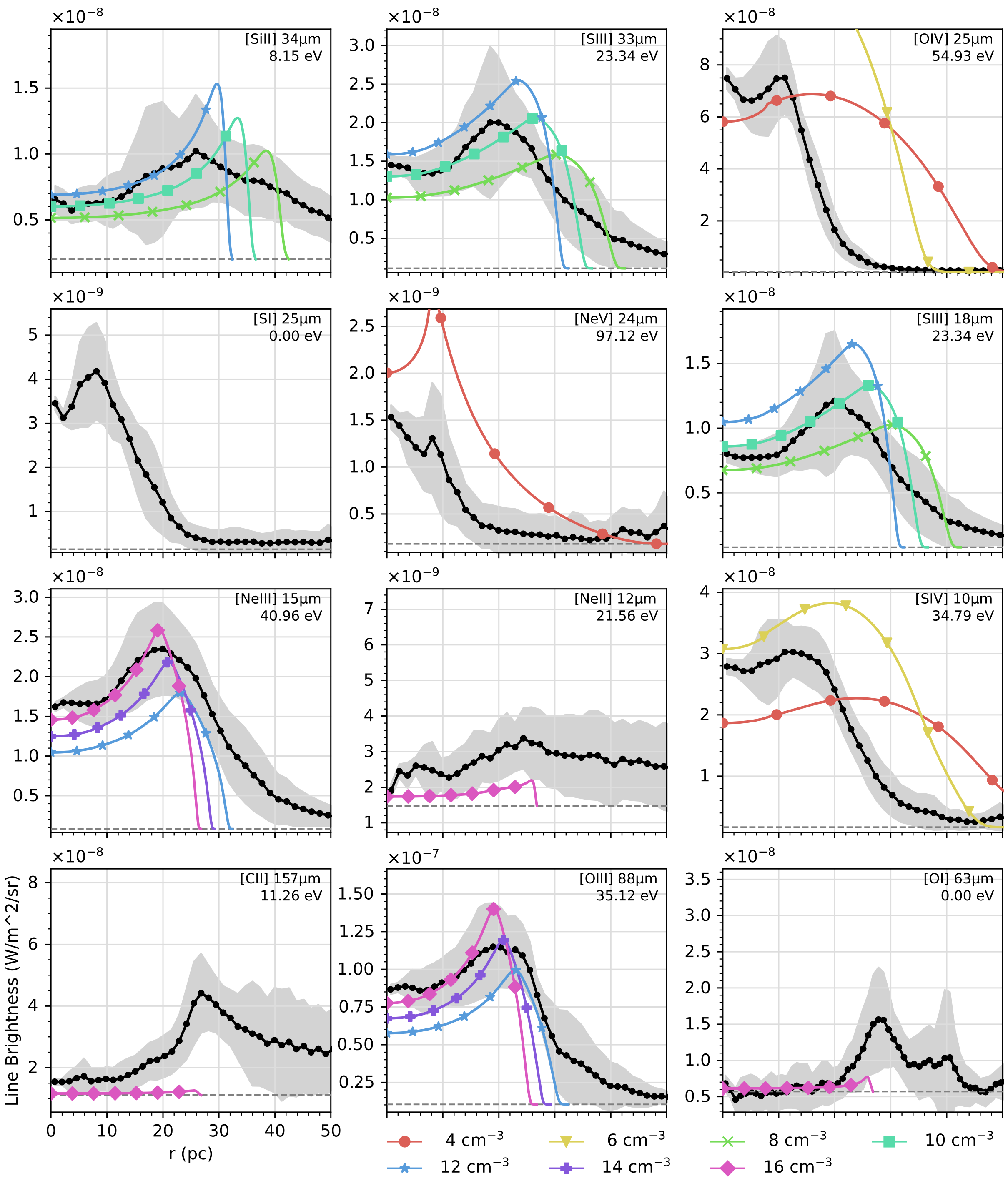


Spitzer/IRS spectrum

Emission Line Images



- Construct images through CUBISM (Smith+ 2007a) and PAHFIT (Smith+ 2007b)
  - Shells of ionization structure
  - Mystery: presence of [SI] 25.25 μm near center of the nebula
- Photoionization model conditions:
  - PoWR stellar atmosphere models for AB7's SED (Todt+ 2015)
  - 8 pc wind-blown cavity required by data
  - SMC abundances
  - Constant density
  - Only modeling HII region (not PDR)
- Method: match radial brightness of the spatially resolved emission lines to projected values from the photoionization code Cloudy



Results of Photoionization Models

Matching the spatially resolved emission yields much more information than using total intensity

- Constant density Cloudy models of $n_H \approx 4 - 16$ cm^{-3} reproduce the ionized gas (E_{ion} > 13.6 eV) emission lines well (constant pressure is similar)
- Lines with E_{ion} < 13.6 eV:
  - Most of the C and O is in higher ionization states and in lower density neutral gas: little [CII] from HII
  - Cloudy can reproduce all of the [SiII] emission, depending on the depletion (e.g., Tchernyshyov+ 2015)
- [OIII] is the brightest line, well reproduced by just photoionization from AB7
- Production mechanism for [SI] remains a mystery
- Diffuse emission from [SIII], [NeII], and [NeIII] 100 pc away from AB7 may indicate photon leakage from N76

Future Prospects

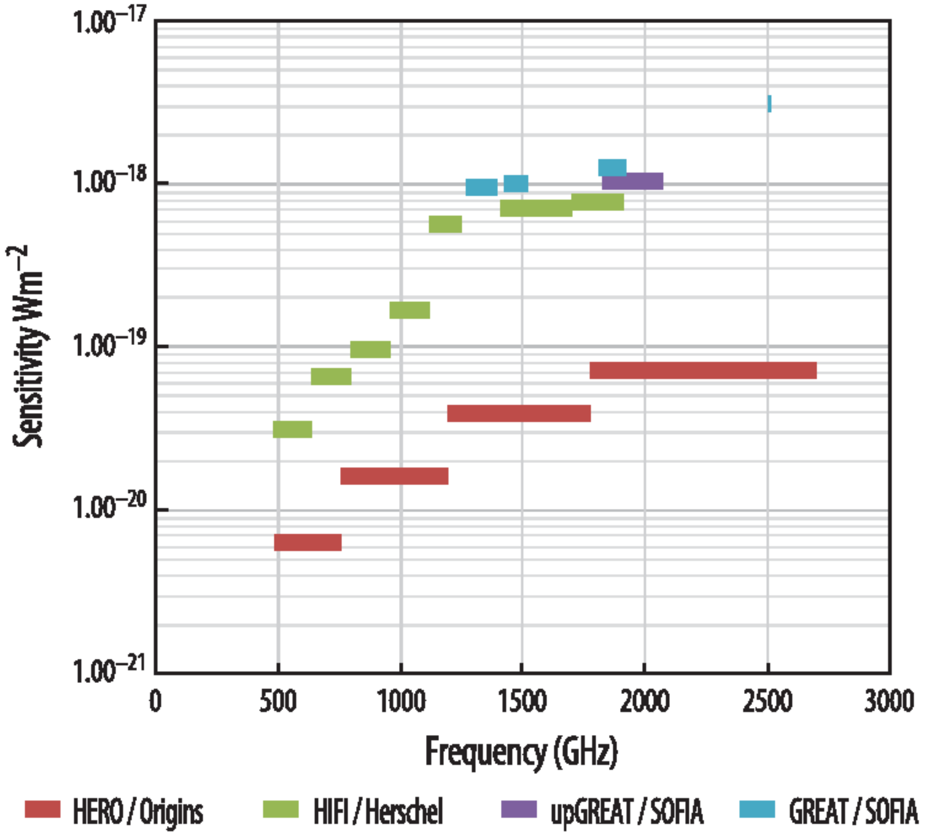
- JWST will be able to observe up to 28.5 μm, but the FIR lines are critical to understand ISM properties (e.g., [CII], [OIII], [OI])
  - ≈0.5 THz – 2.5 THz

A future FIR probe that prioritizes **spatially** and **spectrally** resolved observations will maximize synergy with JWST

- Velocity-resolved observations at **≲10 km/s** resolution can:
  - Quantify stellar feedback in HII regions (e.g., Pabst+ 2020)
  - Disentangle multiphase [CII] emission (e.g, Tarantino+ 2021)
  - Determine self-absorption effects in [OI] and [CII] (e.g., Okada+ 2019, Goldsmith+ 2021)

Heterodyne Receiver for Origins (HERO)

R ~ 10^7



Wiedner+ 2021