

THE BIRTH AND LIFE OF STARS
*SCIENCE CASES FOR A FUTURE
GEMINI NORTH AO SYSTEM*

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Scope: the birth ~~and life~~ of stars

- ⦿ Not covering **advanced stages of stellar evolution**, characterized by heavy mass loss
 - *LBV, AGB, PN, WR, ...*
- ⦿ AO has provided many critical observations to understand the late stages of stellar evolution
 - *Worth thinking about it...*

Scope: the birth of stars and planets

- ⦿ Planet formation comes hand and hand with star formation: study both at once!
- ⦿ Focus in this talk: **initial conditions and early stages of planet formation**
 - *Only gas-rich disks (around PMS stars)*
 - *See Fitzgerald & Marois talks for debris disks and exoplanets science*

Isolated star formation paradigm

- ⦿ As a prestellar core collapses, a **circumstellar disk** is formed; it plays a key role for
 - *Angular momentum evolution*
 - *Planet formation*
- ⦿ **Accretion and ejection** phenomena are active
 - *Angular momentum evolution*
 - *Feedback on surrounding cloud*

The modern star formation paradigm

- ◎ Star formation is **a much more dynamic process** than previously thought
 - *Cores and larger clouds fragment very easily*
 - *Multiple systems are very common*
 - *Clustered star formation is the dominant mode*
- ◎ However, this does not diminish the importance of disks and jets
 - *It's all happening at once...*

Relevant spatial/angular scales

- ◎ **A very broad range of spatial scales**
 - *Prestellar core* ~ 0.1 pc
 - *Binaries*: < 0.1 AU to 10^5 AU
 - *Disks*: 10s to 100s of AU
 - *Planet forming region*: ~ 1 to ~ 20 AU
 - *Jet launching*: < 1 AU
- ◎ **Distances to star-forming regions**
 - *Low-mass star formation*: ~ 150 pc and beyond
 - *High-mass star formation*: ~ 450 pc and beyond

Why adaptive optics?

- ◎ Resolution, resolution, resolution...
 - From “super-seeing” to diffraction-limited
 - Resolution also yields contrast
- ◎ Competition/complimentary facilities
 - HST ($D=2.5\text{m}$, *mostly optical*)
 - JWST ($D=6\text{m}$, essentially *NIR-MIR*)
 - TMT / E-ELT ($D=30\text{-}40\text{m}$)
 - ALMA ($<0.1''$ resolution, *submm*)

Star/planet formation and AO

- ⦿ Adaptive optics has been a workforce for star and planet formation for the last 15 years (and counting)
- ⦿ Most science cases for a possible new AO system are extensions and/or generalizations of projects already underway
 - *Will new ideas emerge from the workshop?*

Star formation: open questions

- ◎ Understanding the physics of core collapse and fragmentation
 - *Role of magnetic field*
 - *Origin and importance of turbulence*
 - *Kinematics of prestellar cores*
- ◎ Task for ALMA, not for AO

Star formation: open questions

- ◎ Understanding stellar multiplicity as a fossil record of core fragmentation
 - *Is it universal or does it depend on environment? How does it vary with mass?*
- ◎ Possible target populations:
 - *PMS stars in clusters: relatively pristine*
 - *Embedded protostars: initial conditions*
 - *Field stars: systems with $q \ll 1$ (OB stars)*

Star formation: open questions

- ◎ **Improving evolutionary models**, critical to assess mass of substellar objects
- ◎ Monitor orbital motion of close low-mass binaries, either PMS or MS
 - *Astrometry + RV monitoring* → M_{dyna}
 - *Photometry + spectroscopy* → M_{HRD}

Star formation: open questions

- ◎ Understanding the **Initial Mass Function**
 - *Is it universal?*
 - *If not, what governs variations?*
- ◎ AO can help tremendously to beat the severe crowding of some regions
 - *Not really needed for nearby SFRs*
 - *Search for VLMS/BD in 0.5-2 kpc clusters*
 - *Search for low-mass stars in more distant regions*

Star formation: open questions

- ◎ Formation at both extremes of the IMF
 - *Same formation process for BDs and low-mass stars?*
 - *High-mass stars: isolated cores, competitive accretion, stellar mergers?*
- ◎ Imaging of disks/jets/outflows
- ◎ Multiplicity statistics

Star formation: open questions

- ◎ Understanding the physics of the accretion/ejection processes
 - *Exact role of magnetic field*
 - *Importance for angular momentum ejection*
 - *Exact importance of energetic feedback*
- ◎ Measure kinetics and collimation of jets
- ◎ Measure rotation around jet's axis

Planet formation: open question

◎ Probing the diversity of initial conditions

- *Do all disks eventually form planets? If not, what are the necessary conditions?*

◎ Assess the overall structure of disks

- *Why are so many disks hard to image in scattered light?*
- *Evidence for dust evolution: grain growth, settling*

Planet formation: open questions

- ◎ Search for protoplanets embedded in their parent disk
- ◎ Indirectly
 - *Spiral structure in disks*
 - *Gaps in disks (transition disks)*
- ◎ Directly
 - *Faint point sources in disks*

AO requirements

- ⦿ Most projects are **targeted observations, with relatively high contrast needed**
 - *High Strehl (>50%), single-guide star AO*
 - *Decent correction in the optical great for jets*
- ⦿ IMF projects require wide-field correction, though a 10-20% Strehl can go a long way
- ⦿ **Most young stars are “faint” ($V > 12$)**
 - *LGS probably needed to achieve sufficient Strehl*